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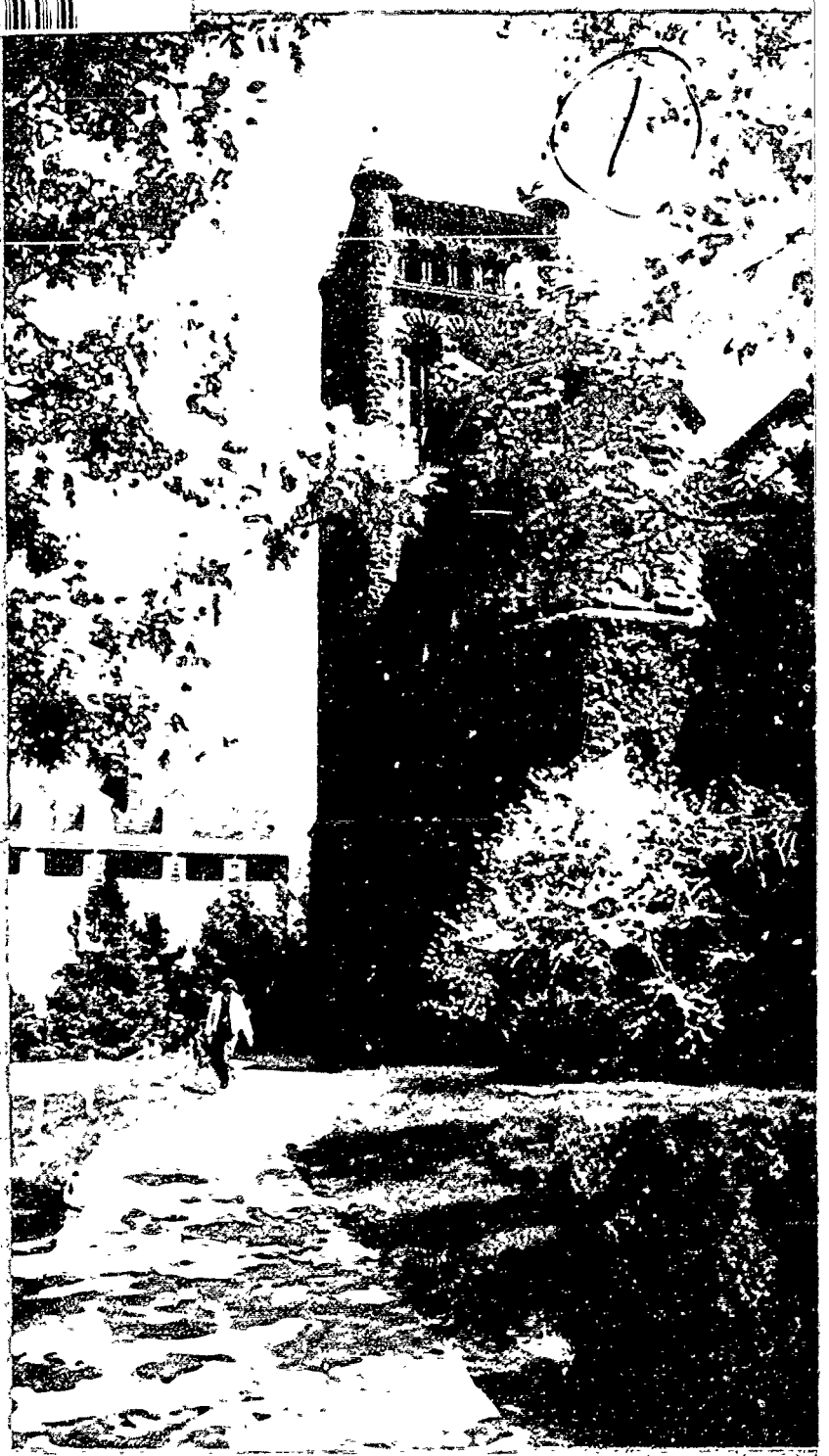
Bulletin of the American Physical Society



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Volume 35, Number 8 September 1990

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Bulletin of the American Physical Society

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Editorial Assistant: M. Scanlan
The *Bulletin of the American Physical Society* is published 11× yearly, monthly except July/August when bimonthly, by the American Physical Society, 335 East 45th St., New York, NY 10017, (212) 682-7341, through the American Institute of Physics. It contains advance information on meetings of the Society, including abstracts of papers to be presented, news of the Society and its Divisions, Sections, Topical Groups, and Forum, minutes of business meetings, etc. Instructions for authors on the submission of abstracts are printed in the *Bulletin* whenever space permits. Reprints of papers can only be obtained by writing directly to the authors.

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Free to members by 2nd class mail. Members may receive optional *Air Mail Delivery* for the period 1 July 1990–30 June 1991 for the fee listed: United States $26; Canada, Mexico, Central America, West Indies $47; Europe, South America, Mediterranean Africa $75, and USSR, Asia, Africa, Pacific $101. Another option for the same period is *Airfreight*. Europe, Asia, Africa, and Oceania $35. **Members of other AIP Member and Affiliated Societies:** domestic $70, Canada, Mexico, Central and South America, and Caribbean $85. optional Airfreight to Europe, Asia, Africa, and Oceania $105. **Nonmembers:** domestic $310, Canada, Mexico, Central and South America, and Caribbean $325; Europe, Asia, Africa, and Oceania $345. Backnumbers: $40 per issue, $45 for the APS Membership Directory issue and $45 for the issue that includes the AIP/DPAS Directory. Complete volumes available on microfilm.

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Altgeld Hall, University of Illinois, Urbana-Champaign, IL. Photograph courtesy of the Department of Physics, University of Illinois.

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Eleventh International Conference on the Application of Accelerators in Research and Industry

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Jerome L. Duggan

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16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Small Accelerator Usage

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This conference, as its name implies, is the Eleventh International Conference in this series. The conference is held every other year on even years. For the convenience of the reviewers of this proposal, the table of contents for the 1988 conference in this series is attached to the back of the proposal. Three hundred and fifty-six papers were published in these two volume proceedings. Another one hundred and eighty papers that were presented at the conference do not appear in the proceedings because they were either rejected by the referees, not submitted for publication, or not published for lack of room in the proceedings. The content of the 1990 conference will be quite similar to that of the 1988 proceedings attached to this proposal. The major change will be an expansion in the area of materials science with ion beams and the deletion of some topics that are

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REPORT DOCUMENTATION PAGE, DD Form 1473, Continued

19. ABSTRACT, continued
perhaps not quite as popular. The growth of nuclear science techniques in materials science is not surprising since accelerators are just beginning to be utilized in this area of research. The entire field of Materials Science is growing rapidly, as is evidenced by the Materials Research Society being one of the fastest growing scientific societies in the world. Another interesting bit of data in this regard, is that one company which is the largest manufacturer of electrostatic accelerators has in the last few years processed more orders for materials analysis accelerators than it has produced for this application in its twenty-four year history. The Organizational Committee for this conference tries to stay in tune with all of the recent developments with research and industrial applications of accelerators. We hope that the quality of our past conferences has proven this point and if funded, we will keep the same high standards for the conference outlined in this proposal.

ACCOUNTABILITY OF FUNDING RECEIVED RE:

ELEVENTH INTERNATIONAL CONFERENCE
ON THE APPLICATION OF ACCELERATORS IN RESEARCH AND INDUSTRY,
NOVEMBER 5, 6, 7, 8, 1990, UNIVERSITY OF NORTH TEXAS, DENTON, TEXAS

GRANTING AGENCY	AWARDED	EXPENSES				
	Award	Secretarial	Conference Proceedings	Travel	APS Bulletin	Materials Supplies
National Science Foundation	340,000. In Indian Rupees for Indian Scientists Note: This amount was rescinded by NSF at the request of the Indian Government.					
National Science Foundation	8,000.	2,000.	2,000.	4,000.		
U.S. Department of Energy	20,000.	4,000.	8,000.			*8,000. *Includes Printing, Mailing and Meeting Rooms.
Office of Naval Research	10,000.		10,000.			
National Institute of Standards and Technology	12,000.		12,000.			
Oak Ridge Associated Universities	6,000.		6,000.			

Bulletin of the American Physical Society

American Physical Society
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Announcements of Topical Conferences

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APS Reports

NEWLY ELECTED FELLOW

Walter E. Massey
Citation: For his excellence in the administration of major scientific organizations and for the development of innovative ways to convey the excitement of physics to students and the general public.

"STEP" TRAVEL GRANTS TO HELP FOREIGN GRADUATE STUDENTS ATTEND APS MEETINGS

APS is again participating in the 1991 "Short Term Enrichment Program" (STEP) of the Office of Student Support Services of the U.S. Information Agency. This program, which is administered through the Institute of International Education, provides awards to foreign graduate students studying in the United States to help defray part of their travel expenses to attend professional meetings. The maximum permissible award to an individual student is $300, but because the demand so much exceeds the available funds, awards are likely to be substantially smaller.

IN 1991 THE *MAXIMUM* NUMBER OF AWARDS TO ANY ONE MEETING THAT WILL BE MADE TO STUDENTS AT ANY ONE INSTITUTION WILL BE AS FOLLOWS:

NUMBER OF PHYSICS GRADUATE STUDENTS	MAXIMUM NUMBER OF AWARDS
LESS THAN 50	1
51–100	2
MORE THAN 100	3

APS "STEP" AWARDS MAY BE AVAILABLE FOR THE FOLLOWING 1991 MEETINGS

General Meetings: San Antonio, TX, 21–24 January 1991; Cincinnati, OH, 18–22 March 1991; Washington, DC, 22–25 April 1991.

Divisional Meetings: Nuclear Physics, Urbana, IL, 25–27 October 1990; Plasma Physics, Cincinnati, OH, 12–16 November 1990; Fluid Dynamics Physics, East Lansing, MI, 18–20 November 1990.

To be eligible for a STEP award, an applicant must be a foreign full-time graduate student at a U.S. institute of higher learning who has not received a STEP grant previously. Students with refugee, immigrant, or tourist visa status are not eligible. University assistants are normally eligible, but U.S. Government employees, and those having U.S. Government fellowship or travel grants are not.

Applicants should submit a letter stating their need for travel funds, their nationality and visa category, and affirming their status as full-time graduate students in the U.S.; a letter of nomination from their department head; and a copy of the abstract of the contributed paper to be presented at the meeting. While the deadlines for STEP applications for each meeting are the same as the deadlines for the receipt of abstracts for publication in the *Bulletin of the American Physical Society,* these two submissions should be made separately. The complete STEP application should be sent to:

STEP Travel Grant Program
The American Physical Society
335 East 45th Street
New York, NY 10017

Highlights of *What's New*

WHAT'S NEW is a weekly electronic communication to members of the American Physical Society. Its purpose is to provide an "early warning" of government policy issues that affect the health of physics. The approach is frankly editorial. It can be accessed without charge by any member. All that is needed is a terminal and a modem.

ACCESS INSTRUCTIONS. Just dial the local Telenet number and follow these instructions. (1) At the CONNECT prompt, hit the return key twice, (2) at the TERMINAL prompt, hit the return key, (3) at the @ prompt, type TELEMAIL, and hit the return key, (4) for USERNAME, type GMEMBER, and hit the return key, (5) for PASSWORD, type APS692, and hit the return key. After the current "What's New" page appears on the terminal, the user will automatically be disconnected from Telemail.

Highlights edited by Robert L. Park

(18 May 90)
Last Year You Learned to Spell "Sequestration." This year it could eat your lunch. A four-month sequestration took 1.5% across the board last year. Coupled with a 0.43% tax to support the war on drugs, it created some havoc among science programs. This year, private estimates of the sequestration required to take care of the projected deficit range from a White House figure of 18.3% to a paralyzing 23.8% estimate on Capital Hill—and the numbers keep rising as revenues lag. If the thought of cut-

ting appropriations, which aren't doing too well anyway, by nearly one-fourth alarms you just hope that it does the same to the negotiators at the budget summit. So far, the two sides seem to be playing a game of chicken.

(25 May 90)

Darman Hopes to Exempt NASA's Huge Increase from Gramm-Rudman. According to *Aviation Week*, the OMB Director wants NASA left out of negotiations at the budget summit. That would increase the burden on everyone else, particularly NSF, which comes under the same appropriations subcommittee. The President's request for a 24% increase in NASA's budget, most of which is targeted for the manned space station, was apparently intended to create a welfare program for the aerospace industry, which faces big defense cuts. In Senate testimony last week, Fred Spilhaus of the American Geophysical Union said he knew of no scientific society prepared to justify space station *Freedom*. Don't look at us.

(25 May 90)

At What Point Does Foolish Science Become Blatant Misconduct? Perhaps when a lawyer is hired to intimidate critics into withholding contradictory evidence. In an article in *Nature* on 29 Mar 90, ten scientists at the University of Utah who were allowed to monitor cold fusion cells in Pons's laboratory reported that over a five-week period last year they found no fusion emissions. Each coauthor has since received a demand from Pons's lawyer that the article be retracted or they will face legal action. And it gets uglier. The *Salt Lake City Tribune* reports that the lawyer has been paid more than $50,000 dollars by the University of Utah for legal work related to cold fusion ($62,000 to date). The stunned coauthors say they undertook the monitoring at the behest of the University. There are reports that scientists involved in assaying the Utah cathodes for helium and at least one journalist have also been threatened with legal action. This challenge to free academic inquiry raises serious questions about the resolve of University of Utah officials to police academic misconduct.

(1 Jun 90)

N. Richard Werthamer Has Been Named to Succeed William Havens, Jr., who will retire in January as Executive Secretary of the American Physical Society after 23 years. Werthamer graduated summa cum laude from Harvard in 1956 and received his Ph.D. in Physics from the University of California, Berkeley, in 1961. He joined Bell Laboratories in 1962, where he was a central figure in developing the theory of quantum crystals of solid helium. He became the first APS Fellow to the U.S. Congress in 1973 and has since held a number of positions in technical management. He is a Fellow of the Society and served on the APS Council and the Panel on Public Affairs. Over the next seven months he will work with Havens to ensure a smooth transition. Today is his first day.

(1 Jun 90)

A Reorganized Education Program at NSF Leaves Shakhashiri Out. NSF Director Erich Bloch today announced a new Directorate for Education and Human Resources with responsibility for managing education and minority programs. Luther Williams, the architect of the reorganization plan, will head the new Directorate. He is former President of Atlanta University. As head of the education directorate, Bassam Shakhashiri was the second most visible personality at NSF. He can't be fired, but it was suggested to him that he might want to return to Wisconsin. Despite this lame-duck status, Bloch is thought to be planning further purges.

(1 Jun 90)

A West German Court Has Dismissed the Gordon-and-Breach Suit against the APS and AIP (WN 9 Mar 90). The suit charged that an article comparing cost effectiveness of physics journals was in fact comparative advertising, which is not permitted in Germany.

(8 Jun 90)

The Electric and Magnetic Field Research and Information Act of 1990 (H.R.4801) has been introduced by Rep. Frank Pallone (D-NJ). The bill would authorize $34M over the next five years to: (1) research health effects of exposure to electric and magnetic fields, (2) find ways to reduce the exposure, and (3) inform the public about what is learned. What scientist would oppose a bill that calls for additional research and an informed public? Much of what the bill calls for, however, is already underway. Last September, the National Cancer Institute undertook a four-year large-scale epidemiological study to look for any possible link between electromagnetic fields and acute lymphocytic leukemia. Manufacturers, meanwhile, are happily selling "low-field" electric blankets and video terminals to worried consumers.

(8 Jun 90)

Utah President Chase Peterson Is Getting It from All Sides. Following disclosure that the source of an "anonymous donation" of $5M to the University's National Cold Fusion Institute was the University of Utah itself (WN 1 Jun 90), the Academic Senate passed a resolution on Monday calling on the Board of Regents to examine whether "continuation in office of the current president is in the best interest of the University and the community it serves." In other action, the Fusion-Energy Advisory Panel, which oversees the state's $5M investment in cold fusion, met yesterday and called for a financial and scientific audit of the program by 20 Aug. No one at the University has ever had a look at Pons's data. If that wasn't enough, Peterson himself reportedly received one of the legal threats from Pons's lawyer (WN 25 May 90).

(8 Jun 90)

Tritium Contamination of the Palladium Used in Cathodes has been identified as the source of some of the persistent "Elvis sightings" that have kept the spark of hope alive in the breasts of cold fusion loyalists. Kevin Wolf, a Texas A&M physicist who has reported small amounts of tritium in cold fusion cells, has traced the origin to a single supplier of palladium. The same palladium

was used at Los Alamos and in the Chemistry Department at A&M by John Bockris. The contaminated palladium does not explain the occasional large tritium bursts reported by Bockris, but the source of that tritium is expected to be revealed soon. Be patient, the long night of cold fusion is almost at an end.

(15 Jun 90)
Utah Faculty Are Reclaiming the University from the Hucksters. On Monday, President Chase Peterson, responding to a vote of no confidence by the faculty senate, announced his early retirement. The following day, the Vice President for Academic Affairs issued a statement affirming the University's "absolute adherence to the principles of academic freedom and free scientific inquiry," and outlining the steps being taken to resolve the issues raised by the attempts of a lawyer to intimidate faculty into recanting findings that contradicted cold fusion claims (WN 25 May 90). The University has severed all connection with the lawyer, a boyhood friend of Pons, and affirmed its obligation to defend its faculty from legal attack. The University has also agreed to a financial audit of the cold fusion effort and to a full scientific review.

(15 Jun 90)
And at Texas A&M, the Word "Fraud" Is Finally Out in the Open. In an article in today's *Science*, stories that have been circulating for months were made public. The article stops just short of pointing a finger, but a strong circumstantial case is made that cold fusion cells in the Chemistry Department at A&M were deliberately spiked with tritium. The A&M administration, which has steadfastly refused to investigate, has now responded by criticizing *Science* for airing the controversy. With the tritium reports impeached, there is not much left of cold fusion claims but a couple of labs that can't seem to get calorimetry straight But stay tuned, the tragicomic story of the double-blind, round-robin helium assay of Pons's cathodes is yet to come out. 'Erratum. Last week, *What's New* identified Kevin Wolf as a physicist, Wolf is a Fellow of the APS, but he is in chemistry.)

(11 Jun 90)
Sen. Danforth (R-MO) Is Again Leading the Fight Against Pork. Thursday, the Senate Rules Committee held hearings on a Danforth resolution to establish a point of order against earmarking research funds for designated institutions without competition. A similar rule in the Armed Services Committee already blocks the earmarking of Defense funds. The Danforth resolution would expand the anti-earmarking fight to cover the entire Federal Government. Unfortunately, Sen. Ford (D-KY), who chairs the Rules Committee, opposes any restriction on earmarking on the grounds that merit review is an "old boy network" that unfairly favors a few major institutions. Ford is unlikely to permit the resolution to come up for a vote. A bill introduced by Danforth with Sam Nunn (D-GA) and Terry Sanford (D-NC) calls for the Comptroller General to review the effectiveness and fairness of agency policies and procedures for distributing Federal funds, but Ford is likely to bottle up that as well. The American Physical Society submitted a statement deploring the funding of scientific projects that have not been subjected to the normal process of proposal submission and expert review.

(22 Jun 90)
A Criminal Investigator in the NSF Inspector General's Office is a sign of the times. In fact, a year ago the NSF didn't even have an IG Office. The second Semiannual Report to Congress by the IG concerns mostly misuse of funds and sloppy record keeping of a generally minor sort, but now a criminal investigator with a background in "economic crime" has been hired who presumably will be stalking bigger prey. The Office has begun a survey of journal editors in an attempt to ascertain the frequency of misconduct involving fabrication, falsification, and plagiarism in reporting research results. The initial conclusion is that editors see very few cases of misconduct and do not keep very good records of them in any case. The report invites whistle blowers to come forward.

(29 Jun 90)
Fang Lizhi, the Dissident Chinese Astrophysicist, Left China this week along with his wife, physicist Li Shuxian, after a year of sanctuary in the American Embassy in Beijing. On Tuesday, they arrived in Britain, where Fang will assume a position at Cambridge University. Last month, the American Physical Society joined with other groups to urge Fang's release (WN 25 May 90). China insists the decision to permit Fang to leave is consistent with its policy of leniency toward leaders of the democracy movement, but most experts connect the action to severe economic problems caused by an end to tourism and the drying up of foreign loans since the Tiananmen Square massacre. As if to prove they still know how to deal with troublemakers, the National People's Congress this week adopted a tough law banning flag burning.

Invitation to Name Candidates for Prizes and Awards

The following prizes and awards will be bestowed at the General Meetings of the Society in 1991, although some will be available for bestowal in the latter part of 1990. Members are invited to nominate candidates to the respective committees charged with the privilege of recommending the prize winners, or, in the case of the Heineman Prize, selecting the winners. Addresses of the Prize Committee Chairpersons to whom

MARCH MEETING HOUSING FORM

1991 MARCH MEETING OF THE AMERICAN PHYSICAL SOCIETY
17–21 March 1991
Cincinnati, Ohio

1. Complete all information requested and mail form to APS-91 Housing Bureau by 22 February 1991. NO PHONE RESERVATIONS WILL BE ACCEPTED.
2. An Acknowledgment of your reservation assignment will be sent by the Housing Bureau within a 2-week period. Check the acknowledgment immediately to be sure all information is correct. The acknowledgment will be followed by the actual confirmation from the hotel.
3. Rooms are held until 6 p.m. on arrival date unless guaranteed for late arrival. Reservations may be guaranteed by supplying major credit card information on this form or by sending a one-night deposit directly to the hotel after confirmation is received from the hotel.
4. All changes and cancellations should be made in writing directly with the Housing Bureau. The phone number of the Housing Bureau is 513 621 2119. This number should be used only for last-minute changes or cancellations. Changes will be on an availability basis after the 22 February 1991 cut-off date.
5. Number all hotels in order of preference. Room assignments are made on first-come, first-serve basis.
6. In the event that all hotels listed are sold out, the Housing Bureau will secure hotel rooms at the next closest available hotel.

* DO NOT MAIL FORM TO AMERICAN PHYSICAL SOCIETY OFFICE IN NEW YORK *

HOTELS & RATES (Number all hotels in order of preference.)

	Single 1 bed 1 person	Double 1 bed 2 persons	Dbl/Dbl 2 beds 2 persons	Triple 2 beds 3 persons	Quad 2 beds 4 persons
____ Hyatt Regency (HQ)	$86.00	$103.00	$103.00	$118.00	$118.00
____ Clarion Hotel	$80.00	$98.00	$98.00	$116.00	$134.00
____ Terrace Hilton	$78.00	$87.00	$130.00 (Jr. Suite)		
____ Westin	$93.00	$99.00	$99.00	$124.00	$149.00
____ Omni Netherland Plaza	$82.00	$92.00	$92.00	$112.00	$132.00

* Suite Rates Available upon Request from Bureau *

Indicate type of room requested: Single ____ Double ____ Dbl/Dbl ____ Triple ____ Quad ____

Arrival Date: _____ Time: _____ Guarantee late arrival: yes ____ no ____

Departure Date: _____ Guarantee to: _____ _____
type of major credit card — expiration date

_____ _____
credit card number — signature

Name of Occupants (Bracket names sharing room)

_____ _____

_____ _____

Person to whom confirmation should be mailed:

Name: _____

Affiliation: _____

Address: _____

City: _____ State: _____ Zip: _____

Phone Number: ( ) _____

Complete and mail form to. APS-91 Housing Bureau, 300 West Sixth Street, Cincinnati, OH 45202

MARCH MEETING PREREGISTRATION FORM **M**

MARCH MEETING OF THE AMERICAN PHYSICAL SOCIETY
18–22 March 1991
Cincinnati, OH

This form *must be received* by 22 February 1991
Please print or type:

Name: _____

APS Membership Number: _____

Affiliation: _____

Address: _____

City: _____ State: _____ Zip: _____

Daytime Telephone Number: _____

I am planning to present a paper at this meeting. Yes No (Circle one)

Preregistration Fees: Circle One	ALL WEEK	ONE DAY Circle One
Member	$140.00	$ 70.00 (M T W Th F)
Unemployed Member	25.00	25.00
Retired Member	25.00	25.00
Graduate Student Member	25.00	25.00
Nonmember	240.00	120.00 (M T W Th F)

APS Half Day Tutorials (Please note that the titles are abbreviated. For additional information, see March Meeting Announcement.) Circle choices:

Computational Advances	($60)	Methods and Applications	($60)
Ultrafast Physics	($60)	Synchrotron Radiation	($60)
Space Groups	($60)	Challenges in Electronics	($60)
Applications/Liquid Crystals	($60)	Electronic Structure	($60)

DHPP Two-Day Short Course "Polymer Surfaces and Interfaces." (See Divisional Announcement for description.) ($250)

COMPANIONS PROGRAM

(Please note. Tours may be cancelled at the discretion of the operator. See announcement for details.)

____ @$39.00 Highlight Tour–Riverboat (3/18) ____ @$34.00 Kentucky Horse Park
____ @$31.00 Historic Lebanon, OH (3/19)

Payment can be made via check, money order, or credit card (American Express, Visa, or MasterCard ONLY). Checks must be in U.S. funds drawn on a U.S. bank. Your payment must accompany this form or it will be returned to you.

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Please note that the corresponding fees at the registration desk on-site are as follows. ALL WEEK. Member–$160, Nonmember $240; Unemployed or Retired Member $25, Graduate Student Member–$25. ONE DAY. Member–$80; Nonmember $120. Nonmembers do not qualify for a preregistration discount. Graduate student members registering on-site must present student ID.

PREREGISTRATIONS RECEIVED AFTER THE 22 FEBRUARY 1991 DEADLINE WILL NOT BE PROCESSED AND WILL BE RETURNED TO THE SENDER. PREREGISTRATION FORMS THAT ARRIVE WITHOUT PAYMENT, OR PAYMENT THAT ARRIVES WITHOUT THE PREREGISTRATION FORM, ALSO WILL BE RETURNED TO THE SENDER.

Send this form and your payment to: The American Physical Society
March Meeting Preregistration
335 East 45th Street
New York, NY 10017

Hotel reservations are handled separately. **WE ARE NOT RESPONSIBLE FOR HOUSING FORMS THAT ARE SENT TO THIS OFFICE.**

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Account Number - H0441

Delta Airlines is offering the attendees to the 1991 March Meeting of The American Physical Society **SPECIAL DISCOUNT RATES** to attend the upcoming meeting in Cincinnati, OH. These rates are available through Delta Airlines as the official airline for the 1991 March Meeting. They are offering the following discounts to our attendees:

40% Off Regular Coach Fare
5% Off Any Restricted Fare

To get these discounts, you need to use the following account number when booking your flight:

H0441

These rates are subject to the advance purchase requirements of Delta Airlines, so book your flight soon. These rates also are subject to the following restrictions:

—No Stayovers between the meeting site and your destination, or departure city.
—These offers are good only for travel to and from the March Meeting, from 14 March 1991 to 25 March 1991.
—These offers are good only for travel within the continental United States.

Please call this toll-free number **1-800-241-6760** between 8:00 A.M. and 8:00 P.M. Eastern Time.

Don't forget—you must use the account number (H0441) to procure these special discounts.

nominations should be sent are given below.

AWARDS

1991 SHOCK COMPRESSION SCIENCE AWARD

Sponsored by Friends of the Topical Group on Shock Compression of Condensed Matter Physics.

Purpose. To recognize contributions to understanding condensed matter and nonlinear physics through shock compression.

Nature: This award, to be presented biennially, consists of a plaque citing the accomplishments of the recipient, an allowance for travel to the meeting at which it is given, and a cash award of $2000.

Establishment and Support. The award was established in 1987 by the Friends of the Topical Group on Shock Compression of Condensed Matter Physics.

Rules and Eligibility: All members of the scientific community are eligible for nomination. A single award normally will be given to no more than one individual and will be presented at the biennial Topical Conference.

Send name of proposed candidate and supporting information to Malcom F. Nicol, Department of Chemistry and Biochemistry, University of California, Los Angeles, California 90024-1569, to arrive before 1 February 1991.

Recipients of Prizes and Awards of the American Physical Society

1990 AWARD FOR EXCELLENCE IN PLASMA RESEARCH

Dr. E. Michael Campbell of Lawrence Livermore National Laboratory, Dr. Peter L. Hagelstein of Massachusetts Institute of Technology, Dr. Dennis L. Matthews of Lawrence Livermore National Laboratory, Dr. Mordecai D. Rosen of Lawrence Livermore National Laboratory, and Dr. Szymon Suckewer of Princeton University have been named the recipients of the 1990 Award for Excellence in Plasma Research. The award will be presented at the annual meeting of The America Physical Society's Division of Plasma Physics, 12–16 November 1990, in Cincinnati, Ohio. The citation reads, "For the first laboratory demonstration of a soft X-Ray Laser, achieved through pioneering laser target design, theoretical modeling of the states of highly ionized atoms in laser-produced plasmas, and novel spectroscopic diagnostics of such plasmas."

1990 JAMES CLERK MAXWELL PRIZE IN PLASMA PHYSICS

Dr. William L. Kruer of Lawrence Livermore National Laboratory has been awarded the 1990 James Clerk Maxwell Prize in Plasma Physics. The prize will be bestowed at the annual meeting of The American Physical Society's Division of Plasma Physics, 12–16 November 1990, in Cincinnati, Ohio. The citation reads, "For outstanding and seminal contributions to the theoretical and experimental understanding of the interaction of intense electromagnetic waves with plasmas and for numerous contributions to the understanding of basic plasma phenomena via numerical simulation."

THE 1990 SIMON RAMO AWARD

Dr. Margaret Murnane has been named recipient of the 1990 Simon Ramo Award for Outstanding Doctoral Thesis Research in Plasma Physics, sponsored by TRW and the American Physical Society's Division of Plasma Physics. The award will be presented at the Division of Plasma Physics annual meeting, 12–16 November 1990, in Cincinnati, Ohio. The citation reads, "For all aspects of a benchmark experiment opening up the new field of high-density, high-temperature plasmas created by ultrashort laser pulses."

Announcements of General Meetings

1991 MARCH MEETING OF THE AMERICAN PHYSICAL SOCIETY
18–22 March 1991
Cincinnati, Ohio

The 1991 March Meeting of The American Physical Society will be held in Cincinnati, OH, 18–22 March 1991. The Hyatt Regency Cincinnati Hotel has been designated the headquarters hotel, although most of the technical sessions will be held just across the street in the Cincinnati Convention Center. Sleeping rooms will be provided by the Hyatt Regency, the Clarion Hotel, the Terrace Hilton Hotel, the Westin Hotel, and the Omni Netherland Plaza Hotel. The housing form is on page 1598. The deadline for housing and preregistration is 22 February 1991.

HOTEL RESERVATIONS FORM

THIRTY-SECOND ANNUAL MEETING
AMERICAN PHYSICAL SOCIETY-DIVISION OF PLASMA PHYSICS
12-16 November 1990; Cincinnati, OH

1. Complete all information requested and mail form to APS Housing Bureau by October 19. NO PHONE RESERVATIONS WILL BE ACCEPTED.

2. An Acknowledgement of your reservation assignment will be sent by the Housing Bureau within a 2 week period. Check the acknowledgement immediately to be sure all information is correct. The acknowlegement will be followed by the actual confirmation from the hotel.

3. Rooms are held until 6 p.m. on arrival date unless guaranteed for late arrival. Reservations may be guaranteed by supplying major credit card information on this form or by sending a one nights deposit directly to the hotel after confirmation is received from the hotel.

4. All changes and cancellations should be made directly with the Housing Bureau in writing. The phone number for the Housing Bureau is 513/621-2119. This number should be used only for last minute changes or cancels.

5. Number all hotels in numerical order of preference. Room assignments are made on first-come, first serve basis.

6. In the event that all hotels listed are sold out, the Housing Bureau will secure hotel rooms at the next closest available hotel.

* DO NOT MAIL FORM TO AMERICAN PHYSICAL SOCIETY OFFICE IN NEW YORK *

HOTEL & RATES (Number all hotels in order of preference.)

	Single 1 bed 1 person	Double 1 bed 2 persons	Dbl/Dbl 2 beds 2 persons	Triple 2 beds 3 persons	Quad 2 beds 4 persons
_____HYATT REGENCY (HQ)	$86.00	$99.00	$99.00	$114.00	$129.00
_____CLARION HOTEL	$72.00	$86.00	$86.00	$101.00	$116.00
_____TERRACE HILTON	$76.00	$85.00	$130.00 (JR. SUITE)		

* SUITE RATES AVAILABLE UPON REQUEST FROM BUREAU *

Indicate type of room requested:

Single_____Double_____ Dbl/Dbl_____ Triple_____ Quad _____

ARRIVAL DATE _____ TIME _____ Guarantee late arrival: yes ___ no___

DEPARTURE DATE _____ Guarantee to: _____
type of major credit card

_____ _____
credit card number expiration date

NAME OF OCCUPANTS (Bracket names sharing room)

_____ _____

_____ _____

Person to whom confirmation should be mailed:

Name _____

Company _____

Address _____

City_____ State_____ Zip _____

Phone Number ( ) _____

Complete & Mail Form to:

APS Housing Bureau
300 West Sixth Street
Cincinnati, OH 45202

PREREGISTRATION FORM

Thirty-Second Annual Meeting
American Physical Society—Division of Plasma Physics
12–16 November 1990
Cincinnati, Ohio

This form must be received by 19 October 1990.

Please print or type:

Name: _____

Affiliation: _____

Address: _____

City: _____ State: _____ Zip: _____ Country: _____

Preregistration Fees (Circle One):

United States Participants		Overseas Participants (Pay On-Site)	
Member	$ 80.00	Member	$ 80.00
Nonmember	$120.00	Nonmember	$120.00
Retired/Unemployed Member	$ 20.00	Retired/Unemployed Member	$ 20.00
Graduate Student Member	$ 20.00	Graduate Student Member	$ 20.00
_____ (# of) Banquet Tickets @	$ 20.00	_____ (# of) Banquet Tickets @	$ 20.00

(Note. Overseas preregistration fees are honored only if we have received the form prior to the 19 October 1990 deadline.)

TOURS

(Note. Tours must be paid for to be reserved. This includes overseas participants. Tours may be cancelled at the discretion of the operator.)

Cincinnati Historical Tour	(11/12)	$33.00	_____ # of Tickets
Shakertown Tour	(11/13)	$40.00	_____ # of Tickets
Washington/Kentucky	(11/14)	$30.00	_____ # of Tickets

☐ AMERICAN EXPRESS ☐ MASTERCARD ☐ VISA	CREDIT CARD NUMBER	EXPIRATION DATE	AUTHORIZED SIGNATURE

Payment can be made via check, money order, or credit card (American Express, Visa, or MasterCard ONLY). Checks must be in U.S. funds drawn on a U.S. bank. Your payment must accompany this form or it will be returned to you.

Please note that the corresponding fees at the registration desk on-site are as follows. Member, $100, Nonmember, $150, Unemployed or Retired Member, $20; Graduate Student Member, $20. Graduate Student Members registering on-site must present student ID.

PREREGISTRATIONS RECEIVED AFTER THE 19 OCTOBER 1990 DEADLINE WILL NOT BE PROCESSED, AND WILL BE RETURNED TO THE SENDER. PREREGISTRATION FORMS THAT ARRIVE WITHOUT PAYMENT, OR PAYMENT THAT ARRIVES WITHOUT THE PREREGISTRATION FORM, WILL ALSO BE RETURNED TO THE SENDER.

Send this form and your payment to: The American Physical Society
DPP '90 Meeting Preregistration
335 East 45th Street
New York, NY 10017

REFUNDS OR ADJUSTMENTS WILL BE GIVEN IF THE REQUEST IS SUBMITTED IN WRITING, AND ARRIVES IN THE APS OFFICE BY 2 NOVEMBER 1990. AFTER THAT DATE, THEY MAY BE OBTAINED AT THE DISCRETION OF THE DIVISION OF PLASMA PHYSICS SECRETARY/TREASURER.

DELTA

We Love To Fly And It Shows.™

DELTA AIRLINES SPECIAL DISCOUNT RATES FOR THE THIRTY-SECOND ANNUAL MEETING OF THE AMERICAN PHYSICAL SOCIETY'S DIVISION OF PLASMA PHYSICS
12–16 NOVEMBER 1990
CINCINNATI, OH

Account Number - U0039

Delta Airlines is offering the attendees to The American Physical Society's Division of Plasma Physics (DPP) Meeting **SPECIAL DISCOUNT RATES** to attend the upcoming meeting in Cincinnati, OH. These rates are available through Delta Airlines as the official airline for the Thirty-Second Annual DPP Meeting. They are offering the following discounts to our attendees:

40% Off Regular Coach Fare
5% Off Any Restricted Fare

To get these discounts, you need to use the following account number when booking your flight:.

U0039

These rates are subject to the advance purchase requirements of Delta Airlines, so book your flight soon. These rates also are subject to the following restrictions:

—No Stayovers between the meeting site and your destination, or departure city.
—These offers are good only for travel to and from the DPP Meeting, from 8 November 1990 to 19 November 1990.
—These offers are good only for travel within the continental United States.

Please call this toll-free number **1-800-241-6760** between 8:00 A.M. and 8:00 P.M. Eastern Time.

Don't forget—you must use the account number (U0039) to procure these special discounts.

SATELLITE MEETING ROOM RESERVATION FORM

AMERICAN PHYSICAL SOCIETY—DIVISION OF PLASMA PHYSICS ANNUAL MEETING
12–16 NOVEMBER 1990—CINCINNATI CONVENTION CENTER, CINCINNATI, OHIO

Please fill out this form completely, and return no later than 19 October.

Name: _____

Affiliation: _____

Address: _____

City: _____ State: _____ Zip: _____

Daytime Phone Number: _____

Name of Meeting: _____

Meeting Date: _____ Start Time: _____ End Time: _____

Room Setup: (Theater, conference) _____ Attendance: _____

Food Service?: _____ Audio Visual Required?: _____

Name and Address for billing purposes (only if different from information atop this page):

Name: _____

Address: _____

Please return this form to:

Mr. Michael Scanlan
APS-DPP '90
335 East 45th Street
New York, NY 10017

The deadline for the submission of contributed abstracts for the regular program is 30 November 1990. All abstracts should be sent to Dr. W. W. Havens, Jr., The American Physical Society, 335 East 45th Street, New York, NY 10017. Abstracts must be submitted in triplicate, and must arrive in this office before 17:00 on 30 November 1990 for inclusion in the program. As always, the abstracts must conform to the rules and guidelines for the submission of abstracts as published in the *Bulletin* (see page 1629).

Only APS members may submit abstracts of papers to APS meetings. This year, for the first time, the APS membership number is requested on the abstract, for statistical purposes only. The APS membership number is on the top line of the mailing label on every member's *Physics Today* and *Bulletin of The American Physical Society,* and all other mailings, including the dues bill.

Division of High Polymer Physics

The Division of High Polymer Physics will be meeting in conjunction with the General Meeting again this year. Their announcement appears on page 1611 of the *Bulletin.* They will also be sponsoring a two-day short course, entitled "Polymer Surfaces and Interfaces." A tentative syllabus can be found on page 1611.

Tutorials

Once again, half-day tutorials are being offered at the March Meeting. They are scheduled on the morning and afternoon of Sunday, 17 March. A list of subjects and lecturers follows. The cost of the tutorials includes a continental breakfast and coffee, or an afternoon snack and coffee. Tutorial times and locations will be published in subsequent announcements.

Computational Advances in Condensed Matter Physics. *John Joannopoulos, MIT.*

Ultrafast Physics of Semiconductors. *Daniel S. Chelma, AT&T Bell Laboratories.*

Methods and Applications of Nanofabrication. *Harold G. Craighead, Cornell University.*

Synchrotron Radiation in the 1990s: Resonant Scattering Time Resolved Studies and Imaging. *Denis B. McWhan, Brookhaven National Laboratory.*

A Practical Guide to Space Groups for Solid State Scientists. *Gerald Burns, IBM Thomas J. Watson Research Center.*

Limits and Challenges in Electronics. *R. W. Keyes, IBM Thomas J. Watson Research Center.*

Science and Applications of Polymer Dispersed Liquid Crystals. *J. W. Doane, Kent State University.*

Electronic Structure in Transition Metal Oxides. *John B. Goodenough, University of Texas.*

Program Notes

In addition to the Ceremonial and Prize Winners sessions, a total of 76 symposia are being arranged. Listed below are the number of invited sessions organized by the individual Divisions, Topical Groups, Committees, and Forum:

Condensed Matter Physics	40
Applications of Physics	10
Chemical Physics	7
Instrument & Measurement Science	4
Biological Physics	4
Material Physics	2
Laser Science	2
Fluid Dynamics	2
International Physics Group	1
Forum	3
Committee on Education	1

Air Travel to the Meeting

The official airline carrier for the March Meeting is Delta Airlines. They are offering attendees a 40% discount on coach fares and a 5% discount on restricted fares. For more information, see the announcement on page 1600.

Exhibit & Placement Center

The American Institute of Physics will sponsor an Exhibit Show and Placement Center at the meeting. The Exhibit will run from Tuesday, 19 March 1991 to Thursday, 21 March 1991. For more information concerning the exhibit, please contact Mr. Ed Greeley, AIP, Advertising Division, 335 East 45th Street, New York, NY 10017 (212-661-9404). The Placement Center, where interviews are arranged between prospective employees and employers, will be open Monday through Thursday. Further information can be obtained from Beverly Citrynell, Placement Center, AIP, 335 East 45th Street, New York, NY 10017 (212-661-9404).

Announcements of Divisional Meetings

THIRTY-SECOND ANNUAL MEETING OF THE DIVISION OF PLASMA PHYSICS
Cincinnati, Ohio
12–16 November 1990

The scientific program will be divided into nine half-days of review, invited, and contributed papers. Review papers will be given in a daily plenary session. Invited papers will be given each morning and afternoon at the same time as the contributed papers.

Conference preregistration will offer a substantial discount if received before 19 October 1990.

Accommodations will be at the Hyatt Regency, Clarion, and Terrace Hilton. The Hyatt Regency is the headquarters hotel for this meeting.

Deadline for discounted rates is 19 October 1990.

Program Committee

Noah Hershkowitz,
Chairman (U. Wisconsin)
(608) 263-4970, fax. 262-6707
William Barletta (UCLA)
(213) 206-4541
Abraham Bers (MIT)
(617) 253-4195
Tom Chang (MIT)
(617) 253-7523
Nathanial Fisch (PPPL)
(609) 243-2643
Thomas Jarboe (U. Wash.)
(206) 534-4333
Glenn Joyce (NRL)
(202) 767-6785
Michael Manuel (Columbia U.)
(212) 854-4455
George Morales (UCLA)
(213) 825-4318
Christof Ritz (U. Texas)
(512) 471-3675
Paul Terry (U. Wisconsin)
(608) 263-0487
Wolf Seka (U. Rochester)
(716) 275-3815
Henry Straus (NYU)
(212) 998-3268
Mary Ann Sweeney (Sandia)
(505) 844-6354

Local Arrangements

Ronald Gilgenbach (U. Michigan)
(313) 763-1261; fax: 763-4540

APS Meetings Department

Michael Scanlan (212) 682-7341

Late abstracts will not be accepted because of the deadline for printing the *Bulletin*. Abstracts must be prepared in strict compliance with the rules of the American Physical Society, as published in the APS *Bulletin*. Please review these guidelines carefully before submitting the abstract. The first author is expected to present the paper and each contributor can be a first author only once; additional papers with the same first author will be assigned to the supplementary program. For uniformity, please use 12-pitch type in the Prestige Elite typeface if possible. Spacing and capitalization should conform to the *Bulletin* instructions and the following information should appear on the same page as the abstract: (a) Subject heading(s); (b) preference for oral or poster session; (c) Special requests for placement of abstracts (e.g., relative to other abstracts) (no guarantee can be made on placement requests), (d) requests for special audio-visual equipment (see below); and (e) signature of an author who is an APS member or, if no author is a member, the signature of a member sponsoring the paper's submission.

Registration

Preregistration will offer substantial savings if the forms on pages 1603 and 1602 are received by the APS before **19 October 1990**. Forms received after the deadline will be returned.

Fee Schedule

Preregistration	
APS Members	$80.00
Nonmembers	$120.00
Students and Retirees	$20.00
Overseas Members	$80.00
Overseas Nonmembers	$120.00
On-site Registration	
APS Members	$100.00
Nonmembers	$150.00
Students and Retirees	$20.00
Overseas Members	$80.00
Overseas Nonmembers	$120.00

Satellite Meeting Rooms

Reservations for Satellite Meeting Rooms must be received by the deadline of **5 October 1990** by Mr. Michael Scanlan, American Physical Society, 335 East 45th Street, New York, NY 10017; telephone: (212) 682-7341. Specify desired date, time, number of attendees, desired food service, and method of payment.

Special Audio-Visual Equipment

Requests for audio-visual equipment, other than overhead projectors and 35-mm slide projectors, as well as any audio-visual requests for poster sessions or meetings must be received in writing by Michael Scanlan before the deadline of **19 October 1990.**

Banquet

The conference banquet will be held on Wednesday evening, 14 November. Heavily subsidized tickets can be purchased for $20 by preregistration or at registration on a space-available basis. The Division reserves the right to limit the number of subsidized tickets and all sales are nonrefundable. Tickets must be presented for admission at the door to the banquet room. A no-host cocktail reception will precede the banquet. The banquet program will include presentation of the Maxwell Prize, the Excellence in Plasma Physics Award, the Simon Ramo Award, and the recognition of new fellows. The guest speaker will be announced in the *Bulletin*.

Accommodations

Accommodations will be at the Hyatt Regency (headquarters), Clarion, and Terrace Hilton. All hotels are within a short walking distance (via skyways) from the Cincinnati Convention Center. Room rates have been discounted and are given in the reservation form. In order to obtain these special rates, the hotel reservation form on page 1602 must be received by **19 October 1990.**

Hotel	Single	Double
Hyatt Regency	$82	$99
Clarion	$72	$86
Terrace Hilton	$76	$85

The Hyatt Regency and the Clarion are both located across the street from the conference center. The Terrace Hilton is located two blocks from the conference center. A large number of restaurants are located within several blocks of the conference center; lists will be provided at registration.

Transportation

The Greater Cincinnati International Airport is located about 12 miles from the hotel and conference center. Discounted airfare is available (see page 1604). Taxi and coach service are available for the 15-minute trip to the hotel. Parking is

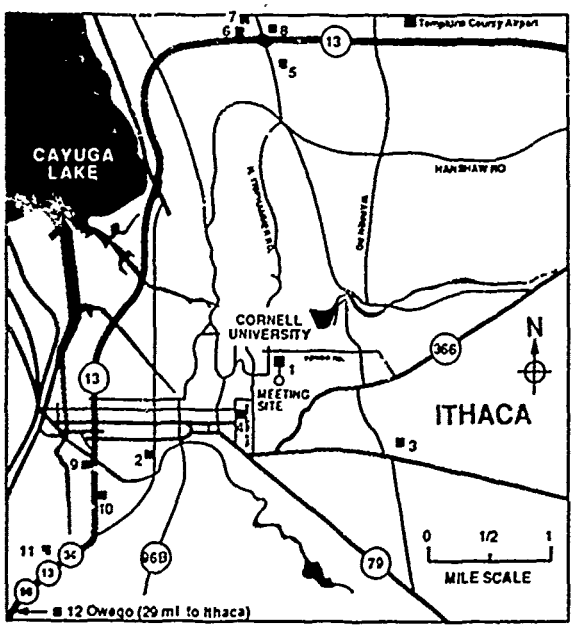
ACCOMMODATION INFORMATION
43rd Annual Meeting, Division of Fluid Dynamics
Cornell University
Ithaca, New York
18-20 November 1990

1.	STATLER INN The East Avenue, Ithaca, NY 14853 The meeting will be held at the Statler. Free Airport transportation.	1-800-541-2501 or 607-254-2602 Single/Double: $95.00 - $108.00
2.	RAMADA INN/DIVI 222 S. Cayuga St., Ithaca 14850 Free airport transportation	1-607-272-1000 Single/Double: $55.00-$85.00
3.	BEST WESTERN UNIVERSITY INN East Hill Plaza Free airport transportation	1-607-272-6100 Single/Double: $50.00
4.	COLLEGETOWN MOTOR LODGE 312 College Avenue	1-800-666-7666 or 607-273-3542 Single/Double: $59.00-$87.00
5.	SHERATON INN One Sheraton Drive Free airport transportation	1-607-257-2000 Single/Double: $66.00
6.	HOWARD JOHNSON LODGE 2300 N. Triphammer Rd.	1-607-257-1212 Single/Double: $50.00-$60.00
7.	HOLIDAY INN 2310 N. Triphammer Rd. Free airport transportation	1-607-257-3100 Single/Double: $60.00-$65.00
8.	ECONO LODGE 2303 N. Triphammer Rd.	1-607-257-1400 Single/Double: $38.00-$48.00
9.	SUPER 8 MOTEL 400 S. Meadow St.	1-607-273-8088 Single/Double: $36.88-$42.88
10.	MEADOW COURT MOTEL 529 S. Meadow St.	1-607-273-3885 Single/Double: $50.00-$55.00
11.	JOURNEY'S END 356 Elmira Rd.	1-607-272-0100 Single/Double: $47.88-58.88
12.	OWEGO TREADWAY RT. 17C, Owego, NY 13827	1-607-687-4500 Single/Double: $50.00- $55.00

All rates are subject to a 10% tax. A Bed & Breakfast list is available from the Meeting Secretary.

For the convenience of conference participants, blocks of rooms have been reserved and special rates arranged at nearby hotels and motels. Hotel accommodations are not included in the conference fee and are the responsibility of the individual attendee. **It is necessary to indicate that you are attending the American Physical Society's Meeting when making reservations.** Early booking is advised since most hotels will release any unsold rooms on October 17, 1990.

Taxi fare from the Ithaca Airport to the hotels is approximately $6. Transportation between hotels and meeting site will be provided during meeting hours. Parking is available on Campus on Sunday. Paid visitors parking ($6/day) should be available on Monday and Tuesday.



REGISTRATION FORM

43rd Annual Meeting, Division of Fluid Dynamics
18-20 November 1990
Cornell University
Ithaca, New York

Advance registration is encouraged. Accordingly, a reduced registration fee of $100 for APS members, $140 for non-members and $65 for students will be charged if preregistration is received on or before 30 September 1990. The regular registration fees are $130, $190 and $85, respectively.

Hotel accommodations and meals are not covered by the registration fee. Refreshment service will be provided during the meetings.

Check or money order (in US Dollars) made out to: **CORNELL UNIVERSITY** should be mailed with registration form to:

APS/DFD
P. O. Box No. 637
Ithaca, NY 14851

Registration and reservations should be sent in as soon as possible.

cut here mail below

REGISTRATION FORM - 43 Ann. Meeting, Division of Fluid Dynamics, American Physical Society

Name: _____ Date_____

Affiliation: _____

Title: _____ Phone: ( )_____

Address: _____

_____

I would like to register for the 43rd Annual DFD Conference to be held 18-20 November 1990. I enclose.

	Preregistration On or before 30 September		After	
Registration Fee (Members)	☐	$100	☐	$130
Registration Fee (Non-Members)	☐	$140	☐	$190
Registration Fee (Students)	☐	$65	☐	$85
Conference Banquet (Monday evening)	☐	$35		

Total Amount Enclosed: $____

available for $8/day in private structures adjacent to the Hyatt.

Guest Tours

Information is provided on the preregistration form (page 1603).

Plasma Fusion Show

Commerical exhibits will be on display in the Conference Center from Tuesday, 13 November, through Thursday, 15 November.

FORTY-THIRD ANNUAL MEETING OF THE DIVISION OF FLUID DYNAMICS

Ithaca, New York
18–20 November 1990

First Announcement and Call for Papers

The Forty-Third Annual Meeting of the Division of Fluid Dynamics will be hosted by Cornell University. The organizing, program, and arrangements committees consist of Professors D. A. Caughey, P. T. DeBoer, S. Jones, D. L. Koch, S. Leibovich, J. L. Lumley (Chair), F. K. Moore, M. S. Nelkin, W. L. Olbricht, S. B. Pope, E. L. Resler, Jr., R. N. Sudan, S. F. Shen, Z. Warhaft, and C. H. K. Williamson.

The meeting will be headquartered and all scientific sessions held in the Statler Hotel on the Cornell campus. Alternate hotels are identified in the accommodation information form. Shuttle buses will run between these hotels and the campus during the meeting. Please note that the meeting will begin Sunday morning and end Tuesday evening. A conference dinner is planned for Monday evening on the Cornell campus.

The scientific program will consist of invited lectures and contributed papers. On Sunday afternoon, the ONR Prize will be received by Professor John L. Lumley of Cornell, the 1990 Otto Laporte Memorial Lecture will be presented by Professor Tony Maxworthy, University of Southern California, and this will be followed by a reception. During the meeting, invited lectures will be given by D. Bushnell (NASA Langley), R. J. Donnelly (University of Oregon), P. G. de Gennes (Ecole Supérieure de Physique et de Chimie, Paris), M. Farge (Ecole Normale Supérieure, Paris), E. J. Hopfinger (University of Grenoble), L. G. Leal (University of California at Santa Barbara), R. S. Lindzen (M.I.T), S. B. Pope (Cornell), U. Schumann (DFVLR), and K. R. Sreenivasan (Yale).

Contributed papers are solicited in all areas of fluid dynamics. Recent topics have included general fluid dynamics, hydrodynamic stability, boundary layers, transition and turbulence, chaos, jets, wakes, mixing layers, separated flows, aerodynamics, aeroacoustics, thermal convection, heat transfer, viscous flows, rotating and stratified flows, geophysical flows, biofluid dynamics, hypersonics, magnetohydrodynamics, compressible flows, non-Newtonian fluids, quantum fluids, films, combustion, reacting flows, suspensions, vortex dynamics, multiphase flow, flow in porous media, computational fluid dynamics, and experimental techniques.

Advance registration is encouraged. Accordingly, a reduced registration of $100 for APS members, $140 for nonmembers, and $65 for students will be charged if preregistration is received on or before 30 September 1990. The regular registration fees are $130, $190, and $85, respectively. The banquet is not included in this fee. The forms for registration and accommodations are found on pages 1608 and 1609.

The Eighth Annual Picture Gallery of Fluid Motion will be held during the meeting; entries are invited. The Gallery will include computational fluid dynamics entries, and entries in video format. A description of all entries must be *received* no later than 30 September 1990. Video equipment is limited, and all video requirements must be discussed with Mary Helen Cathles at (607) 255-8010, or by fax at (607) 255-1222 *at the time the entry is submitted.*

The Tompkins County Airport is served by U.S. Air, TWA, Continental, and Mohawk. It also is possible to fly to Syracuse International Airport, and take a taxi or rental car to Ithaca (about 1.25 hours distant). Binghamton is also a possibility at about the same distance; Rochester is about two hours distant by car. Limousine service and taxi service are available from the Tompkins County airport to area hotels (approximate cost is $6–10) and several car rental agencies are located at the airport. Note that this meeting occurs during Thanksgiving week, and that there will be heavy student use of all transportation facilities due to the long weekend. In addition, on Saturday, 17 November, Cornell plays the University of Pennsylvania at Cornell, and this will probably be one of our best-attended games. Significant airline savings are possible if you stay over Saturday night; the meeting begins at 9:00 a.m. on Sunday. At this time of year the weather in Ithaca is highly variable; the average high temperature for this period is 42° F and the low is 28° F.

Questions regarding any aspect of the conference should be directed to the conference secretary, Mary Helen Cathles, at APS/DFD, P.O. Box 637, Ithaca, NY 14851, or at (607) 255-8010 or by fax at (607) 255-1222.

Sorting Categories

1. Turbulence
   (a) Turbulent Jets
   (b) Turbulent Boundary Layers
   (c) Turbulent Wakes
   (d) Compressible Mixing Layers
   (e) Incompressible Mixing Layers
   (f) Free-Shear Layer Control
   (g) Turbulence Simulation
   (h) Turbulence Theory
   (i) Turbulence Modeling
   (j) Turbulent Boundary Layer Control
   (k) Turbulent Convection
   (l) Turbulent Mixing
2. Stability
   (a) 2D Boundary Layer Stability
   (b) 3D Boundary Layer Stability
   (c) General Stability

(d) Free-Shear Layer Instabilities
(e) Convective Instabilities
(f) Rayleigh-Taylor Instability
(g) Taylor-Couette Instabilities
(h) Instabilities of Thin Films
(i) Instabilities of Jets and Wakes
(j) Control of Boundary Layer Instabilities
(k) Interfacial Instability
(l) Secondary Instabilities
(m) Compressible Boundary Layer Instabilities
(n) Richtmeyer-Meshkov Instability
(o) Channel Flow Instabilities
3. Reacting Flows—Experiment
4. Reacting Flows—Theory and Modeling
5. Computational Fluid Dynamics
6. Viscous Flows
7. Acoustics
8. Geophysical Fluid Dynamics
9. Chaos
10. Vortex Dynamics
11. Suspensions
12. Separated Flows
13. Aerodynamics
14. Multiphase Flows
15. Drops and Bubbles
16. Shock Waves, Detonations, and Deflagrations
17. Experimental Techniques
18. Waves
19. Compressible Flows
20. Rotating Flows
21. Flow in Porous Media
22. Boundary Layer Receptivity
23. Pattern Selection
24. Laminar Flows
25. Surface Tension
26. Graphics and Visualization
27. Hypersonic Flows
28. Buoyancy Driven Flows
29. 3D Vortex Flows
30. Non-Newtonian Flows
31. Materials Processing
32. Particle Laden Flows.
33. Local Disturbances
34. Fractals
35. Hele-Shaw Flow
36. Computational Methods

1991 REGULAR MEETING OF THE DIVISION OF HIGH POLYMER PHYSICS
Cincinnati, Ohio
18–22 March 1991

The 1991 Regular Meeting of the Division of High Polymer Physics will once again be held jointly with the General Meeting of the Society, 18–22 March 1991. The meeting will be held in the Cincinnati Convention Center, and the Hyatt Regency has been designated as the Headquarters Hotel. Both invited and contributed papers will be scheduled. Abstracts of contributed papers intended for presentation at sessions of the Division should be sent (in triplicate) to the program chairman, Jeffrey Koberstein, Institute of Materials Science, U-136, University of Connecticut, Storrs, CT 06269-3136, to reach his office by the deadline of *16 November 1990.* Please note that this date is *two weeks* in advance of the deadline for the receipt of abstracts for the General Meeting of the Society. Contributors are reminded that abstracts must be prepared in strict accordance with the rules governing the submission of abtracts, published in this *Bulletin* on page 1629. Information regarding housing and preregistration can be found in the announcement of the General Meeting, on page 1601.

The Division is also sponsoring a short course, prior to the meeting, on 16–17 March 1991. The title of the short course is "Polymer Surfaces and Interfaces," and the $250 cost includes coffee breaks in the morning and afternoon on both days. The course is being organized by Matthew Tirrell, University of Minnesota. A tentative syllabus and lecturers follows.

Introduction and Overview. M. Tirrell.

Chemistry of Polymer Surfaces and Interfaces. T. J. McCarthy, *University of Massachusetts.*

Physical Structure of Polymer Surfaces and Interfaces. T. P. Russell, *IBM* and F. S. Bates, *University of Minnesota.*

Adsorbed Polymer Layers. M. Tirrell.

Theory of Polymer Surfaces and Interfaces. G. H. Frederickson, *University of California, Santa Barbara.*

Applications: Colloidal Stability. M. Tirrell.

Strength and Adhesion at Interfaces. H. R. Brown, *IBM.*

Polymer Interdiffusion and Segregation. E. J. Kramer, *Cornell University.*

Microphase Separation in Block Copolymers. F. S. Bates, *University of Minnesota.*

Polymer Dynamics in Adsorption and Lubrication. S. Granick, *University of Illinois.*

Announcements of Sectional Meetings

1990 FALL MEETING OF THE NEW YORK STATE SECTION
Poughkeepsie, New York
19–20 October 1990

The 1990 Fall Meeting of the New York State Section of the American Physical Society will be held on Friday and Saturday, 19–20 October 1990, at the IBM Country Club near Poughkeepsie, NY.

Friday, 19 October 1990

8:00 Registration.
8:45 Opening. Martin A. Abkowitz, Chair NYS Section, APS.
Welcome.

Session I. Science Applications of Supercomputers.
A. Goland, presiding

9:00–9:30 J. Davenport, Brookhaven National Laboratory *First Principles Molecular Dynamics Studies of Liquid and Solid Sodium.*
9:40–10:10 J. Kogut, University of

PREREGISTRATION FORM

Deadline 2 October 1990

1990 Joint Spring Meeting of the Texas Sections of APS and AAPT and SPS Zone 10
9–10 November 1990
College of the Mainland
Texas City, Texas

Name: _____ Phone: ( ) _____
(for Name Badge)

Address: _____

_____

_____

Institutional Affiliation: _____
(if not given above)

Check if member of: APS ____ AAPT ____ SPS ____
Do you wish to have your registration fee also include a year's membership in the Texas Section of the AAPT? Yes ____ No ____

Preregistration is necessary to obtain tickets for meal functions.

The program will be mailed out to preregistrants prior to the meeting.

Registration Fee: Regular	$15.00	
Student	$ 5.00	_____
Department Chair Breakfast (Friday morning, 9 November)	_____@$ 6.00	_____
Luncheon (Friday noon, 9 November)	_____@$ 6.50	_____
Banquet (Friday evening, 9 November)	_____@$12.00	_____
	TOTAL	$_____

Make checks payable to "Texas Section AAPT" and mail to be received by 2 October 1990 to:

John L. Hubisz
College of the Mainland
1200 Amburn Road
Texas City, TX 77591
(409) 938-1211 x325 (after 27 August 1990)
(409) 938-4098 (summer, evenings, and weekends)

Illinois. *Simulating Quantum Chromodynamics on a Supercomputer.*
10:20 Coffee break.
10:50–11:20 S. Broyde, New York University. *DNA Structures and Interaction of Carcinogens with DNA.*
11:30–12:00 S. Shapiro, Cornell University. *Building Black Holes: Supercomputer Cinema.*
12:10 Lunch.

Session II. Supercomputer—Architecture and Performance
W. Heller, presiding

2:00–2:30 G. Fox, Syracuse University. *Parallel Computing Architecture and Software.*
2:40–3:10 J. Caviness, National Science Foundation. *Networks for Scientific Computing.*
3:20 Coffee break.
3:50–4:20 M. Kalos, Cornell University. *Perspectives of Scientific Computing.*
4:30–5:00 W. Wilcke, IBM Research, Yorktown Heights. *VICTOR: A Message-Passing Computer.*
6:15 Social hour.
7:15 Banquet.
8:15 Public Lecture.

Saturday, 20 October 1990

Session III. Science Applications of Supercomputers.
D. Awschalom, presiding

9:00–9:30 M. Dupuis, IBM, Kingston. *Supercomputers for Computational Chemistry.*
9:40–10:10 K. Jensen, MIT. *Supercomputer Simulation of 3D Fluid Flow and Materials Processing.*
10:20 Coffee break.
10:50–11:20 R. Wetherald, Geophysical Fluid Dynamics Laboratory. *Effects of Increased Computer Resolution on the Prediction of Climate Simulation.*
11:30–12:00 L. Brown, Cornell University. *Seismic Exploration of the Continents.*
12:10 Adjournment.

Details concerning transportation, local hotel and/or motel accommodations, meals, parking, travel directions, and registration are available upon request from the local organizing committee. Please contact: Dr. William Heller, IBM Data Systems Division, Department D-18, Building 705, P.O. Box 390, Poughkeepsie, NY 12602. Telephone. (914) 435-6307.

1990 FALL MEETING OF THE NEW ENGLAND SECTION
New Haven, Connecticut
19–20 October 1990

The 1990 Fall Meeting of the New England Section of the American Physical Society will be held Friday and Saturday, 19–20 October 1990, at Yale University, New Haven, Connecticut. The theme of the session on Friday will be "Major Research Facilities in the Northeast for the 1990s: The Yale ESTU Tandem Van de Graaff Accelerator and the MIT/BATES High-Duty Cycle Electron Accelerator." The speakers will discuss both the technical details of these machines and the physics programs. Potential users of these facilities from the region will find much of interest here. A social hour and banquet will be held on Friday evening.

The theme on Saturday morning will be "Tests of Discrete Symmetries in Atomic, Molecular, and Nuclear Physics." A talk of a general nature on symmetries will precede the specialized talks on these topics. A tour of the Wright Nuclear Structure Laboratory at Yale that houses the 22-MV Tandem Van de Graaff Accelerator will take place on Saturday afternoon.

Contributed papers (each lasting 10 min) will be presented in parallel sessions on Friday afternoon and Saturday morning. Two copies of each abstract should be sent to. Professor Moshe Gai, NES/APS, Department of Physics, Yale University, P.O. Box 6666, New Haven, CT 06511; telephone (203) 432-5195, fax (203) 432-3522, and BITNET GAI@YALEVM. *The deadline for receipt of abstracts is 5 October 1990.* Authors who wish to have their abstract published in the *Bulletin* (in the standard format) should enclose a check for $25.00, payable to NES/APS.

Details concerning the program, registration, accommodations, travel information, etc. will be given in another announcement in the September or October *Bulletin*, and will be sent to all members of APS in New England; they will be available to others upon request.

The Local Organizing Chairman is Professor Frank Firk, Department of Physics, Yale University, P.O. Box 6666, New Haven, CT 06511; telephone (203) 432-3652 or 3650.

1990 FALL MEETING OF THE OHIO SECTION
Bowling Green, Ohio
2–3 November 1990

The 1990 Fall Meeting of the Ohio Section of the American Physical Society will be held 2–3 November at Bowling Green State University in Bowling Green, Ohio, hosted by the Department of Physics and Astronomy.

The general theme of the meeting is "Computational Physics." Invited speakers include Dr. Kenneth Wilson (Ohio State University), Dr. David Landau (University of Georgia), Dr. Frank Pinski (University of Cincinnati), and Dr. Michael Norman (University of Illinois).

On Friday evening there will be a social hour and banquet, and an after-dinner talk by Dr. John Rigden (American Institute of Physics). Afterward, a show will be presented in the Bowling Green Planetarium, followed by an astronomical observing session, if weather permits.

Ten-minute contributed papers in any area of physics and physics education are welcome. In addition to parallel oral sessions on Saturday morning, a poster session will be held on Friday afternoon. Abstracts following the standard APS format should be sent to arrive by 19 October to the address below; all abstracts received by the deadline will be published in the local program. Abstracts accompanied by the publication fee of $40, made payable to OSAPS/BGSU, will appear in a later issue of the *Bulletin of the American Physical Society.*

All APS members in Ohio and adjoining states are cordially invited to attend this meeting. More detailed information including schedules, accommodations, and registration materials will be sent to Ohio Section members in mid-Summer, and will be available on request from the local chairman, Dr. R. I. Boughton, Department of Physics and Astronomy, Bowling Green State University, Bowling Green, Ohio 43403.
Telephone: 419-372-2421
BITNET:
BOUGHTON1@BGSUOPIE
INTERNET:
boughton@andy.bgsu.edu

1990 FALL MEETING OF THE TEXAS SECTION
Texas City, Texas
9–10 November 1990

The 1990 Fall Meeting of the Texas Section will be hosted by the College of the Mainland in Texas City, Texas, on Friday and Saturday, 9–10 November 1990. It is a joint meeting with the Texas Section of the American Association of Physics Teachers and Zone 10 of the Society of Physics Students.

The APS portion of the meeting will feature invited papers on the frontiers of physics. In addition, contributed papers in all areas of physics are welcome.

Abstracts for invited and contributed papers in APS sessions should be prepared in the standard format as specified on page 1629, and three copies should be sent to the Secretary-Treasurer of the Section: Dr. David Gavenda, Physics Department, The University of Texas at Austin, Austin, TX 78712 (telephone: 512-471-3201). The deadline for receipt of abstracts is 2 October 1990. Each abstract which the author wishes to have published in the *Bulletin* should be accompanied by a check for $15.00 made payable to "APS Texas Section" to help defray publication costs.

Besides parallel sessions of contributed papers, the Texas Section of AAPT is organizing several workshops and invited paper sessions on "Textbooks, Lab Manuals, and Other Teacher Aids."

Titles of contributed papers in the AAPT or SPS sessions should be sent on forms available from Dr. John L. Hubisz, Physics Department, College of the Mainland, Texas City, TX 77591. Abstracts are not requried; however, if you wish to submit an abstract and have it published, follow the guidelines given above. The deadline for receipt of titles is 2 October 1990.

HOUSING FORM
1990 Annual Meeting of the Southeastern Section of The American Physical Society
15–17 November 1990

The Holiday Inn Decatur Conference Center is the headquarters hotel for this meeting. All rooms are available at the rate of $72 (plus tax) for 1–4 occupants. Please indicate your choice below.

No. of occupants: _____ 2 double beds _____ *or* 1 king size bed _____

_____ smoking _____ nonsmoking date of arrival: _____ date of departure: _____

Name: _____ We accept VISA, MasterCard, American Express, Discover, Diners Club, and Carte Blanche

Address: _____ Credit Card: _____

City: _____ State: _____ Zip: _____ Number: _____ Exp. Date: _____

Telephone: _____ Signature: _____

A block of rooms has been reserved for SESAPS. Your reservation *must* be received prior to **13 October 1990** or the rooms will be made available to the public and our regular rates will apply. In case of cancellation, please notify our reservation office at the number listed below.

(Please check) _____ **Guaranteed Arrival–if "no show" you will be billed for the first night.**

Please return this form with your payment to: Holiday Inn Decatur Conference Center
130 Clairemont Avenue
Decatur, GA 30030

Phone: 1-800-225-6079 (Outside Georgia)
404-371-0204 (Georgia only)

Blocks of rooms have been set aside at three local motels. Reservations at the rates quoted must be made before the date indicated. All prices are subject to tax if you do not have the proper documentation to waive it. The host motel will be Holiday Inn (409-986-9777, $50.00 + $7.00 per additional person, Ref. "AAPT-APS," 8 October 1990). Rooms are also available at Pelican Inns (409-986-6575, $21.95 single, $23.95 double, Ref. "AAPT-APS," 15 October 1990), and La Quinta Motor Inn (409-948-3101, $31.00 single, $35.00 double, and $39.00 three or four persons, Ref. "Reservation slot #26537," 21 October 1990).

Additional information on preregistration, meals, and free airport transportation, along with maps, will be sent to all Texas Section members and others requesting it. The program will be mailed before the meeting to all those who preregister or submit papers.

The meeting of the Section Executive Committee will be held at 19:30 Thursday evening, 8 November 1990, at the host model. For further information contact Dr. Hubisz at the address above, or call 409-938-4098 (evenings and weekends) or 409-938-1211 x325.

1990 ANNUAL MEETING OF THE SOUTHEASTERN SECTION
Atlanta, Georgia
15–17 November 1990

The 57th meeting of the Section will be held in Atlanta, Georgia on 15–17 November 1990. Our hosts will be the members of the departments of physics of the four major academic institutions in Atlanta. The chairman of the Local Arrangements Committee is Professor Edward W. Thomas of The Georgia Institute of Technology.

The headquarters hotel will be the Holiday Inn Decatur Conference Center. All sessions will be held at that location. The Center is at 130 Clairemont Avenue, Decatur, GA 30030. Decatur is a small town whose origins predate Atlanta itself but which has now become a suburb of the city. It is about 8 miles from downtown Atlanta. It is, however, almost adjacent to a station of the excellent Atlanta rapid transit system (MARTA) and thus it is only some minutes and some cents from the Atlanta Airport, downtown Atlanta, and many areas of interest in Atlanta. There is a special rate of $72 (plus tax) per room (1 to 4 occupants). Booking *must* be made using the form on page 1614, or by calling the hotel's number shown on that form and mentioning your attendance at SESAPS. Hotel reservations at the reduced rate for rooms cannot be arranged through the Holiday Inn 800 number. The SESAPS Banquet will be held at the Center Friday night.

On 13–14 November, immediately prior to the SESAPS meeting, there will be held, at the same location, the Atlanta Conference on the Superconducting Supercollider. Details of the program may be obtained by calling Dr. William L. Dunn of Quantum Research, Inc. at (919) 544-4952. Accommodations at that meeting are restricted and preregistration is essential.

Registration fees will be $15 for SESAPS or APS members; $25 for nonmembers; $3 for graduate students or retired physicists; and undergraduate students may register free at the SPS desk. For the first time at a SESAPS meeting, preregistration is requested. We anticipate that the combination of the two associated meetings, the ACSSC on 13–14 November and SESAPS on 15–17 November, will result in a rather high demand for hotel room space, particularly on the night of 14 November. We urge that you make plans early and respond promptly with the preregistration form on page 1616.

Atlanta is easily reached by car via Interstates I-20, I-75, and I-85, and by almost any airline that flies in the Southeast. Limousines and taxis, although not cheap, are available at the airport. For the economy-minded, use the MARTA train. To reach the Holiday Inn Conference Center, take the train from the station in the airport to the central station called Five Points. Transfer there to the East line and get off at station E6 in Decatur.

Delta Airlines is the Designated Carrier for the SESAPS meeting. They will provide a 40% reduction on standard coach fares and a 5% reduction from the lowest published fare. To make bookings at these rates you (or your travel representative) must call Delta at 1-800-241-6760 and quote file number **J21038**, which is in the name of the Southeastern Section of the American Physical Society (SESAPS).

The deadline for receipt of contributed paper abstracts in the office of the Program Chairman was *Friday, 31 August 1990.* The program chairman is Dr. Frank Avignone, Department of Physics and Astronomy, University of South Carolina, Columbia, SC 29208. All abstracts of contributed papers must be furnished in quadruplicate and must follow the APS rules for submission of abstracts on page 1629. If you missed that deadline, send in your abstract before 1 November and it will be added to the program in the best place possible.

All regular session rooms will have overhead projectors and blackboard systems. If you need other audio-visual aids, including 35mm projectors or 8mm movie projectors, request them in writing. The best time and place for such requests is to type them near the bottom of the page on your abstract in a place where it will NOT be photocopied with the abstract.

Sessions of invited papers on current physics topics are now being arranged. General areas of the invited papers are. high-energy physics; nuclear physics, astronomy; atomic, molecular, and optical physics; con-

PREREGISTRATION FORM
1990 Annual Meeting of the Southeastern Section
of The American Physical Society
15–17 November 1990

Name: _____

Name for Badge: _____

Affiliation: _____

Address: _____

City: _____ State: _____ Zip: _____ Phone: _____

CONFERENCE FEES:

APS or SESAPS Member	_____	$15	$_____
Nonmember	_____	$25	_____
Graduate Student	_____	$ 3	_____
Retired Physicist	_____	$ 3	_____
Undergraduate	_____	free at SPS desk	_____
		TOTAL ENCLOSED:	$_____

Tickets for the banquet will be paid for and dispersed at the registration desk.
How many will you need? _____

Full refunds will be granted upon written request received prior to 13 October 1990 at the address above. Make checks payable to. Georgia Institute of Technology. SESAPS cannot accept reservations or payment for lodging.

Send this form with payment to: SESAPS
Education Extension R
Georgia Institute of Technology
Atlanta, GA 30322-0385

densed matter physics, and the teaching of physics. Most of the invited papers will be planned for persons who are not specialists in the area of the paper.

L. W. Seagondollar, Secretary
Department of Physics
Box 8202
North Carolina State University
Raleigh, NC 27695-8202

1991 SPRING MEETING OF THE TEXAS SECTION
San Antonio, Texas
21–24 January 1991

The 1991 Spring Meeting of the Texas Section will be held in conjunction with the last joint winter meeting of the APS and the AAPT in San Antonio, Texas, on 21–24 January 1991. The officers of the Texas Section have arranged a series of invited papers on the frontiers of physics. Section members are urged to submit contributed papers from all areas of physics to the Executive Secretary of the Society at the APS headquarters office in accordance wth instructions printed in this *Bulletin* on page 1629. Please note the early deadline for submitting abstracts for this meeting: 1 October 1990.

Announcements of Topical Conferences

INTERDISCIPLINARY CONFERENCE ON ELECTRIFIED INTERFACES
Asilomar, California
16–21 September 1990

A topical conference on the physics and chemistry of Electrified Interfaces will be held at the Asilomar Conference Center, Pacific Grove, California, 16–21 September 1990. This will be the sixth in a series of interdisciplinary conferences on this subject begun in Snowmass, Colorado, in 1979, and most recently held in Bologna, Italy, in 1988. The purpose of this conference will be to bring together physicists and chemists to discuss theory and *in situ* and *ex situ* experimental techniques for the study of electrified interfaces. There will be invited talks and poster sessions. Ample time for formal and informal discussions will be allowed.

The topics to be covered are the theory of the structure of the electrified interface, the experimental characterization of the interface, redox and interfacial electron transfer, and colloids. This meeting is cosponsored jointly by the American Physical Society, the International Society of Electrochemistry, and the IBM Corporation. Additional information is available from:

Douglas Henderson
Owen Melroy
IBM Almaden Research Center
K33/801
650 Harry Road
San Jose, California 95120-6099
Telephone: 408-927-2462
FAX: 408-927-2100
bitnet: DJH4169@ALMVMC

SEVENTH INTERNATIONAL SYMPOSIUM ON CAPTURE GAMMA-RAY SPECTROSCOPY AND RELATED TOPICS

Asilomar, Pacific Grove, California
14–19 October 1990

First Bulletin

The Seventh International Symposium on Capture Gamma-Ray Spectroscopy and Related Topics will be held at the Asilomar Conference Center on the Monterey peninsula in California on 14–19 October 1990. This symposium is the seventh in the series of meetings; previous locations were Studsvik, Sweden (1969), Petten, The Netherlands (1974), Brookhaven, U.S.A. (1978), Grenoble, France (1981), Knoxville, U.S.A. (1984), and Leuven, Belgium (1987). Primary sponsorship of the symposium is being provided by the Lawrence Livermore National Laboratory, U.S. Department of Energy.

The symposium program will continue the general themes of the earlier conferences, with emphasis on recent experimental and theoretical developments in low-energy nuclear physics as determined with relatively less complex nuclear probes such as capture reactions. Topics to be discussed during the symposium may include, but will not be limited to, the following:

*nuclear structure (bound states, states near the nucleon binding energy, collective and single-particle phenomena, odd-odd nuclei, shape isomerism);

*nuclear theory (shell model, algebraic models, Hartree-Fock-Bogolyubov calculations, microscopic models of deformed nuclei);

*neutron and proton capture (high-resolution gamma-ray spectroscopy, short lifetimes, reaction mechanisms, polarized neutrons);

*statistical properties of nuclear levels (spacing distributions, density fluctuations, chaotic behavior);

*fundamental physics with neutrons, neutron and proton resonances, and photon and neutron strength functions;

*nuclear astrophysics (nucleosynthesis, chronometry, proton capture);

*new facilities (cold-neutron sources, neutron guide halls, "Troisieme Souffle" at the ILL); new instrumentation (multidetector systems—what role in capture spectroscopy?); new neutron sources (LANL neutron sources, Gatchina reactor, U.S. Advanced Neutron Source);

*applications (activation analysis, prompt-capture gamma rays).

The program for this five-day symposium will include invited and contributed papers in the form of oral or poster presentations. Nominations for the invited talks are being accepted from members of the advisory committees. Contributed papers are important to this symposium and some of these will be selected for oral presentation. All other accepted contributions will be presented in poster sessions. The proceedings of the conference will be published as a hardcover book. The conference language will be English. There will be no simultaneous translation.

Address inquiries to:

R. W. Hoff
7th ISCGRSART
Mailstop L-234
Lawrence Livermore National Laboratory
Livermore, CA 94550

Phone: 415-422-6664
Fax: 415-422-3160
Bitnet: hoff@lll-winken.llnl.gov

FORTY-THIRD GASEOUS ELECTRONICS CONFERENCE

Urbana-Champaign, Illinois
16–19 October 1990

The Forty-Third Annual Gaseous Electronics Conference will be held on 16–19 October 1990, hosted by the University of Illinois, Urbana, Illinois. The meeting is a topical conference of The American Physical Society and is sponsored by the Division of Atomic, Molecular, and Optical Physics.

The Gaseous Electronics Conference invites papers on basic phenomena and plasma processes in ionized gases, and on the relevant theory and measurement of basic atomic and molecular collisional processes. Specifically, papers are encouraged on the roles of such fundamental processes in electric discharges, arcs, gas lasers, ion sources, breakdown, switching, plasma and atmospheric chemistry, plasma-surface interactions, plasma processing, ionospheric phenomena, and similar topics. Although most papers will deal with low-energy processes, papers that concern electronic or radiative processes produced by high-energy electrons or heavy particles are appropriate and are encouraged. Topics selected for special emphasis in 1990 include: Lamp modeling and diagnostics; lasers, physics of high-power devices; plasma chemistry, plasma processing, discharge physics, and surface interactions, novel experimental techniques for and fundamental aspects of electron and heavy particle collision physics. Also planned is a sequel to the 1989 workshop on "Cross Sections I Wish I Knew."

Abstracts on these and related topics are solicited. The abstracts must conform to the formatting rules of the APS and will be published in the *Bulletin*. The abstract must briefly and accurately describe the scientific work to be presented at the conference. The Conference Executive Committee reviews all abstracts to determine their appropriateness to the meeting. Some papers are presented in poster sessions at the request of authors or the discretion of the Executive Committee. At the request of authors willing to meet additional constraints, papers will be considered for a longer presentation time.

Inquiries should be sent to:

Joseph T. Verdeyen, Secretary
Gaseous Electronics Conference
Department of Electrical and Computer Engineering
University of Illinois
1406 West Green Street
Urbana, Illinois 61801
Telephone: 217-888-2480

SPIE INTERNATIONAL CONFERENCE ON PHYSICAL CONCEPTS OF MATERIALS FOR NOVEL OPTOELECTRONIC DEVICE APPLICATIONS
Aachen, Federal Republic of Germany
27 October–2 November 1990

Conference Chair: Manijeh Razeghi, Thomson-CSF (France).

Cooperating organizations: German Physical Society, IEEE Electron Devices Society, IEEE Lasers and Electrooptics Society, IEEE Microwave Theory and Techniques Society, The Institute of Physics, Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen, VDI/VDE-Technologiezentrum.

In North America contact:

SPIE
P.O. Box 10
Bellingham, WA 98227-0010
Telephone: 206/676-3290
Telex: 46-7053
Telefax: 206/647-1445;
Opto-Link: 206/733-2998

In Europe contact:

SPIE
Lennéstrasse 55
D-5300 Bonn 1
Federal Republic of Germany
Telephone: 49/228-219062
Telex: 181479 speco d
Telefax: 49/228-219066

In the Far East, Australia, and New Zealand contact:

SPIE
c/o O.T.O. Research Corporation
Takeuchi Building
1-34-12 Takatanobaba
Shinjuku-ku, Tokyo 160, Japan
Telephone: 03 280 7821
Telex: 232 4119 OTORES J
Telefax: 03 200 7889

THIRTY-FIFTH ANNUAL CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS
San Diego, California
29 October–1 November 1990

The Thirty-Fifth Annual Conference on Magnetism and Magnetic Materials will be held at the Town and Country Hotel, San Diego, California. The conference annually brings together scientists and engineers interested in recent developments in all branches of fundamental and applied magnetism. Emphasis is traditionally placed on experimental and theoretical research in magnetism, the properties of synthesis of new magnetic materials, and advances in magnetic technology. The program will consist of invited and contributed papers. Selection of contributed papers is based on abstracts which are received by the submission deadline of 16 May 1990. An Abstract Booklet will be available in advance of the conference from the American Institute of Physics for a fee of $15.00. Registrants will receive this booklet at the conference. Proceedings will be published in the *Journal of Applied Physics*.

Individuals who are not on the conference mailing list may obtain conference information and details concerning the preparation of abstracts in the prescribed format by writing Dr. John T. Scott, American Institute of Physics, 335 East 45th Street, New York, New York 10017 or Diane Suiters, Courtesy Associates, 655 15th Street NW, Suite 300, Washington, D.C. 20005.

This topical conference is sponsored jointly by the American Institute of Physics and the Magnetics Society of the IEEE in cooperation with the American Physical Society, the Office of Naval Research, the Metallurgical Society of the AIME, the American Society for Testing and Materials, and the American Ceramic Society. The meeting will be open to all persons subject to a registration fee of approximately $200.00 (marked reduction for students).

ELEVENTH INTERNATIONAL CONFERENCE ON THE APPLICATION OF ACCELERATORS IN RESEARCH AND INDUSTRY
Denton, Texas
5–8 November 1990

The Eleventh International Conference on the Application of Accelerators in Research and Industry will be held at the University of North Texas in Denton, Texas, 5–8 November 1990. The proceedings of the conference will be published in *Nuclear Instruments and Methods* in April 1991. The editors of these proceedings will be Jerome L. Duggan of The University of North Texas and I. L. Morgan of IDM, Inc. The abstracts of the manuscripts will be published in the September 1990 issue of the *Bulletin of the American Physical Society* (APS). The conference is being organized by The University of North Texas.

The purpose of the conference is to review research and the wealth of industrial applications that are in progress with accelerators throughout the world. The conference is composed of two symposia which run in parallel. These are the Research Symposium and the Industrial Applications of Accelerators. Some of the sessions that are of general interest will be held common to both groups. Participants can easily interchange between the two symposia. Three hundred and fifty invited

papers will be given at these symposia, and contributed papers will be accepted in the following areas: Atomic Physics and Related Phenomena, Trace and Surface Analysis with Ion Beams, Electron Beam Processing, Nuclear Physics, CTR and Related Phenomena, Neutron Activation Analysis and Bulk Analysis with Accelerators, Radiological Safety Aspects of Accelerators, Ion Implantation with Particular Emphasis on Semiconductors and Metallurgical Applications, Geosciences and Related Phenomena, Charged Particle Microprobes, Super SIMS, Carbon Dating, Computed Tomography, Synchrotron Light Source Experiments, *In situ* Beams, Radiation Interaction with Ion Beams, Accelerator and Component Design and Automation, Targetry, Detectors, and Electronics, Medical Applications with Accelerators, Biological and Chemical Applications, Material Analysis with Ion Beams, Channeling, and Stopping Power and Radiation Effects.

Most of the contributed papers will be presented in poster sessions. Designated times will be assigned for the participants to be present at their poster stations.

Further information, application blanks, poster information, manuscript materials, and other conference information can be obtained by contacting Jerome L. Duggan, Physics Department, The University of North Texas, P.O. Box 5368, Denton, Texas 76203-5368, phone: 817-565-3252. Our FAX number is: 817-565-2227. Our Bitnet number is: BITNET%FC66@UNTVAX. BITNET.

IEEE CONFERENCE ON NEURAL INFORMATION PROCESSING SYSTEMS— NATURAL AND SYNTHETIC

Denver, Colorado
26–29 November 1990

This is the fourth meeting of an interdisciplinary conference which brings together neuroscientists, engineers, computer scientists, cognitive scientists, physicists, and mathematicians interested in all aspects of neural processing and computation. Several days of focused workshops will follow at a nearby ski area. Major categories and examples of subcategories for paper submissions are the following:

1. Neuroscience: Neurobiological models of development, cellular information processing, synaptic function, learning and memory; studies and analyses of neurobiological systems and development of recording tools.

2. Implementation and Simulation: Hardware implementation of neural nets; practical issues for simulations, simulation tools, simulations on parallel machines.

3. Algorithms and Architectures: Description and experimental evaluation of new net architectures and/or learning algorithms; data representation, static and dynamic nets, modularity, rapid training, learning pattern sequences, implementing conventional algorithms.

4. Formal Analysis: Theoretical analysis of: learning, algorithms, generalization, complexity, scaling, capability, stability, dynamics, fault tolerance, sensitivity, relationship to conventional algorithms.

5. Cognitive Science and AI: Nets for cognitive modeling, natural language understanding, high-level representation and reasoning, and other AI domains.

6. Applications: Nets applied to signal processing, communications, speech, vision, motor control, robotics, adaptive systems.

Technical Program

Plenary, contributed, and poster sessions will be held. There will be no parallel sessions. The full text of presented papers will be published.

Mail requests for registration material to:

Kathie Hibbard
NIPS 90 Local Committee
Engineering Center
Campus Box 425
Boulder, CO 80309-0425
email:
hibbard@boulder.colorado.edu

Organizing Committee

General Chair: Richard Lippmann, MIT Lincoln Laboratory
Program Chair: John Moody, Yale University
Publicity: Stephan Hanson, Siemens
Publications: David Touretzky, Carnegie-Mellon University
Local Arrangements: Kathie Hibbard, University of Colorado
Workshop Program: Alex Waibel, Carnegie-Mellon University
IEEE Liaison: Ed Posner, Caltech
Neurosciences Liaison: James Bower, Caltech
APS Liaison: Larry Jackel, AT&T Bell Labs

INTERNATIONAL SYMPOSIUM ON HEAVY ION INERTIAL FUSION

Monterey, California
3–6 December, 1990

This symposium is the latest of a series being held every two years which started with the 1976 ERDA Summer Study of Heavy Ions for Inertial Fusion. Several workshops were held before the symposium assumed its present form. It will be held at the Sheraton Hotel in Monterey, California. The symposium provides an opportunity for members of the worldwide scientific community involved in the varied fields required for accelerator-based inertial fusion to assemble and communicate. Both oral and poster sessions will be available. Some of the subject areas of interest are: beam physics, beam-plasma interactions, beam transport, accelerator technology for inertial fusion, heavy ion injectors, target issues, inertial fusion reactor studies, and fusion plant system studies. There will be time set aside for information workshop dis-

cussions during the symposium. Written papers will be required for inclusion in the published proceedings. The important dates to remember are:

Call for abstracts—30 May 1990
Abstracts due—31 August 1990
Deadline for registration—
15 October 1990
Symposium—3–6 December 1990

To be put on the mailing list for further information and announcements, contact:

Mollie Field
Conference Coordinator
Lawrence Berkeley Laboratory
1 Cyclotron Road, MS 50B/2270
Berkeley, CA 94720
Telephone: (415) 486-6386
FAX: (415) 486-5401

JOINT MEETING OF THE FIFTEENTH TEXAS SYMPOSIUM ON RELATIVISTIC ASTROPHYSICS AND THE FOURTH ESO-CERN SYMPOSIUM ON ASTROPHYSICS, COSMOLOGY, AND FUNDAMENTAL PHYSICS
Brighton, United Kingdom
16–21 December 1990

The 15th Texas Symposium on Relativistic Astrophysics and the 4th ESO-CERN Symposium on Astrophysics, Cosmology, and Fundamental Physics will be combined into a Joint Texas/ESO-CERN Symposium. The symposium is to be held at the Conference Centre in Brighton, United Kingdom, from Sunday evening, 16 December 1990, to Friday afternoon, 21 December 1990.

The Scientific Organizing Committee (Joint Chairmen: M. J. Rees and G. Setti) has outlined the following program:

Morning plenary lectures on: Early Universe; Quantum Cosmology; High-Energy Physics—Latest Results; Nucleosynthesis; Galaxy Formation and High-z Objects; Large-Scale Structure; Dark Matter; X-Ray and γ-Ray Astronomy, Pulsars, Gravitational Lensing, Background Radiation; Solar Oscillations, Neutrinos and Underground Physics; Gravitational Theory.

Afternoon mini-symposia on. Astrophysics of Neutron Stars and Black Holes (Organizer: R. D. Blandford); Underground Physics (Co-organizers. B. Sadoulet and P. F. Smith); Large-Scale Structure and Galaxy Formation (Organizer: G. Efstathiou).

The registration fee is £75 (£25 for students). A limited amount of financial support may be available, especially for those from the Third World.

If you are interested in attending and would like more information, please contact one of the following persons:

I. Robinson
Programs in Mathematical Sciences
University of Texas at Dallas
Richardson, TX 75083-0688

G. Setti
European Southern Observatory
Karl-Schwarzschild-Strasse 2
D-8046 Garching-bei-Munchen
Federal Republic of Germany

J. P. Ellis
CERN
CH-1211 Geneva 23
Switzerland

WASHINGTON MATERIALS FORUM: SUPERCONDUCTORS AND SEMICONDUCTORS
Washington, D.C.
28 February–1 March 1991

This conference is being held in conjunction with the Spring Forum of the Solid State Sciences Committee (SSSC) of the National Research Council, which will be held in Washington, D.C. on 27 February 1991 to consider "The Effectiveness of Consortia in Industrial Competitiveness." The SSSC, often in conjunction with the National Materials Advisory Board (NMAB), holds this forum to inform the technical community of current science policy and funding issues and to afford attendees the opportunity to discuss funding issues with representatives from government funding agencies and staffers from House and Senate Committees. In previous years, the forum has contained a brief technical session in a selected area of current interest. In 1991, the technical meeting described in this announcement will replace this technical session. It will enable its participants to discuss their latest technical results with their peers as well as allow them access to the Washington community. Cosponsorship of this meeting by several technical societies is expected to reduce proliferation of meetings in Washington while providing all associated societies access to the Washington community.

Symposium Topics

High-T_c Superconducting Films for Electronic Applications

This symposium will focus on the preparation and properties of thin film high-temperature superconducting oxides with emphasis on the material properties and problems important for electronic applications. Papers are solicited in the following areas:

Deposition techniques for high-T_c superconducting films

Materials properties and problems critical to device and circuit applications

Integration of high-T_c superconducting materials into conventional semiconductor technologies

Magnetic and electrical properties of films

Technique for fabricating device structures

New approaches to film evaluation

Novel electronic applications of high-T_c superconducting films

The Science Behind Semiconductor Processing: Advances in Plamsa and CVD Research

Significant developments have occurred recently in research related to the synthesis and processing of semi-

conductor materials and devices. Advances have been made in the fundamental characterization, modeling, and understanding of processing as a science. Results are leading to predictive methods for improving processing and synthesis techniques. This symposium will focus on advances in the science of plasma and CVD processing as it applies to semiconductor fabrication. The emphasis will be on unifying themes for understanding deposition, etching, and growth processes. Topics will include plasma and vapor-phase chemistry, surface kinetics, species transport, gas-phase surface nucleation, growth mechanisms, and modeling techniques. The scientific basis for plasma and CVD processing will be addressed in both invited and contributed sessions.

Location

The conference will be held in Washington, D.C. on 28 February–1 March 1991, following the Wednesday, 27 February 1991 Solid State Sciences Committee Spring Forum.

Abstract Deadline

Abstracts of contributed papers (two copies) must be received by the Conference Chairs no later than *10 December 1990.* Abstract templates may be obtained from MRS Headquarters at the address listed below, or your may construct your own template as follows: Using heavy, white bonded paper, trace a block 5 in (12.7 cm) wide by 6 in (15.2 cm) long in nonreproducing blue ink or in dark lines on a backup sheet. The text must be confined to the area within these borders.

Cosponsoring Societies

American Ceramic Society (ACerS)
American Chemical Society (ACS)
American Physical Society (APS)
  Division of Condensed Matter
  Materials Physics Topical Group
ASM International
American Vacuum Society (AVS)
Federation of Materials Societies
Materials Research Society (MRS)

Conference Chairs

A. Wayne Johnson
Sandia National Laboratories
Division 1126
P.O. Box 5800
Albuquerque, NM 87185
Telephone: (505) 844-8782
Fax: (505) 844-3211

Paul S. Peercy
Sandia National Laboratories
Division 1140
P.O. Box 5800
Albuquerque, NM 87185
Telephone: (505) 844-4309
Fax: (505) 846-2009

Julia M. Phillips
AT&T Bell Laboratories
Room 1D-158
600 Mountain Avenue
Murray Hill, NJ 07974-2070
Telephone: (201) 582-4428
Fax: (201) 582-2521

James B. Roberto
Oak Ridge National Laboratory
Solid State Division
Building 3025, MS 6030
Oak Ridge, TN 37831
Telephone: (615) 576-0227
Fax: (615) 574-4143

The Program Committee will be pleased to consider abstracts on the topics listed above. To receive further announcements about the Washington Materials Forum contact Jane Stokes at MRS Headquarters:
Washington Materials Forum
c/o Materials Research Society
9800 McKnight Road
Pittsburgh, PA 15237
Telephone: (412) 367-3003
Fax: (412) 367-4373

1991 PARTICLE ACCELERATOR CONFERENCE

San Francisco, California
6–9 May 1991

The fourteenth biennial Particle Accelerator Conference will be held at the Sheraton Palace Hotel, San Francisco, California, from 6–9 May 1991. The subject of the meeting will be new developments in the science, technology, and use of particle accelerators. The conference is being organized by Stanford Linear Accelerator Center and Lawrence Berkeley Laboratory under the auspices of IEEE. For further information, contact the Conference Chairman: Dr. Matthew Allen, SLAC, P.O. Box 4349, Stanford, CA 94309; telephone (415) 926-2820; BITNET MATALLEN@SLACVM; telefax: (415) 926-3654.

Program

The 1991 conference continues the tradition of providing a channel of communications for accelerator scientists and engineers and for persons concerned with the applications of accelerators. The conference will include invited oral presentations and contributed oral and poster presentations. The topics to be covered include accelerator technology, new methods of acceleration, low-, medium-, and high-energy accelerators and rings, synchrotron radiation sources, injectors and ion sources, beam dynamics, and free electron lasers. Papers will be published in the Conference Record.

Abstracts and Deadline

The first conference mailing will be in June. All abstracts of invited and contributed papers must follow the rules of the American Physical Society, as described in the *Bulletin of the American Physical Society.* The deadline for receiving abstracts is Monday, 3 December 1990. Abstracts should be sent to the Program Chairman, Dr. Klaus Berkner, Lawrence Berkeley Laboratory, 50-149, 1 Cyclotron Road, Berkeley, CA 94720. The accepted abstracts will be published in the May 1991 issue of the *Bulletin of the American Physical Society.*

Sponsorship

The 1991 Particle Accelerator Conference will be sponsored jointly by the American Physical Society, Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, Department of En-

ergy. National Science Foundation, and Office of Naval Research.

SEVENTH TOPICAL CONFERENCE ON SHOCK COMPRESSION OF CONDENSED MATTER

Williamsburg, Virginia
17–20 June 1991

The Seventh Biennial Conference of the American Physical Society Topical Group on Shock Compression of Condensed Matter will meet at Williamsburg, Virginia, 17–20 June 1991. The meeting will be international, with France, Great Britain, Israel, Japan, People's Republic of China, and U.S.S.R. participation expected. The conference emphasis is on the physics of materials at elevated pressures.

Submission of Abstracts

We invite abstracts on the following: New Fundamental Research; Optical and Spectroscopic Phenomena; Elastic-Plastic Response; Impact and Penetration Mechanics; Static High Pressure Work; Experimental Techniques; Geophysical Materials; Fracture; Shock Chemistry; Equation of State; Theoretical Studies; Numerical Calculations; Energetic Materials; Laser and Particle Beam Shock; and Generators.

The abstracts will be published in the APS *Bulletin* prior to the conference. Abstracts for invited and contributed papers must conform to the APS formats that are regularly published in the *Bulletin*. The deadline for abstract submission will be late January 1991. Proceedings of the conference will be published.

Conference Location

The official conference hotel will be the Williamsburg Hilton, where 300 rooms have been reserved for participants at a single occupancy rate equaling the U.S. Government Department of Defense lodging rate (now $62.00). Room reservations will be made through the Hilton Hotel. Later announcements will include registration forms for the conference and the hotel.

Conference Committee

Richard D. Dick
Chairman
University of Maryland
(301) 454-8948

J. Stephen Rottler
Exhibits
Sandia National Laboratories

Douglas G. Tasker
Vice-Chairman and Local Arrangements
Naval Surface Warfare Center

Stephen C. Schmidt
Publications
Los Alamos National Laboratory

E. Ray Lemar
Finances
Naval Surface Warfare Center

Wanda Morat
Publications Assistant
Naval Surface Warfare Center

For information contact:

Naval Surface Warfare Center
Attn: Wanda Morat, E221, 1-370
1991 APS Topical Conference on Shock Compression of Condensed Matter
10901 New Hampshire Ave.
Silver Spring, MD 20903-5000

EIGHTH SYMPOSIUM ON TURBULENT SHEAR FLOWS

Munich, Federal Republic of Germany
9–11 September 1991

The Eighth Symposium on Turbulent Shear Flows aims to advance understanding of the physics of turbulent motion and capabilities for predicting momentum, heat, and mass transport processes in turbulent shear flows of engineering importance.

Approximately 20 technical sessions are planned. Contributed papers are invited on original work in the following general areas:

Fundamentals: Measurements, theories, and concepts that illuminate the nature of turbulence.

Turbulence models. Developments in single and two-point closures; large-eddy and other numerical simulations.

Experimental techniques: Improved experimental methods for single- and two-phase turbulent flow.

Computation techniques: Advances in computation methods for single- and two-phase turbulent flow.

Heat and mass transfer: Developments in scalar modeling; related measurements and calculations.

Combustion: Developments in modeling of turbulent flames and their application; experiments and calculations of combusting flows.

Applications: Contributions to applied turbulent flows including those concerned with internal and external aerodynamics, geophysical flows, and engineering processes.

Abstracts

Paper selection will be based upon a review of extended abstracts of approximately 1000 words which should be double-spaced and state clearly the purpose, results, and conclusions of the work, with supporting figures as appropriate. Five copies of the abstract should be submitted to: Professor F. W. Schmidt, Secretary, Turbulent Shear Flows, Department of Mechanical Engineering, The Pennsylvania State University, University Park, PA 16802; telephone: 814-865-2072; fax: 814-863-4848.

Deadlines

Final date for receipt of abstracts: 15 November 1990. Authors informed concerning acceptance: 15 March 1991. Final date for receipt of camera-ready manuscript: 31 May 1991.

1991 INTERNATIONAL CONFERENCE ON ION SOURCES

Darmstadt, Federal Republic of Germany
30 September 1991–4 October 1991

The 1991 International Conference on Ion Sources (ICIS'91) will be organized by the Gesellschaft fur Schwerionenforschung (GSI),

Darmstadt, Federal Republic of Germany. The conference will be held during the first week of October 1991.

The aim of the conference is to encourage interest in the various areas of ion source applications and to promote the exchange of ideas and theories on ion sources.

Contributed and review papers will be presented from such areas as ion implantation, isotope separation, neutral beams for controlled fusion, light and heavy ion inertial confinement fusion, space propulsion, particle accelerator injection, lithography, surface analysis, and other basic and applied fields.

The emphasis will be on ion sources and not on specific applications. General technological problems of all of the above areas will be reviewed. A half-day will be reserved for parallel meetings for those from various fields and will be organized by one of the specialists attending.

The precise location is yet to be fixed, but will probably be at Bensheim, about halfway between Darmstadt and Heidelberg, about 50 miles south of Frankfurt.

A first announcement and call for papers will be sent out shortly. For further information and for inclusion on the mailing list, contact the conference chairman:

Dr. Bernard Wolf
GSI
Postfach 110552
6100 Darmstadt 11
Federal Republic of Germany
Telephone. (49) (6151).359320
Fax: (49) (6151) 359785.
Email: UL13@ddagsi3.Bitnet

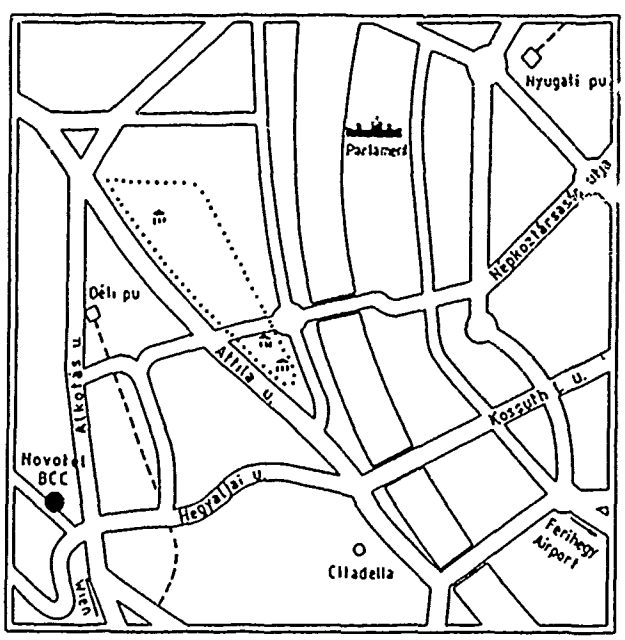
FOURTH EUROPEAN CONFERENCE ON APPLICATIONS OF SURFACE AND INTERFACE ANALYSIS
Budapest, Hungary
14–18 October 1991

Aims and Scope

ECASIA 91 is the fourth international conference of a series to be

Access Routes and Links

By air: Terminal 1 of Ferihegy Airport is 22 km and Terminal 2 is 28 km from the Centre. The town center terminal for airport coaches, in Engels tér, is 3 km away.
By rail: All the railway stations in Budapest are in easy reach. It is five minutes to the Déli (Budapest South) and 20 minutes to the Nyugati (Budapest West) and the Keleti (Budapest East) stations.
By road: The Centre has access to the M7 motorway and it is near to the international mainroads.



Contact Address:

ECASIA 91
MTA ATOMKI
Pf. 51,
H-4001 Debrecen
Hungary

Phone: (36)-52-16181
Telex: 72210 (atom h)
Fax: (36)-52-16181

REPLY FORM

I am interested in ECASIA 91 and would like to receive the second circular.

Name: _____
Title: _____
Institution/Company: _____
_____
_____
Street: _____
City: _____ Zip code: _____
Country: _____
Phone: _____ Telex: _____
Fax: _____

I may be able to submit a paper on the following topic:

_____
_____
_____
_____

Please send the second circular also to:

Name: _____
Address: _____
_____
_____

held biannually in various European countries. Its main purpose is to bring together users, theoreticians, and suppliers of surface analytical equipment.

ECASIA 91 will be a place for truly international exchange of information about the application of different techniques to the solution of surface and interface related problems. Plenary and keynote lectures, oral presentations in parallel sessions, poster contributions, and a full instrument exhibition will constitute the scientific program.

ECASIA 91 will encourage contributions on:

●Applications of surface and interface analytical techniques and methods to technological and industrial problems, such as metallurgy, corrosion, coatings, ceramics, glasses, mineralogy, polymers, catalysis, microelectronics, superconductors, adhesion, tribology and wear, biomedical, and environmental studies.

●New developments in surface and interface analytical Techniques (instruments and experimental methods) and related microanalytical methods.

●Progress in the Quantification and related problems such as calibration, data analysis, and interpretation.

An abstract booklet will be given to the participants at the opening of the conference. Conference proceedings will be issued in the form of a special volume of *Surface and Interface Analysis.*

The conference language is English.

Second Circular

The second circular with the list of invited speakers and call for papers will be mailed in November 1990 to those returning the reply form on page 1623.

This conference is organized by the Institute of Nuclear Research of the Hungarian Academy of Sciences (MTA ATOMKI) and the Austrian Society for Microchemistry and Analytical Chemistry.

Organizing Committee

Chairmen:	D. Berényi Debrecen, Hungary M. Grasserbauer Wien, Austria
Secretary:	L. Kövér Debrecen, Hungary

Venue

The Budapest Convention Centre (BCC) building connected to the four-star Hotel Novotel is situated in an old chestnut park in the greenbelt area of the beautiful capital Budapest, offering ideal and peaceful surroundings and advanced facilities for holding international conferences. The Centre is only a few minutes from both the city center and the Buda castle area, which is rich in cultural and historical monuments, churches, museums, etc.

Contact Address:

ECASIA 91
MTA ATOMKI
Pf. 51
H-4001 Debrecen
Hungary
Phone: (36)-52-16181
Telex: 72210 (atom h)
Fax: (36)-52-16181

Announcements of Affiliated Societies

1990 SECTIONAL MEETINGS OF THE PHYSICAL SOCIETY OF JAPAN

Members of The American Physical Society are welcome to present their original papers at the 1990 Sectional Meetings of the Physical Society of Japan, which are to be held as follows:

1st Sectional Meeting

Date: Sunday, 30 September–Wednesday, 3 October 1990
Location: Nara Women's University, Nara-shi, Nara-ken

Sections involved: Elementary Particle Theory; Elementary Particle Experiments; Nuclear Theory; Nuclear Experiments; Cosmic Rays

2nd Sectional Meeting

Date: Tuesday, 2 October–Friday, 5 October 1990
Location. University of Gifu, Gifu-shi, Gifu-ken

Sections involved. Radiation Physics; Crystal Growth; Lattice Defects; Dielectrics; Semiconductors; Ionic Crystals and Optical Properties; Molecular Crystals, Organic Semiconductors and Liquid Crystals; Atoms and Molecules; Quantum Electronics; Magnetism; Magnetic Resonance; Metals; Surfaces; Low Temperature; Statistical Mechanics and Basic Theory of Condensed Matter; X Rays and Corpuscular Beams; High Polymers; Biophysics; Applied Mathematics, Mechanics and Fluid Physics; Discharges; Plasma Physics and Nuclear Fusion;

Acoustics and Phonon Properties; Physics Education; History of Physics

Presentations of papers at the meetings of The Physical Society of Japan by members of The American Physical Society are subject to the same rules as for members of The Physical Society of Japan, in accordance with the agreement between these two organizations.

All inquiries for detailed information about these Sectional Meetings should be addressed to:

The Physical Society of Japan
Room 211, Kikai-Shinko Building
3-5-8, Shiba-Koen, Minato-ku
Tokyo 105, Japan

1991 SECTIONAL MEETINGS OF THE PHYSICAL SOCIETY OF JAPAN

Held in late March and/or early April 1991.
1st Sectional Meeting: Science University of Tokyo, Shinjuku-ku, Tokyo
2nd Sectional Meeting: Gakushuin University, Toshima-ku, Tokyo

1991 ANNUAL MEETING OF THE PHYSICAL SOCIETY OF JAPAN

Held in late September and/or early October 1991 at Hokkaido University, Sapporo-shi, Hokkaido.

All inquiries for detailed information about these Meetings should be addressed to:

The Physical Society of Japan
Room 211, Kikai-Shinko Building
3-5-8 Shiba-Koen, Minato-Ku
Tokyo 105, Japan

Tel. (03) 434-2671

NOTICE FROM THE PHYSICAL SOCIETY OF JAPAN

Members of the American Physical Society may subscribe to the *Journal of the Physical Society of Japan* at the same rates as for members of the Physical Society of Japan, in accordance with the Agreement between the two Societies concerned. Annual member rates for subscription to Vol. 59 (1990) of the *Journal of the Physical Society of Japan* are as follows:

Address / Mail	Japan	Asia (except Japan & USSR), Australia, New Zealand, and Oceania	USA (including Alaska & Hawaii), Canada, and Central America	Europe (including USSR), Africa, Middle East, and South America
Surface	¥ 9,000	¥ 14,000	¥ 14,000	¥ 14,000
Air		¥ 30,600	¥ 34,800	¥ 39,000

All inquiries for subscriptions should be addressed to: The Physical Society of Japan, Room 211, Kikai-Shinko Building, 3-5-8, Shiba-Koen, Minato-ku, Tokyo 105, Japan.

The American Physical Society

INDUSTRIAL SUMMER INTERN PROGRAM—1991

DESCRIPTION: The American Physical Society Industrial Summer Intern Program is another phase of the Society's efforts to increase the coupling between the academic and industrial members of the physics community. It provides an opportunity for well-qualified physics students to spend time in an industrial environment during the summer months.

QUALIFICATIONS OF APPLICANTS: Any senior undergraduate or graduate student in physics may apply. Applicants should expect to spend the period June through August as an intern and to participate in existing projects in the host laboratory. Since the program is competitive, applicants should have good academic records and a high degree of motivation, and should present evidence of some research or technical experience.

STIPEND: The stipend for interns will be about $2,000 per month, varying somewhat with each industrial company. Provision for relocation expenses and fringe benefits will be made according to the practice of each host laboratory.

SELECTION PROCEDURE: A review committee appointed by the APS President will screen all completed applications in hand on 31 October 1990. The files of appropriately qualified applicants will be distributed to research managers at the industrial laboratories which have asked to participate in the program. Those companies who choose to do so will offer internships directly to the students whom they have selected from the pool. The Society will not participate in the negotiations for any particular appointment. It is expected that negotiations will be completed on or about 3 April 1991.

INDUSTRIAL ORGANIZATIONS: Industrial organizations interested in participating in this Internship Program are invited to contact the Program Administrator. No commitment, other than willingness to consider appropriately qualified interns, is required before resumes are distributed. Interns are expected to give the guarantees with respect to patents and proprietary information ordinarily required of all technical personnel in a given laboratory.

APPLICATION PROCEDURE: Applicants should complete and return the application form and arrange to have two letter-of-reference forms in addition to the chairman's endorsement form sent to the Program Administrator. Transcripts may be included with the application form or sent to the Program Administrator by the school. Completed applications and supporting material must be received by 31 October 1990. COPIES OF ALL FORMS ARE AVAILABLE IN THE OFFICE OF THE CHAIRMAN OF YOUR DEPARTMENT OR BY WRITING DIRECTLY TO THE ADDRESS BELOW.

FOR FURTHER INFORMATION:
Summer Intern Program Administrator
The American Physical Society
335 East 45th Street
New York, NY 10017
(212) 682-7341

DEADLINE FOR RECEIPT OF COMPLETED APPLICATIONS IS 31 OCTOBER 1990.

The American Physical Society

Program of

CORPORATE SPONSORED SCHOLARSHIPS FOR MINORITY UNDERGRADUATE STUDENTS WHO MAJOR IN PHYSICS

TWELFTH ANNUAL COMPETITION, 1991–1992

Purpose: The American Physical Society Committee on Minorities in Physics, in collaboration with the Corporate Associates of the American Institute of Physics, has organized this scholarship program for minority undergraduate students in physics. The purpose of this program is to increase significantly the level of underrepresented minority participation in physics in this country.

Sponsorship: Each scholarship will be sponsored by a corporation, and will normally be designated as the "(Sponsor/APS) Scholarship for Minority Undergraduate Students in Physics at (Host College)." Corporations may and do sponsor more than one scholarship. The scholarship funds are donated by the sponsoring corporation to The American Physical Society, which administers the scholarship awards.

Qualifications: Any Black, Hispanic, or American Indian U.S. citizen who is *majoring or plans to major in physics* and who is a high school senior or college freshman or sophomore is qualified to apply. The scholarships are limited to assist students who are majoring in physics in their freshman, sophomore, or junior years of college.

Stipend: Each scholarship for the academic year 1991–1992 consists of $2,000 awarded to the student for tuition, room, or board, and $500 awarded to each college or university physics department that hosts one or more APS minority undergraduate scholars. The scholarship may be renewed one time. Renewal is granted with the approval of the APS Selection Committee, the host institution, and the corporate sponsor.

Selection Procedure: A Selection Committee of the APS Committee on Minorities in Physics and appointed by the APS President will select the scholarship recipients and match the recipient with an available scholarship from a host corporate sponsor. The Selection Committee will provide an accomplished physicist as a mentor for each scholarship recipient.

Host Institutions: Students and prospective students from all U.S. colleges and universities are eligible to apply for an APS minority undergraduate scholarship. It is the intention of the Selection Committee to give approximately half the awards to students in institutions with historically or predominantly Black, Hispanic, or American Indian enrollment and the other half to students in other colleges and universities.

Application Procedure: Applicants should submit a completed application form, with a personal statement, to APS for receipt prior to the deadline of February 25, 1991. *Three completed REFERENCE FORMS*, and a copy of applicant's high school records should be mailed *directly* to the APS Office. College undergraduates should send academic records from both high school and college directly to the APS office. The deadline for receipt of all references and transcripts is February 25, 1991.

For Further Information: APPLICATION FORMS, REFERENCE FORMS, and other information about this program may be obtained from:

APS Minorities Scholarship Program
The American Physical Society
335 East 45th Street
New York, NY 10017-3483
(212) 682-7341

DEADLINE FOR RECEIPT OF COMPLETED APPLICATIONS IS 25 FEBRUARY 1991.

Summary of Physics and Astronomy Classification Scheme—1990

00. GENERAL
- 01. Communication, education, history, and philosophy
- 02. Mathematical methods in physics
- 03. Classical and quantum physics; mechanics and fields
- 04. Relativity and gravitation
- 05. Statistical physics and thermodynamics
- 06. Measurement science, general laboratory techniques, and instrumentation systems
- 07. Specific instrumentation and techniques of general use in physics

10. THE PHYSICS OF ELEMENTARY PARTICLES AND FIELDS
- 11. General theory of fields and particles
- 12. Specific theories and interaction models; particle systematics
- 13. Specific reactions and phenomenology
- 14. Properties of specific particles and resonances

20. NUCLEAR PHYSICS
- 21. Nuclear structure
- 23. Radioactivity and electromagnetic transitions
- 24. Nuclear reactions and scattering: general
- 25. Nuclear reactions and scattering: specific reactions
- 27. Properties of specific nuclei listed by mass ranges
- 28. Nuclear engineering and nuclear power studies
- 29. Experimental methods and instrumentation for elementary-particle and nuclear physics

30. ATOMIC AND MOLECULAR PHYSICS
- 31. Electronic structure of atoms and molecules: theory
- 32. Atomic spectra and interactions with photons
- 33. Molecular spectra and interactions of molecules with photons
- 34. Atomic and molecular collision processes and interactions
- 35. Experimentally derived information on atoms and molecules; instrumentation and techniques
- 36. Studies of special atoms and molecules

40. FUNDAMENTAL AREAS OF PHENOMENOLOGY (INCLUDING APPLICATIONS)
- 41. Electricity and magnetism: fields and charged particles
- 42. Optics
- 43. Acoustics
- 44. Heat transfer, thermal and thermodynamic processes
- 46. Classical mechanics and rheology
- 47. Fluid dynamics

50. FLUIDS, PLASMAS, AND ELECTRIC DISCHARGES
- 51. Kinetic and transport theory of fluids; physical properties of gases
- 52. The physics of plasmas and electric discharges

60. CONDENSED MATTER: STRUCTURE, MECHANICAL AND THERMAL PROPERTIES
- 61. Structure of liquids and solids; crystallography
- 62. Mechanical, acoustical, and rheological properties of condensed matter
- 63. Lattice dynamics and crystal statistics
- 64. Equations of state, phase equilibria, and phase transitions
- 65. Thermal properties of condensed matter
- 66. Transport properties of condensed matter (nonelectronic)
- 67. Quantum fluids and solids; liquid and solid helium
- 68. Surfaces and interfaces; thin films and whiskers (structure and nonelectronic properties)

70. CONDENSED MATTER: ELECTRONIC STRUCTURE, ELECTRICAL, MAGNETIC, AND OPTICAL PROPERTIES
- 71. Electron states
- 72. Electronic transport in condensed matter
- 73. Electronic structure and electrical properties of surfaces, interfaces, and thin films
- 74. Superconductivity
- 75. Magnetic properties and materials
- 76. Magnetic resonances and relaxations in condensed matter; Mössbauer effect
- 77. Dielectric properties and materials
- 78. Optical properties and condensed-matter spectroscopy and other interactions of matter with particles and radiation
- 79. Electron and ion emission by liquids and solids; impact phenomena

80. CROSS-DISCIPLINARY PHYSICS AND RELATED AREAS OF SCIENCE AND TECHNOLOGY
- 81. Materials science
- 82. Physical chemistry
- *84. Electromagnetic technology
- *85. Electrical and magnetic devices
- 87. Biophysics, medical physics, and biomedical engineering
- *89. Other areas of research of general interest to physicists

90. GEOPHYSICS, ASTRONOMY, AND ASTROPHYSICS
- 91. Solid Earth physics
- 92. Hydrospheric and atmospheric geophysics
- 93. Geophysical observations, instrumentation, and techniques
- 94. Aeronomy and magnetospheric physics
- 95. Fundamental astronomy and astrophysics; instrumentation, techniques, and astronomical observations
- 96. Solar system
- 97. Stars
- 98. Stellar systems; galactic and extragalactic objects and systems; the Universe

***APPENDICES**
- 02. Mathematical methods in physics
- 43. Acoustics

**These sections are outside the ICSTI International Classification for Physics*

Submission of Abstracts

REVISED INSTRUCTIONS FOR THE SUBMISSION OF ABSTRACTS FOR CONTRIBUTED PAPERS AUGUST 1989

Please note that these rules apply to all contributed abstracts that are to be published in the *Bulletin of the American Physical Society*, not just those submitted for presentation at General Meetings of the Society.

I. SUBMISSION OF ABSTRACTS

A. Submitting abstracts. Contributed abstracts must be submitted by a member in good standing of The American Physical Society. This includes new members whose completed application for membership and payment of the first year's dues are in the APS office at the time of the submission of the abstract. Each abstract must be signed by the member in the lower right hand corner at the abstract, with the member's name and address printed below the signature. The name of the submitter must be appear either as a co-author in the text of the abstract or as a footnote thusly *Submitted by (MEMBER'S NAME).

B Where to send abstracts Send the original and two copies to the address indicated in the announcement of the meeting for which you are submitting the abstract. Abstracts for General Meetings of the Society should be sent to the Executive Secretary of the Society at the APS headquarters office.

C Acknowledgment of receipt of abstracts. For General Meetings of the APS, if you wish to be contacted when your abstract is received, you must include a self-addressed stamped envelope or postcard with your abstract. We cannot acknowledge receipt of abstracts unless this is done. Acknowledgment of receipt does not guarantee acceptance of the abstract into the program, only that the submission was received.

D Deadlines. All deadlines are firm. Deadlines dates are published in the announcements of the meetings, as well as the inside back cover of the *Bulletin* Abstracts received after the published deadline date will not be included in the regular program. If the meeting for which you are submitting an abstract has a postdeadline program, please be cognizant of the rules which govern postdeadline submissions for that particular meeting. The APS is not responsible for late submissions due to mail difficulties The APS recommends that you mail your abstract at least two weeks prior to the deadline date, unless you are using an express mail courier.

II. PREPARATION OF AN ABSTRACT

A. Size. Bulletin copy is prepared by direct photoreproduction (at 71%) of the typescript submitted. To conform with this and other printing requirements, the abstract must fit into a rectangle that measures 12-cm-wide by 10.5-cm-long This space must include the title of the abstract, the author's names and affiliations, and all footnotes and references (See the example on the next page.) If you wish to draw a guide on the paper, please use *a nonreproducible light blue pencil.* Please do not use any other color—a light blue rectangle will not reproduce. Do not exceed the margins of 12-cm-wide by 10.5-cm-long. Abstracts that are wider or longer will be rejected. You may acquire a limited supply of preprinted abstract forms by sending a self-addressed stamped envelope to the Meetings Department of the APS.

B. Style. Indent the first line of the abstract 8 spaces, so that the time of presentation and the paper number may be inserted during printing. Underline the title. Type each author's name in capital letters. Then abbreviate and underline the author's affiliation. Place a dash between the affiliations and the beginning of the text of the abstract. To conserve space in the printed program, the entire abstract (including title, author's names, author's affiliation, and text) should proceed in a continuous fashion within the specified rectangle. However, please skip one line between the text of the abstract and any footnotes and references that would appear after the text.

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E. Special symbols. If special scientific symbols are not available on the typewriter, they may be inserted using black ink. Please be aware of reproducibility requirements. Consult the current edition of the American Institute of Physics Style Manual for standard symbols and abbreviations. The Style Manual can be purchased through AIP by writing AIP at 335 East 45th Street, New York, NY 10017.

F. Indexing. Different Divisions, Sections, and Topical Groups may use different categorizing schemes and instructions for sorting their abstracts and placing them in appropriate sessions. For General Meetings of the APS, place the category number in the upper right and an appropriate session title in the upper left. (See example on the next page.) For the Spring Meeting, the categories are listed in the "Shorthand Version" of the *Physics and Astronomy Classification Scheme*, published periodically in the *Bulletin.* For the March Meeting, the categories are listed in the March Meeting Contributed Abstract Form, also published periodically in the *Bulletin.* If there is a particular person that would be a good chairperson for the session in which the paper would be presented, it should be suggested below the submitting member's signature.

G. Corrections. Authors should note that no corrections of any kind can be made on the abstract by the office that has received it. Any errors in format, size, reproducibility, or style, will cause the abstract to be rejected under the above guidelines. A typographical or substantive error can be corrected only by sending a corrected version of the abstract to the office which received the original abstract. The deadline for such corrections is dependent on the production schedule of the program, and should be obtained by calling the appropriate office handling the particular meeting. In the case of General Meetings of the Society, contact the Meetings Department of the APS. A copy of the original abstract, *clearly labeled as such,* must be enclosed with the corrected version of the abstract, and two copies of the corrected version. No guarantees are made for replacing the original abstract with the corrected version after the abstract deadline date has passed.

H. Withdrawals. An abstract can be withdrawn any time prior to the abstract deadline date, if the withdrawal is submitted in writing to the appropriate office that is handling the program. After the deadline, withdrawing an abstract is dependent on the production schedule of the program. As above, the request must be in writing. No guarantees are made for withdrawal of an abstract from the printed program after the abstract deadline date.

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C. Supplementary papers. Supplementary papers that have been included in the regular program may be presented in a standard oral session, time permitting, and at the discretion of the chairperson of that session. Except in rare instances, designated by the program committee or the Executive Secretary, a speaker will only be permitted to present one primary paper and one supplementary paper.

D. Choice of presentation. Instructions regarding the placement of an abstract in a poster session, in an oral session, for presentation on a particular day, or following or preceding other abstracts, will be honored to the best of the ability of the program committees. Please indicate these requests on the bottom of the abstract itself and not on a covering letter or under separate cover. If the instructions regard the ordering of several abstracts, the instructions should appear on all abstracts. If the author does not indicate a preference, the program committee will place the abstract in whichever session appears to be most appropriate.

E. Audio-visual requirements. At General Meetings of the Society, overhead projectors are provided for each contributed session. No audio-visual equipment is provided for poster sessions. If you require additional audio-visual equipment at a General Meeting of the Society, please indicate such needs in writing under separate cover to the APS Meetings Department. You will be required to pay a rental free for additional equipment.

F. Poster papers. Please be aware that poster presentations should be devised so that a number of people may view the presentation at one time. Please pay particular attention to the production of effective visuals. Type and figure size should be appropriate for communication with groups of people gathered around the poster board. The display and text should carry the message without requiring additional comment. The size of the poster board can be found in the Preamble to most meeting programs. Please clear the board promptly at the end of the session.

IV. POSTDEADLINE PAPERS

Abstracts received after the published deadline date cannot be included in the regular program Abstracts placed in postdeadline sessions are not published in the program of the meeting. They may be published in a future issue of the *Bulletin* if the program committee of that meeting so decides Postdeadline abstracts are subject to all of the above guidelines Please be cognizant of the other rules regarding postdeadline submission of abstracts for each individual meeting.

QUICK REFERENCE—CONTRIBUTED ABSTRACT FORM

* 12 cm by 10.5 cm ($4\frac{3}{4}$ in. by $4\frac{1}{8}$ in.).
* Submitted by an APS member—signature, name, and address in lower right.
* One primary paper per first author and one supplementary paper.
* Note the deadline!! APS not responsible for mailing delays.
* Continuous text—no floating titles.
* Indent before title.
* Underline title.
* Readable and printable.
* Special instructions—lower left.
* Subject category upper right.
* Name and date of Meeting center top.

Abstract Submitted
for the _____ Meeting of the
American Physical Society

Meeting Date

Suggested title of session
in which paper should be placed
Optical Properties of Film Structures

Physics and Astronomy
Classification Scheme
Number 25.85

One-dimensional Heterojunction Structures in Polysilylenes. N.MATSUMOTO, H.ISAKA, NTT Basic Research Labs.--- UV absorption, luminescence and excitation spectra of poly(di-n-hexylsilane) solid films have been observed at temperatures from 4K to 400K. The UV spectrum, under the melting point (Tc), exhibits two peaks corresponding to a crystalline portion (365nm at 4K: Phase I) and an amorphous fraction (319nm at 4K: Phase II). The luminescence spectrum, on the other hand, has only one peak emitted from phase I. Two luminescence peaks (348nm and 381nm) can be observed only near Tc and there is only one luminescence peak from Phase II above Tc. When Phase I and Phase II form a one-dimensional heterojunction structure along a chain as in the case of temperatures below Tc, electrons and holes excited in the wide-gap Phase II relax toward the narrow-gap Phase I and recombine radiatively. When two phases are spatially independent on the different chains, or when the third phase exists as a trap along a chain, the energy transfer between the two phases is disturbed. The former case corresponds to the above luminescence observation near Tc. The latter case has been confirmed by the observation of two-peak luminescence in rapidly cooled films with the third phase (UV peak:350nm)

Signature of APS Member

Same name typewritten

Address

( ) Prefer Poster Session
( ) Prefer Standard Session
( ) No preference

March Meeting Sorting Category Scheme

This sorting list is to be used solely for the 1991 March Meeting of The American Physical Society in Cincinnati, OH, 18–22 March 1991. Use of these categories will greatly assist the sorting process, and will enhance the likelihood that your contributed abstract will be placed in an appropriate session. All contributed abstracts must conform to the rules and regulations for contributed abstracts, published on page 1629 of the *Bulletin*.

SORTING CATEGORIES

Follow general instructions on preparation of contributed abstracts.

1. Applications
   (a) Microelectronics/Device Physics
   (b) Magnetics
   (c) Detectors and Diagnostics
   (d) Modeling
   (e) Manufacturing
2. Biophysics
   (a) General
   (b) Heme proteins
   (c) Biomolecular Structure
   (d) X-Ray absorption
3. Chemical Physics
   (a) General
   (b) Spectroscopy
   (c) Collision Dynamics and Photochemistry
   (d) Quantum Chemistry
   (e) Statistical Mechanics
   (f) Surfaces
   (g) Clusters
4. Clusters
   (a) General
   (b) Metallic
   (c) Inert Gas and Semiconducting
5. Complex Fluids
   (a) General
   (b) Liquid Crystals
   (c) Lyotropics, Microemulsions, & Micelles
   (d) Colloids
   (e) Interfacial Phenomena
   (f) Nonequilibrium Phenomena
6. Disorder and Composites
   (a) General
   (b) Small Particles
   (c) Glassy Behavior in Crystals
   (d) Porous Media
   (e) Fractals
   (f) Structural Dynamics in Glass
7. Electronic Structure
   (a) General
   (b) CDW
   (c) Metals and Alloys
   (d) Semiconducting Compounds
   (e) Insulators
   (f) Transport Properties
8. Experiments and Measurements
   (a) National Facilities
   (b) Instrumentation and Measurement
9. Fluids
   (a) General
   (b) Theory
   (c) Quantum Liquids
   (d) Classical Liquids
   (e) Hydrogen
10. Glassy and Amorphous Systems
   (a) General
   (b) Elemental and Compound Glasses
   (c) Amorphous Metals
   (d) Oxide and Halide Glasses
   (e) Silica and Silicon
11. Highly Correlated Metals
   (a) General
   (b) Mixed Valence
   (c) Heavy Fermion
   (d) Kondo Lattice
   (e) Superconductivity
12. Hydrogen in Metals
13. Layered Systems
   (a) General
   (b) Intercalated Graphite
   (c) Transition Metal Chalcogenides
   (d) Metallic Superlattices
   (e) Metallic Sandwiches
14. Magnetic Order
   (a) General
   (b) Local Moment Systems
   (c) Itinerant Magnets
   (d) Spin Glasses
   (e) Low Dimensional Magnetism
15. Materials Physics
   (a) The Role of Phonons in the High-T_c Cuprates
   (b) Theory of Materials
   (c) Electronic Polymers
   (d) Optical Materials
   (e) Semiconductor Interfaces and Microstructures
   (f) Surface Magnetism
   (g) Boron Compounds
   (h) Defects in Metallic Systems, Especially Alloys
   (i) Phase Transformations
   (j) Quasicrystals
   (k) Hydrogen in Crystalline Semiconductors
   (l) Adhesion, Fracture, and Interfaces
   (m) Time-Resolved Structural Kinetics of Materials
   (n) Epitaxy Layers of High-T_c Superconductors
   (o) Two- and Three-Dimensional Nanocrystalline Solids
16. Metal-Insulator Transition
   (a) General
   (b) Doped Semiconductors
   (c) Metal Alloys
   (d) Organic Conductors
   (e) Localization in Low Dimensional Systems
17. Mesoscopic Systems
   (a) General
   (b) One Dimensional Systems
   (c) Quantum Dots
   (d) Fabrications
18. Nonlinear Phenomena
   (a) General
   (b) Chaos
   (c) $1/f$ Noise
   (d) Instabilities
   (e) Pattern Formation
19. Optical Properties
   (a) General
   (b) Surface Reflectance
   (c) Transient and Non-linear
   (d) Ions in Solids
   (e) Photoemission
   (f) Inverse Photoemission
   (g) Squeezed States
20. Phase Transitions
   (a) General
   (b) Ferroelectric
   (c) Expanded Metals
   (d) Phase Transitions at Surfaces
   (e) Experiments
21. Phonons
   (a) General
   (b) Impurity Vibrations, Lasers
   (c) Raman
   (d) Lattice Dynamics
22. Polymers
   (a) Chain Dynamics
   (b) Crystallinity, Structure, & Morphology
   (c) Phase Transitions
   (d) Rigid Rod and Liquid Crystalline Polymers
   (e) Computer Simulations and Theory
   (f) Electrically and Optically Active Polymers
   (g) Surfaces Interfaces and Thin Films
   (h) Amorphous and Crystalline Solids
   (i) Polymeric Liquids: Solutions and Melts
   (j) Gels
   (k) Properties
   (l) General
23. Quasicrystals
24. Semiconductors: Bulk
   (a) General
   (b) Optical Properties
   (c) Transport
   (d) Dilute Magnetism
25. Semiconductors: Defects
   (a) General
   (b) Shallow Levels
   (c) Deep Levels
26. Semiconductors: Heterostructure
   (a) General
   (b) Optical Properties
   (c) Transport
   (d) Quantum Hall Effect
   (e) Tunneling
   (f) Inversion Layers
   (g) Schottky Barriers
   (h) VLSI
27. Semiconductors: Superlattices
   (a) General
   (b) Optical Properties
   (c) Transport
   (d) Impurities
   (e) Amorphous Systems
28. Superconductivity
   (a) General
   (b) Tunneling
   (c) Organic
   (d) Magnetic
29. Superconductivity; High T_c
   (a) Materials
   (b) Spectroscopy: Photon in Photon out

(c) Spectroscopy: Photon in Electron out
(d) Spectroscopy: Electron in Electron out
(e) Magnetic Properties
(f) Theory: Electronic Structure
(g) Theory: Hubbard/Heisenberg
(h) Theory: Mechanisms

30. Surfaces: Metallic
(a) General
(b) Structure
(c) Electron and Ion Interactions
(d) Physisorption
(e) Chemisorption
(f) Surface Magnetism
(g) Scanning-Tunneling Microscopy

31. Surfaces: Semiconductors
(a) General
(b) Structure
(c) Adsorption
(d) Electron and Ion Interactions
(e) New Techniques

32. Theory
(a) General
(b) Many-Body Theory
(c) Density Functional Theory
(d) Molecular Dynamics
(e) Simulated Annealing
(f) Quantum Simulations—GFMC; Path Integrals

33. Thin Films
(a) General
(b) Epitaxy
(c) MBE/MOCVD
(d) Transport
(e) Laser Annealing

34. X-Ray and Neutron Scattering
(a) General
(b) EXAFS
(c) Diffraction
(d) Quasicrystals and Alloys
(e) Spectroscopy

SAMPLE ABSTRACT

Abstract Submitted
for the 1990 March Meeting
12-16 March 1990

Suggested Session Title:
Surface Structure and Dynamics

March Sorting Category:
21a

Surface Structure and Surface Dynamics of $SrTiO_3$. J. PRADE and U. SCHRÖDER, Univ. Regensburg (FRG), W. KRESS, Max-Planck-Institut, Stuttgart (FRG), F. W. DE WETTE* and A. D. KULKARNI, Univ. of Texas at Austin. — $SrTiO_3$ is of interest because of its antidistortive bulk phase transition at 105 K, and its present use as a base material for the deposition of thin films of high-T_c superconductors. Recently, the relaxation of the (001) surfaces of $SrTiO_3$ has been studied by LEED.[1] We report on calculations of the structure and the dynamics of the two (001) surfaces, carried out in the framework of the shell model. We present results on the relaxation and the surface dynamics of these surfaces and compare the former with the recent experiments.[1] Finally, we discuss the possibility of a surface phase transition and its relation to the bulk antidistortive phase transition. This question is of particular interest since these phase transitions occur at temperatures comparable to the transition temperatures of the high-T_c superconductors.

*Supported by NSF grant DMR-8816301 and Robert A. Welch grant F-433.

[1]N. Bickel *et al.* Phys. Rev. Lett. **62**, 2009 (1989).

Prefer Standard Session

F. W. de Wette
Department of Physics
University of Texas
Austin, TX 78712

Workshops to Be Held in Conjunction with the APS & the Division of Nuclear Physics

WORKSHOP PREAMBLE

Two workshops will be held in parallel on 24 October at the Physics Department of the University of Illinois at Urbana-Champaign. Registration will begin at 8:00 in the southwest lobby of the Loomis Laboratory of Physics, and one registration shall cover both workshops. The workshop on the Effects of Correlations in Nuclei will be held in Room 141 in the Loomis Laboratory of Physics. The workshop on Opportunities with Low-Energy Antiprotons will be held in Room 151 in the Loomis Laboratory of Physics. Both workshops will commence at 9:00.

WORKSHOP ON EFFECTS OF CORRELATIONS IN NUCLEI

Organizing Committee: G. A. Baym, V. R. Pandharipande (Chair), C. N. Papanicolas

The study of the influence of correlations in nuclei has been extensive, both theoretically and experimentally. The purpose of this workshop is to bring together experimentalists and theorists concerned about this issue, to review the progress made in understanding this issue, and to explore possible future directions of investigation.

SESSION I
Chairperson: J. Heisenberg

9:00
WA 1 Introduction. V. R. PANDHARIPANDE, *University of Illinois at Urbana-Champaign.*

9:15
WA 2 Correlation Effects from the Complex Nucleon-Nucleon Mean Field. C. MAHAUX,* *University of Liege, Belgium.*

The extrapolation of the optical-model potential towards negative energy provides a complex mean field for bound nucleons. The imaginary part of this field describes the spreading of the single-particle strength. The extrapolation is performed by means of a dispersion relation that connects the real to the imaginary part of the field. This approach enables the calculation of the spectral functions i.e. of the amount of strength per unit energy interval in the nuclei with (A+1) and with (A-1) nucleons. These strength distributions are usually characterized by several quantities, namely the quasiparticle energies, widths, strengths, spectroscopic factors and occupation probabilities. It will be emphasized that some of these quantities only have a limited physical meaning. Numerical results will be presented and compared with experimental data, mainly for protons and neutrons in ^{208}Pb.

*In collaboration with R. Sartor.

9:55
WA 3 CERES—A Sum Rule Approach to Occupation Numbers.*
GERHARD J. WAGNER, *Universität Tübingen, Federal Republic of Germany.*

Nucleon-nucleon correlations are expected to affect the shell-model occupancies of nuclear ground states. For the 3s-proton orbital in ^{208}Pb occupancies varying between 60% and 90% of the shell-model limit have been predicted. During the past years an extended effort to determine this quantity by transfer experiments has been made by us. A sum rule (CERES) has been proposed[1] and developed[2] which combines relative spectroscopic factors from proton removal experiments on neighbouring nuclei with a quantity derived from their charge density differences. This sum rule avoids the uncertainty of absolute spectroscopic factors and accounts, in an approximate way, for the defects arising from the neglect of high-lying spectroscopic strengths. Jointly with groups from Amsterdam, Groningen, Indiana and Saclay we have accurately measured cross sections of (d,^{3}He), (e,e'p) and (^{3}He,d) reactions on ^{206}Pb, ^{205}Tl and ^{204}Hg, all *relative* to ^{208}Pb. Together with the available mean-field interpretation of the charge density differences between these nuclei, their 3s-proton occupancies were derived. For ^{208}Pb, a value of about 85% is obtained. This result does not contradict the small absolute spectroscopic factors from (e,e'p) experiments provided that short-range correlations produce high-energy tails of the spectral functions. But it suggests that occasionally the effects of short-range correlations on ground-state occupancies may have been overestimated.

*This work has been funded by the German Federal Minister for Research and Technology (BMFT) under contract number 06 Tü 460/1 and by a NATO travel grant.
[1]H. Clement, P. Grabmayr, H. Röhm and G. J. Wagner, Phys. Lett. B183 (1987) 12 and Nucl. Phys. A494 (1989) 244.
[2]G. J. Wagner, Prog. Part. Nucl. Phys., Vol. 24, in press.

10:35 COFFEE BREAK

11:00

WA 4 Strong Nucleon-Nucleon Correlations in the Atomic Nucleus? The Issue of Absolute Spectroscopic Factors. PETER K. A. DEWITT HUBERTS, *NIKHEF-K, Amsterdam, The Netherlands.*

Recent high-resolution data of the exclusive proton knockout reaction (e,e'p) have provided evidence for the importance of nucleon-nucleon correlations in atomic nuclei. Thus similarity of nuclei with a correlated Fermi liquid rather than an uncorrelated Fermi gas of quasi-independent particles is indicated. We discuss empirical evidence in terms of the mass dependence and sparation-energy systematics of spectroscopic strength deduced from the exclusive (e,e'p) reaction. The validity of the DWIA description of the mechanism of the (e,e'p) reaction is gauged by applying a sum rule technique that combines values of relative spectroscopic factors with change density difference information deduced from elastic electron scattering. A critical comparison with the findings of the proton pickup reaction (e.g. (d,^{3}He)) is then made. It is argued that spectroscopic results from the electromagnetic and hadron reaction may be reconciled by employing proper information on the radial extension on the bound state wavefunctions as deduced from the (e,e'p) data. In a comparison with correlated nucleon many theory fair agreement is obtained.

11:40

WA 5 Nucleon-Nucleon Correlations from Pion Double Charge Exchange. W. R. GIBBS, *Los Alamos National Laboratory.*

Since the pion double charge exchange reaction requires that at least two nucleons be involved it provides an excellent technique for probing two-nucleon correlations in the nucleus. For transitions to double analog states, since the structure of the initial and final state is very nearly the same, the correlation function of the two nucleons comes into the calculation twice, and the problem of distinguishing initial- from final-state correlations is virtually eliminated. Recent studies of the calcium isotopes have clearly revealed the presence of correlation effects altering the relative cross sections by an order of magnitude.[1] We are now approaching the point of being able to use absolute measurements of angular distributions to extract the correlation structure of the valence neutrons and infer the shell model components. Up to four basis states have been used at the present time.[2] The shell model wave functions extracted with this analysis agree reasonably well with those obtained from fitting the energy levels.

[1]Z. Weinfeld et al., Phys. Rev. C37, 902 (1988); Z. Weinfeld et al., Phys. Lett. B237, 33 (1990); N. Auerbach et al., Phys. Rev. Lett. 58, 1076 (1987), Phys. Rev. C38, 1277 (1988).
[2]W. B. Kaufmann and W. R. Gibbs, Proceedings of the Second International LAMPF Workshop on Pion Double Charge Exchange, Aug. 9-11, 1989.

SESSION 2
Chairperson: C. Ciofi degli Atti

14:00

WA 6 Correlation Effects in the Longitudinal and Transverse Response of the Nuclei. J. MORGENSTERN, *CEN de Saclay, France.*

Separated response functions have been obtained in (e,e') and (e,e'p) experiments on nuclei. We discuss the kinematic conditions for the knock-out of one and two nucleons. A quenching of the longitudinal response which increases with the density of the nucleus is observed in the quasi-elastic region; this can be partially explained by correlations. The transverse response exhibits a one-body behavior for small energy transfers i.e. $\omega<\omega_0 = q_\mu^2/2M_p$. At larger energy transfers, contributions from two-nucleon processes become more important relatively to the one-body process. Evidence of electron scattering from a correlated nucleon pair is observed in e,e'p reaction on ^{3}He, ^{4}He, ^{16}O and in e,e'd reaction on ^{6}Li. This phenomenon dominates the cross section when high momentum components (>300 MeV/c) of the nucleon inside the nucleus are sampled.

14:40

WA 7 Scaling and Correlations in Nuclei.* D. B. DAY, *University of Virginia.*

The scaling of high q inclusive electron scattering in the quasielastic region has received a great deal of attention in the last 15 years.[1] As a result y-scaling is fairly well understood and it is possible to extract information about the nuclear spectral function, $S(k,E)$, from the behavior of the experimental scaling function, $F(q,y)$. In this talk, the derivation of y-scaling in the PWIA will be reviewed and a scaling analysis for light and heavy nuclei presented. Scale breaking mechanisms and non-scaling contributions to the inclusive cross section in the quasielastic region will be discussed. ^{3}He will be given special attention since, in addition to the large body of data at high q, exact non-relativistic wave functions for the ground state are available. A comparison of the scaling behavior predicted by theory with the experimental scaling function for ^{3}He at large values of y will be presented. This analysis[2] finds that experimental data shows q-independence at much lower q, suggestive that the high-k strength in the spectral function is correlated

with *low* E, in contradiction with the (e,e'p) results from ^{3}He. Recent analyses[3] will also be discussed which recognize the non-asymptotic q of experiment and the q-dependence of FSI interactions. These show that $n(k)$ derived from the asymptotic scaling function $F(\infty,y)$ agrees well with the exclusive results.

*This work is supported in part by funds provided by the U.S. Department of Energy under contract #DE-FG0586ER40261 and by funds from the Commonwealth of Virginia Center for Nuclear and High Energy Physics.

[1]D. B. Day, J. S. McCarthy, T. W. Donnelly, and I. Sick, preprint, MIT/CTP #1856 and UVA/INPP #90-13, to be published in *Ann. Rev. of Nucl. and Part. Sci.*, Vol. 40 (1990) and references therein.
[2]C. Ciofi degli Atti, E. Pace, and G. Salmè, *Phys. Lett.* 127B (1983) 303, D. B. Day, Proceedings of the Topical Workshop on Two-Nucleon Emission Reactions, Isola d'Elba, Italy, 1989.
[3]C. Ciofi degli Atti, E. Pace and G. Salmè, *Nucl. Phys.* A508 (1990) 349c.

15:10 COFFEE BREAK

15:30 Panel Discussion
W. BERTOZZI, *MIT,* M. MacFARLANE, *Indiana University,* E. MONIZ, *MIT,* V. R. PANDHARIPANDE, *University of Illinois* (convenor); J. SCHIFFER, *Argonne National Laboratory;* M. STRIKMAN, *Leningrad.*

AUTHOR INDEX

WORKSHOP ON OPPORTUNITIES WITH LOW-ENERGY ANTIPROTONS

Organizing Committee: R. A. Eisenstein, D. W. Hertzog (Chair), A. M. Nathan

The goal of this workshop is to highlight the diverse and multidisciplinary physics problems that make use of the unique characteristics of antiprotons in the sub-eV to multi-GeV range. Atomic, nuclear, and high-energy physicists are involved in many current experiments as well as in the planning for possible new facilities at CERN, FNAL, and KAON.

SESSION 1
Chairperson: G. A. Smith

9:00
WB 1 Ultra-Cold Antiprotons and Gravity Tests. M. H. HOLZSCHEITER, *Los Alamos National Laboratory.*

A fundamental experiment in gravity is the measurement of the gravitational force on antimatter. Different attempts to develop a quantum field theory of gravity lead to the prediction of massive partners of the tensor graviton as additional carriers of the force of gravity, therefore predicting a difference in the acceleration of protons and antiprotons in the Earth's gravitational field, and therefore a violation of the Weak Equivalence Principle. The availability of low energy antiprotons at CERN has made such an experiment feasible, and a proposal to carry out such a measurement has been accepted by the CERN program committee.

We plan to use a time-of-flight technique similar to that pioneered by Fairbank and Witteborn in their measurement of the gravitational force on an electron. Very slow particles are launched into a vertical drift tube and the time-of-flight spectrum of these particles is recorded. This spectrum will exhibit a cut-off point directly related to the gravitational acceleration of the particles. Obtaining very slow antiprotons involves several stages of deceleration. Antiprotons from LEAR will be initially decelerated from 2 MeV to tens of kilovolts by degrading their energy in a thin foil. After capture and cooling in a series of ion traps, the antiprotons will be in a distribution with a temperature of a few degree Kelvin. These ultra-cold antiprotons will then be released a few at a time into the drift tube. A detector will measure the arrival time of the particles at the exit of the drift tube. H^- ions, which have almost identical electromagnetic properties to the antiprotons, will be used for comparison and as a calibration standard.

The different technical aspects of the experiment and the requirements on LEAR, as well as progress in the different areas, will be presented.

9:40
WB 2 A 1000-Fold Improvement in the Measured Antiproton Mass[1] (and Other Possible Measurements with Cryogenic Antiprotons). G. GABRIELSE, *Harvard University.*

Comparisons of antiproton and proton cyclotron frequencies yield the ratio of inertial masses $M(\bar{p})/M(p)$ = 0.999 999 985±0.000 000 042. The fractional uncertainty of 4×10^{-8} is 1000 times more accurate than previous measurements of this ratio using exotic atoms and is the most precise test of CPT invariance with baryons. Independent comparisons to electrons yield the mass ratios $M(\bar{p})/M(e^-)$ = 1836.152 6380±0.000 083 and $M(p)/M(e^-)$ = 1836.152 660±0.000 088. Cryogenic antiprotons (near 4 K) stored in a Penning trap for 2 months (much longer than reported for high energy storage rings) establish a storage lifetime longer than 3.4 months. This energy is more than 10 orders of magnitude lower than for the lowest energy antiproton storage ring (LEAR at CERN). Other possible experiments with cryogenic antiprotons will be discussed.

[1]The mass measurement is a collaboration with X. Fei, L. A. Orozco, R. L. Tjoelker, J. Haas, H. Kalinowsky and T. A. Trainor.

10:20 COFFEE BREAK

10:40
WB 3 CP Violation in Hyperon Decay. G. A. MILLER, *University of Washington.*

A new approach to computing CP violating (CPV) observables in baryon processes has been developed.[1] The idea is to use measured hadronic matrix elements (including the CPV kaon observables) to compute Feynman graphs in terms of hadrons. By employing the hadronic basis one avoids the difficult steps of obtaining the quark CPV parameters from the kaonic system and inserting these quark parameters into the matrix elements involving the baryons. This hadronic approach is applied to computing the neutron electric dipole moment and to the differences between Λ and $\bar{\Lambda}$ decay observables. The numerical results are similar to other approaches that use quark operators.

[1]M. J. Iqbal and G. A. Miller, Phys. Rev. D., in press.

11:20
WB 4 High-Resolution Charmonium Spectroscopy at the Fermilab Antiproton Accumulator. KAMAL K. SETH, *Northwestern University.*

The charmonium ($c\bar{c}$) and the beauty-onium ($b\bar{b}$) systems provide much of the empirical evidence for the nature of the quark-quark interaction. Almost all our knowledge about these systems comes from e^+e^- collisions in which only the $^3S_1(1^{--})$ states are resonantly produced and are accessible to precision measurements. Other states are populated by the decay of these 1^{--} states and our knowledge about them is comparatively limited and less precise. In contrast, in $p\bar{p}$ annihilation, which proceeds through two and three gluons, all states ($J\leq3$) can be resonantly produced and studied with great precision. At the Fermilab antiproton accumulator ($T(\bar{p})\leq 8$ GeV) an experiment (E760*) has been designed to study charmonium states by their resonant production in $p\bar{p}$ collisions. The stochastically cooled circulating $\bar{p}$ beam interacting with a hydrogen gas-jet target provides a luminosity of $\sim10^{31}$ cm^{-2} sec^{-1} and a mass resolution of $\leq$ 300 keV for masses $\leq$4.3 GeV. This makes it possible to measure widths of narrow states [e.g., $^3P_1(\chi_1)$], identify states so far not seen [e.g., $^1P_1, \eta_c$], measure angular correlations, look for exotic states [e.g., glueballs, $q^2\bar{q}^2$ states, $c\bar{c}$-nucleus bound states], etc. The experiment, with its full operating detector is receiving beam presently. The first results and the future plans will be described.

*E760 Collaboration: Fermilab, Ferrara, Genoa, Irvine, Northwestern, Penn State, and Torino.

SESSION 2
Chairperson: P. Barnes

14:00
WB 5 QCD Spectroscopy with Antiprotons: Glueballs, Exotics, and Hybrids. NATHAN ISGUR, *CEBAF.*

One of the greatest challenges in the study of QCD is to understand why the quark model is such a good representation of low energy spectroscopy and to anticipate where and how it will break down. In particular, the gluonic degrees of freedom of QCD must eventually play a role in spectroscopy (in the form of glueballs and hybrids). There are also good reasons to expect that multiquark states play a more important role in low energy hadronic interactions than normally imagined. I will discuss these issues with special emphasis on the important role low energy antiprotons can play in the search for life beyond the quark model.

14:40
WB 6 Experimental Searchers for Glueballs, Exotics, and Hybrids at LEAR. R. LANDUA, *CERN, Switzerland.*

"Exotic" (non-$q\bar{q}$) mesons are probably produced in $\bar{p}$-p annihilation at rest and in flight, together with "normal" ($q\bar{q}$) mesons. Evidence for the existence of exotic states is increasing, but since many of their properties are similar to normal mesons, the final experimental proof is still missing. The present status of the search and an outline of different and complementary experimental strategies to find the "smoking gun" will be given.

3:30 COFFEE BREAK

15:40
WB 7 Antihyperon-Hyperon Production at LEAR.* FRANK TABAKIN, *University of Pittsburgh.*

Interest in antinucleon-nucleon reactions has been revitalized by the impressive experimental program at the Low Energy Antiproton Ring (LEAR). A review of recent theoretical studies of $p\bar{p}\rightarrow\bar{Y}Y$ reactions, where Y denotes the hyperons (Λ,Σ and Ξ) and $\bar{Y}$ antihyperons, will be presented. Antiproton-proton reactions have many open channels and consequently large annihilation cross-sections. In addition to understanding annihilation, the important problems are to unfold the basic strangeness production mechanism, resonance effects, initial and final state effects, coupled-channel and threshold phenomena. Recent measurements of $\bar{p}p\rightarrow\bar{\Lambda}\Lambda$ differential cross-sections, polarizations, and spin correlations, as well as cross-sections for $\bar{\Sigma}\Lambda+\Sigma\bar{\Lambda}$ production, elastic scattering, charge exchange, and pion and kaon production are all being pursued at LEAR. Theoretical understanding of these complex processes has been sought by invoking either one hadron-exchange (π, K, N, Σ, etc. exchange) or by quark-based models. The various views and conclusions in the literature will be analyzed. In addition, recent results from a momentum space coupled-channels (CC) model starting from the one-hadron-exchange mechanism, will be presented, with emphasis on threshold, resonance, cusp effects and the interplay and competition among various channels and comparison to recent data. Efforts to include quark dynamics at short distances will also be discussed.

*Research supported in part by the U.S. National Science Foundation.

16:20
WB 8 Nuclear Tests of QCD Using Low-Energy Antiprotons.[1] STANLEY J. BRODSKY, *Stanford Linear Accelerator Center.*

I will discuss several novel aspects of QCD which can studied in anti-proton annihilation processes in nuclei: 1) Charm threshold phenomena and the production of nuclear-bound charmonium in $\bar{p}$-nucleus collisions; 2) exclusive antiproton reactions in QCD; 3) $\bar{p}$-p annihilation into charmonium in nuclei as a test of QCD color transparency; 4) probing high momentum components of nuclei using $\bar{p}$ annihilation; and 5) formation zone effects, initial state interactions, and higher twist subprocesses in $\bar{p}$-p annihilation.

[1]Work supported by the Department of Energy, contract DE-AC03-76SF00515.

17:00
WB 9 New Machine Opportunities at FNAL and KAON. F. E. MILLS, *Fermi National Accelerator Laboratory.*

Recent studies, at Breckenridge and elsewhere, have helped to define more clearly the physics to be done with low energy antiprotons and the accelerators needed to carry out the experiments. At Fermilab, the mature antiproton source needs to be augmented with at least two new rings to carry out, say, baryon-antibaryon experiments to measure CP violation and to decelerate antiprotons for trap and antihydrogen experiments. The deceleration ring needs low energy electron cooling, and an RFQ to decelerate to trap capture energies. Similarly, although an antiproton accumulation system has not been designed for KAON, studies for LAMPF II indicate that rapid cycling proton accelerators will be capable of providing sources perhaps ten times more intense than those presently in operation.

AUTHOR INDEX

HOTEL RESERVATION FORM

1990 Fall Meeting of the American Physical Society
Division of Nuclear Physics
25-27 October 1990
Urbana, Illinois

(1) University Inn (10/23-10/27)
302 East John Street Single: $47 ___ Double: $54 ___
Champaign, IL 61820
(800) 322-8282
(800) 252-1368 (within Illinois)

(2) The Chancellor Hotel (10/23-10/27)
1501 South Neil Street Single: $47 ___ Double: $54 ___
Champaign, IL 61820
(800) 257-6667

(3) Days Inn-University (10/23-10/27)
1701 South Neil Street Single: $32 ___ Double: $32 ___
Champaign, IL 61820 (Special rate not available through 800#)
(217) 359-8888

The University Inn is within walking distance of Loomis Lab (meeting site). Shuttle buses will be used for the other hotels. Rooms are available as indicated above. Please indicate that you will be attending the meeting of the Nuclear Physics Division of the American Physical Society in order to receive the special rates listed. All room rates will be charged applicable taxes. All rooms will be held until 6 PM unless guaranteed for late arrival.

Reservations should be made in advance by telephoning the hotel of your choice or by mailing this form to the hotel (please, no checks). Please make your arrangements early as the rooms will be released on September 19, 1990.

Name: _____

Affiliation: _____

Address: _____

City: _____ State: _____ Zip: _____

Daytime Telephone Number: _____

Arrival Date: _____ Time: _____

Departure Date: _____ Time: _____

I wish to share a room with: _____
(If another conference attendee is named here, this person also must send in a hotel form.)

Credit Card: _____ Expiration Date: _____
(MC/VISA/AMER EXP) Number

PRE-REGISTRATION FORM

1990 Fall Meeting of the American Physical Society
Division of Nuclear Physics
25-27 October 1990
Urbana, Illinois

Surname/Family Name First Name M.I.

Mailing Address

City State Zip Code Country

Telephone number where you can be reached during the day, including area code.

APS Meeting Pre-registration fee:

$ 80.00 for members (+$10.00 if received after 9/7/90) _____

$120.00 for non-members (+$10.00 if received after 9/7/90) _____

$ 10.00 for retired & students (+$10.00 if received after 9/7/90) _____

Workshop (Antiprotons) (Oct. 24) U.S. $20 _____
(Fee waived for students)

Workshop (Correlations) (Oct. 24) U.S. $20 _____
(Fee waived for students)

Banquet (Oct. 26) U.S. $30 _____

Total _____

Form of Payment

We are unable to accept credit cards. Checks are to be made payable to DNP 1990. Send this form along with your check to:

Ms. Penny Sigler
Conference Secretary
University of Illinois
Nuclear Physics Laboratory
23 Stadium Drive
Champaign, IL 61820
(217) 333-3190

DEADLINE: 7 September 1990

UNITED AIRLINES

UNITED AIRLINES SPECIAL DISCOUNT RATES FOR THE 1990 APS DIVISION OF NUCLEAR PHYSICS FALL MEETING

Profile Number 444EZ

United Airlines is offering the attendees of the 1990 Fall Meeting of The American Physical Society **SPECIAL DISCOUNT RATES** to attend the upcoming meeting in Urbana, Illinois. These rates are available through United Airlines as the official carrier for the 1990 Division of Nuclear Physics Fall Meeting of the APS. They are offering the following discounts to our attendees:

40% Off Regular Coach Fare
5% Off Any Restricted Fare

To get these discounts, you need to use the following "Profile Number" when booking your flight:

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UNITED AIRLINES

These rates are subject to the advance purchase requirements of United Airlines, so book your flight soon. These rates also are subject to the following restrictions:

—These offers are good only for travel to and from the Fall Meeting, from 21 October 1990 to 30 October 1990.

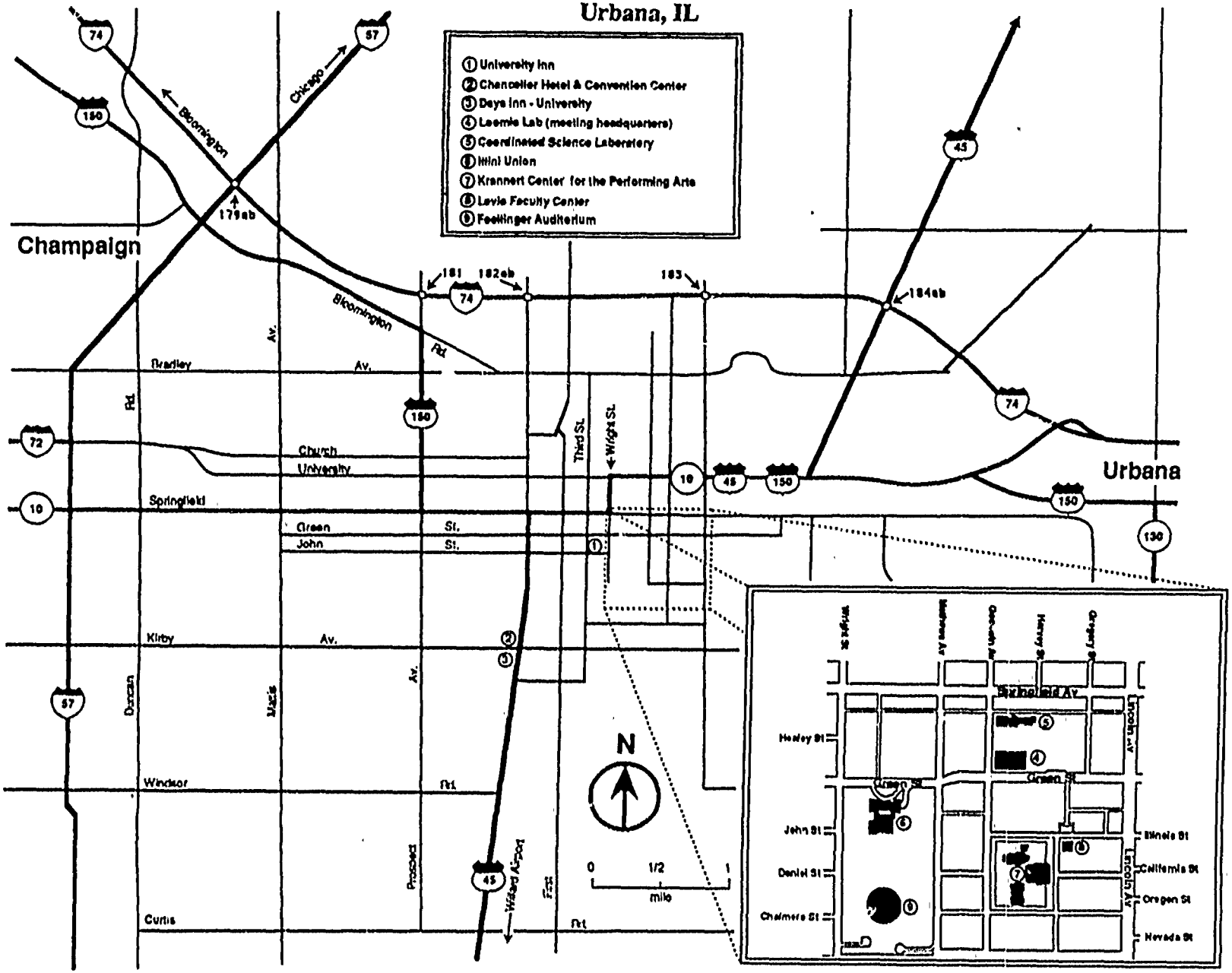
—These offers are good only for travel within the continental United States.

—Offers good on **United Airlines and United Express Only!**

Please call this toll free number **1-800-521-4041** between 8:00 AM and 11:00 PM.

Don't forget—you must use the profile number (444EZ) to procure these special discounts.

Fall 1990 Division of Nuclear Physics Meeting
Urbana, IL



Program of the 1990 Annual Fall Meeting of the Division of Nuclear Physics

Urbana-Champaign, Illinois; 24–27 October 1990

PREAMBLE

The Annual Fall Meeting of the Division of Nuclear Physics will be held 24–27 October, at the University of Illinois at Urbana-Champaign. These dates include the Wednesday workshops. The hosts for these events are the Nuclear Physics Laboratory and the Department of Physics. The meetings will be held at the Loomis Laboratory of Physics.

The University of Illinois is the academic home for about 35,000 students and about 2,000 faculty. The university houses one of the nation's premiere science and engineering campuses and provides education to about 5,000 undergraduate science and engineering students. The physics department consists of about 70 members of faculty and 300 graduate students, and its research comprises condensed matter physics, nuclear and particle physics, astrophysics, and biophysics.

The University is situated in east-central Illinois amidst some of the world's richest farmland. The towns of Urbana and Champaign have a population of about 100,000 people (exclusive of students), and are expanding and vibrant communities.

MEETING PROGRAM

The meeting consists of six sessions of invited papers, one of which is a plenary session, and 18 sessions of contributed papers. Speakers for two invited sessions have been selected by the program committee, using nominations from the DNP membership. These speakers have been placed in the sessions on "New Ideas on Old Problems" and "Exploring the Nucleus with Heavy Ions." Two sessions of invited papers have been arranged by subcommittees on topics selected by the program committee. One session on "Physics and Detectors at RHIC" has been arranged by S. Nagamiya. Another session on "Electromagnetic Structure of Baryons" has been arranged by R. G. Arnold. The local committee has arranged a session on "Nuclear Astrophysics."

The 191 contributed abstracts were arranged into 18 sessions by J. M. Dairiki, K. T. Lesko, W. D. Meyers, and H. G. Ritter of LBL, and J. D. Anderson and R. W. Bauer of LLNL. The chairpersons of the invited sessions have been selected by the program committee. The arrangers selected chairpersons for the contributed sessions, mainly from suggestions from the local committee. A plenary session "Nuclear Physics in Society" will be held on Thursday afternoon. There will be a "Town Meeting" at 16.00 on Friday afternoon.

WORKSHOPS

Prior to the divisional meeting, two workshops will be held on 24 October. A workshop on "Effects of Correlations in Nuclei" has been organized by V. R. Pandharipande, G. A. Baym, and C. N. Papanicolas. A second workshop, "Opportunities with Low-Energy Antiprotons," has been organized by D. W. Hertzog, R. A. Eisenstein, and A. M. Nathan.

PLENARY SESSION

The Plenary Session at the divisional meeting will address a new set of issues this year. Under the general title of "Nuclear Physics in Society," the session will examine areas in which nuclear physics has had, or is having, an important role to play in society at large. The session will begin on Thursday, 25 October, at 13:30 in the Foellinger Auditorium on the University of Illinois campus. The three speakers and their topics will be Sidney Drell (Stanford University), "Nuclear Physicists and Nuclear Weapons"; Paul DeLuca, Jr. (University of Wisconsin), "Recent Advances in the Use of Particle Accelerators for Radiation Therapy"; and Hans Bethe (Cornell University), "The Importance of Nuclear Power." Each talk will be 40-minutes long with 15 minutes for questions at the end.

DEPARTMENT COLLOQUIUM

At the close of the Plenary Session, the Foellinger Auditorium will be the site of the normal physics department colloquium, which for this date is being given in conjunction with the divisional meeting. John Bahcall of the Institute for Advanced Study in Princeton will discuss "Solar Neutrinos." This talk is linked to the invited session scheduled for the next morning on the topic of nuclear astrophysics.

BUSINESS MEETING/TOWN MEETING

As part of a continuing effort to provide timely information to the DNP membership and to provide a forum for public comment on issues that affect our field, the division will hold a one-hour "town meeting" style business meeting at 16.00, Friday afternoon. Reports on recent happenings of interest to the DNP, a report on recent NSAC activities, and updates from the funding agencies will be presented.

USERS' GROUP MEETINGS

The ATLAS Users' Group Meeting will be held at 18:00, Thursday, 25 October, in Room 209 of the Illini Union

The CEBAF Users' Information Meeting will be at 18:00, Thursday, 25 October; preceding this there will be a CEBAF Users' Social at 17:30. Both events will be held in Room 314A of the Illini Union.

The Indiana University Cyclotron Facility (IUCF) User's Group Meeting will be held at 18.00, Thursday, 25 October, in the General Lounge of the Illini Union.

There will be a meeting at 18.00, Thursday, 25 October, in Room 314B of the Illini Union to discuss a Radioactive Ion-Beam Facility Users' Group. A status report will be given by the steering committee, and a Users' Group will be formed. (See DNP Newsletter, No. 83, July 1990, for more details.)

Bates Users' Group Meeting will be held at 17:00, Friday, 26 October, in Room 136 of the Loomis Laboratory of Physics.

The Michigan State University National Superconducting Cyclotron Laboratory (MSUNSCL) will have a Users' Group Meeting at 17:00, Friday, 26 October, in Room 158 of the Loomis Laboratory of Physics.

HHRIF will have a Users' Group Meeting at 17:00 on Friday, 26 October, in Room 144 of the Loomis Laboratory of Physics.

HIGH SCHOOL TEACHERS' DAY

The Division of Nuclear Physics in concert with the Education Office is planning a special day for high school teachers on Thursday, 25 October. The program will consist of lectures by noted physicists and demonstrations by high school teachers for high schoolers. A luncheon and handout materials are planned.

PARKING

Limited free parking is available in Lot B13 at the corner of Springfield Avenue and Gregory Street. These spots are intended for those who arrive via car. Others should use the shuttle bus service.

SHUTTLE BUS SERVICE

Shuttle buses will be available to transport people from the Days Inn University, the Chancellor Hotel, and the University Inn to the conference site. Detailed information (time schedule and bus stop locations) will be included in the registration packet.

RECEPTION AND BANQUET

A welcoming reception is planned for Wednesday evening, 24 October 1990, from 20.00–23.00 at the University Inn. A banquet is planned for Friday, 26 October 1990, at the Illini Union. A cash bar reception will precede the banquet in the South Lounge of the Illini Union.

No formal companion's program is offered during the meeting, but information about cultural and sporting activities and about sights of interest in the surrounding area will be available.

REGISTRATION

The preregistration fees are $80 for APS members, $120 for nonmembers, $10 for retired and student members, and $20 for workshop attendance (fee waived for students). A late fee of $10 will be added after 7 September 1990. The preregistration form is located on page 1639.

Registration will begin at 8:00 in the southwest lobby of the Loomis Laboratory of Physics for both workshops on Wednesday, 24 October. Registration also will take place at the Welcoming Reception, Wednesday evening, 24 October, at the University Inn. Registration will continue on Thursday, 25 October, at 8:00 in the Loomis Laboratory of Physics.

TRAVEL AND LODGING

Urbana is located approximately 140 miles south of Chicago and 120 miles west of Indianapolis. It is served by the University of Illinois Willard Airport. There are frequent connecting flights between Champaign-Urbana and St. Louis, Chicago (both O'Hare and Midway), and Dayton, OH airports. We have made arrangements with United Airlines for special discount fares for this meeting. In addition to offering 40% off regular unrestricted coach fares, United also will discount restrictive fares by 5%. To reserve these fares, call United at 1-800-521-4041 and use the profile number 444EZ reserved for attendees of this meeting. The University of Illinois is only 10–15 minutes from Willard Airport and limousine service is both efficient and available at all times. Rental cars also are available. Urbana is approximately $2\frac{1}{2}$ hours by car from Chicago, 2 hours from Indianapolis, and $3\frac{1}{2}$ hours from St. Louis.

A block of rooms has been reserved at three local hotels for conference attendees and their guests at a special rate (plus applicable taxes). To obtain these special prices, telephone the hotel of your choice or mail the reservation form on page 1638 to the respective hotel by the *19 September 1990 deadline.*

LOCAL COMMITTEE

Members of the local organizing committee are C. N. Papanicolas (Chairman), G. A. Baym, R. A. Eisenstein, D. W. Hertzog, A. M. Nathan, and V. R. Pandharipande. For further information, please contact the conference coordinator: Ms. Penny Sigler, University of Illinois, Nuclear Physics Laboratory, 23 Stadium Drive, Champaign, IL 61820. Telephone: 217-333-3190; FAX. 217-333-1215; BITNET: SIGLER@UIUCNPL.

EPITOME

(Chairpersons are in parentheses. Names without initials indicate invited speakers. Meeting Rooms 136, 141, 144, 151, and 158 are in the Loomis Laboratory of Physics.)

WEDNESDAY EVENING

20:00–23:00 Registration and Reception. Concorde Room, University Inn.

THURSDAY MORNING

9:00 AA Physics and Detectors at RHIC. Ledoux, Ludlam, Satz, Harris. (G.R. Young). Room 141.

AB Low-Energy Heavy-Ion Reactions. (DiGregorio). Room 151.

AC Nuclear Structure I: $A < 100$. (M. A. Deleplanque-Stephens). Room 144.

AD Neutron Physics. (S. Grimes). Room 136.

AE Theory I: Structure. (V. R. Pandharipande). Room 158.

THURSDAY AFTERNOON

13:30 PA Plenary Invited Session: Nuclear Physics in Society. Drell, DeLuca, Jr., Bethe. (R. A. Eisenstein). Foellinger Auditorium, University of Illinois.

16:30 Department Colloquium. Bahcall. (G. Baym).

THURSDAY EVENING

18:00 Atlas Users' Group. Illini Union, Room 209.

18:00 CEBAF Users' Group. Illini Union, Room 314A (17:30 Social).

18:00 IUCF Users' Group. Illini Union, General Lounge.

18:00 Radioactive Ion Beam Facility Users' Group Formation Meeting, Illini Union, Room 314B.

FRIDAY MORNING

9:00 BA Nuclear Astrophysics. Turner, Lattimer, Lamb, Nagle. (G. Baym). Room 141.

BB Instrumentation I. (R. Laszewski). Room 151.

BC Nuclear Structure II: $A > 100$. (D. Balamuth). Room 144.

BD Polarization and Few Nucleon. (H. Weller). Room 136.

BE Theory II: Reactions. (J. Vary). Room 158.

FRIDAY AFTERNOON

13:30 CA New Ideas on Old Problems. Mitchell, Chupp, Weller, Magnon. (B. Clark). Room 141.

CB Intermediate Energy Heavy-Ion Reactions. (G. Westfall). Room 151.

CC Instrumentation II. (P. Debevec). Room 144.

CD Nuclear Reactions. (C. Goodman). Room 136.

16:00 PB Town Meeting. Paul, Hendrie. (J. Ball). Room 141.

17:00 Bates Users' Group, Room 136.

17:00 MSUNSCL Users' Group, Room 158.

17:00 HHRIF Users' Group, Room 144.

FRIDAY EVENING

18:00 Cash Bar. Illini Union, South Lounge.

19:00 Banquet. Illini Union, Rooms A, B, and C.

SATURDAY MORNING

9:00 DA Electromagnetic Structure of Baryons. Filippone, Bosted, Carlton, Mukhopadhyay, Nathan. (R. G. Arnold). Room 141.

DB High-Energy Heavy-Ion and $p\bar{p}$ Reactions. (T. Ludlam). Room 151.

DC Weak Interactions, Fundamental Symmetries, and Novel Nuclear Phenomena. (D. Beck). Room 144.

DD Nuclear Astrophysics and Radioactive Beams. (C. N. Papanicolas). Room 136.

DE Theory III: High Energy. (J. M. Lattimer). Room 158.

SATURDAY AFTERNOON

14:00 EA Exploring the Nucleus with Heavy Ions. Robinson, DiGregorio, McVoy, Vary. (C. Gossett). Room 141.

EB Electron Scattering. (M. K. Brussel). Room 151.

EC Giant Resonances. (S. Williamson). Room 144.

ED Theory IV: General. (D. G. Ravenhall). Room 136.

MAIN TEXT

INVITED SESSION AA: PHYSICS AND DETECTORS AT RHIC

Thursday morning, 25 October 1990; Room 141, Loomis Laboratory at 9:00; G. R. Young, presiding

9:00

AA 1 What Have We Learned from the Heavy-Ion Collisions at the BNL-AGS and CERN-SPS?
ROBERT LEDOUX, *Massachusetts Institute of Technology.*

Relativistic heavy ion beams have been available at Brookhaven National Lab (14.6 GeV-A, 16O and 28Si) and CERN (60-200 GeV-A, 16O and 32S) since 1986. A review of the data obtained from a wide variety of experiments will be given with particular emphasis on results which are not easily explained as an incoherent superposition of p+p collisions. Driving the study of these heavy-ion collisions is the expectation that a new state of matter, a Quark-Gluon Plasma (QGP), might be observed. The latest results from these experiments will be presented and evaluated with respect to proposed signatures of plasma formation.

9:36

AA 2 Overview of the RHIC Project.* T. LUDLAM, *Brookhaven National Laboratory.*

The Relativistic Heavy Ion Collider (RHIC) project at Brookhaven is scheduled to start construction in 1991 and is expected to begin carrying out experiments by mid-1997. A high energy collider for heavy ion beams, the RHIC facility will collide the heaviest nuclear beams at center-of-mass energies up to 200 GeV per nucleon, providing the means for studying new phenomena in nuclear matter at extreme conditions of temperature and density.
As preparations are made to begin construction of the accelerator and its detectors, R&D for the project has been underway since 1987, supported by the U.S. Department of Energy. This past April, Brookhaven Laboratory issued a call for Letters of Intent for experiments at RHIC, and a community-wide effort is now in progress to design experiments and develop detector techniques for the project.
This talk will describe the basic physics issues which RHIC is intended to address, and the corresponding design and performance goals for the machine. The status of R&D work on the major components of the machine, expecially the superconducting magnets will be adressed, as well as other accelerator issues which relate to the ultimate performance of the collider. The detector R&D program will be discussed, as will the status of Brookhaven's plans for implementing the research program at RHIC.

*Work performed under the auspices of the United States Department of Energy under contract DE-AC02-76CH00016.

10:12

AA 3 Theoretical Insight of RHIC Physics. H. SATZ, *CERN.*

10:48

AA 4 Prospective RHIC Experiments: Physics, Detectors and R&D. JOHN W. HARRIS, *Lawrence Berkeley Laboratory.*

With the prospect of a Relativistic Heavy Ion Collider on the horizon, physics interests have been discussed and collaborations have formed to pursue various experiments. These experiments include. a large solid angle lepton (muon and electron) pair experiment to search for a predicted suppression of the J/ψ resonance in a quark-gluon plasma, an electron pair experiment to measure low mass pairs to study effects of chiral symmetry restoration in addition to J/ψ production, spectrometers of small and large solid angle (up to $\Delta\Omega = 1$ sr) to study particle production in detail via spectra and correlations, large acceptance tracking experiments to study aspects of particle production on an event-by-event basis, large acceptance calorimeter experiments to measure energy density and jet production, as a means of studying the propagation of quarks and gluons through hadronic and quark matter, an experiment to measure photons produced directly from the plasma, and various experiments of smaller scale studying specific aspects of plasma formation. With the possibility of RHIC experiments in 1997, there is a large amount of research and development work necessary before effective design and fabrication of experiments can take place. An overview of prospective RHIC experiments and their respective physics goals will be presented. Areas of immediate need for research and development (R & D) projects and progress on R & D projects already underway will be pointed out.

*This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department Of Energy under Contract DE-AC03-76SF00098

SESSION AB: LOW-ENERGY HEAVY-ION REACTIONS

Thursday morning, 25 October 1990
Room 151, Loomis Laboratory at 9:00
D. DiGregorio, presiding

9:00

AB 1 Spin Distributions in Heavy Ion Fusion-fission Reactions* B. B. BACK, R. R. BETTS, P. FERNANDEZ, B. G. GLAGOLA, T. HAPP, AND D. HENDERSON, Argonne National Laboratory, Argonne, IL, H. IKEZOE, J.A.E.R.I, Ibaraki-ken, Japan, Ph. BENET, Purdue University, West Lafayette, IN. Fission fragment angular distributions have been measured for the reaction $^{16}O+^{232}Th$ at beam energies of 78.2, 82.2, 86.6, and 100.6 MeV. In this experiment, it was possible to determine the relative contributions of fragments from both the fission decay of the completely fused ^{248}Cf system, and the sequential fission decay of nuclei in the Th region, populated in inelastic scattering and/or transfer reactions on the Th target. This separation was made possible by using time-of-flight measurements. It was found that fragments from fission of ^{248}Cf showed a somewhat smaller angular anisotropy as compared with earlier measurements in which the sequential fission component was not excluded. The anisotropies found in the present experiment are, however, even with this correction, somewhat larger than expected on the basis of theoretical models.

*This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract W-31-109-ENG-38 and DE-FG-02-87ER40346.

9:12

AB 2 **Gamma-ray Multiplicity Distributions in the Sub-Barrier Fusion of $^{16}O+^{152,144}Sm$.*** A. H. WUOSMAA, B. B. BACK, Ph. BENET, R. R. BETTS, M.P. CARPENTER, P.B. FERNANDEZ, B. G. GLAGOLA, T. HAPP, R.V.F. JANSSENS, T.L. KHOO, F. SCARLARASSA, **Argonne National Laboratory** – We have measured γ -ray multiplicity distributions from the fusion of ^{16}O and $^{152,144}Sm$ at energies near and below the Coulomb barrier. Evaporation residue-γ-ray coincidences were obtained at five energies ranging from E_{lab}=80 to 60 MeV. Evaporation residues were separated from the beam using an electrostatic deflector and detected using a 25 element silicon detector array. Discrete-line γ ray data and γ -ray multiplicity information were obtained using the Argonne-Notre Dame BGO γ-ray spectrometer. An analysis of discrete-line data as well as γ-ray multiplicity distributions will be presented.

* Supported by the U.S. DOE, Nuclear Physics Division, under contract W-31-109-ENG-38.

9:24

AB 3 Refractive Effects in ^{12}C + ^{14}N Elastic Scattering at 20 MeV/nucleon M E BRANDAN, S.SOBERANO, E BELMONT-MORENO, A.MENCHACA-ROCHA, Instituto de Fisica, U.N.A.M., Mexico D.F., M.GONIN, R.WADA, and J.NATOWITZ, Cyclotron Institute, Texas A&M University, College Station, Texas. The elastic scattering of 280 MeV ^{14}N off ^{12}C has been measured using a beam from the new K-500 cyclotron at TAMU. The angular distribution, up to 38° in the c.m., displays a Fraunhofer crossover followed by an structureless falloff. The optical model analysis, using phenomenological and folding model (DDM3Y effective interaction) potentials, indicates important nuclear refractive contributions to the scattering, but cannot resolve the ambiguity between weakly- or strongly-absorbing potentials. The consistency of these results with others recently obtained for ^{12}C + ^{12}C and ^{12}C + ^{16}O at similar energies will be discussed.

9:36

AB 4 Alpha-particle emission from the ^{32}S + ^{24}Mg reaction. F.W. Prosser, A.T. Hasan, and S.J. Sanders, University of Kansas, D.G. Kovar, B.B. Back, C. Beck, D.J. Henderson, R.V.F. Janssens, and T.F. Wang, Argonne National Laboratory.—The spectra of alpha particles emitted in the interaction of ^{32}S + ^{24}Mg have been obtained at E(^{32}S) = 121 and 142 MeV. These spectra are being compared with predictions of the Monte-Carlo, statistical-evaporation code PACE. The results of these comparisons, at energies where incomplete momentum-transfer processes are expected to be negligible, will serve as calibration standards for use in the analysis of planned higher energy experiments where significant incomplete fusion is expected. Alpha-heavy-residue coincidence spectra have also been obtained to further constrain the analysis. This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under Contracts DE-FG02-89ER40506 and W-31-109-Eng-38.

9:48

AB 5 Light Particles, Fission Fragments, and Evaporation Residues from ^{28}Si + ^{121}Sb Reactions at 344 MeV C. COPI, P.A. DEYOUNG, J. SARAFA, Hope College, M. KAPLAN, P. KAROL, D. MOSES, W. PARKER, E. VARDACI, Carnegie-Mellon U., G. GILFOYLE, U. of Richmond, and E. REHM, Argonne Nat. Lab. -We have studied the decay of $^{149}Tb^*$ nuclei produced at an excitation energy of 240 MeV by the reaction 344-MeV ^{28}Si + ^{121}Sb at the ATLAS facility. Light charged particles and fission fragments were measured using Si telescopes and time-of-flight, and evaporation residues were detected in a split-pole magnetic spectrograph which served to eliminate contamination from other reaction products. In addition to singles measurements, coincidences were recorded between light particles and fission fragments, light particles and evaporation residues, and light particles and other light particles. The combination of singles data with the various coincidence measurements provides strong constraints on the analyses of the de-excitation channels, and yields insight into the de-excitation mechanisms of hot nuclei.
This work was supported by the NSF and the DOE

10:00

AB 6 Light Particle - Light Particle Correlations from ^{32}S + ^{27}Al Reactions at 105 and 215 MeV J. SARAFA, P.A. DEYOUNG, C. GELDERLOOS, R. SEDLAR, Hope College*, R.L. MCGRATH, G. GILFOYLE, and V. DATAR SUNY, Stony Brook† -We have measured small angle correlations between light particles (p,d,t,α) at the two beam energies of 105 and 215 MeV for the ^{32}S + ^{27}Al system. As for earlier work[1], at these energies and at the angles chosen for the detectors, significant numbers of light particles originate from statistical emission from a compound nucleus. Thus the measured correlation functions should reflect source sizes and time scales consistent with a long lived, relatively large emitter. The results of p-p and p-d correlation functions will be compared with the results of a model based on statistical emission. The small angle correlation functions will also be compared to the results from earlier work.
*Supported by the NSF and by a William and Flora Hewlett Grant of Research Corporation.
†Supported by the NSF and the DOE
[1]P.A. DeYoung, et al., Phys. Rev. C41, R1885 (1990).

10:12

AB 7 Cross Sections of Intermediate Masses from ^{16}O + ^{27}Al Reactions at 140 MeV P.A DEYOUNG, C. COPI, Hope College†, L.L LEE, Jr , R.L. MCGRATH, A.L. CARALEY, W.J. KERNAN, C.F. LIANG, and J.C. MAHON SUNY, Stony Brook† -We have measured $\frac{d\sigma}{dE\,d\Omega}$ for particles of mass 1 to mass 12 from the ^{16}O + ^{27}Al

system at 140 MeV. The narrow timing properties of the SUNY-Stony Brook LINAC made it possible to determine mass from time of flight with single element Si detectors. The single element configuration resulted in energy thresholds which ranged from 1.5 MeV for mass 1 to 5 MeV for mass 12 (primarily limited by the flight path) and the angle range covered was 30° to 175° The experimental configuration was optimized to measure emission of these masses from the compound nucleus The implications of these results for understanding the previously measured[1] correlation functions involving the breakup of particle unbound resonant states will be discussed.
†Supported by the NSF
[1]P.A. DeYoung, et al., Phys. Rev. C41, R1885 (1990).

10:24
AB 8 Selective population of states in ^{28}Si from the symmetric fission of ^{56}Ni. S.J. Sanders, F.W. Prosser, University of Kansas, B.B. Back, Ph. Benet, R.R. Betts, M.P. Carpenter, D.J. Henderson, R.V.F. Janssens, T.L. Khoo, F. Moore, F.L.H. Wolfs, A H Wuosmaa, Argonne National Laboratory, and K.B. Beard, Notre Dame University.—We have studied the population of states in ^{28}Si produced in the ^{32}S+^{24}Mg reaction at $E_{lab}(^{32}S)$ = 120 MeV. Particle-γ coincidences were measured using the Argonne-Notre Dame γ-ray facility. ^{28}S identification was achieved by detecting in coincidence both fragments from the binary breakup of the ^{56}Ni compound nucleus. Two 20 cm x 20 cm position-sensitive, multiwire proportional counters, located on opposite sides of the beam axis at ±35°, were used for the particle detection. The positioning of these detectors at large angles selects events where the ^{28}Si fragments are fully energy damped. Coincident γ-rays were detected using eight Compton suppressed Ge detectors and a 42 element, close-packed array of BGO detectors. A non-statistical population of states in the ^{28}Si fragments is observed. The implications of these results on our understanding of the structure of the scission configuration will be discussed. This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under Contracts DE-FG02-89ER40506 and W-31-109-Eng-38.

10:36
AB 9 Energy Dependence of Quasi-Elastic Transfer Reaction in the ^{32}S+^{93}Nb System *, J. F. Liang, J. C. Mahon, A. A. Soler, R. J. Vojtech, and L. L. Lee, Jr S.U.N.Y. at Stony Brook Energy integrated differential cross sections have been measured for few- nucleon transfer reactions in ^{32}S + ^{93}Nb at laboratory ^{32}S energies of 116 MeV (the Coulomb Barrier) and 140 MeV. Mass identification of the sulfur -like reaction products was obtained through time-of-flight, using the bunched LINAC beam as time reference. Where possible Z identification was also made by using ΔE-E telescopes. These measurements can be combined with our earlier results[†,‡] at other near-barrier energies to provide a picture of the energy evolution of these reactions. Comparison will be made with the predictions of DWBA calculations and other approaches to describing the reaction mechanism.

Work supported by the National Science Foundation
[†]J. F. Liang *et al.* Bull. Am. Phys. Soc. 34,1808 (1989)
[‡]R. B. Roberts *et al.* Bull. Am. Phys. Soc. 34,1809 (1989)

10:48
AB 10 Quasielastic Scattering and Transfer Reactions for ^{206}Pb + ^{235}U*. K.G. Helmer, C.Y. Wu, D. Cline, E.G. Vogt, W.J. Kernan, A.E. Kavka *University of Rochester*, M.A. Stoyer, M.A. Deleplanque, R.M. Diamond, M. Lee, A.O. Macchiavelli, R. McDonald, J.O. Rasmussen, F.S. Stephens *LBL*, and X.T. Liu, *University of Tenessee*—The reaction ^{206}Pb+^{235}U at a beam energy of 1394 MeV was studied using LBL's SuperHILAC and 14 Compton-suppressed Ge detectors. In the one-neutron pickup reaction ^{235}U(^{206}Pb, ^{207}Pb)^{234}U, spin states up to $28^+(30^+)$ were identified from $\gamma-\gamma$ coincidence spectra. Evidence for a band crossing is noted in the spin 20 region. A comparison is made with the transferred angular momentum in the inelastic excitation and in the one-neutron transfer $\gamma-\gamma$ coincidence spectra, with those of a previous experiment[†] using ^{58}Ni as the projectile. Results will be compared with semiclassical calculations of the inelastic populations for each projectile.

*This work supported by the NSF and DOE
[†]C.Y. Wu, X.T. Liu *et. al.* Phys. Lett. B 188 25 (1987)

11:00
AB 11 Evaporation Residues at $E^* \approx 400$ MeV.[§] R.A ESTERLUND, S. BEIERSDORF, M. KNAACK, B. JÄCKEL, W. WESTMEIER, P. PATZELT, F.P. HEßBERGER AND V. NINOV, Institut für Kernchemie Marburg and GSI Darmstadt. - Using offline gamma-ray spectrometry together with the velocity separator SHIP at GSI, we have measured cross sections and angular distributions for evaporation residues (ER) in the reaction 15 MeV/u ^{40}Ar + ^{154}Sm. The compound nucleus (CN) ^{194}Hg has an initial excitation energy of *ca.* 400 MeV. The gaussian-like ER mass-yield distribution has its centroid at A ≈ 160 and an area of *ca.* 1.9 mb. When corrected by the calculated SHIP efficiency $\epsilon \approx 0.04$, this gives a total deduced ER cross section of *ca.* 48 mb ($l_{ER} \approx 33$). The product moving-frame angular distributions as well as genetic analyses of parent-daughter decay curves indicate that products with A ≥ 160 are pure ER, whereas lower-mass product yields require small corrections for deep-inelastic contributions. As empirical systematics derived *for much lower energies* predict an $l_{ER} \approx 35$ for ^{194}Hg, we consider our deduced ER yield to be surprisingly large. Such data might be explained by an initial de-excitation stage of the CN in which sizeable nucleon emission multiplicities provide sufficiently fast cooling so as to prevent fission.
[§] Research supported by the BMFT, contract number 06 MR 107.

11:12
AB 12 Study of fission dynamics via prompt muon-induced fission. V.E. OBERACKER, A.S. UMAR, J.C. WELLS, Vanderbilt Univ., J. WU, M.R. STRAYER, C. BOTTCHER, ORNL.* -- Prompt fission of actinide nuclei induced by muon beams allows us to study the nuclear viscosity during fission. Following atomic muon capture, the inner-shell transitions may proceed by inverse internal conversion, i.e. the muonic excitation energy is transferred to the nucleus. In actinides, the 2p->1s and 3d->1s transition energies are of order 6.5 - 10 MeV and result in excitation of the E1 and E2 giant resonances which act as doorway states for fission. We solve the time-development of the muonic wavefunction (4-spinor) in the Coulomb field of the fissioning nucleus, using a 3-d lattice representation of the Dirac equation. The muon attachment to the light fission fragment is a measure of the nuclear viscosity between saddle and scission point.
* Supported by grants from DOE and the National Center for Supercomputing Applications (NCSA)

Supplementary papers

AB 13 Search for Berry's Phase Effects in Rotational Nuclei* K.G. Helmer, C.Y. Wu, D. Cline, A.E. Kavka, W.J. Kernan, E.G. Vogt *University of Rochester*, M.W. Guidry, X.L.

HAN, R.W. KINCAID, X.T. LIU, H. SCHECTER *University of Tenessee*, J.O. RASMUSSEN, A. SHIHAB-ELDIN, M.A. STOYER *LBL*, AND M.L HALBERT, I.Y. LEE, *ORNL*—The idea of diabolic pair transfer has recently been of great interest and has been explained[†] as a manifestation of Berry's Phase in rotational nuclei. An experiment has been performed to look for evidence of this effect in the rare-earth region. The reaction ^{156}Gd +^{206} Pb at a beam energy of 888 MeV was studied using the Spin Spectrometer, the scattered ions were detected in coincidence with the deexcitation γ rays. Fifteen Compton-suppressed Ge detectors were used. Data for both two-neutron pickup and stripping reactions (leading to ^{158,154}Gd) was analyzed. The results will be presented and compared with the predictions of a semiclassical calculation that includes CHFB form factors.

*This work supported by the NSF and DOE

†R.S. Nikam and P. Ring, Phys. Rev. Lett 58 980 (1987)

AB 14 Variation of Fissionlike Angular-Distribution Anisotropies with Exit-Channel Mass Asymmetry.[§] R. A. ESTERLUND, M. KNAACK, B. JÄCKEL, W. WESTMEIER, and P. PATZELT, Institut für Kernchemie Marburg. - The dependence of the angular distribution anisotropy A_n = W(0°, 180°)/W(90°) for fission/fissionlike processes on exit-channel product mass asymmetry α has been determined for the systems 5.2 MeV/u ^{40}Ar + ^{165}Ho, ^{181}Ta. As in the system 5.3, 7.5 MeV/u ^{40}Ar + ^{197}Au, we observe an increase in A_n with increasing |α|, although not as pronounced as in the latter system. As before, asymmetry about 90° in the rest frame is observed at large |α|, even though the corresponding mass bins lie within the symmetric component. Comparisons of Transition-State Model (TSM) and Statistical Scission Model (SSM) predictions for A_n with data at mass symmetry show overall good agreement, in contrast to the system ^{40}Ar + ^{197}Au. Some measurements elsewhere of gamma multiplicities as a function of fission product mass show a decrease with increasing |α|, which correlates with a decrease in exit-channel product spin I_f with |α|. This decrease in I_f can in turn be correlated *via* the SSM with an increase in A_n, which is consistent with our observations on the behavior of A_n with |α|.

§ Research supported by the BMFT, contract number 06 MR 107.

SESSION AC: NUCLEAR STRUCTURE I: $A<100$
Thursday morning, 25 October 1990
Room 144, Loomis Laboratory at 9:00
M.-A. Deleplanque-Stephens, presiding

9:100
AC 1 The (^{9}Be,^{6}He) Reaction on ^{9}Be, ^{10}B, ^{11}B and ^{12}C.* L.M. COMER, E.L. REBER, S.M. AZIZ, and K.W. KEMPER, Florida State U. and J.D. BROWN, Princeton U -- The possibility that the isolated single peaks observed in the (p,π^+) reaction[1] around 22 MeV in excitation in ^{13}C, ^{14}C and ^{15}N are $T_>$ states has led us to investigate the (^{9}Be,^{6}He) reaction. This reaction can populate these states if the three particle transfer is not cluster-like. Data have been taken at bombarding energies of 40 and 73 MeV. The differential cross sections range from a high of 80μb/sr on ^{9}Be to about 10μb/sr on ^{12}C. The 0^+, T=1 state at 2.31 MeV in ^{14}N is not observed. Spectra for all ejectiles from ^{10}Be down to ^{4}He will be presented.

1. E. Korkmaz et al., Phys. Rev. C40, 813 (1989); S.M. Aziz, Ph.D. Dissertation (1988).

*Work supported by the National Science Foundation.

9:12
AC 2 The 1-forbidden Gamov-Teller Decay of ^{39}Ca. B. HAGBERG, T.K. ALEXANDER, G.R. DYCK, V.T. KOSLOWSKY, G.C. BALL, J.S. FORSTER, J.C. HARDY, H. SCHMEING, Atomic Energy of Canada Limited. J.R. LESLIE and H.-B. MAK, Queen's University. --- The β decay from ^{39}Ca to the first excited state in ^{39}K is 1 forbidden (0d3/2 → 1s1/2). It can thus proceed only through second order effects such as core polarization, meson-exchange currents and delta excitations in the nucleus. The same is true for the M1 transition connecting the first excited state in ^{39}K with the ground state (1s1/2 → 0d3/2); in fact a comparison between the M1 and GT transitions provides a powerful constraint on the theory behind these second order effects.

At present, theory and experiment do not agree. There are several consistent sets of data on the M1 transition but only one measurement of the GT matrix element. We are therefore in the process of re-measuring the GT transition. The difficulty in this experiment is that a very weak branch (~2x10^{-5}) has to be measured in the presence of the dominating ground-state decay branch. Care has to be taken to minimize the γ-ray background generated by this strong transition. Our experimental procedure will be outlined and a status report on the experiment will be given.

9:24
AC 3 MASS MEASUREMENT OF NEON THROUGH ARGON NEUTRON-RICH NUCLEI* X.G. Zhou, X.L. Tu, V.G. Lind, Utah St. U., D.J. Vieira, J.M. Wouters, Los Alamos Nat. Lab., Z.Y. Zhou, Nanjing U. & Los Alamos Nat. Lab., H.L. Seifert, U. Giessen & Los Alamos Nat. Lab. The masses of several neutron-rich nuclei for the isotopes of neon through argon have been measured using the TOFI recoil spectrometer located at LAMPF. The nuclei were produced via the bombardment of a 1 mg/cm^2 ^{nat}Th target with 800MeV protons. Two fast timing detectors at the entrance and exit of the TOFI spectrometer were used to measure the ion's TOF with high precision ($t/\Delta t>3000$) since the TOF is directly proportional to an ion's mass-to-charge ratio. A Bragg-curve gas ionization counter, located at the end of TOFI, was used to determine the atomic number and energy of the recoils. By combining a velocity measurement, as determined before the spectrometer with the energy and mass-to-charge ratio information, the charge of each ion could be defined. Since charge is quantized one can obtain a high precision measurement of an ion's mass directly from the mass-to-charge measurement. The new masses of this experiment will be compared with several mass models and a recent sdfp shell calculation[(1)].

(1)E.K. Warburton, et al., Phys. Rev. C 41, 1147 (1990)

* Work supported by U.S. Department of Energy.

9:36
AC 4 EXTENSION OF THE MASS SURFACE FOR EXOTIC NEUTRON-RICH ISOTOPES IN THE Z=17-26 REGION* X. L. Tu, X.G. Zhou, V.G. Lind, Utah St. U., D.J. Vieira, J.M. Wouters, Los Alamos Nat. Lab., Z Y Zhou, Nanjing U. & Los Alamos Nat. Lab., H L Seifert, U.Giessen & Los Alamos Nat. Lab. Over 30 neutron rich isotope masses from chlorine through iron have been measured by using the TOFI spectrometer at LAMPF. This large new set of data has enabled us to extend neutron and proton pairing energy calculations to more neutron-rich nuclei and evaluate the reported neutron-excess (I) dependence in a region (Z=21-26) where pairing energies are expected to be relatively large and the mass surface reasonably smooth. The investigation leads to the mixed conclusion that an I^2 dependence is evident in Z=21-23 nuclei, but that little or no dependence is observed in the Z=24-27 isotopes. Moreover, our data delineates a new region of enhanced binding centered around ^{53}Sc ,

but not for the predicted doubly magic nucleus ^{52}Ca. Finally we have compared our masses to several mass models and found that many of these models tend to overpredict the binding for the most neutron-rich isotopes of V through Fe with the exception of mass predictions using the Garvey-Kelson mass relationship and the modified shell-model mass equation [(1)].

(1) C. N. Davids, Phys. Rev. C 13, 887 (1976).

* Work supported by U.S. Department of Energy.

9:48

AC 5 **The Level Structure of ^{64}Ge.*** P.J. ENNIS, C.J. LISTER, **Yale University** B.J. VARLEY, **University of Manchester** P.A. BUTLER, T. HOARE, **University of Liverpool** W. GELLETLY, H.G. PRICE, **S.E.R.C. Daresbury** W. NAZAREWICZ, **Warsaw Institute of Technology**--Several recent calculations predict the presence of low-lying octupole correlations in the N=Z nucleus ^{64}Ge due to the mutual excitation of $p_{3/2} \rightarrow g_{9/2}$ neutrons and protons Because of the low production cross section for ^{64}Ge (~ 5 mb), no $\gamma\,\gamma$ coincidence data were previously available We have studied the reaction ^{12}C(^{54}Fe,2n)^{64}Ge at 165 MeV using the Daresbury Recoil Separator, operated in conjunction with the Polytessa γ-array. Using recoil-γ-γ data and recoil-γ angular distribution data, we have placed 20 transitions in the ^{64}Ge energy level scheme. The level scheme appears to have a candidate $J^{\pi}=3^-$ state at 2.97 MeV which follows the systematics of the heavier Ge isotopes, but is not indicative of strong octupole collectivity The negative parity states appear to be connected to the ground state band by intense E1 transitions which are forbidden in self-conjugate nuclei, and indicate possible mixing between T=0 and T=1 states.

*Supported by USDOE Contract No. DE-AC02-76ER-03074

10:00

AC 6 **The shape of the N = Z + 1 nucleus ^{71}Br†.** J. ARRISON, T. CHAPURAN, U. J. HUTTMEIER, D. P. BALAMUTH, *Department of Physics, University of Pennsylvania.* Electromagnetic transitions in the previously unknown neutron-deficient nucleus ^{71}Br have been identified in the ^{40}Ca(^{34}S,$p\,2n$) reaction using a 4π charged particle spectrometer[1] in coincidence with a large-volume neutron detector. Fifteen γ rays were placed in a decay scheme using a separate $n-\gamma-\gamma$ coincidence experiment A $\Delta J = 2$ decoupled band is observed built on an isomer with a half-life of 30 5 ± 4.5 ns which is attributed to the $g_{9/2}$ intruder orbital This suggests an interpretation in terms of the odd proton coupled to a core with prolate shape, in contrast to the situation observed[2] in the $N = 35$ system ^{69}Se, where the existence of a strongly coupled band has been cited as evidence of a theoretically predicted[3] transition to stable oblate shape in the vicinity of ^{70}Br.

†Work supported by the National Science Foundation.

[1]T. Chapuran *et al.*,Nucl. Instr. Methods A272, 767 (1988).
[2]M. Wiosna *et al.*, Phys. Lett. 200, 255 (1988); J. W. Arrison *et al.*, Phys. Rev. C 40 2010 (1989).
[3]R. Bengtsson *et al.*, Phys. Scr. 29, 402 (1984).

10:12

AC 7 **Charged Particle and Gamma-ray Spectroscopy of ^{84}Zr.*** C.J. LISTER, D.J. BLUMENTHAL, P. CHOWDHURY, B CROWELL, P.J ENNIS, Ch. WINTER, **Yale University,** H.R. ANDREWS, G.C. BALL, D. RADFORD, D. WARD, **Chalk River Nuclear Laboratories,** V P. JANZEN, **CRNL and McMaster University,** T. DRAKE, A. GALINDO-URIBARRI and G. ZWARTZ, **University of Toronto**--The N=44 isotones have attracted interest, both because of a recent report of structure dependent charged particle emission in their population[1], and because of predictions of superdeformed bands[2]. We have investigated both aspects of the structure of ^{84}Zr using the reaction ^{58}Ni(^{29}Si,2pn)^{84}Zr at 110 MeV. The Chalk River 8π spectrometer was used in conjunction with an array of 16 CsI charged particle detectors. The experiment had high statistics (7×10^7 proton-γ-γ events with BGO multiplicity > 5) and revealed discrepancies with the previously published decay scheme[3] at the highest spins. Aspects of discrete line, continuum and charged particle data will be presented.

* Work supported by USDOE Contract No. DE-AC02-76ER03074.

1. D.G. Sarantites et al., Phys. Rev. Lett. 64 (1990) 2129.
2. I. Ragnarsson and T. Bengtsson, Conf. on Nuclear Structure of the Zirconium Region, Ed. J. Ebeth, Publ. Springer 1988, p. 193.
3. H.G. Price et al., Phys. Rev. Lett. 51 (1983) 1842.

10:24

AC 8 **Spectroscopy of N=45 Isotones ^{85}Zr and ^{87}Mo.*** Ch. WINTER, D. BLUMENTHAL, P. CHOWDHURY, B. CROWELL, P.J. ENNIS, C.J. LISTER **Yale University**--The transition from single-particle to collective excitation in the neutron deficient A~80 region is abrupt, the N=44 isotones have well developed bands linked by enhanced E2 transitions, while N=46 isotones at low spin are dominated by non-collective states. In order to investigate the microscopic structure of this abrupt change we have studied the N=45 zirconium and molybdenum isotopes. The ^{58}Ni(^{31}P,3pn)^{85}Zr, ^{56}Fe(^{32}S,2pn)^{85}Zr and ^{58}Ni(^{32}S,2pn)^{87}Mo reactions were studied with beams from the ESTU accelerator and radiation detected in the Yale Gamma-X array. Only four states in ^{85}Zr have been previously reported [1] and none in ^{87}Mo. We have found clear-cut isotonic trends, with evidence for bandstructure developing above the low-lying three-quasi-particle states. The properties of these nuclei and the development of collectivity will be discussed.

1. T. Kuroganagi et al., Nucl. Phys. A484 (1988) 264.

*Supported by USDOE Contract No. DE-AC02-76ER-03074

10:36

AC 9 **High-Spin DSAM Lifetime Measurement in ^{86}Zr.*** P. CHOWDHURY, D.J. BLUMENTHAL, B. CROWELL, P.J. ENNIS, C.J. LISTER, Ch. WINTER, **Yale University,** H.R. ANDREWS, D. RADFORD, D. WARD, **Chalk River Nuclear Laboratories,** V.P. JANZEN, **CRNL and McMaster University,** J. JOHANSSON, A. OMAR, D. PREVOST, J.C. WADDINGTON, **McMaster University,** T. DRAKE and A. GALINDO-URIBARRI, **University of Toronto.**--In order to quantify the evolution of spin stabilized deformation in the transitional ^{86}Zr nucleus[1], we have performed DSAM lifetime measurements at high spin via the ^{60}Ni(^{30}Si,2p2n)^{86}Zr reaction at 135 MeV with the 8π spectrometer at Chalk River. The transitions of interest form a strongly coupled band built on a 14^+ state, with M1 transitions and E2 crossovers, which exhibit a staggering in both the M1 transition energies and M1/E2 branching ratios. Previous lifetime measurements[2] in this nucleus showed an absence of collective strength at low spins. In contrast, the transitions at the top of the high-spin band show Doppler shifts in the present data, implying significant collectivity. The detailed line shape analyses will be discussed in the context of structure changes in this transitional nucleus.

* Work supported by USDOE Contract No. DE-AC02-76ER03074.

1. P. Chowdhury et al., Proc. ACS Symp. on Exotic Nuclear Spectroscopy, Miami Beach, 1989.
2. E.K Warburton et al., Phys. Rev. C31, 1211 (1985).

10:48

AC 10 **B(E2) Strengths in $^{90-96}$Sr and Strong Subshell Effects in Sr Nuclei*** F.K. WOHN, JOHN C. HILL, Ames Lab. and Iowa State U., H. MACH, U. Uppsala, K. SISTEMICH, G MOLÁR, KFA Jülich, R.L. GILL, W. KRIPS, M. MOSZYNSKI, BNL, D.S. BRENNER, Clark U. — β-γ-γ fast timing[1] was used to measure lifetimes of 2_1^+ levels in $^{90-96}$Sr. The B(E2,$0_1^+ \rightarrow 2_1^+$) values, which fill the N=52-58 gap in the known Sr B(E2) values for $40 \le N \le 62$, are exceptionally small and provide direct evidence for a strong subshell effect at Z=38 for

N=52-58. The B(E2) values establish a close similarity between Sr and Zr nuclei with N=52-58, which form a region of the lowest B(E2) values (for nuclei with A>56) second only to $^{204-210}$Pb. Unique to the B(E2) systematics of Sr and Zr is a sudden, large change in the B(E2) strength, by a factor of ~15, at N=60 where the sudden onset of deformation occurs. Recent laser spectroscopic measurements of Sr radii can be interpreted in terms of quadrupole and octupole contributions to the rms radii.

*Work supported by the U.S. Department of Energy under Contract No. W-7405-ENG-82 and AC02-76CH0016.
[1]H. Mach, et al., Nucl. Instr. Meth. A280, 49 (1989).

SESSION AD: NEUTRON PHYSICS

Thursday morning, 25 October 1990
Room 136, Loomis Laboratory at 9:00
S. Grimes, presiding

9:00

AD 1 Energy Dependence of the n-^{208}Pb Surface Imaginary Optical Potential at Low Energies. R.E. SHAMU, J. BARNES, S.M. FERGUSON, Western Michigan Univ., and G. HAOUAT, J. LACHKAR, Centre d'Etudes de Bruyères-le-Châtel.---A phenomenological optical model analysis of n-^{208}Pb differential cross sections for elastic scattering has been performed over the neutron energy range 7.5-13.5 MeV using a spherically-symmetric central potential. The central potential geometry and spin orbit potential employed were those utilized for an analysis of neutron total cross sections.[1] The imaginary volume potential was assumed to be zero. Our $\sigma(\theta)$-derived values of the real potential strength V are in excellent agreement with σ_t-derived values; however, our values of the surface imaginary potential strength W_D are significantly larger than σ_t-derived values at the low end of the energy range. We attribute this large difference in W_D to strong coupling between the ^{208}Pb ground state and low-lying collective states; i.e., coupled-channel calculations are required here. For linear V(E) the σ_t-derived W_D(E) sharply increases in slope near 8 MeV. This feature may be caused by the opening of the ^{208}Pb (n,2n) channel (IQI = 7.4 MeV).

[1]J. Barnes and R.E. Shamu, J. Phys. G. 15, L179 (1989).

9:12

AD 2
A Dispersion-Relation Optical Model for n + ^{28}Si, M. A. ALOHALI, J. P. DELAROCHE, C. R. HOWELL, W. TORNOW and R. L. WALTER, Duke University and Triangle Universities Nuclear Laboratory (TUNL)*.--Howell *et al.*[1] showed that $A_y(\theta)$ and $\sigma(\theta)$ data for (n,n) and (p,p) scattering from ^{28}Si can be fairly well described with a single spherical optical model (SOM) potential. The data base for neutron scattering included $A_y(\theta)$ data from TUNL at 10 to 17 MeV and $\sigma(\theta)$ data from TUNL and elsewhere from 8 to 40 MeV. In particular, above about 11 MeV the model gave a good description of $\sigma(\theta)$ and neutron total cross section σ_T and a reasonable description of $A_y(\theta)$. However, the $\sigma(\theta)$ agreement for (n,n) deteriorated in the 8- to 11-MeV region and the σ_T prediction was poor when the model was extrapolated beyond 4 MeV. (Coupled-channels calculations offered only a slight improvement.) In order to attempt to understand the discrepancies and to establish a more complete picture of the SOM, both for the scattering region (positive energy region) and the bound-state region (negative energies), we applied the dispersion relation (DR) formalism[2] to the n + ^{28}Si problem. Our goal was to explain all the features in the $A_y(\theta)$, $\sigma(\theta)$ and σ_T at energies between 2 MeV ≤ E ≤ 80 MeV. Results of the DR model will be presented.

*Work supported by the U.S. DOE, Office of High Energy and Nuclear Physics, under Contract No. DE-AC05-76ER01067.
[1] C. R. Howell et al., Phys. Rev. C38, 1552 (1988).
[2] See example in C. H. Johnson, D. J. Horen and C. Mahaux, Phys. Rev. C36, 2252 (1987).

9:24

AD 3 The (n,p) Reaction on Sulfur for Incident Neutron Energies of 50 MeV - 250 MeV.* B.K. Park[1], X. Aslanoglou[1], F.P. Brady[3],G. Fink[1],R.W. Finlay[1], C.R. Howell[4],A. Ling[2], P.W. Lisowski[2], J. Rapaport[1],J.L. Romero[3],D. Sorenson[3], W. Tornow[4], J.L. Ullmann[2]. The white neutron source at Los Alamos National Laboratory was used to study the (n,p) reaction on ^{NAT}S. Data for neutron energy range of 50 MeV to 250 MeV will be presented for Gamow-Teller transitions and compared with data from the (p,n) reaction[1].

[1]Ohio University, Athens, OH 45701, [2]Los Alamos National Laboratory, Los Alamos, NM 87544, [3]University of California, Davis, CA 95616, [4]Duke University, Durham, NC 27707
*Supported by the NSF and DOE
1. B.D. Anderson, et al., Phys. Rev. C36, 2195 (1987).

9:36

AD 4 Level Density and Level Widths of ^{29}Si,* V. MISHRA, S.M. GRIMES, N. BOUKHAROUBA, K. DOCTOR, R.S. PEDRONI, Ohio University, R.C. HAIGHT, J.A. BOUNDS, Los Alamos National Laboratory -- Neutron total cross sections of ^{28}Si have been measured from 4.5 to 150 MeV with an uncertainty of less than 3% using a TOF facility at WNR. The time resolution is better than a nanosecond. Level density and level widths of the compound nucleus ^{29}Si will be discussed as a function of excitation energy and angular momentum over the region in which an Ericson analysis could be made. The techniques used to obtain these parameters and the parameters themselves will be compared with those from previous measurements, made elsewhere. The systematics will also be compared with theoretical predictions.

* Work supported by the U.S. Department of Energy.

9:48

AD 5 Excitation of $(d_{5/2}, p_{3/2}^{-1})4^-$ Stretched-State Strength in the ^{14}C(p,n)^{14}N Reaction at 135 MeV.* L.A.C. GARCIA, B.D. ANDERSON, A.R. BALDWIN, R. MADEY, D.M. MANLEY, R. POURANG, E. STEINFELDS, J.W. WATSON, Kent State U., C.C. FOSTER, A. BACHER, Indiana U., R. LINDGREN, B. CLAUSEN, U. of Virginia -- Neutron time-of-flight spectra for this reaction were obtained with the beam-swinger system at the IUCF. Energy resolutions were about 300 keV. Neutron TOF spectra, obtained at 12 angles between 0° and 63°, were converted to excitation-energy spectra. The 4^- strength is split into three isospin components: 75% of the extreme single-particle-hole model (ESPHM) T=0, 4^- strength is observed in a single state at 8.5 MeV; 42% of the ESPHM T=1, 4^- strength is observed in two states at 13.7 MeV and 19.4 MeV; 42% of the ESPHM T=2, 4^- strength is observed in a single state at 26.4 MeV. The observed 4^--state excitation energies and strengths are in good agreement with the analog T=1 and 2, 4^--states observed in the (e,e') reaction.[1] The observed 4^- strength compares well with a PSD shell-model calculation.

* Supported in part by the National Science Foundation.
[1] M.A. Plum, U. Mass Ph.D. Dissertation (1985).

Supplementary paper

AD 6 Microscopic Optical Model Analysis of Neutron Scattering Cross Sections at 65 MeV over a Wide Range of

A Values. L.F.Hansen, Lawrence Livermore National Laboratory*, E.L.Hjort, F.P.Brady, J.Drumond, B.McEachern, G.H.Osborne, and J.L.Romero, Crocker Nuclear Laboratory & Physics Department, University of California, Davis** The neutron differential cross sections for C, Si, Ca, Fe, Sn, and Pb measured at 65 MeV between 6° and 47°, using a wire chamber based neutron detector[1], are compared with calculations done with the microscopic OM potentials of JLM (with M3Y spin-orbit interaction) and Yamaguchi et al. The fits to the measurements were obtained with only three parameters: the normalization constants for the real (λ_V) and imaginary (λ_W) parts of the central potential, and for the real SO potential (λ_{SO}). The latter has a constant value of 1.3 for all the targets. The quality of the agreement with the measurements is very close for both calculations and also with fits obtained earlier[2] with phenomenological potentials for a much larger number of parameters. The A dependence of λ_V and λ_W will be discussed.
*Work performed under the auspices of USDOE, Contract W-7405-ENG-48. **Supported by NSF grant PHY 84-19380.
[1]F.P. Brady et al., Nucl. Instr. & Meth. 228, 89 (1984)
[2]E.L. Hjort, BAPS, 34, 1831 (1989).

SESSION AE: THEORY I: STRUCTURE

Thursday morning, 25 October 1990
Room 158, Loomis Laboratory at 9:00
V. R. Pandharipande, presiding

9:00
AE 1
The Effects of Central, Spin-Orbit and Tensor Interactions in Nuclei, *D. C. Zheng and L. Zamick*, Rutgers Univ. – To study the different components of the nucleon-nucleon interaction, we devise a schematic interaction $V_c + xV_{so} + yV_t$ which for $x=1$, $y=1$ fits some standard bare interactions like Kuo-Brown or Bonn A approximately. Then we study the effects of varying x and y from 0 to 2. We calculate the single-particle energies ϵ_j with the *same* interaction as we use for rest of the nuclear structure. We find that the single particle energies relative to a doubly closed core like ^{16}O are independent of the strength of the tensor force. When applied to negative parity 1p-1h states in ^{16}O, we find that in a TDA calculation, the weighted average of the eigen energies $\sum_J (2J+1)\sum_i E_i(J,T)$ is zero for a pure tensor interaction or a pure two-body spin-orbit interaction. The effect of the tensor interaction for isoscalar (T=0) states is to lower the energy of even spin states 0^-, 2^-, 4^- and to raise the energy of odd spin states 1^-, 3^- in an *average* sense. For isovector (T=1) states, the effect is much smaller. For the 1^+ states in ^{12}C, a 1p-1h diagonalization leads to very low eigen states with $E^*(T=0) \sim 1.6 MeV$ and $E^*(T=1) \sim 4.1 MeV$ as compared with experiment ($12.7 MeV$ for T=0 and $15.1 MeV$ for T=1). Only a full scalar shell model calculation brings these states up a respectable energy. When the core is ^{12}C, the effect of the tensor interaction is to lower the $p_{1/2}$ single-particle energy relative to $p_{3/2}$. This is precisely opposite to what the two-body spin-orbit interaction does. We reconsider the old problem of the effect of the spin orbit and tensor interactions on the near vanishing Gamow-Teller matrix element $^{14}C(J=0,T=1) \rightarrow {}^{14}N(J=1,T=0)$. If we increase the spin-orbit interaction, then we also have to increase the tensor interaction in order to maintain a vanishing GT matrix element.

9:12
AE 2 Study of Nuclear Ground State Properties in the Framework of a Relativistic Point Coupling Model. T. HOCH, B. A. NIKOLAUS, and D. G. MADLAND, Los Alamos Nat. Lab.--An extended version of a relativistic point coupling model proposed by Manakos and Mannel[1] is used in Hartree-Fock approximation to calculate nuclear ground state properties. The explicitly non-renormalizable model Lagrangian includes scalar and vector (both isoscalar and isovector) four-fermion interactions as well as higher powers in the fermion field and derivative couplings. The latter simulate the finite ranges of the σ and ω mesons in mean field models. A self-consistent procedure was developed to solve the model in H-F approximation for several nuclei simultaneously by use of a generalized non-linear least-squares adjustment algorithm.[2] With this procedure we determine the nine coupling constants of our model so as to reproduce measured ground state binding energies, rms charge radii, and spin-orbit splittings of selected closed shell and closed subshell nuclei in non-deformed regions. The coupling constants obtained in this way reproduce ground state binding energies and rms charge radii of a much larger set of closed (sub) shell nuclei to good accuracy and predict these quantities for similar nuclei far off the line of beta stability.
[1]P. Manakos and T. Mannel, Z. Phys. A 330, 223 (1988).
[2]B.A. Nikolaus and D. G. Madland (to be published).

9:24
AE 3 *A Green's Function Approach to Superfluidity in Nuclear Matter.* Brian E. Vonderfecht and Willem H. Dickhoff, *Washington University, St. Louis, MO* 63130 -- A self-consistent solution of the nuclear matter problem is studied using Green's functions. Special attention is paid to the dynamics of the system's single particle properties since recent experiments have established the significance of non-mean field correlations. The theory allows a unified description of short-range correlations and superfluidity appropriate for realistic interactions including tensor forces. The effective interaction is obtained using an extension of Brueckner ladder diagrams that is symmetric with respect to particles and holes and includes possible pairing solutions. The binding energy is calculated and consequences for saturation properties are considered. Spectral functions and a momentum distribution are presented which display depletion of around twenty percent. This is compatible with recent experiments, but in contrast to the traditional shell model.

9:36
AE 4 Multiparticle-Multihole Configuration Mixing Calculations in the IBM-2. A. F. BARFIELD and B. R. BARRETT, U. Arizona.*--Low-lying multiparticle-multihole (np-mh) configurations are well-known features in nuclear structure. Work by Zheng et al.,[1] has called attention once again to this phenomenon in light-medium mass nuclei, and Iachello[2] has recently emphasized its possible importance in heavy-mass nuclei, particularly regarding superdeformed bands. In the interest of formulating a unified picture of this effect, we have expanded the configuration mixing approach of Duval and Barrett[3] within the n-p Interacting Boson Model (IBM-2) from two to several configurations. Applications to the Hg isotopes will be given for the mixing of (0p-2h), (2p-4h), (4p-6h), and (6p-8h) proton configurations.

*Supported in part by NSF grant PHY87-23182
[1]D. C. Zheng, D. Berdichevsky, and L. Zamick, Phys. Rev. C38, 437 (1988)
[2]F. Iachello, in "Proc. Symp. Nucl. Phys. 1990's," May 1-5, 1990, Santa Fe, NM
[3]P. D. Duval and B. R. Barrett, Nucl. Phys. A376, 213 (1982).

9:48
AE 5 Weak Interaction Rates in ^{16}O. W. C. HAXTON, University of Washington and C. W. JOHNSON, Caltech. ---We describe a full nonspurious $4\hbar\omega$ shell model calculation that successfully reproduces the low-lying spectrum of ^{16}O, including the superdeformed 0^+ (6.05 MeV) state, and discuss its connection with the coexistence model. This treatment provides a realistic microscopic framework for discussing various electroweak processes. E2 transitions in ^{16}O, the role of exchange currents and the pseudoscalar coupling constant in the $0^- \leftrightarrow 0^-$ β-decay and μ-capture transition, and the evaluation of the Gamow-Teller inclusive response function.

10.00
AE 6 Alpha-deuteron Structure of ^6Li as Predicted by Three-body Models.* J.P.Woloschek, D.R.Lehman, The George Washington University ---NN interactions in three-body (αNN) models of ^6Li are used to examine the role of the np

interaction in the alpha-deuteron structure of ^{6}Li. The ^{6}Li bound state wave functions are obtained by solving the Schrodinger equation with an αN interaction containing $S_{1/2}$, $P_{1/2}$ and $P_{3/2}$ components and with a $^3S_1$-$^3D_1$ np interaction. Nine np interactions are used: four are phenomenological rank-1, rank-2 or rank-4 separable interactions which reproduce scattering phase shifts and deuteron properties, and the remaining five interactions are rank-1, rank-4 or rank-6 representations of the full Paris potential. The ^{6}Li wave functions are used to calculate the s- and d-wave ^{6}Li → α + d momentum distributions, the percentage of s- and d-wave αd components, the effective s- and d-wave configuration-space wave functions, the S- and D-wave ^{6}Li → α + d asymptotic normalization constants and the αd projected contribution to the full quadrupole moment.

* Work supported in part by U.S. DOE.

10:12

AE 7 β-decay Between Mirror Nuclei in the 1f-2p Shell. M. SULTAN PARVEZ, F. B. MALIK, Southern Illinois University at Carbondale.--A detailed experimental study[1] of the beta decay of the ground state of ^{43}Ti to the low-lying levels of ^{43}Sc has revealed some interesting descrepancies between the data and the calculations based on shell model incorporating 1f-2p configuration. The low-lying level scheme of ^{43}Sc and many other odd nuclei in the 1f-2p shell can, on the other hand, be reasonably reproduced by the Coriolis coupling model[2]. It is, therefore, of interest to examine the β-decay rate between some mirror nuclei within the framework of this model. In the Coriolis coupling model, ^{43}Ti might have different collective parameters and in that case the β-decay of Ti to Sc is no longer superallowed, but normal allowed in nature. The calculate log ft values are in broad agreement with the observed ones. Calculation for other nuclei are in progress.

1. J. Honkanen et. al., Nucl. Phys. A 471, 489 (1982).
2. W. Scholz and F. B. Malik, Phys. Rev. 150, 919 (1966).

10:24

AE 8

Highly Deformed States in $N=Z$ Nuclei: Beyond the $8p$-$8h$ State in ^{40}Ca, *L. Zamick and D. C. Zheng,* Rutgers Univ. - Using the deformed Hartree-Fock approach with a Skyrme interaction SK3, we search for highly deformed states in $N=Z$ nuclei. We characterize these states by the integer n, which is the number of nucleons which we transfer from below the *spherical* fermi sea to one or more major shells above the *spherical* fermi sea. We give the intrinsic energy (in *MeV*), the projected $J=0^+$ state energy and the deformation parameter $\beta_0=\sqrt{5/\pi}Q_0/(A\langle r^2\rangle)$ for these states:

Nucleus	n	E_{int}	E_{0+}	β_0
^{40}Ca	8	11.4	7.1	0.60
	12	24.4	18.7	0.97
^{44}Ti	8	17.0	12 0	0.81
	12	25.6	19 9	0.99
^{48}Cr	8	23.9	19.0	0.85
^{52}Fe	8	28.6	24.3	0.71
	12	32.1	26.4	0 91
	16	42.7	35.7	1.14
^{56}Ni	16	38.1	31.6	1.05
	20	51.6	41.7	1.22

For the $n=12$ state in ^{40}Ca, eight nucleons are transferred into the $N=3$ f-p major shell and four into the $N=4$ g-d-s major shell. The possibility of identifying the quasimolecular resonance in ^{48}Cr (^{24}Mg + ^{24}Mg) as the $J=36$ member of the $n=8$ intrinsic state is considered. For ^{80}Zr the $n=12$ state (12 nucleons transferred from f p to g d s) is the *ground* state.

10:36

AE 9 Hybrid Representation of the Two-Body T-Matrix by a Separable and a Perturbative Part. G. H. RAWITSCHER, Univ. of Connecticut, and L. CANTON, I.N.F.N., Padova, Italy. -- In finding separable representations of the n-n T-Matrix, we have shown[1] that the error ΔT is of the order of the error ΔV in the potential expansion, even though T can be a few orders of magnitude smaller than the potential V. Thus, rather than adding more and more terms in order to achieve high accuracy, we present an alternate procedure in which only the first few separable terms are kept, and the rest is included by a perturbative expansion which is non-separable but small. This approach is equivalent to finding a separable representation of $T - V - V G_0 V$, which in turn can be understood by means of variational principles. When using positive energy Sturmians, the errors are well understood and are shown to be smaller than for the conventional separable representations. Numerical applications to the singlet S Reid soft core, and the Malfliet-Tjon potentials will be presented.

* Supported in part by NSF Grant PHY-8901627.
1 L. Canton and G. H. Rawitscher, submitted for publication.

10:48

AE 10 Correlation Energies and the Curvature Energy N.Ju[1], A.Bulgac[1], G.Bertsch[1] and P.Schuck[2] MSU-NSCL[1] and Grenoble[2] There is a disturbing contradiction between the parameters of the liquid drop formula for the binding energies (which lead to a vanishing $A^{1/3}$ term) and mean field theoretical predictictions for the curvature energy (on average 10 $A^{1/3}$ MeV). There is one effect, which has not been not been considered so far in this respect and which might be responsible for the discrepancy, the quantum corrections arising from the zero point oscillations of the nuclear surface. It seems very natural to link curvature corections to the binding energy with the surface oscillations, which when excited modify the local curvature. A rough estimate of the zero point surface oscillations contributions to the binding energy gives something like 10-40 $A^{1/3}$ MeV. One has to include particle-hole excitations with relatively high angular momenta and high excitation energies. We present calculations of the ring ph-diagrams for spherical nuclei, in order to extract the A-dependence. The extracted curvature energy (depending on the NN-force) has the right order of magnitude (and sign).

Supplementary paper

AE 11

Spin Dependent Effects in the Quark Cluster Model: C.J. Benesh and J.P. Vary, Physics Department*, Iowa State University. -- Using the quark cluster model, we calculate the spin dependent structure functions of the deuteron and ^{3}He. In particular, we find that measurement of the first moment of these distributions provides a constraint on the size of the six quark cluster component of the nuclear wavefunction. We compare these constraints with the measured value of g_A for mass 3 nuclei, and give predictions for the spin dependent structure of ^{3}He, which will be measured in forthcoming experiments.

*Supported by the USDOE under Grant No. DE-FG02-87ER40371.

PLENARY INVITED SESSION PA: 'NUCLEAR PHYSICS IN SOCIETY
Thursday afternoon, 25 October 1990; Foellinger Auditorium, University of Illinois at 13:30; R. A. Eisenstein, presiding

Note Special Times. Each speaker will have 45 minutes with 10 minutes for discussion. There will be a 15-minute coffee break at 16.15.

13:30
PA 1 Nuclear Physicists and Nuclear Weapons. S. DRELL, *SLAC.*

14:25
PA 2 Recent Advances in the Use of Particle Accelerators for Radiation Therapy. P. DELUCA, JR., *University of Wisconsin.*

15:70
PA 3 The Importance of Nuclear Power. H. BETHE, *Cornell University.*

16:15–16:30 COFFEE BREAK

Department Colloquium

16:30
PA 4 Solar Neutrinos. JOHN N. BAHCALL, *Institute for Advanced Study, Princeton.*

The most recent results of solar neutrino experiments will be discussed and compared with improved predictions of standard models: electroweak and solar. New experimental approaches to solving the solar neutrino problem will also be reviewed.

ATLAS USERS' GROUP
Thursday evening, 25 October 1990
Room 209, Illini Union at 18:00

IUCF USERS' GROUP
Thursday evening, 25 October 1990
General Lounge, Illini Union at 18:00

CEBAF USERS' GROUP
Thursday evening, 25 October 1990
Room 314A, Illini Union at 18:00

RADIOACTIVE ION BEAM FACILITY USERS' GROUP FORMATION MEETING
Thursday evening, 25 October 1990
Room 314B, Illini Union at 18:00

INVITED SESSION BA: NUCLEAR ASTROPHYSICS
Friday morning, 26 October 1990; Room 141, Loomis Laboratory at 9:00; G. Baym, presiding

9:00
BA 1 Nucleosynthesis in the Early Universe. M. TURNER, *FNAL.*

9:36
BA 2 Neutron Stars and the Equation of State. JAMES M. LATTIMER, *State University of New York.*

The role of the equation of state of dense matter in the astrophysics of neutron stars is reviewed. Specfic aspects of the equation of state influence theoretical models of supernovae, neutron star birth, pulsars and pulsar glitches, and neutron star decompression. In return, observations of these phenomenon can constrain the form of the equation of state. For example, the maximum mass and the maximum rotation rate of neutron stars serve as global constraints, while the total energy and the diffusion timescale of

neutrinos emitted during the aftermath of a supernova explosion probe the interior density structure of a neutron star. The process of neutron star compression in decaying neutron star binaries is sensitive to the minimum neutron star mass. Major uncertainties exist in some equation of state parameters, particularly the compression modulus of nuclear matter, the degree of softness of the subnuclear equation of state, the density dependence of the symmetry energy, and the existence or absence of phase transitions at supernuclear densities, to name but a few. It may not be possible, in the near future, to resolve these issues in terrestrial nuclear experiments. The extent to which these uncertainties can be eliminated through a combination of theoretical modelling and future astrophysical observations is discussed.

10:12
BA 3 Neutron Stars. FREDERICK K. LAMB, *University of Illinois.*

Neutron stars provide many examples of exotic nuclear phenomena, including neutron superfluidity, proton sup neutrino emission by superfluids. The evidence concerning neutron star masses, radii, inertial moments, magne rates is summarized. The implications for neutron star equations of state and internal structure are described recognition that the thermal and magnetic evolution of neutron stars is closely intertwined with their rotational evo millisecond pulsars has provided new evidence concerning the formation and evolution of rapidly rotating neutron s and timing observations have significantly constrained the thermal and dynamical properties of neutron s observations have determined the angles between the magnetic dipole and spin axes of some 150 pulsars. The r previous models of rotational and magnetic field evolution in neutron stars are incorrect. The results of recent theor nuclear composition of the crust, the interaction of neutron vortices with proton flux tubes in the core and with nuc dynamical properties of rapidly rotating neutron stars, and the evolution of neutron star magnetic fields are describe

10:48
BA 4 The CYGNUS Experiment at Los Alamos: An Air Shower Facility for the Study of PeV Cosmic Rays.
D. E. NAGLE, *Los Alamos National Laboratory.*

The CYGNUS installation consists of an array of 205 scintillation detectors, plus a collection of muon detectors. It is sensitive to energies above 50 TeV. Recent activities of members of the collaboration include searches for point sources, a study of the shadows of the moon and the sun, and a search for diffuse emission from the Galactic plane.

SESSION BB: INSTRUMENTATION I
Friday morning, 26 October 1990
Room 151, Loomis Laboratory at 9:00
R. Laszewski, presiding

9:00
BB 1 Measurement of Ground-State β^- Branching Intensities Using a Total Absorption Gamma Spectrometer.* R. C. GREENWOOD, D. A. STRUTTMANN and K. D. WATTS, Idaho National Engineering Laboratory -- A method has been developed to measure ground-state β^- branching intensities using a total absorption γ spectrometer at the INEL ISOL facility. This spectrometer, which is used to measure beta-strength function distributions of short-lived fission-product nuclides, consists of a large well-type NaI(Tl) scintillation detector together with a Si β^- detector located in the tape transport line within the well. With this spectrometer, a direct measurement of an absolute ground-state β^- branching intensity can be obtained from a simple ratio of the β-γ coincidence to β singles count rate. Results obtained in initial testing of the method, for several fission-product isotopes of Cs, Ba, La and Ce, are compared to existing data obtained using conventional nuclear spectroscopic methods.

* Supported by U. S. DOE under contract No. DE AC07 76ID01570 with EG&G Idaho, Inc.,

9:12
BB 2 Iso-Octane and C_3F_8, Heavy Gases for Charged Particle Detectors E. NORBECK*, R. DAYRAS, C. MAZUR, E.C. POLLACCO, Saclay; D. SWAN, NSCL Michigan State U., J.X. ZHANG, U. of Iowa--With large area gas detectors operating in a vacuum, one would like to reduce the counting gas pressure without reducing the quantity of gas. This can be done by putting more atoms into each molecule of gas. In low pressure ion chambers, substituting C_3F_8 for CF_4 allows more than a factor of two reduction in pressure. The C_3F_8 gas must be completely free of unsaturated fluorocarbons which have a large cross section for capturing electrons. In low pressure avalanche detectors, the heavier iso-octane gives the same performance at 2.5 to 3.0 Torr as isobutane at 5 Torr. Iso-octane is a liquid with a vapor pressure of 40.6 Torr at 21°C, about the same as the lighter n-heptane used in some laboratories. The vapor must be free of air and water to keep the counter from sparking at a low voltage. The surface of the evaporating liquid must be colder than the line to the gas handler. Otherwise the liquid will transfer to the coldest point.
*Supported in part by the Research Corp. Present address U of Iowa.

9:24
BB 3 A 95 PS (FWHM), HIGH-EFFICIENCY FAST TIMING DETECTOR FOR THE TOFI SPECTROMETER.* H.L. Seifert, U.Giessen & Los Alamos Nat.Lab., D.J. Vieira,

J.M. Wouters, G.W. Butler, Los Alamos Nat.Lab, X.G. Zhou, X.L. Tu, Utah St.U. The mass resolving power of the Time-of Flight Isochronous (TOFI) spectrometer is primarily limited by the timing precision obtained from two fast-timing microchannel plate (MCP) detectors and their associated electronics. The timing information is derived from secondary electrons produced when recoil ions pass through a thin Al_2O_3 foil. One of the major limitations of the detector-electronic system is the amplitude-to-time walk in the constant-fraction-discriminators (CFD) caused by the Poisson distribution of the secondary electrons. To increase the secondary electron yield we have coated our thin Al_2O_3 foils with CsI. The pulse height resolution (FWHM/centroid) improves from 1.2-1.5 for an uncoated Al_2O_3 foil to 0.6 for a similar foil coated with 25 $\mu g/cm^2$ CsI in tests with ^{241}Am α-particles. We also find that the detection efficiency increases from ~ 75 to 98%. We have investigated the pulse height distributions for CsI coatings with different thicknesses and the timing resolution of the system using a new CFD. The performance of the MCP detectors in tests with α particles and in a recent experiment at LAMPF will be presented.

* Work supported by U. S. Department of Energy.

9:36

BB 4 **Improvement in the Energy Resolution of a Ge Detector by Software Techniques*.** M. P. CARPENTER, T. L. KHOO, F. L. H. WOLFS, R. V. F. JANSSENS, Argonne National Laboratory, I. G. BEARDEN, Purdue University. – One factor which limits the energy resolution of a Ge detector is the charge collection process. Electronic circuits have been developed to correct for defects attributed to this process. (analog correction).[1,2] We have taken a different approach and implemented these corrections using computer software by digitally encoding 3 parameters. the pulse heights at two different amplifier shaping times and the cross over time of a bipolar signal. In general, equivalent improvements in energy resolution were obtained by software correction as those previously reported using analog corrections for non radiation damaged detectors. However, the software technique proved superior when radiation damage was present. A typical result for an 80% n type Ge detector (shaping time = 2μsec) showed a decrease in the FWHM of a 1332 keV γ ray from 2.61 keV to 2.17 keV. The technique and its application to a small (25%) and large (80%) n-type Ge detector will be discussed.

* Supported by the U.S. DOE, Nuclear Physics Division, under contracts W-31-109-ENG-38 and DE-FG-02-87ER40346.

[1]F. Goulding, D. Landis, IEEE Trans. Nucl. Sci. 35 (1988) 119.
[2]S.M. Hinshaw and D.A. Landis, to be published.

9:48

BB 5 **A Large Acceptance Detector for Photo-Nuclear Physics** N.R. KOLB, E.B. CAIRNS, H. FIELDING, L.G. GREENIAUS, E.D. HACKETT, L. HOLM, D.A. HUTCHEON, F.C. KHANNA, E. KORKMAZ, P. LANGILL, D. MACK, W.J. MCDONALD, B.A. PETERSON, N.L. RODNING, J. SOUKUP, I.J. VAN HEERDEN, W. ZIEGLER, University of Alberta; J C BERGSTROM, H S CAPLAN, R.E. PYWELL, D.M. SKOPIK, J.M. VOGT, Saskatchewan Accelerator Lab. J JURY, Trent University. J CAMERON, IUCF. The Saskatchewan Alberta Large Acceptance Detector (SALAD) has been constructed as a hadron detector for use with the tagged photon facility at the Saskatchewan Accelerator Lab (SAL). Charged particles produced in a gas target cell, with scattering angles between 7 and 173 degrees, are tracked through four cylindrical wire chambers surrounded by 24 sets of ΔE E scintillator sections. Due to the extended geometry of SALAD, a Monte Carlo simulation is used to predict the effective acceptance of the detector. The code was tested by measuring p p elastic scattering at TRIUMF and comparing to the well known cross section. Preliminary results, from the commissioning run, with tagged photons of 180-220 MeV on the deuteron will be presented.

10:00

BB 6 **KBr(Eu) Scintillator Crystals as Heavy Ion Detectors.** E. BELMONT-MORENO, A. MENCHACA-ROCHA, M.E.BRANDAN, J.HERNANDEZ A., Instituto de Fisica, U.N.A.M. Mexico D.F., M. GONIN, K. HAGEL, R.WADA, AND J.B.NATOWITZ, Cyclotron Institute, Texas A&M University, College Station, Texas. The results of a study aimed at evaluating the capabilities of KBr(Eu) scintillator crystals as heavy ion detectors will be presented. An optimum Eu doping of 0.1 mole % has been established by measuring the dependence of the light output response as a function of Eu concentration. The KBr(Eu) samples, used as E detectors in a DE-E telescope arrangement, were exposed to E/A<20 MeV, 2<Z<7 ions from $^{14}N+^{12}C$ reaction residues. The experiments were carried out with a 280 MeV 14N beam from the K-500 Superconducting Cyclotron at TAMU. The KBr(Eu) response to ions is compared with that of a commercial CsI(Tl). The resolution of KBr(Eu) is found to provide adequate element separation, although its luminosity is found to be considerably smaller than that of CsI(Tl).

10:12

BB 7 **A High Resolution Lead / Scintillating Fiber Electromagnetic Calorimeter for LEAR** D.W. HERTZOG, P.T. DEBEVEC, R.A. EISENSTEIN, M.A. GRAHAM, S.A. HUGHES, P.E. REIMER, and R.L. TAYLOE U. of Illinois at Urbana-Champaign‡-Electromagnetic calorimeter modules based on a uniform array of plastic scintillating fibers embedded in a lead alloy have been built and tested. Techniques have been developed to assemble large volumes of this composite material and to machine it into the tapered trapezoidal modules appropriate for modern, hermetically-sealed calorimeters with pointing geometry. Using this technique, a 300-element array of such modules has been built and instrumented. Prototypes and subsets of the larger array have been tested in electron and photon beams ranging in energy from 0.035 to 5.0 GeV. Improvements in fiber characteristics, assembly procedures, and geometrical optimization have led to substantial performance gains over previous similar detectors. The average resolution of these detectors is determined to be $\sigma/E \approx 6.3\% / \sqrt{E(GeV)}$. The techniques of fabrication and the detector tests will be described.

‡Research supported in part by the National Science Foundation and the University of Illinois Campus Research Board.

10:24

BB 8 **A Silicon Calorimeter for Measuring Charged Particle Evaporation Spectra.*** D.J. BLUMENTHAL and C.J. LISTER, Yale University An open question in compound nuclear decay is the effect of shell structure on the statistical evaporation of particles. A recent measurement has indicated changes in proton evaporation spectra in coincidence with discrete gamma ray transitions in different rotational bands[1]. In order to improve on present experiments which use highly segmented scintillators and are limited by resolution, both in energy and particle emission angle, we are building a silicon calorimeter designed to measure evaporated proton energies to ~15 and their emission angles to a precision of a few degrees. The calorimeter consists of a 16-element octagonal barrel

of position sensitive PIN diodes, each 50mm x 10mm and 700μ thick, subtending 48% of 4π. A Monte Carlo simulation of detector performance, including target thickness, absorber foil, position uncertainty, and energy uncertainty effects has been carried out. Source tests on prototype detectors are in progress, and these results will be discussed along with the Monte Carlo simulations.

* Work supported by USDOE Contract No. DE-AC02-76ER03074.
1. D.G. Sarantites, et al., Phys. Rev. Lett. 64, (1990) 2129.

10:36

BB 9 "A Low-Energy 180° Electron Scattering System.*" D. SOBEK, J. CONNELLY, H. CRANNELL, L. FAGG, J. O'BRIEN, and M. PETRAITIS, CATHOLIC UNIVERSITY, and R. DEINING..., and S. WILLIAMSON UIUC--A low energy (20-90 MeV) 180° electron scattering system has been designed, constructed, and installed at the UIUC microtron facility. The system features a 3-magnet chicane plus a separating magnet which is located inside the target scattering chamber. Both the spectrometer and the separating magnet are rotated in taking inelastic spectra. A quadrupole doublet and a set of Helmholtz coils between the target and beam dump are effective in reducing background. The performance of the system will be discussed.
*Work supported in part by NSF under Grant Nos. PHY8217076 and PHY8820654

10:48

BB 10 Nuclear Charge Separation of Heavy Ions at Low Energies* F. SCARLASSARA, K. E. REHM, B. G. GLAGOLA, A. H. WUOSMAA, Argonne National Laboratory+. Recently developed recoil mass separators provide excellent mass separation for heavy nuclei produced in compound nucleus reactions. A satisfactory charge identification for these nuclei with traditional E-ΔE or Bragg peak methods is limited to energies ≳1 MeV/a.m.u. for ions of A≳50. We have investigated if a gas filled magnet can be used for nuclear charge identification for ions at low velocities. This method exploits the difference in the average charge state $\bar{q}$ for ions with different nuclear charge Z moving in a gaseous medium. First test experiments were performed with a split pole spectrograph with ^{58}Ni and ^{58}Fe ions at energies between 1.5 and 0.5 MeV/nucleon. The results show that at these energies Fe and Ni are separated in the focal plane by about 10 cm. The charge separation is only weakly dependent on the incident energy. The results have been compared with various simulation calculations and good agreement between theory and experiment has been observed. Results for charge separation involving different magnet geometries will be presented.
*Submitted by K. E. Rehm.
+Work supported by the U.S. Department of Energy, Nuclear Physics Division, under contract W-31-109-ENG-38.

Supplementary papers

BB 11 A High Energy Polarimeter for Linearly Polarized Photons. D.S. DALE, R.M. LASZEWSKI, R. ALARCON U of Illinois*--A polarimeter for linearly polarized photons based on the phenomenon of pair production in the field of an electron (triplet production) has been constructed. Such a polarimeter can be expected to be effective from about 10 MeV to several GeV. Preliminary tests with unpolarized photons clearly identify the triplet events. Results of a measurement of the polarization dependence of the process performed with highly polarized tagged photons will be presented.
*Research supported in part by the National Science Foundation.

BB 12 Calibration of ^{3}He-Polarization using NMR Techniques. W. LORENZON, H. GAO, T. GENTILE and R. McKEOWN, Caltech.* ---Asymmetry measurements in spin-dependent scattering of longitudinally polarized electrons from a polarized ^{3}He gas target require accurate determination of both electron and target polarization. A systematic study of the calibration of the optical polarization signal in ^{3}He using NMR techniques is in progress. The target polarization is calibrated directly by comparing with a water sample. A precision of better than 5% can be obtained.

* Supported by the National Science Foundation.

SESSION BC: NUCLEAR STRUCTURE II: $A > 100$

Friday morning, 26 October 1990
Room 144, Loomis Laboratory at 9:00
D. Balamuth, presiding

9:00

BC 1 Level Lifetimes in ^{116}Sn, J. L. WEIL, J. D. BOONE, R. GO and Z. GACSI*, Univ. of Kentucky.** --- The lifetimes of more than forty excited levels have been deduced for the nucleus ^{116}Sn using the Doppler shift attenuation method. Doppler shifts were measured for some sixty γ-rays observed in the ^{116}Sn(n,n'γ) reaction at an incident neutron energy of 4.5 MeV. In the calculation of the F(τ) vs. τ curves, the Doppler shifts were averaged over all kinematically allowed directions of the recoiling nucleus, since the scattered neutrons were not observed. Lifetimes in the range of 4 fs to 500 fs were observed. The γ-ray multipole strengths in Weisskopf units will be presented for those levels where the decay multipolarity is known.

*Permanent address: Institute of Nuclear Research, Debrecen, Hungary
**Supported in part by NSF Grant #PHY-90-01465.

9:12

BC 2 Band structures in ^{123}I* Y. Liang, J.R. Hughes, D.R. LaFosse, R. Ma, E.S. Paul, P. Vaska, N. Xu, and D.B. Fossan SUNY Stony Brook, The ^{116}Cd(^{11}B, 4n) reaction at 45 MeV has been used to investigate ^{123}I with an array of 6 Compton-suppressed Ge detectors along with a 14-element BGO multiplicity filter. The unique negative-parity $\Delta I = 2$ band built on a $\pi h_{11/2}$ orbital was observed showing an indication of band termination at $\hbar\omega$ 0.37 MeV. The previously identified $\Delta I = 1$ $\pi g_{9/2}$ hole band was extended up to $27/2^+$. Two additionally observed bands, which are believed to be associated with prolate and oblate $\pi g_{7/2}$ midshell orbitals, show the expected different characteristics. A decrease in the energy of the oblate $\pi g_{7/2}$ orbital with N has been theoretically predicted[1]. For both of the prolate and oblate $\pi g_{7/2}$ bands, rotational alignment of an $h_{11/2}$ neutron pair was observed. These experimental results and the systematics for odd-A iodine isotopes will be presented.
[1] W. Nazarewicz; R. Wyss, private communications.
* Supported in part by the National Science Foundation.

9:24

BC 3 Comparison of Experimental with Calculated p-n Interactions in Doubly Magic Regions.* W.-T. CHOU, BNL, J.-Y. ZHANG, BNL, CCAST, Inst. Mod. Phys, Lanzhou, ORNL,

R. F CASTEN, BNL, D. S. BRENNER, Clark U., C. WESSELBORG, BNL, U. Koln.--Recently, empirical values for the residual p-n interactions of the last proton with the last neutron have been obtained. The overall smooth systematics is modulated by rather strong fluctuations. This is particularly true near closed shells where low and high j orbits are being filled sequentially. In these regions, the quadrupole component of the p-n interaction is particularly large since, viewed in a Nilsson scheme, it is where the sharply up- or down-sloping orbits occur, and p-n spatial overlaps vary rapidly. To study these fluctuations, we have calculated the quadrupole p-n interaction in the Nilsson/BCS scheme for the ^{90}Zr, ^{132}Sn and ^{208}Pb regions. Excellent agreement with the experimental trends is found. Research performed under contracts DE-AC02-76CH00016 and DE-FG02-88ER40417 with the USDOE.

9:36

BC 4 Discrete Spectroscopy in ^{144}Gd*
PH. BENET[a], I. AHMAD[b], K. BEARD[c], P.J. DALY[a], M.W. DRIGERT[d], P.B. FERNANDEZ[a], T. HAPP[b], R.V.F. JANSSENS[b], T.L. KHOO[b], E.F. MOORE[b], F.L.H. WOLFS[b], D. YE[c]. Using the ^{98}Mo(^{50}Ti,4n) reaction at 219 MeV and the Argonne-Notre Dame BGO γ-ray facility, the states in ^{144}Gd were studied from a coincidence matrix with ~2 10^8 events. The level scheme is rather complex and indicative of "particle alignment" as the mode of angular momentum generation along the yrast line and in its close vicinity. The structure of ^{144}Gd will be compared with that of neighboring nuclei.

a)Purdue University, West Lafayette, IN, 47907
b)Argonne National Lab., Argonne, IL, 60439
c)University of Notre Dame, Sound Bend, IN 46556
d)INEL., EG&G, Idaho Falls, ID, 83415

*This work was supported by the U.S Department of Energy, Nuclear Physics Division, under contract W-31-109-ENG-38, DE-AC07-76ID1570 and DE-FG-02-87-ER40346 and the NSF under grants PHY-88-02279.

9:48

BC 5 Gamma-ray Studies of Transfer Products from ^{36}S + ^{160}Gd and ^{37}Cl + ^{160}Gd Collisions*. R. H. MAYER, I. G. BEARDEN, Ph. BENET, P. J. DALY, Z. W. GRABOWSKI, Purdue Univ., I AHMAD, M. P. CARPENTER, P. B. FERNANDEZ, R. V. F JANSSENS, T L. KHOO, E. F. MOORE, Argonne NL and M. W DRIGERT, INEL --- Gamma-ray coincidence measurements for the systems ^{160}Gd + 159 MeV ^{36}S and ^{160}Gd + 167 MeV ^{37}Cl were performed with the Argonne-Notre Dame BGO γ-ray facility. By selecting events of moderately high γ-ray multiplicity, we could identify states up to about I~12 in few-nucleon transfer product nuclei around A~160, and estimate relative yields for the various reaction channels. Results of note include the ground state band up to 10^+ in neutron excessive ^{162}Gd, which was little studied up to now. The range of application of this method of study will be discussed.

*Supported by the U.S. DOE.

10:00

BC 6 Electromagnetic Properties of Tungsten Nuclei. C.Y. WU, D. CLINE, E.G. VOGT, W.J. KERNAN, T. CZOSNYKA, K. HELMER, R. IBBOTSON, A KAVKA, B. KOTLINSKI, NSRL University of Rochester, R.M. DIAMOND, LBL --- The quadrupole collectivity in ^{182,184}W has been studied by Coulomb excitation using ^{58}Ni and ^{136}Xe projectiles. A total of 35 E2 transition and diagonal plus 4 M1 matrix elements for both the ground-state and γ bands were determined for ^{182}W. A similar set was measured for ^{184}W. In a separate experiment the lifetimes for these collective states were measured using the recoil distance method. These lifetime measurements are in good agreement with the Coulomb excitation results. The correlations of the extracted E2 matrix elements examined using the Cline-Flaum sum-rule technique[1] will be discussed in the framework of various collective models. These correlations are well described with quadrupole shape degrees of freedom. Strong mixing between the β- and γ-vibration degrees of freedom, claimed in the pairing-plus-quadrupole model of Kumar and Baranger, is not supported by the present results.

1) D. Cline, Ann. Rev. Nucl. Part. Sci. 36, 683 (1986).

10:12

BC 7 On-Line Nuclear Orientation of ^{184}Au. Y.-S. XU, K. S. KRANE, M. A. GUMMIN, and J. T. ELLIOTT, Oregon State Univ., H. K. CARTER and I. C. GIRIT, UNISOR, D. RUPNIK and E. F. ZGANJAR, Louisiana State Univ., J. L. WOOD, Georgia Tech., P. F. MANTICA, JR. and B. E. ZIMMERMAN, Univ. of Maryland.*---Gamma-ray angular distributions have been measured for more than 100 transitions emitted in the decay of 53-s ^{184}Au oriented on-line at a temperature of 8 mK. Based on the anisotropies of the gamma rays and on spectroscopic data (conversion coefficients, gamma-gamma and electron-gamma coincidences), we will propose a new level scheme for ^{184}Pt that removes many of the ambiguities in level placements and spin assignments of the previous scheme. Of particular interest is the use of E2/M1 mixing ratios of $\Delta I = 0$ interband transitions to determine the character of states of the low-lying coexisting spherical and deformed bands and to determine unambiguously the E0 content of the transitions.

*Supported in part by the U.S. DOE under contracts DE-FG06-87ER40345 (OSU), DE-AC05-76OR00033 (UNISOR), DE-FG05-84ER40159 (LSU), DE-FG05-87ER40330 (Ga. Tech.), DE-FG05-88ER40418 (Md.).

10:24

BC 8 High Spin Studies in the Nucleus ^{190}Hg*
I.G. BEARDEN[a], R.V.F. JANSSENS[b], M.P. CARPENTER[b], P.J. DALY[b], I. AHMAD[b], PH. BENET[a], M.W. DRIGERT[c], P.B. FERNANDEZ[b], U. GARG[d], Z.W. GRABOWSKI[a], E.F. MOORE[b], T.L. KHOO[b], W. REVIOL[d], F.L.H. WOLFS[b], D. YE[d]. High spin states in the nucleus ^{190}Hg were populated with the ^{160}Gd(^{34}S,4n) at 159 MeV. Several band structures have been established from the γ-γ coincidence data. Most of these structures correspond to the collective rotation of the oblate deformed ^{190}Hg nucleus, but a structure with irregular energy spacings probably corresponds to particle alignment of a prolate non-collective nucleus (γ=-120°). Finally, a superdeformed band has also been observed. Comparisons with neighboring nuclei will also be presented.

a)Purdue University, West Lafayette, IN, 47907
b)Argonne National Lab., Argonne, IL, 60439
c)INEL., EG&G, Idaho Falls, ID, 83415
d)University of Notre Dame, Sound Bend, IN 46556

*This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract W-31-109-ENG-38, DE-AC07-76ID1570 and DE-FG-02-87-ER40346 and the NSF under grants PHY-88-02279.

10:36

BC Population of Superdeformed States and Co[illegible]n with Fission* E.F. MOORE, R.V.F. JANSSENS, T. [illegible] Kno[illegible] I. AHMAD, M.P. CARPENTER, R.R. CHASMAN, and [illegible] WOLFS. Argonne National Laboratory, Argonne,

Illinois 60439* K.B. BEARD, D. YE, and U. GARG University of Notre Dame, Notre Dame, Indiana 46556 PH. BENET, P.J. DALY, and Z.W. GRABOWSKI, Purdue University, West Lafayette, Indiana 47907, M.W. DRIGERT, Idaho National Engineering Laboratory, EG&G Idaho, Idaho Falls, Idaho 47907, USA. We have measured the average entry points for superdeformed (SD) and normal states in ^{192}Hg using the ^{160}Gd(^{36}S,4n) reaction at several beam energies between 154 and 172 MeV. Compared with normal states, the superdeformed states have entry spins ~10 h higher and internal excitation energies (U = E* - E_{yrast}) at least 2 MeV lower. Clearly the initial population for the SD band originates from higher spin. By comparison with calculated ℓ - distributions of evaporation residues, using CASCADE to compute the fission competition, we find that the initial population of the SD band originates from the tail of the evaporation residue spin distribution. For this system, there is also a rapid onset of fission with increasing ℓ, severely limiting the survival probability at highest ℓ(>40 h).

*This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract No. W-31-109-ENG-38.

10:48

BC 10 The Structure of ^{196}Au and its possible implications to Supersymmetry. S. Fischer, A. Aprahamian, University of Notre Dame, E. A. Henry, L. Mann, R. A. Meyer, N. Roy, and G. Struble, Lawrence Livermore National Laboratory---We have undertaken a study of the odd-odd ^{196}Au nucleus to test the validity of supersymmetry concepts[1,2] in the nuclear domain. The ^{196}Au nucleus has been studied by electron-gamma and gamma-gamma coincidences following the (t,2n) reaction on ^{195}Pt and by gamma-gamma coincidences following the (p,n) reaction on ^{196}Pt. We will present the resulting, low-lying, level scheme and discuss it in terms of supersymmetry.

[1]A. Arima and F. Iachello, Phys. Rev. Lett. 44, 772 (1980).
[2]P. Van Isacker, J. Jolie, K. Heyde, and A. Frank, Phys. Rev. Lett. 54, 653 (1985).

11:00

BC 11 Neutron Single-particle States above N=152 Subshell* I. AHMAD, R. R. CHASMAN, A. M. FRIEDMAN+, Argonne National Laboratory, S. W. YATES, University of Kentucky. Identification of single-particle states, in particular, the 1/2+[880] arising from the $k_{17/2}$ shell state, is important for the calculation of shell corrections which are relevant to the stability of superheavy elements. To identify these states one must study level structures of nuclei with neutron numbers greater than 152, so that the levels of interest are close to the ground. We have therefore studied the levels in ^{251}Cf populated in ^{250}Cf(d,p) reaction at the Argonne FN tandem Van de Graaff accelerator. The outgoing protons were analyzed with an Enge split-pole magnetic spectrograph with high resolution (FWHM=7 keV). In the spectrum we identified all particle states between N=152 and N=164 subshells. In particular, we have made a definite identification of the 1/2$^-$[750] band at 633 keV and tentative identification of the 1/2$^-$[761] band at 1250 keV. From the energies of these two states one can determine the locations of the $h_{11/2}$ and $j_{13/2}$ shells. We did not find the 1/2$^+$[880] band below 1 MeV excitation energy.

*Work supported by the U.S. Department of Energy, Nuclear Physics Division, under contract W-31-109-ENG-38.
+Deceased.

SESSION BD: POLARIZATION AND FEW NUCLEONS

Friday morning, 26 October 1990
Room 136, Loomis Laboratory at 9:00
H. Weller, presiding

9:00

BD 1 **Complete Spin Observables for Polarized Proton Scattering from Polarized ^3He and ^{13}C.** G. HE, R.H. LANDAU, and T. MEFFORD, Oregon State University*. — The scattering matrix for two spin $\frac{1}{2}$ particles has the spin-space structure

$$T = \frac{1}{2}[(a+b)+(a-b)\sigma_p\cdot\hat{n}\sigma_2\cdot\hat{n}+(c+d)\sigma_p\cdot\hat{m}\sigma_2\cdot\hat{m} + (c-d)\sigma_p\cdot\hat{l}\sigma_2\cdot\hat{l}+e(\sigma_p+\sigma_2)\cdot\hat{n}+f(\sigma_p-\sigma_2)\cdot\hat{n}] \quad (1)$$

We have organized the 36 independent polarization observables for the general scattering of two spin $\frac{1}{2}$ particles into different classes based on the difficulty of their measurement (the number of initial and final polarizations required), and have separated the large or significantly varying ones.

We have used a microscopic, momentum space optical potential to predict all polarization observables for 250-650 MeV proton scattering from the ^3He and ^{13}C nuclei. This includes proper off-shell kinematics, no small angle approximations, and off-energy-shell NN T matrices based on modern phase shifts and potentials. The observables are presented in three-dimensional plots.

* Research supported in part by the U.S. Department of Energy

9:12

BD 2 Report on Measurement of C_{NN} and A_y for $\vec{p}(\vec{n},d)\gamma$ at T_n = 183 MeV. C. BLOCH, S.F. PATE, S.E. VIGDOR, J. SOWINSKI, S.W. WISSINK, H.O. MEYER, W.W. JACOBS, S.M. BOWYER, T.W. BOWYER, E. PIERCE, C. WHIDDON, G. XU, IUCF, M.A. PICKAR, U. of Kentucky, P.L. JOLIVETTE, Hope College. - Recent calculations of $\vec{n}\vec{p} \leftrightarrow d\gamma$ observables[1,2] suggest that measurement of the spin correlation parameter C_{NN} is a more sensitive test of relevant reaction mechanisms than are the analyzing powers or differential cross section. In particular, one should be able to distinguish between different methods for including mesons and isobars. We have begun to measure A_y^n, A_y^p, and C_{NN} at IUCF. Polarized neutrons, produced by the $\vec{d}(\vec{p},\vec{n})pp$ reaction, are incident on a polarized proton target. Deuterons and γ-rays are detected in coincidence over the laboratory angle range θ_{lab}^{γ} = 34° - 132°. We present a status report with some preliminary data.

[1] W. Jaus and W.S. Woolcock, Nucl. Phys. A480, 573 (1988).
[2] H. Arenhövel, 1986 CEBAF Summer Study.

9:24

BD 3 σ, A_y, and $D_{NN'}$ Measurements for 200 MeV Proton Scattering from ^{208}Pb*, J. LISANTTI, E. J. STEPHENSON, A. D. BACHER, P. LI, R. SAWAFTA, P. SCHWANDT, S. P. WELLS, S.W. WISSINK, Indiana University Cyclotron Facility
We have measured the cross section, analyzing power and the normal spin-transfer coefficient $D_{NN'}$ for 200 MeV proton scattering from ^{208}Pb at lab angles of 8, 10, 12 and 15° covering an excitation energy of 2 to 24 MeV. The resolution of the data is 40 keV. The cross section data will be compared to electron scattering data[1] of a similar resolution in order to study the fine structure of the giant resonance region. Spin-flip data along with spin-flip cross sections will be presented in comparison to RPA calculations[2] in order to help determine spin-flip

dipole and quadrupole distributions.

*Work supported in part by NSF grant PHY 87-14406

1. G. Kilgus, Z. Phys A 326,41 (1987)
2. J. Wambach, private communication

9:36

BD 4 Estimates of parity-violation with polarised neutrons. E. D. DAVIS*, U. of Arizona, A. MÜLLER and H.-L. HARNEY, MPI f. Kernphysik, FRG, and V E. BUNAKOV, Leningrad Institute of Nuclear Physics, USSR Remarkable violations of parity have been observed in polarised epithermal neutron transmission. A model has been developed[1] which incorporates parity violation into the statistical theory of nuclear reactions, thereby permitting a systematic theoretical study. The fundamental parameter of the theory is the spreading width Γ_l^{PV}. The consistency of the model with the most extensive experimental study[2] to date of parity violation in a given nucleus (^{239}U) is discussed. With the acquisition of additional information on Γ_l^{PV} in mi d, wide-ranging estimates of parity violation are presented for both epithermal neutrons and neutrons of kilovolt and higher energies.

* Supported by NSF grant PHY87-2382.

[1] A. Müller, et al., submitted to PRL.
[2] J. D. Bowman, et al., submitted to PRL.

9:48

BD 5 Polarization Effects in the ^{3}He(d,^{3}Hep)n and ^{3}He(d,tp)p Reactions at E_d = 17 MeV. Z. AYER and S.E. DARDEN, U. of Notre Dame*, S.SEN, Thomas More College, and R.E. WARNER, Oberlin College---To investigate the role played by nucleon-nucleon final-state interactions in the deuteron breakup on ^{3}He, we have measured triply-differential cross sections and vector analyzing powers for the ^{3}He(d,^{3}Hep)n and ^{3}He(d,tp)p reactions in kinematically complete geometry at E_d = 17 MeV. Breakup spectra produced by bombardment of a ^{3}He gas target were detected by four counter telescopes placed symmetrically on either side of the beam. ^{3}He-p and t-p coincidence spectra were obtained at five sets of ^{3}He/t and p angles. The kinematic loci for these angle pairs contain regions where the relative nucleon-nucleon energy is close to zero. Our results will be presented and compared to predictions of simple two-step calculations. We have also measured tensor analyzing powers T_{20} & T_{22} for one of these angle pairs. In addition, comparisons will be made between Impulse Approximation calculations and our measurements in the kinematic regions where the quasi-free scattering/reaction mechanism is dominant.

*supported by the National Science Foundation under Grant No. PHY 8803035.

10:00

BD 6 Spin Observables in the $^{18}O(\vec{p},\vec{n})$ and $^{28}Si(\vec{p},\vec{n})$ Reactions at 135 MeV.* J.W. WATSON, M. RAHI, B.D. ANDERSON, A.R. BALDWIN, R. MADEY, MARCO R. PLUMLEY, J. SCHAMBACH, Kent State U., P.J. PELLA, Gettysburg College C C FOSTER, IUCF We measured the analyzing power $A_y(\theta)$, the polarization function $P(\theta)$ and the transverse polarization-transfer coefficient $D_{nn}(\theta)$ for the $^{18}O(\vec{p},n)$ and $^{28}Si(\vec{p},n)$ reactions at 135 MeV. Data were taken with a calibrated, high-efficiency, neutron polarimeter[1] for θ=0°, 5°, and 10°. Data for D_{nn} will be compared with results for ^{16}O,[2] $^{40,48}Ca$[3] and ^{208}Pb.[4] Large values of P-A_y are observed for some final states.

[1] J.W. Watson et al., Nucl. Instr. & Meth. A272, 750 (1988)
[2] J.W. Watson et al., proceedings of the 7th International Conference on Polarization Phenomena in Nuclear Physics Paris, France, 1990
[3] J.W. Watson et al., Phys. Lett. 181B, 47 (1986)
[4] Marco R. Plumley et al., Bull. Am. Phys. Soc. 33, 1582 (1988)

10:12

BD 7 Absolute differential cross section for deuteron photodisintegration at 67 MeV. P.T. DEBEVEC, P. D. HARTY, R. T. JONES, U. of Illinois at Urbana-Champaign, and D. A. JENKINS, VPI&SU.‡-The absolute differential cross section for d(γ,p) has been measured with a large acceptance detector and a tagged photon beam at a mean energy of 67 MeV. The data are in excellent agreement with the compilations of De Pascale *et al* 1 and by Rossi *et al.*2 The data are compared to theoretical calculations due to Arenhovel[3], Cambi *et al.*[4], Jaùs and Woolcock[5], Laget[6], Nagornyi *et al.*[7], Partovi[8], Rustgi *et al.*9 and Ying *et al.*[10], not all of which account for the data equally well.

‡Research supported in part by the National Science Foundation.

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3H. Arenhovel, private communication, and to be published in Few-Body Systems.
4A. Cambi *et al.*, J. Phys. G 10, L11 (1984) and private communication.
5W. Jaus *et al.*, Nucl. Phys. A 473 667, 685 (1987), and private communication.
6J. -M. Laget, Phys. Lett. B 199, 493 (1987) and private communication.
7S. I. Nagornyi *et al.*, Sov. J. Nucl. Phys. 44 760 (1986), and private communication.
8F. Partovi, Ann. Phys. 27, 79 (1964).
9M. L. Rustgi *et al.*, Phys. Rev. C33, 1823 (1986), and private communication.
10S. Ying *et al.*, Phys. Rev. C 38, 1584 (1988), and private communication.

10:24

BD 8 Measurement of the Cross Section for the Reaction $p+p \rightarrow p+p+\pi^\circ$ Near Threshold.* M.A. ROSS, A. BERDOZ, F. DOHRMANN, J.E. GOODWIN, H.O. MEYER, M. G. MINTY, H. NANN, P. V. PANCELLA, R. POLLOCK, T. RINCKEL, F. SPERISEN, B. von PRZEWOSKI, S. PATE, Indiana University Cyclotron Facility The first nuclear physics experiment at the IUCF Cooler ring is a measurement of the cross section for the reaction $p + p \rightarrow p + p + \pi^\circ$ near threshold. The Cooler, together with a thin internal H_2 gas jet target, allows for a precise cross section measurement by providing well-defined interaction energies and by eliminating background from p-nucleus pion production which has a much lower threshold. A cylindrically symmeteric detector system has been installed in one of the straight sections of the ring and is used to detect the coincident protons with good energy and angular resolution. The mass of the unobserved particle is then deduced. Elastically scattered protons were detected at the same time and by the same detector as the pion production events. Elastic scattering was used for normalization to obtain an absolute $p + p \rightarrow p + p + \pi^\circ$ cross section. Cross section data has been obtained at 9 bombarding energies in the range 282-325 MeV.

*Work supported by the National Science Foundation.

10:36

BD 9 The D-state of ^{3}H determined from the sub-Coulomb $^{95}Mo(d,t)^{94}Mo$ reaction.* R.K.Das, D.J.Abbott, T.B.Clegg, E.R.Crosson, K.A.Fletcher, H.J.Karwowski, S.Lemieux and E.J.Ludwig, Univer North Carolina at Chapel Hill and Triangle Universities uclear Laboratory. Angular distributions of differential cross sec on and tensor analyzing powers (TAP) have been measured he g.s. transition of this reaction at 7.0 MeV. The motivation for this experiment was to determine the D-state probability (D_2) in the triton wave function using the finite-range DWBA calculation to calculate TAP, since the TAP are sensitive to the D_2 parameter[1]. Several favourable conditions for precise determination of the D_2 parameter are present in this reaction.

(1) Since both the deuteron and the triton are prevented from penetrating into the nuclear interior, the transferred nucleon wave function can be accurately calculated. (2) The reaction cross-section is small compared to the elastic cross section due to the weak coupling of the channels at this energy and therefore the DWBA calculations are insensitive to the optical model parameters used in the calculations. (3) The reaction has a unique *j* transfer, and its spectroscopic factor is very well predicted by the sd-shell model calculations. The results of this analysis will be presented.

*Work supported in part by the USDOE Contract No. DE-AS05-76ER02408

[1]L.D.Knutson,et al. Phys.Rev.Lett 35,1570(1975).

10:48

BD 10 Ground-State Widths of ^{5}He and ^{5}Li, M.J. BALBES, L.H. KRAMER, G. FELDMAN, H.R. WELLER, Duke University and TUNL,* D R TILLEY, North Carolina State University and TUNL* -- The 3/2$^-$ ground states of ^{5}He and ^{5}Li are unbound to nucleon decay by 0.89 and 1.97 MeV respectively. We have measured the widths of these states using the ^{3}H(d,γ)^{5}He and the ^{3}He(d,γ)^{5}Li reactions at E_d = 8.6 MeV. The γ rays were detected at θ(lab)=90° by two anticoincidence-shielded 25.4 cm x 25.4 cm NaI(Tl) spectrometers. A tritiated titanium foil was used to measure γ rays from ^{5}He and a gaseous ^{3}He target was used to measure γ rays from ^{5}Li. The γ-ray spectra were fit with a convolution of the NaI lineshape response function, as measured with the ^{3}H(p,γ)^{4}He reaction, and a Breit-Wigner (B-W) single-level expression. With the energy dependent shift function omitted from the B-W expression, the "observed" widths, Γ^0_n=0.71±0.04 MeV for ^{5}He and Γ^0_p=1.75±0.15 MeV for ^{5}Li, are consistent with previously accepted values.[1] The "proper" widths, which include the effects of the energy-dependent shift function, were extracted from the spectra and found to be Γ_n=1.36±0.19 MeV for ^{5}He, and Γ_p=2.44±0.21 MeV for ^{5}Li. If the reduced widths for neutron decay of ^{5}He and proton decay of ^{5}Li are equal ($\gamma_p^2=\gamma_n^2$), then the ratio of the widths, Γ_p/Γ_n, is predicted to be the ratio of the penetrabilities, $P(E_{p,res})/P(E_{n,res})$ = 1.79. The ratio of the "proper" B-W widths is in agreement: Γ_p/Γ_n = 1.79±0.29.

1) F. Ajzenberg-Selove, Nuclear Physics, A490, 3 (1988)

*Partially supported by USDOE Contract no. DE-AC05-76ER01067

11:00

BD 11 Energy-Weighted Coulomb Sum Rule for Mass-3.

B. DOYLE and B. GOULARD, Université de Montréal* and G. CORY, Collége Militaire Royal de Saint-Jean*-We focus on the role of the short-range part of the nucleon-nucleon interaction in the three-nucleon system by calculating the energy-weighted coulomb sum rule (EWCSR)[1]. We use the bound state Faddeev wavefunctions to calculate the EWCSR. We find results using the SSC, Argonne, Paris and Bonn realistic nucleon-nucleon interactions.

*Supported in part by the National Science and Engineering Research Council of Canada.

[1]V.R. Pandharipande, *Nucl. Phys.* A497, 43c (1989).

11:12

BD 12 How Accurate is the Determination of the E2 Amplitude in the $N(\gamma,\pi)\Delta$ Reaction? A M BERNSTEIN, MIT, R BECK, Univ of IL, T. S. H. LEE, ANL, S. NOZAWA, TRIUMF. - - - Our only experimental information on the E2/M1 ratio in the $N \rightarrow \Delta$ electromagnetic excitation in from multipole analysis of the $N(\gamma,\pi)$ reaction. Its determination is made difficult by the dominance of the M1 amplitude and because the E2 amplitude has both resonant and non-resonant contributions. The particle data group quote the value of 1.3 ± .5% but values varying from 0 to -5% have been obtained from the same data set indicating a large model dependence. There has been no specific study of the sensitivity of the observables (differential cross sections and polarizations) to the magnitude of the E2 amplitude. We have performed calculations to study this sensitivity using the model of Nozawa, Blankleider and Lee for the $N(\gamma,\pi)$ reaction. Most of the observables, including the differential cross section, are insensitive to the E2 contribution. The largest sensitivity is the polarized photon asymmetry which changes by ~ 10% for a 3% E2/M1 contribution. We conclude that the experimental errors are too large at this time to have an accurate determination of the resonant E2 contribution to the $N \rightarrow \Delta$ transition. We shall present suggestions on how to determine the (theoretically interesting) resonant part of the E2 amplitude from future polarization experiments.

SESSION BE: THEORY II: REACTIONS

Friday morning, 26 October 1990
Room 158, Loomis Laboratory at 9:00
J. Vary, presiding

9:00

BE 1 A Model for Large Cluster Transfer Reactions Leading to Heavy Actinides.M.T.MAGDA, SUNY at Stony Brook--- A mechanism is proposed to describe transfer reactions leading to heavy actinides, based on the assumption that large clusters produced by projectile fragmentation are captured as a whole by the target nucleus. The primary cross sections are corrected for neutron emission from the excited nuclei. Data obtained at LBL and GSI for the Bk-,Cf-,Es-,Fm-,Md-,No- and Lr-isotopes produced in reactions induced by various projectiles, ranging from C to Ca are well described by the model.

9:12

BE 2 Inverse Reactions and the Statistical Evaporation Model:Ingoing-Wave Boundary-Condition and Optical Models. JOHN M.ALEXANDER, M.T.MAGDA,SUNY at Stony Brook, S.LANDOWNE, Argonne National Laboratory.--- The calculation of transmission coefficients for emitted particles is fundamental to applications of the statistical evaporation model for the decay of the compound nucleus. In this work we compare the usual type of optical model calculation of transmission coefficients for neutron,proton,deuteron,triton and alpha particles with corresponding ingoing-wave boundary cor tion calculations. In the latter case the tr. ission coefficients simply give the probab..ity for transmission through the real potential barrier. This comparison highlights features that are specific to the optical model such as transparency,shape resonances and peripheral absorption. It also draws attention to the issue of whether simple barrier transmission coefficients are more appropriate for use in the statistical evaporation model.

9:24

BE 3 Glauber Calculations For The Elastic Scattering Of Radioactive Nuclei H.N. Chehime*,U. Wisconsin-Madison. Stimulated by recent experimental results [(1)] on radioactive weakly bound systems like.^{11}Li, a Glauber approximation was used to calculate the elastic cross section for $^{11}Li+^{12}C$ at $E/A = 85MeV$. The Glauber calculations have shown some agreement with folding model optical calculations. Contrary to expectations, the weakly bound di-neutron halo in ^{11}Li had no significant effect on the cross section. The Glauber calculations show an enhancement of the far- side component of the elastic cross section when compared with $^{12}C+^{12}C$ thus implying a more refractive nature in the weakly bound system which can't be simply explained by the di-neutron halo.

*Research supported in part by the National Science Foundation.

1. I. Tanihata et al.,Nucl. Phys. A488 (1988) 113c.

9:36
BE 4 The Langevin Equation Description of Nuclear Fission NEIL L ROETH*, U. Wisconsin-Madison - The Langevin equation description has been applied to nuclear fission. The input to this description is a temperature, a friction/fluctuation parameter, an initial configuration, and a choice of suitable coordinates. If the coordinates are the elongation and mass asymmetry, the output from this description will include fission rates as a function of time, and mass distributions. This choice of coordinates also leads to coordinate dependent inertial, friction, and fluctuation terms in the equations. Two aspects of the numerical solution of the Langevin equation have been studied and evaluated for efficiency and accuracy: integration schemes higher than first order, and a variety of random number generators. The Langevin equation is a stochastic differential equation. Higher order schemes for stochastic differential equations can be derived by the same procedure used for ordinary differential equations, but the stochastic term severely limits the attainable efficiency. The accuracy of the results is highly dependent on the uniformity and period of the random number generator.
*Research supported in part by the National Science Foundation.

9:48
BE 5 Coulomb Effects in Proton-Nucleus Elastic Scattering.† C.R. CHINN, Physics Dept., LLNL, CH. ELSTER, Dept. of Physics, Ohio State Univ. and R.M. THALER, Theory Div., LANL and Case Western Reserve Univ. — The recently proposed exact method for the momentum space calculation of a charged particle scattering from a combined Coulomb and short-range potential[1] has been implemented into the WIZARD program[2] for the case of elastic proton-nucleus scattering. The short-ranged potential used will be the first-order KMT impulse approximation[2]. The adaptation of the KMT prescription to include the Coulomb interaction will be discussed. Numerical results for angular distributions and spin-observables for protons scattered from various target nuclei at incident energies from 200 to 800 MeV will be presented. These results will also be compared with previous approximations to the Coulomb distortions and their conclusions will be reexamined.
† Research supported in part by the Department of Energy.
[1] Ch. Elster, L.C. Liu, R.M. Thaler, Sub. to Phys. Rev. C
[2] A. Picklesimer, P.C. Tandy, R.M. Thaler, and D.H. Wolfe, Phys. Rev. C 30 (1984), 2225.

10:00
BE 6 The Quasi-molecular State and the Nature of N-N Interaction in Heavy Ion Collisions. Y. R. WAGHMARE, Indian Institute of Technology--Heavy ion fusion reactions using classical and semi-classical approaches are considered. Dependence of fusion cross sections on the nature of the effective N-N interaction is investigated. It is observed that the cross sections are sensitive to the long range part of the interaction. Reactions involving ^{16}O, ^{12}C and ^{40}Ca nuclei are considered. In the classical approach the concept of a nucleon consisting of "partons" is used to simulate Pauli principle. Good agreements are obtained between theory and experiment.

10:12
BE 7 Description of Nuclear Structure Effects in Fusion by the Interacting Boson Model J. BENNETT and A.B. BALANTEKIN*, U. Wisconsin Madison, One commonly utilized approximation to the multidimensional barrier penetration problem in fusion reactions below the Coulomb barrier is the sudden approximation, in which the internal degree of freedom is assumed to have a degenerate spectrum. So far attempts to incorporate nuclear structure effects in the description of subbarrier fusion via the sudden approximation used the geometrical model of Bohr and Mottelson or its simplifications. In this talk a preliminary report on the use of the Interacting Boson Model to describe nuclear structure effects is presented.
*Research supported in part by the University of Wisconsin Research Committee with funds granted by the Wisconsin Alumni Research Foundation and in part by the National Science Foundation.

10:24
BE 8 Effective Potentials for Deuteron-Nucleus Scattering from a Poincaré Invariant Relativistic Wave Equation*, V.K. MISHRA, Kent State Univ.--Recently a new class of higher spin relativistic wave equation based on Poincaré invariance has become available.[1] These give causal and well-behaved solutions for arbitrary spin Coulomb scattering. We investigate the spin-one equation in external vector and scalar potentials and derive the effective potentials for deuteron-nucleus scattering. Comparison with traditional spin-one equations like KDP, Proca and Weinberg will also be presented.

1. W.I. Fushchich, A.G. Nikitin and W.M. Susloparow, Nuovo Cimento 87A, 415 (1985).

*Work supported by National Science Foundation.

10:36
BE 9 Structure of Exotic Nuclei, A. SUSTICH MSU-NSCL* - The structure of exotic nuclei is studied by examing the reaction and breakup cross sections for secondary beams of these nuclei on a variety of targets. A new diffractive eikonal model has been developed to calculate the nuclear reaction and breakup cross sections. We examine reactions involving exotic projectiles at 790 MeV/A. Fundamental differences are observed in the behavior of these cross sections compared to those for more stable nuclei.

* Work supported by the National Science Foundation under Grant PHY-8714432.

10:48
BE 10 Effects of Distortions in the (N,N'π) REACTION. R. MEHREM, J.T. LONDERGAN, and G. E. WALKER, Nuclear Theory Center, Indiana U.*— Results for the distorted wave calculations of the exclusive reaction $^{16}O(p,p'\pi^+)^{16}N^*$, using an isobar dominated microscopic model, will be presented and compared with earlier plane wave calculations.[1] The distorted waves are taken as a superposition of plane waves with the coefficients obtained from experimental input. The significance of the intermediate pion self energy will also be discussed.
*Supported by the NSF.
[1] R. Mehrem, J.T. Londergan and G.E. Walker, Bull. Am. Soc. 35, 1019(1990).

11:00
BE 11 Microscopic Calculations of the ^{208}Pb-^{208}Pb System.† J.F. BERGER*, C.R. CHINN, and M.S. WEISS, Physics Dept., Lawrence Livermore National Laboratory — Static simulations of the collision of two ^{208}Pb nuclei have been performed using a constrained Hartree-Fock-Bogolyubov calculation. Preliminary

results of the ^{208}Pb-^{208}Pb system contain variations of the fusion and fission sequences found in a previous ^{238}U-^{238}U calculation[1] Indications are that in light of anomalous e^+-e^- pair production discussions, the ^{208}Pb-^{208}Pb system may produce a very different situation. These calculations are being examined in detail. Results and conclusions will be presented.

† Research supported in part by the Department of Energy.

* Permanent address. Service de Physique et Techniques Nucléaire, Commissariat à l'Energie Atomique Bruyéres-le-Châtel, France.

[1] J.F. Berger, J.D. Anderson, P. Bonche and M.S. Weiss, To be Published in Phys. Rev. C.

INVITED SESSION CA: NEW IDEAS ON OLD PROBLEMS

Friday afternoon, 26 October 1990; Room 141, Loomis Laboratory at 13:30; B. Clark, presiding

13:30

CA 1 Chaos in Nuclei? G. E. MITCHELL, *North Carolina State University.*

Searches for quantum systems which display chaotic behavior have renewed interest in statistical nuclear spectroscopy. Bohigas, Giannoni and Schmit[1] conjectured that quantum analogs of classically chaotic systems display fluctuation properties which coincide with the predictions of the Gaussian orthogonal ensemble (GOE) of random matrix theory. This suggests that the fluctuation properties of nuclear levels may be used as a signature for chaos or regularity. High quality nuclear resonance data display the long and short range order predicted by GOE.[2] For one nucleus, ^{26}Al, all levels are known from the ground state to the resonance region. Analysis of the first 100 positive parity states suggests that the fluctuation properties lie between the GOE and Poisson limits and are independent of excitation energy.[3,4] Although there is no other data set of sufficient quality to permit such analysis in a single nuclide, there are many nuclides whose level schemes are complete over a more limited range of energies.[5] Our analysis of a larger data set (160 sequences of levels in 60 nuclides) shows a strong dependence on the mass number A, with suggestions of effects due to spin and deformation.

*Supported in part by US Department of Energy, Office of High Energy and Nuclear Physics (Grant No. DE-FG05-88ER40441).

[1]O. Bohigas *et al.*, Phys. Rev. Lett. 52, 1 (1984).
[2]R. U. Haq *et al.*, Phys. Rev. Lett. 48, 1086 (1982).
[3]G. E. Mitchell *et al.*, Phys. Rev. Lett. 61, 1473 (1988).
[4]J. F. Shriner, Jr. *et al.*, Z. Phys. A 335, 393 (1990).
[5]T. von Egidy *et al.*, Nucl. Phys. A454, 109 (1986); Nucl. Phys. A481, 189 (1988).

14:06

CA 2 Probing Neutron Structure Via Polarized Electron-Polarized ^3He Scattering.* TIMOTHY E. CHUPP, *Harvard.*

Experiments scattering polarized electrons from polarized ^3He at the quasi-elastic peak and in deep inelastic scattering provide new probes of neutron structure. At the quasi-elastic peak, the spin dependence is predominantly due to scattering from the neutron whose polarization according to a Feddeev calculation is 87% in the ^3He ground state. With the proper choice of target spin orientation the neutron's elastic electric form factor can be extracted. In deep inelastic scattering, the previously unmeasured spin dependent structure function of the neutron can be measured. The deep inelastic data will complement the data on the proton and test the Bjorken sum rule and models of the nucleons. Ongoing experiments at Bates, including those employing a high density ^3He target based on spin exchange with laser optically pumped Rb, have extracted asymmetries in quasielastic scattering. An approved experiment at SLAC will measure deep inelastic scattering from a fixed, high density ^3He target. The high density ^3He target has a thickness of $4x10^{20}$ nuclei/cm^2 and attained polarization greater than 40%. The polarization was not noticeably affected by up to 22 μampere of 574 MeV electrons.

*This work was supported by the National Science Foundation and the DOE.

14:42

CA 3 Resolution of the $(\gamma,p)/(\gamma,n)$ Ratio Problem in ^4He.* H. R. WELLER, *Duke University.*

Previous experimental work on ^4He appeared to have established a ratio $R_\gamma = \sigma(\gamma,p)/\sigma(\gamma,n)$ of 1.7-to-1.2 for E_γ = 25-35 MeV. Most theoretical efforts to account for this ratio have failed, and those which succeeded were erroneous or seem unphysical.[1] A recent measurement of the (γ,p) cross section on ^4He using monoenergetic photons gives a smaller cross section than before and produces a ratio of 1.01 ± 0.06 for E_γ = 28.6 - 42.4 MeV.[2] We have remeasured the $^3H(p,\gamma)^4He$

cross section in an effort to provide independent confirmation of this result. Our results confirm these new (γ,p) cross sections and produce a ratio consistent with conventional theoretical predictions, although the new (γ,p) absolute cross sections are not reproduced by these calculations. Other recent related experiments and theoretical calculations will be reviewed.

*Work supported in part by US Department of Energy, Office of High Energy and Nuclear Physics, Contract No. DE-AC05-76ER01067.

[1]J. R. Calarco, B. L. Berman and T. W. Donnelly, Phys. Rev. C27, 1866 (1983).
[2]R. Bernabei *et al.*, Phys. Rev. C38, 1990 (1988).

15:18

CA 4 New Views of the (*e,e'p*) Knockout Reaction. A. MAGNON, *C.E.N. de Saclay, France.*

A systematic study of the (e,e'p) reaction on ^{2}H, ^{3}He, ^{4}He, and ^{40}Ca, in which the magnetic and coulomb structure functions are determined, is ending at Saclay. Momentum transfers, q, up to 0.85 GeV/c at recoil momenta, pr, in the quasi elastic regime were probed. It will be shown that, within the limits of validity of the impulse approximation, the q-dependence provides a direct test of "nucleon swelling" effects. Anomalies in the coulomb/magnetic responses relative to theory and to similar effects in the inclusive (e,e'p) reaction will be discussed. Data showing nucleon pair correlations at pr beyond the mean field region will also be shown.

SESSION CB: INTERMEDIATE ENERGY HEAVY-ION REACTIONS

Friday afternoon, 26 October 1990
Room 151, Loomis Laboratory at 13:30
G. Westfall, presiding

13:30

CB 1 Studies of Non-Equilibrium Ejectiles in Coincidence with Angle-Correlated Fission Fragments.* D.E. FIELDS, J.L. WILE, K. KWIATKOWSKI, K.B. MORLEY, E. RENSHAW, S.J. YENNELLO, AND V.E. VIOLA, Indiana University and R.G. KORTELING, Simon Fraser University--Light-charged particle (LCP) and intermediate-mass fragment (IMF) spectra have been measured in coincidence with angle-correlated fission fragments in the 270-MeV ^{3}He + ^{232}Th reaction. The position, energy and mass of coincident fission fragments are used to determine the linear momentum transfer and excitation energy associated with the emitting sources of the LPCs and IMFs. Mass- and charge-identified IMFs were detected at several angles between 20° and 160°. Backward-angle LCPs were detected for protons up to 70 MeV.

*Research supported by the NSF, and the U.S. Department of Energy.

13:42

CB 2 Evidence for an IMF Production Mechanism Change in Intermediate Energy ^{14}N + ^{nat}Ag,Au Collisions.* J.L. WILE, D.E. FIELDS, S.J. YENNELLO, V.E. VIOLA, K.KWIATKOWSKI, L.W. WOO, K. MORLEY, E. RENSHAW, Indiana University Cyclotron Facility, R.T. DESOUZA, C.K. GELBKE, W.G. LYNCH, M.B. TSANG, W.G. GONG, H.M. XU, and N. CARLIN, MSU NSCL--Inclusive intermediate mass fragment (IMF) measurements have been performed on the ^{14}N + ^{nat}Ag, Au systems at seven bombarding energies ranging from E/A = 20 -100 MeV. Excitation functions, energy spectra, and angular distributions for IMF's were studied systematically over the entire energy range. An enhancement in heavy (Z>8) IMF production was observed in the energy range of E/A = 60–80 MeV for the ^{14}N + ^{nat}Ag reaction, indicating a change in the IMF production mechanisms for this projectile-target combination. This result, as well as the relative abundances of isotopes at forward angles, will be compared to the ^{14}N + ^{197}Au system.

*Research partially supported by the US Department of Energy and the NSF

13:54

CB 3 Search for Multifragmentation Near Threshold in the ^{3}He + Ag Reaction.* S.J. YENNELLO, K. KWIATKOWSKI, N.R. YODER, J.L. WILE AND V.E. VIOLA, Indiana University, E.C. POLLACCO, C. VOLANT, R. DAYRAS, Y. CASSAGNOU AND R. LEGRAIN, DPhN/SEPN Saclay, FRANCE, and E. NORBECK, University of Iowa -- An array of 36 large solid-angle detector telescopes has been employed to study multifragmentation events in the ^{3}He + Ag reaction at 900 MeV and 3.6 GeV at the SATURNE II accelerator. The inclusive angular distributions, energy spectra and charge distributions for complex fragments (Z > 2) undergo a change in character between the two bombarding energies. Fragment multiplicities are found to be larger for the higher-energy data. The dependence of the fragment kinetic energy spectra and charge distribution on multiplicity will be examined. Simulations based on multifragmentation models will be compared with the data.

*Research partially supported by the US Department of Energy and the NSF.

14:06

CB 4 Observation of a Minimum in Collective Flow for Ar+V Collisions.* D. KROFCHECK, D.A. CEBRA, M. CRONQVIST, R. LACEY, T. LI, A. VANDER MOLEN, K. TYSON, G.D. WESTFALL, W.K. WILSON, NSCL, Michigan State U., A. NADASEN, Univ. of Michigan-Dearborn, E. NORBECK, Univ. of Iowa, *--We have added a new measurement at (E/A)=100 MeV to our previous excitation function for collective flow of light fragments from Ar+V collisions. The previous excitation function showed that flow decreased as the beam energy was raised from (E/A)=45 to 85 MeV. This provided hints to the beam energy at which flow disappeared for this system, but the lack of measurements at higher beam energies precluded the observation of the reappearance of flow. At a beam energy of (E/A)=100 MeV the flow has reappeared and this allows an experimental determination of the region where attractive scattering balances with repulsive scattering for these collisions.

* Work supported in part by the National Science Foundation under Grant No. PHY86-11210.

14:18

CB 5 Azimuthal Distributions In Ar+V Collisions From E/A=35 To 100 MeV W.K. WILSON, W. BENENSON, D.A. CEBRA, J. CLAYTON, M. CRONQVIST, S. HOWDEN, J. KARN, R. LACEY, T. LI, C.A. OGILVIE, A. VANDER MOLEN, A. NADASEN, G.'.

WESTFALL, J.S. WINFIELD, AND B. YOUNG, NSCL, Michigan State U.*--Azimuthal distributions of fragments with respect to the reaction plane are studied as a function of beam energy using the MSU 4π Array in central and peripheral collisons. For near central events, a new method of reaction plane determination using azimuthal correlations is introduced. Light charged particles are found to exhibit an enhanced emission in the reaction plane which increases with the mass of the observed particle. As the beam energy is increased the asymmetry nearly disappears. Possible mechanisms behind the asymmetry, such as rotational collective motion and directed transverse momentum, will be discussed. Use of a projectile-like fragment to determine the reaction plane for peripheral collisions is explored.

* Work supported in part by the National Science Foundation under Grant No. PHY86-11210.

14:30
CB 6 Excited State Populations for Fragments Produced in ^{3}He+Ag Reactions at 200 MeV . F.ZHU, W.G.LYNCH, T.MURAKAMI, C.K.GELBKE, Y.D.KIM, T.K.NAYAK ,R.PELAK, H.M.XU, M.B.TSANG, NSCL, Michigan State U. *, D.E.FIELDS, K.KWIATKOWSKI, R.PLANETA, S.ROSE, V.VIOLA, L.W.WOO, S.YENNELLO, J.ZHANG, IUCF, Indiana U. --We have measured excited state populations for fragments produced in ^{3}He+Ag reactions at 200 MeV. Measurements were performed with a position sensitive hodoscope both at forward angles, where non equilibrium processes are dominant, and at backward angles, where contributions from compound processes are important. The excited state populations for forward and backward angles will be compared to illustrate how these measurements depend on the reaction mechanism. We will also compare the results with the previous measurements using heavier beams.

* Work supported in part by the National Science Foundation under Grant No. PHY86-11210.

14:42
CB 7 Multifragment decays in the reaction ^{197}Au + ^{36}Ar at E/A = 35 MeV--R.T. DESOUZA, Y.D. KIM, D.R. BOWMAN,N. CARLIN, C.K. GELBKE, W.G. LYNCH, L. PHAIR, M.B. TSANG. NSCL, Michigan State U.*--Multifragment decay in the reaction ^{197}Au + ^{36}Ar at E/A = 35 MeV has been studied with the Miniball, a new 4π detector array. Elemental distributions from Z=1 to Z=18, as well as isotopic distributions for hydrogen and helium have been measured. The average multiplicity for non-peripheral events is eleven. Strong correlations between multiplicity and fragment distributions is observed. Initial results will be presented.

* Work supported in part by the National Science Foundation under Grant No. PHY86-11210.

14:54
CB 8 Intensity-interferometric test of nuclear collision geometries obtained from the Boltzmann-Uehling-Uhlenbeck equation. W.G. GONG, C.K. GELBKE, W. BAUER, R.T. DE SOUZA, Y.D. KIM, W.G. LYNCH, D. SANDERSON, M.B. TSANG, H.M. XU, MSU-NSCL, N. CARLIN, U. de Sao Paulo, T. MURAKAMI, Kyoto U., G. POGGI, INFN, S. PRATT, U. Wisconsin, D.E. FIELDS, K. KWIATKOWSKI, R. PLANETA, V.E. VIOLA, JR., S.J. YENNELLO, IUCF.--The dependence of two-proton correlation functions on the total momentum of the emitted proton pairs was measured, with good statistics, for the reactions ^{14}N+^{27}Al and ^{14}N+^{197}Au at E/A=75 MeV. These data are compared to correlation functions predicted for collision geometries obtained from numerical solutions of the Boltzmann-Uehling-Uhlenbeck equation. The calculations reproduce the order of magnitude of the experimental correlation functions, but some discrepancies remain. The sensitivity of the calculated correlation functions to the in-medium nucleon-nucleon cross section and the equation of state will be discussed.

15:06
CB 9 Neutron Spectra from ^{36}Ar+Ag at E/36=35 MeV.* D. Sackett, A. Galonsky, K. Gelbke, H. Hama, L. Heilbronn, D. Krofcheck, W. Lynch, B. Tsang, X. Yang, NSCL, Michigan State U.--F. Deak, A. Horvath, A. Kiss, Z. Seres Budapest; J. Kasagi, Tokyo Inst. Tech., T. Murakami, Kyoto U., H. Schelin, CTA, Brazil. We have detected neutrons at angles of 15, 30, 45, 60, 90, 120, and 160°. The energies were determined by measuring the neutron's time of flight, and neutron events were distinguished from gamma-ray events with a two-dimensional pulse shape discrimination technique. A moving source analysis of the neutron spectra will be presented.

* Work supported in part by the National Science Foundation under Grant Nos. PHY89-13815 and INT86-17863 and by the Hungarian Academy of Sciences.

15:18
CB 10 Isotope Identification of ^{16}O breakup fragments at 70 to 110 MeV.* S.J. PADALINO, S. LASSELL and D. CIGNA, State University of New York at Geneseo and L.C. DENNIS, M. TIEDE and R. ZINGARELLI, Florida State U.--Ratios of carbon, nitrogen and oxygen isotopes have been measured at several bombarding energies from 70 to 110 MeV in the ^{16}O + ^{27}Al, and ^{16}O + ^{28}Si reactions. A TOF plus DE-E system was used to detect energy, mass and charge of ejectiles equal to or lighter than the projectile's mass. An unexpected fluctuation in the ^{15}N to Nitrogen isotope ratio was observed as a function of energy, while over the same energy range the ^{12}C to Carbon ratio dropped monotonically in ^{16}O + ^{27}Al reaction.

*This work was supported in part by a grant from the National Science Foundation.

SESSION CC: INSTRUMENTATION II
Friday afternoon, 26 October 1990
Room 144, Loomis Laboratory at 13:30
P. Debevec, presiding

13:30
CC 1 Fast Timing Properties of Scintillating Fibers.* M. GAI and S. SEN, Yale University--Experiments involving scintillating fiber detectors such as the Yale tandem ^{18}O parity experiment, the CEBAF-CLAS start detector, the BNL-AGS search for strange matter, and the BNL g-2 experiment require good time resolution. We have studied the timing characteristics of 0.976 MeV electrons traversing a single fiber, a fiber bundle (up to three fibers across), and a fiber block in coincidence with a fast (BC422) scintillator. The time resolution could be characterized as FWHM=$\tau/\sqrt{N}$ with τ the phototube's rise time and N the number of photoelectrons. We obtain a time resolution as good as σ=250 psec using fibers. Several different phototubes were used with Bicron BC10 fibers. The results obtained will be discussed together with a suggestion for a readout system, currently under development at Yale, that will allow for both good timing and good x y position.
*Supported by USDOE Contract No. DE-AC02-76ER 03074

13:42
CC 2 **Impurity Measurements in a High Pressure Xenon Ionization Chamber.*** J GERMANI, C LEVIN, J MARKEY, Yale University--A 3 liter Xe gas ionization chamber, operating near the critical point of Xe, has been run at a density of .85 g/cm^3. Ionization from a ^{207}Bi conversion electron source has been drifted over 2.1 and 6.8 cm. By comparing the charge collected from these two drift distances at the same electric field strength a measurement of the electron attenuation length was made. From this an impurity concentration of about 2 ppb oxygen equivalent was found. Measurements have also been made on cosmic ray muons traversing these drift distances. In this case digitized pulses can be fit to determine the impurity concentration. This detector is being developed for a ^{136}Xe double beta decay experiment, but could also be useful in gamma ray astronomy and nuclear gamma ray spectroscopy.

*Work supported by USDOE Contract No. DE-AC02-76ER03074.

13:54
CC 3
Monte Carlo Simulation of Electron Trajectories from ^{136}Xe 0ν ββ Decay.* C. LEVIN, J. GERMANI, J. MARKEY, Yale University- In ^{136}Xe 0ν ββ decay the single electron energy distributions will be different depending on whether or not right-handed currents contribute. A Monte Carlo calculation was developed to simulate electron trajectories in a high pressure gaseous xenon ionization chamber. Bremsstrahlung and delta electron production effects are included and are found to have a significant effect on the charge deposition in the detector. By requiring electron tracks to be contiguous and localized, it is found that the efficiency of detecting 0ν double beta decay depends on whether right-handed currents are present.
*Supported by USDOE Contract No. DE-AC02-76ER-03074

14:06
CC 4 **Pattern Recognition in the E814 Forward Spectrometer.** S.V. GREENE, T.K. HEMMICK, J.T. MITCHELL, B. SHIVAKUMAR, and Ch. WINTER Yale University*, E. O'BRIEN Brookhaven National Laboratory*--The E814 forward spectrometer is used in the identification of heavy ions and minimum ionizing particles emitted in a cone of approximately 0 8 degrees centered around the beam direction. It consists of two dipole magnets, three tracking detectors, a scintillator hodoscope wall, and a wall of segmented calorimeters. Pattern recognition proceeds through the identification of track elements in drift chambers, charge clusters in pad chambers, and hit locations in the scintillator and calorimeter walls. These pieces of information are then combined together, taking into account their differences in character and accuracies, to identify track candidates and particles. The identification happens even when some of these pieces of information are missing. We will present our pattern recognition strategy and discuss the performance of the algorithms.
*Supported in part by the U.S. Department of Energy.

14:18
CC 5 **Performance of the Yale Neutron Ball.*** S.L. RUGARI, M. GAI, R.H. FRANCE III, B.J. LUND, Z. ZHAO, Yale University--The Yale Neutron Ball, a 2π array of 35 neutron detectors consisting of six subunits of six elements each, has been tested using standard neutron sources (Pu-Be and ^{252}Cf, E_n~4MeV, 2MeV respectively) and with monoenergetic neutrons produced by the reaction ^{4}He(^{9}Be,n)^{12}C (E_{Beam}=15MeV). The detectors are aluminum shells filled with liquid scintillator (NE213) to allow neutron gamma ray discrimination. This discrimination, performed with a new zero-crossover Pulse Shape Discriminator[1]), gives a figure of merit of ~ 4.5[2]). Neutron time of flight has been measured with time resolution of Δt 1.2 ns (arising primarily from the detector geometry). Individual intrinsic efficiencies of the order of 25% at 2 MeV neutron energy and pulse height resolution of ~ 15% for 1.33 MeV gamma rays have been measured[3]). Crosstalk measurements from neutron scattering between nearest and next nearest neighbors will be presented.
1) S. Pat et al., Nucl. Inst. and Meth. A278 (1989) 749.
2) FOM≡FWHM(γ)/Peak Separation
3) M. Gai et al., Nature 340 (6 July 1989) 29.
*Supported by USDOE Contract No. DE-AC02-76ER-03074.

14:30
CC 6 Initial Operation of the NSCL Phase II Superconducting Beamlines J.C DEKAMP, H.LAUMER, C.T MAGSIG, J.A.NOLEN, D.P.SANDERSON, B.M.SHERRILL, and A.F.ZELLER, Michigan State University--The NSCL Phase II beamlines are arranged to deliver beam from either the K500 or K1200 superconducting cyclotrons to any of the Phase II experimental vaults. Since the rigidity of the beams can be up to 1.6 GeV/c and the building is relatively small, superconducting quadrupoles were designed and built for these beamlines. Superconducting switching magnets are also being used. The system currently under construction includes 21 quadrupole doublets, 2 triplets, and 9 dipoles. These magnets were designed to be cost efficient in both construction and operation. The magnet cryostats, which operate in a batch-filled mode, are all plumbed to a central liquid helium and liquid nitrogen distribution system with the cryogen transfers being computer controlled; the boiloff rates of individual magnet cryostats which were designed to provide just enough cold gas to cool the leads are 0.2-0.5 l/hr, so that including transfer losses the complete beamline system will use about 10-15% of the helium liquifier capacity. The quadrupoles operate at a peak current of 20 amps and the dipoles at 80 amps A short prototype section of beamline with two quadrupole doublets, a singlet, and a switching magnet was successfully used for research in an interim vault during the calendar year 1989. In May of 1990 the first section of Phase II beamline was used and the remaining sections are expected to be operational by this Fall. A section of the superconducting beamline near the K1200 cyclotron serves as a beam analysis system and a fragment separator for secondary beams, the A1200[1].

Research supported by the US National Science Foundation.
1. B.M.Sherrill, et al. Proc. First Inter. Conf. on Radioactive Nuclear Beams, Oct. 1989 (World Scientific, 1990) p.72.

14:42
CC 7 Application of the Differential Algebra Code COSY-Infinity to Magnetic Spectrograph Design. M.BERZ, J.DITTMANN, K.JOH, J.A.NOLEN, B.M.SHERRILL, and A.F.ZELLER, Michigan State University--The recent application of differential algebra (DA) to beam dynamics[1] has made it practical to extend matrix optics techniques to arbitrary order. We are currently evaluating the usefulness of the code COSY-Infinity in magnetic spectrograph design. Previously, we have used the optimizing code MOTER which includes the program RAYTRACE as a subroutine. Using the NSCL S800 design as a test case we have determined that matrix calculations to seventh order provide precision adequate for 10^4 energy resolution and 1 mr angular resolution, which are the specifications for this spectrograph. There are 50 matrix elements out of a possible several thousand which are relevant to the resolutions at this level. MOTER includes the effects of finite detector resolution in its optimization procedure, whereas, COSY-Infinity currently does not. Our next goal, therefore, is to develop a faster version of MOTER by using the high order matrix tracking techniques of COSY-Infinity in place of the present raytracing method. We also expect DA methods to be useful in developing an algorithm for fast on-line trajectory reconstruction from focal-plane detector position information.

Research supported by the US National Science Foundation.
1. M.Berz, Part. Accel. 24(1989)109.

14:54
CC 8 Secondary Beam Intensities from a Projectile Fragment Separator J. A. WINGER, B. M. SHERRILL, and D. J. MORRISSEY, MSU† Recently, a great deal of interest has been shown in the experimental use of radioactive ion beams. A number of facilities have been built or are under construction world wide which will allow separation of relatively pure radioactive ion beams. One such facility is the A1200, a projectile fragment separator at the NSCL. As part of the work lead-

ing up to experiments using the A1200, we have developed a computer code which allows fast, interactive determination of secondary ion beam intensities and purities for use in the design of experiments. The code has been designed to model any device of design similar to the A1200 by using approximate beam optics equations applied to an idealized initial secondary beam from the production target. The description of the initial beam is based on the Goldhaber model[1] with the production cross section taken from the parameterization of Sümmerer and Morrissey.[2] A discussion of the basic equations used, including all approximations, as well as some comparative calculations will be given.

†Work supported by the NSF grant PHY89 13815.

[1]A. S. Goldhaber, Phys. Lett. 53B, 306 (1974).

[2]K. Sümmerer and D. J. Morrissey, Proceedings of the Workshop on Radioactive Beams, Berkeley, Ca., October 1989 (In press).

15:06

CC 9 Status of the NSCL-A1200 Beam Analysis and Fragment Separator, D.J. MORRISSEY, W. BENENSON, J.A. NOLEN, B.M. SHERRILL, and J.A. WINGER, Michigan State U. -- The A1200 is being constructed at the National Superconducting Cyclotron Lab for routine cyclotron beam analysis and separation of radioactive beams produced by projectile fragmentation reactions is reviewed. A unique feature of the A1200 is its placement at the exit of the K1200 cyclotron allowing it to feed beams to all experimental devices. The device is achromatic with 2 intermediate images and consists of all superconducting magnets, 4 quadrupole doublets, 4 dipoles and 2 quadrupole triplets, except for 4 roomtemperature sextupoles. The device can be run in different modes to analyze the primary beam, separate secondary reaction products and act as a dispersion matched spectrometer. Results from the first operation of the device will be presented.

* Supported by the NSF under grant PHY-89-13815

15:18

CC 10 The Simultaneous Acceleration of Doublet, Triplet and Quadruplet Beams at the Bevalac.* G. J. Wozniak, N. Colonna, Y. Blumenfeld, D. Delis, M. Justice, K. Hanold, M. A. McMahan, J. C. Meng, L. G. Moretto, G. F. Peaslee, P. Roussel-Chomaz, and Q. C. Sui, Lawrence Berkeley Laboratory; -- To calibrate our experimental apparatus requires several different beam species which typically requires retuning the accelerator. To improve the Bevalac's operational efficiency, we have developed a technique to accelerate multiple beams with the same charge-to-mass ratio (Q/A). The tuneup time for a "cocktail" of beam species with identical Q/A takes no more time than a single beam tune During the last year the Bevalac has routinely delivered doublet ($^{20}Ne/^{40}Ar$, $^{28}Si/^{56}Fe$ & $^{86}Kr/^{129}Xe$), triplet ($^{14}N/^{28}Si/^{56}Fe$) and quadruplet ($^{14}N/^{28}Si/^{56}Fe/^{84}Kr$ beams. To be accelerated in both the injector and the sychrotron, the Q/A ratio of the different ion species must be matched at the ion source and after the stripper foil. The above quadruplet beam was produced in the ion source with a Q/A = 1/14 by using a iron electrode with a silicon insert and a krypton/nitrogen support gas mixture. During the acceleration cycle, the ion species were stripped to Q/A of 2/7. The possibility of producing larger beam multiplets will be discussed as well as possible novel uses of multiple beams.

*This work was supported by the U. S. Department of Energy under Contract DE-AC03-76SF00098.

Supplementary paper

CC 11 A 7T Solenoid Magnetic Lens System for Radioactive Nuclear Beam Experiments.[a] F.D. BECCHETTI, J BROWN, W.Z. LIU[b] AND D. ROBERTS, Univ. Michigan. - A 7T multi-coil superconducting solenoid, 40 cm bore, 100 cm long, has been designed and constructed for use as a radioactive nuclear beam (RNB) lens at the Michigan State University National Superconducting Cyclotron Laboratory (MSU-NSCL) heavy-ion facility and elsewhere. This magnet is a scaled-up version of a smaller device (20 cm bore, 3.5T) used successfully for RNB work at lower energies (UM-UND). Provisions have been made for inclusion of radial electric-field lenses, corrective solenoid lenses and mid-plane energy-loss absorbers to provide improved optics and mass separation The good optical properties and the large solid angle of a large-bore s c magnet (50 - 200 msr) result in a system well-suited for production of high-intensity (10^6 - 10^8/sec), well-focused RNBs with E/A up to 50 MeV/u. The short magnet fligth path is well suited for very short-lived RNB such as isomeric nuclei. This system is also usable as a large-solid-angle reaction-product collector for secondary reactions. Results of the initial tests of the magnet will be described.

a) Work supported in part by DoE and the National Science Foundation.

b) Present address: Cyclotron Institute, Texas A&M University, College Station, TX 77843

SESSION CD: NUCLEAR REACTIONS

Friday afternoon, 26 October 1990
Room 136, Loomis Laboratory at 13:30
C. Goodman, presiding

13:30

CD 1 The (p,n) Measurements for Spectra Containing GT Strength Known from β Decay*. Y. WANG, C.D. GOODMAN, W. HUANG, G.C. KIANG, IUCF; R.C. BYRD, L.J. RYBARCYK, T.N. TADDEUCCI, LANL; J. RAPAPORT, Ohio U.; D. MARCHLENSKI, E.R. SUGARBAKER, Ohio State U.; - We have measured the (p,n) spectra at $\theta_{Lab} = 0^0$, 3^0, 6^0 and E_p = 120, 160 MeV for ^{51}V, ^{87}Rb, ^{113}In, ^{118}Sn, ^{141}Pr, which contain Gamow-Teller (GT) strength known from β decay in the medium and heavy mass regions. The specific GT and Fermi (F) cross sections $\hat{\sigma}_{GT}$ and $\hat{\sigma}_F$, $\hat{\sigma}_{GT} = \sigma_{GT}/B(GT)$ and $\hat{\sigma}_F = \sigma_F/B(F)$, and their ratio $R^2 = \hat{\sigma}_{GT}/\hat{\sigma}_F$ are deduced. The measured (p,n) spectra calibrated against β decay can be used to measure GT transition rates inaccessible to β decay including transitions needed to calibrate neutrino detectors. The measurements were made at the IUCF Swinger Facility with an improved neutron detector array.

*Work supported by the National Science Foundation.

13:42

CD 2 Isobaric Analog State Transitions in the (p,n) Reaction at 135 MeV and Density-Dependent Impulse Approximation Calculations* B.D. ANDERSON, M. MOSTAJABODDA'VATI, C. LEBO, R.J. McCARTHY, J.W. WATSON, R MADEY, Kent State U - We compare density-dependent distorted-wave impulse approximation (DD-DWIA) calculations with experimental (p,n) cross section angular distributions at 135 MeV for 0^+ to 0^+, isobaric analog-state, transitions in ten nuclei from A=14 to 208 The experimental measurements were performed with the beam-swinger neutron time-of-flight facility at the IUCF in several different experiments over the last several years. The DD-DWIA calculations use a G-matrix interaction[1] based on the Bonn one-boson-exchange potential and empirical optical-model parameters. The agreement between the calculations and the experimental results is excellent with normalization factors required that are within 10% of unity; these factors are within the experimental scale uncertainties.

* Supported in part by the National Science Foundation.

[1] K. Nakayama and W.G. Love, Phys. Rev. C38, 51 (1988).

13:54
CD 3 Proton-Induced Reactions in ^{52}Cr- C. E. Laird, David Sousa, Gerald Calkin, Philip Esterle, Tammy Hooper and Qiang Shen, Eastern Kentucky University.--Measurements have been made of the cross sections for radiative capture, for elastic and inelastic scattering, and for (p,n) reactions on ^{52}Cr. These data have been analyzed using Hauser-Feshbach optical and Isospin-coupled channel models to obtain appropriate model parameters. Comparisons are made with the potentials determined by Kailas et al.[1] at subCoulomb proton energies for medium-mass nuclei. Kailas' study concluded that there is an anomaly in the absorptive potential in the mass 40-80 region. The present analysis shows that the inclusion of other channels aids the model analyses for this target.

[1]S. Kailas, M.K. Mehta, S.K. Gupta, Y.P. Viyogi and N.K. Ganguly, Phys. Rev. C20, 1272(1979).

14:06
CD 4 Spectral function for p-n pairs in ^{6}Li. R.E. WARNER, Oberlin, E. CHEUNG, C.F. PERDRISAT, V. PUNJABI, William and Mary, C.A. DAVIS, R. HELMER, TRIUMF, A. GALONSKY, L. HEILBRONN, D. KROFCHECK, MSU-NSCL, S. DARDEN, J. KOLATA, Notre Dame, F. BECCHETTI, U. of Michigan, and P. SCHWANDT, IUCF.--The spectral function for p-n pairs in the ^{6}Li ground state (the distribution in n-p relative momentum $\hbar k$ for pairs whose c.m. is at rest in the laboratory) was measured for k ranging from 0.6 to 1.5 fm^{-1}. The ^{6}Li(p,pα)pn reaction was used, and p-α quasielastic scattering events at 56° in the p-α c.m. system were selected. These data, combined with earlier ^{6}Li(α,2α)pn measurements, show that when k increases from 0.1 to 1.5 fm^{-1}, this function decreases by 4 orders of magnitude and is predicted within a factor of 2 (without renormalization) by the plane wave impulse approximation. The asymmetry for the ^{6}Li(p,pα)pn reaction, induced with polarized protons, was measured at 56° c.m. and found to have the same bombarding-energy dependence as that of p-α elastic scattering. The ground-state d-α cluster probability, determined by the ^{6}Li(p,pα)d reaction, was consistent with that found in other intermediate energy experiments.

14:18
CD 5 Global Dirac Optical Potentials for Light Targets* - S. Hama, E.D. Cooper, B.C. Clark, The Ohio State U., R.L. Mercer, IBM Watson Labs. - Global Dirac Optical Potentials for p + ^{12}C and ^{16}O from 65 to 800 MeV are obtained using several assumptions regarding the energy (E) and mass number (A) dependence of the optical potential parameters. The geometry parameters are taken to be both E and A dependent. The strength parameters are assumed to depend only on E. Characteristic features of the global potentials will be discussed.

* Work supported in part by the NSF grant No. PHY8822550.

14:30
CD 6 Coupled Channel Effects in High Energy Alpha Particle Fragmentation on Nuclear Targets. F. A. Cucinotta, L. W. Townsend, and J. W. Wilson, NASA Langley Research Center, and J. W. Norbury#, Rider College. - Double differential cross sections for the two-body dissociation of alpha particles are calculated in the high energy optical model of nuclear multiple scattering. Momentum distributions for forward scattered fragments are often evaluated using a participant-spectator model or the DWBA. Using the high energy optical model, we estimate the importance of coupled channel effects on predictions of inclusive momentum distributions and their role in determining the large momentum components of the two-body overlap functions from small angle data. For elastic fragmentation, interference effects between participant and spectator interactions are shown to be non-negligible for forward scattered fragments.

#Supported by NASA Grant NAG-1-1134.

14:42
CD 7 A Three Alpha-particle Coincidence Search for Collective High Spin States in ^{12}C.* D.D. CAUSSYN, N.R. FLETCHER, J.A. LIENDO, G.L. GENTRY, Florida State U., and J.F. MATEJA, Argonne National Laboratory--A search for theoretically predicted collective high spin states in ^{12}C is made by using position sensitive detectors to make a kinematically complete measurement of the three alpha-particles produced in the decay of excited ^{12}C. The excited ^{12}C is produced in the system ^{12}C + ^{12}C, with a lab energy of 90 MeV. Different decay processes in this system are identified and separated as much as kinematically allowed. Despite the low background and relatively good energy resolution, no predicted, but as yet unseen, states were uncovered in this work. However, from the calculation of detection efficiency, the branching fraction for the decay of ^{12}C from the 4^{+} state at 14.08 MeV excitation to the first excited sta s of ^{8}Be is determined to be 0.83 with an estimated uncertainty of about 0.05. The results of a theoretical calculation of this branching fraction currently being done will be presented along with the experimental spectra.

*This work was supported in part by the National Science Foundation.

14:54
CD 8 Elastic Scattering of 318 MeV ^{6}Li Ions from ^{12}C and ^{28}Si.* A. NADASEN, B. ASHE, J. BRUSOE, U. of Michigan, Dearborn; P. SCHWANDT, IUCF; J. WINFIELD, G. YOO, NSCL; F.D. BECCHETTI, J. BROWN, D. HOTZ, J. JANECKE, D. ROBERTS; U of Michigan, Ann Arbor; and R.E. WARNER, Oberlin College: Differential cross sections have been measured for the elastic scattering of 318 MeV ^{6}Li ions from ^{12}C and ^{28}Si. The 3+ ^{6}Li beams were obtained from the K500 cyclotron of NSCL and the scattered particles were detected with a S320 magnetic spectrometer. The measurements covered seven orders of magnitude over angular ranges of 4.5° to 46.5° for ^{12}C and 3.7° to 38.8° for ^{28}Si in the center-of-mass. The angular distributions exhibit diffractive oscillations forward of 15° followed by smooth exponential fall-off characteristic of nuclear rainbow scattering. The rainbow scattering region is crucial for the determination of unique ^{6}Li-nucleus Optical Model potentials at this energy. Results of the measurements and preliminary Optical Model analysis will be presented.

* Supported in part by the NSF.

15:06
CD 9 Three α-particle Reactions in Special Kinematical Conditions. M.BOGOVAC, D.MILJANIĆ, D.RENDIĆ, M.ZADRO, Ruđer Bošković Institute and

G.CALVI, M.LATTUADA, F.RIGGI, C.SPITALERI, Università di Catania and Laboratorio Nazionale del Sud.--- The $^{10}B(d,\alpha\alpha)^{4}He$ and $^{9}Be(^{3}He,\alpha\alpha)^{4}He$ reactions are studied in the "star" configuration (angles between α-particles are 120° in c.m. system). It is also required that relative energies in each α-particle pair correspond to the excitation energies of ^{8}Be states. The results of the experiments and their possible descriptions will be presented.

15:18

CD 10 Searches for Small Violations of the Pauli Exclusion Principle in Nuclear Reactions. D.MILJANIĆ and A.LJUBIČIĆ, Ruđer Bošković Institute.--- Recently there have been several theoretical and experimental studies considering the possibility of small violations of the Pauli exclusion principle. In the experiments the main emphasis has been on the tests of the principle in atoms. However, we propose several very sensitive tests in nuclear reactions. Experimental results from the searches will be presented.

15:30

CD 11 Finite Range DWBA description of ^{3}He- ^{3}H scattering and reaction cross-sections and analysing powers. C.BLYTH, J.B.A. ENGLAND, G.M.FIELD, O.KARBAN, C.N.PINDER, N.M.CLARKE, G.RAI, R.VLASTOU, L.ZYBERT and G.C.MORRISON. University of Birmingham, Birmingham B15 2TT, England.--- A reasonably accurate and complete set of cross-sections and analysing power data for ^{3}He + ^{3}H elastic scattering and ^{3}He + ^{3}H -> ^{3}H + ^{3}He reactions at incident laboratory energies of 18 to 38 MeV[#], has been gathered and compared with the predictions of full, finite-range, DWBA calculations[¤]. The transfer form-factors were the result of calculations beginning with realistic nucleon-nucleon interactions including the tensor interaction. The incident and exit channel wavefunctions were determined by an optical model analysis of the elastic scattering data and three possible sets of parameters were determined. Only one of the sets however, led to an acceptable description of all the data when included in the DWBA calculations. This set had a real volume integral/nucleon of 1150 MeV fm³. The results will be presented and the acceptability of the conclusions considered.

J.B.A.England, et al. To be submitted to Nuclear Physics A
¤ Program FRESCO. I.J.Thompson Comp Phys Rep 7 (1988) 167

Supplementary paper

CD 12

Microscopic Optical Model Calculations for Nucleon-Nucleus Scattering in Light Nuclei ($6 \lesssim A \lesssim 11$). L.F. Hansen, F.S Dietrich, Lawrence Livermore National Laboratory*, R.L. Walter, Duke University and TUNL**. Differential cross sections and analyzing powers for neutrons and protons elastically scattered from ^{6}Li, ^{9}Be, ^{10}B and ^{11}B in the energy range 8-17 MeV are compared with two microscopic OM calculations using the JLM (with M3Y spin-orbit interaction) and Yanaguchi et al. potentials. Reasonable good fits are found for all the data using only three parameters, λ_V, λ_W and λ_{SO}, which are the normalizing constants to the real and imaginary central potential and the real spin orbit potential respectively. All three parameters showed a smooth energy dependence, as well as an A dependence to be discussed. *Work performed under the auspices of the USDOE, Contract W-7405-ENG-48. ** Work supported by USDOE, Contract No. DE-AC05-76ER01067.

TOWN MEETING
Friday afternoon, 26 October 1990
Room 141, Loomis Laboratory at 16:00
J. Ball, presiding

BATES USERS' GROUP
Friday afternoon, 26 October 1990
Room 136, Loomis Laboratory at 17:00

MSUNSCL USERS' GROUP
Friday afternoon, 26 October 1990
Room 158, Loomis Laboratory at 17:00

HHRIF USERS' GROUP
Friday afternoon, 26 October 1990
Room 144, Loomis Laboratory at 17:00

CASH BAR
Friday evening, 26 October 1990
South Lounge, Illini Union at 18:00

BANQUET
Friday evening, 26 October 1990
Rooms A, B, and C, Illini Union

INVITED SESSION DA: ELECTROMAGNETIC STRUCTURE OF BARYONS

Saturday morning, 27 October 1990; Room 141, Loomis Laboratory at 9:00; R. G. Arnold, presiding

Note Times: 5 Speakers—30 minutes each.

9:00

DA 1 The Origins of Scaling in Inclusive Scattering from Nuclei. BRAD FILIPPONE, *Caltech.*

The data from high energy electron scattering from nuclei indicate several types of scaling. In the deep inelastic regime, scaling in the Bjorken x variable ($x = Q^2/2M\nu$) is observed, indicating incoherent scattering from the nucleon constituents, and providing information on the quark momentum distribution in nuclei. In the quasielastic region, y scaling has been observed suggesting coherent scattering from the nucleons themselves, and possibly shedding light on the nucleon momentum distribution in nuclei. Recent theoretical work and new analyses of the previous data are beginning to provide important clues to the validity of the approximations that predict the scaling behaviour and to possible relationships between the scaling phenomena.

9:30
DA 2 New Measurements of the Nucleon Electric and Magnetic Form Factors at High Momentum Transfers.
PETER BOSTED.* *American University.*

Preliminary results for new measurements of the proton and neutron electric and magnetic form factors will be presented. The measurements were made using liquid hydrogen and deuterium targets and performing Rosenbluth separations for electrons elastically or quasi elastically scattered into the 1.6 GeV and 8 GeV spectrometers in End Station A at the Stanford Linear Accelerator Center. The proton form factors were measured up to $Q^2 = 7$ $(GeV/c)^2$ with typical errors of 2% on G_{Mp} and approximately 5% on G_{Ep}. The neutron form factors will be extracted from the longitudinal and transverse quasi-elastic response functions, measured up to $Q^2 = 4$ $(GeV/c)^2$. The errors are expected to be small enough to distinguish between models where G_{En} remains close to zero and those in which $G_{En}(Q^2) = \frac{Q^2}{4M^2} G_{Mn}(Q^2)$. Comparisons will be made with commonly used form factor parametrizations as well as with new calculations using QCD sum rules and light-front dynamics.

* Reporting on an experiment performed by the NE11 Collaboration (The American University, Lawrence Livermore National Laboratory, University of Tel-Aviv, University of Maryland, NIST, Stanford Linear Accelerator Center, CEBAF, University of Pennsylvannia, University of Massachusetts, University of Washington, Stanford University, and University of Rochester.

10:00
DA 3 Perturbative QCD Predictions for Baryon Resonance Electroproduction at High Q^2.
CARL CARLSON, *College of William and Mary.*

Perturbative QCD gives the following results, valid at high Q^2, for the electroproduction of resonances. The dominant amplitude is the hadron helicity conserving amplitude often called $A^{\frac{1}{2}}$, which falls like $1/Q^3$. Amplitudes $C^{\frac{1}{2}}$ and $A^{\frac{3}{2}}$ are smaller by $1/Q$ and $1/Q^2$, respectively. The ratio of resonance peak to "background" is constant, as is seen for the second resonance. The delta resonance may have a special cancellation. The QCD sum rule wave functions for the nucleon and delta lead to an $A^{\frac{1}{2}}$ whose leading term is anomalously small. If so, the delta peak vs. "background" falls (as is seen) until asymptopia is reached at a higher Q than for most resonances.

10:30
DA 4 Color Magnetism and Electroweak Excitation of Baryon Resonances.
NIMAI C. MUKHOPADHYAY, *Rensselaer Polytechnic Institute.*

Color magnetism[1] in quantum chromodynamics(QCD) is the non Abelian analogue of ordinary magnetism in quantum electrodynamics. It plays a vital role in influencing the quark wave functions for a number of hadrons.[2] I shall show the relevance of electroweak amplitudes for the $N \rightarrow N^*$ transitions in testing this and other aspects of the QCD inspired hadron models, using examples of P33(1232), S11(1535), and F37(1950) resonance excitation. Next I shall review the recent theoretical efforts[3] on the extraction of resonant transition amplitudes from the existing data. Finally, I shall discuss experimental prospects for improving our knowledge of meson photo- and electroproduction, and Compton scattering in the emerging facilities.

[1] A. DeRujula, H.Georgi and S.L. Glashow, Phys. Rev. D12,147(75).

[2] N. Isgur, G. Karl and R. Koniuk, Phys. Rev. D25,2394(82); M. Bourdeau and N. C. Mukhopadhyay, Phys. Rev. Lett. 58,976(87) and 63,335(89); S. Capstick and G. Karl, Phys. Rev. D41,2767(90).

[3] R. Davidson, N. C. Mukhopadhyay and R. Wittman, Phys. Rev. Lett. 56,804(86) and Phy. Rev. D. (in press); M. Benmerrouche, L. Zhang and N. C. Mukhopadhyay, to be published.

11:00
DA 5 Compton Scattering and the Polarizabilities of the Proton.* ALAN M. NATHAN, *University of Illinois at Urbana-Champaign.*

A review is given of recent and planned experiments that measure the electric (α) and magnetic (β) polarizabilities of the proton. These quantities are fundamental structure constants that characterize the second-order response of the proton to external static electric and magnetic fields. They are equal in importance to the mean-square charge or magnetic radius, although known considerably less well. Low energy theorems relate the Compton scattering cross section to α and β. For energies small compared to the pion mass, the elastic photon scattering cross section deviates from that expected for a point structureless proton. The deviation, which to lowest order is quadratic in the photon energy, is directly proportional to the sum and difference of α and β at forward and backward

scattering angles, respectively. We describe in detail an experiment[1] in which the scattering cross section was measured between the energies of 32 and 72 MeV and at laboratory scattering angles of 60° and 135° using the photon tagging technique. The results of that experiment will be presented. and an interpretation in terms of α and β will be given.

*Supported by the National Science Foundation under grant PHY 86-10493.

[1] F. J. Federspiel, Ph. D. thesis, University of Illinois, 1990 (unpublished).

SESSION DB: HIGH-ENERGY HEAVY-ION AND $p\bar{p}$ REACTIONS

Saturday morning, 27 October 1990
Room 151, Loomis Laboratory 9:00
T. Ludlam, presiding

9:00

DB 1 Fission Systematics from the Reactions Fe+Th, Au, Ta and Nb+Au at 50 to 100 MeV/A*. M. N. Namboodiri, H. C. Britt, D. J. Fields, L. F. Hansen, R. G. Lanier, J. E. Larkin, T. C. Sangster, G. L. Struble, Lawrence Livermore National Laboratory, M. Begemann-Blaich, T. Blaich, M. M. Fowler, J. B. Wilhelmy, Los Alamos National Laboratory, S. B. Kaufman, F. Videbaek, Argonne National Laboratory, Y. D. Chan, A. Dacal, A. Harmon, J. Pouliot, R. G. Stokstad, Lawrence Berkeley Laboratory, Z. Fraenkel, Weizmann Institute--We have performed a detailed analysis of the fission systematics in the reactions Fe+Th, Au. Ta and Nb+Au at 50 to 100 MeV/A. The data were collected using the PAGODA[1] detector array at the LBL Bevalac. For each fragment we measure the charge, velocity and position (θ,ϕ). Our results indicate that fission occurs predominantly from peripheral collisions with parallel momentum transfers up to a maximum of about 6 GeV/c and excitation energies less than 1 GeV. The data are consistent with the much lower energy Viola systematics for all systems.
*Work performed under the auspices of the US DoE, contract W-7405-ENG-48. [1]M. M. Fowler et al., NIM A281 (1989) 517-527.

9:12

DB 2 Intermediate Mass Fragment Production from Fe+Au and Nb+Au Reactions at 50 to 100 MeV/A*. T. C. Sangster, H. C. Britt, D. J. Fields, L. F. Hansen, R. G. Lanier, J. E Larkin, M. N. Namboodiri, G. L. Struble, Lawrence Livermore National Laboratory, M. Begemann-Blaich, T. Blaich, M. M. Fowler, J. B. Wilhelmy, Los Alamos National Laboratory, S. B. Kaufman, F. Videbaek, Argonne National Laboratory, Y. D. Chan, A. Dacal, A. Harmon, J. Pouliot, R. G. Stokstad, Lawrence Berkeley Laboratory, Z. Fraenkel, Weizmann Institute--We have measured intermediate mass fragment (IMF) production from the reactions Fe+Au and Nb+Au at 50 to 100 MeV/A using the PAGODA[1] detector array at the LBL Bevalac. The data consists of isotopically identified fragments from protons through the fission mass region. We present a broad overview of the IMF and light particle inclusive systematics for both systems. This includes the angular and mass distributions, the multiplicity distribution and the total production cross sections.
*Work performed under the auspices of the US DoE, contract W-7405-ENG-48.
[1]M. M. Fowler et al., NIM A281 (1989) 517-527

9:24

DB 3 Comparison of Microscopic Calculations of IMF Emission with Experiments for the Reactions Fe+Au and Nb+Au at 50 to 100MeV/A. L.F.Hansen, H.C.Britt, M.N. Namboodiri, T.C.Sangster, Lawrence Livermore National Laboratory*: G.Peilert, H.Stocker, W.Greiner, Institut für Theoretical Physik, JWG-Universität.** Calculations of the fragmentation products from the Fe+Au and Nb+Au reactions at 50 and 100 MeV/A, have been done using the Quantum Molecular Dynamic (QMD) model[1]. The calculated mass distribution of the fragments for $12 \leq A \leq 60$ values, their multiplicities and angular distributions are compared with measurements from the Pagoda detector array at the LBL Bevalac. The mass distributions and multiplicities are reproduced reasonably well by the model. However, the calculated angular distributions are more sharply forward peaked than the experimental data. Details of the QMD calculations will be discussed. *Work performed under the auspices of the USDOE, Contract W-7405-ENG-48. **Supported by the German Federal Minister for Research and Technology (BMFT), Contract 06 OF 772 & the GSI.
[1]J. Aichelin et al., Phys. Rev. C 37, 2451, (1988).

9:36

DB 4 Electromagnetic Dissociation of ^{238}U at Intermediate Energies.* M. JUSTICE, Y. BLUMENFELD, N. COLONNA, D.N. DELIS, K. HANOLD, J. MENG, L.G. MORETTO, G.F. PEASLEE, G.J WOZNIAK, Lawrence Berkeley Laboratory, G. GUARINO, IFN-Bari - Electromagnetic dissociation cross sections of $^{238}U + ^{238}U$ at 80 and 120 A·MeV have been measured at the Berkeley BEVALAC. Due to the very low barrier, uranium decays with high probability into two fission fragments after electromagnetic excitation. Two arrays of position sensitive silicon $\Delta E - E$ telescopes placed concentrically around the beam axis were used to identify the projectile fission fragments. The expected contribution from peripheral nuclear reactions is extrapolated from measurements on a series of light targets. A comparison with models based on the Weizsäcker-Williams method of virtual quanta will be made.
*This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-Ac03-76SF00098.

9:48

DB 5 Bevalac Experiment E848H : Neutron Triple – Differential Cross Sections from Nb + Nb Collisions. M. ELAASAR, R. MADEY, W. ZHANG, J. SCHAMBACH, D. KEANE, B. D. ANDERSON, A. R. BALDWIN, J. W. WATSON, Kent State U.*; G. WESTFALL, Michigan State U.; G. KREBS, H. WIEMAN LBL; C. GALE, McGill U. – – We measured neutron triple-differential cross sections $d^3\sigma/dcos\theta d\phi dY$ from high-multiplicity Nb+Nb collisions at 400 AMeV. The reaction plane for each event was determined with a method proposed by Gyulassy.[1] Neutrons were detected in 18 detectors disposed at polar angles from 3° to 90°. The triple-differential cross sections are peaked at an azimuthal angle of 0° relative to the reaction plane for neutrons with positive cm rapidities and at ±180° for neutrons with negative cm rapidities. Comparison of these measurements with BUU calculations[2] constrains the incompressibility modulus in the equation-of-state.
* Supported in part by the National Science Foundation.
[1] G. Fai, W Zhang, and M. Gyulassy, Phys. Rev. C36, 597 (1987).
[2] G. M. Welke et al., Phys. Rev. C38, 2101 (1988).

10.00
DB 6

Light Fragment Cross Sections from 800·A MeV ^{40}Ar + KCl and ^{40}Ar + Au. M.D. Partlan, J.L. Romero, F.P. Brady, W.B. Christie#, G.P. Grim, C E. Tull, UC Davis.* G. D. Westfall, D.E. Cebra, C. Djalali, A. Vande Molen, K Wilson, Michigan State U., H.Wieman, W. F. J. Müller, D.L. Olson, T.J.M. Symons, LBL. Light fragment cross sections (p, d, t, ^{3}He, ^{4}He), covering from ≈ 5° to 35° lab, were measured at the Heavy Ion Spectrometer System at the LBL Bevalac using an 800 A MeV ^{40}Ar beam on targets of Au and KCl. Fragments were identified and all three components of the momentum were measured The measured cross sections as well as the results of two particle correlations will be presented with the aim of extracting the entropy and temperature of the system.

Associated Western University Graduate Fellow.
* Supported by NSF Grant 84-19380.

10:12
DB 7 Dynamical Effects on Pions in Energetic Nuclear Collisions.* A. F. BARGHOUTY, Roanoke College; G. FAI and D. KEANE, Kent State University—The continuing experimental interest in the properties of pions produced in high-energy nuclear collisions[1] motivated us to revisit model predictions for pion spectra, total yields and pion-charged particle multiplicity correlations. A statistical background calculation carried out with the FREESCO event generator[2] indicates that it is necessary to take account of dynamical effects if the experimental data are to be reproduced. The presence of nuclear matter flow is well-known from the analysis of nucleons and heavier fragments[3] Incorporating the Δ(1231 MeV) resonance gives reasonable agreement with the experimental pion yields as a function of the beam energy for different symmetric systems. We discuss the necessity of further dynamical effects in the model calculation to obtain an approximate reproduction of the pion spectra.

*Supported by US DOE Grants DE-FG02-86ER40251 and DE-FG02-89ER40531 and by NSF Grant INT-8813351
[1]S. I. Chase *et al.*, Proc. Workshop on Nuclear Dynamics VI, Feb. 1990, Jackson Hole, Wyoming, ed. J. Randrup, LBL-28731, 67 (1990).
[2]G. Fai and J. Randrup, Comp. Phys. Comm. 42, 385 (1986).
[3]H. Å. Gustafsson *et al.*, Phys. Rev. Lett. 52, 1590 (1984).

10:24
DB 8 **Proton Distributions in 14.6 GeV per Nucleon Si-Nucleus Collisions.** J.T. MITCHELL for the E814 Collaboration: **BNL*, LANL*, McGill University, U. of New Mexico*, U. of Pittsburgh*, SUNY-Stony Brook**, Tel Aviv, Texas A&M*, Yale University***--We have measured the rapidity, transverse momentum, and multiplicity distributions of protons emitted in interactions between Si projectiles and targets of Al, Cu, and Pb. The measurements were made as functions of event centrality. The degree of centrality was characterized by measurement of transverse energy in the pseudorapidity interval $-0.5 < \eta < 0.8$ using a NaI calorimeter, and charged particle multiplicity in the interval $1.3 < \eta < 4$ using a Si pad array. The protons were detected in a magnetic spectrometer which consists of tracking chambers, scintillators, and calorimeters, and measured the momentum, total energy, charge and time of flight of particles that passed through a 0.8 degree cone in the forward direction. We will present the proton distributions and explore their dependances on event centrality.

*Supported in part by the U.S. Department of Energy.
**Supported in part by the National Science Foundation.

10:36
DB 9 Correlation Studies for Ultra-relativistic Nuclear Collisions. D.SEIBERT, University of Minnesota.--- Correlation studies are one of the most useful tools for studying the process of hadron production in ultra-relativistic nuclear collisions. Current studies show that correlations in nuclear collisions are unexpectedly strong, indicating that we may be observing the decay of bulk hadronic matter, and possibly even quark-gluon plasma. I discuss current methodology for correlation studies, and introduce a new technique for extracting two-body, three-body, and higher effects from sets of moments. This new technique is most effective for high multiplicity collisions, and thus should be very useful for studies of ultra-relativistic nuclear collisions.

10:48
DB 10 Threshold Measurement of the Reaction $\bar{p}p \to \bar{\Lambda}\Sigma$+c.c. R.L. TAYLOE‡ U. of Illinois for the PS185 Collaboration*-The reaction $\bar{p}p \to \bar{\Lambda}\Sigma$ together with its charge conjugate channel (c.c.) has been measured at LEAR. A multi-element, Pb/SCIFI calorimeter was used to detect the prompt γ from the decay $\Sigma \to \gamma\Lambda$. This feature has permitted distinction of the channel $\bar{p}p \to \bar{\Lambda}\Sigma$ from $\bar{p}p \to \bar{\Lambda}\Lambda$; the latter has been reported in our earlier work.[1-4] The incident $\bar{p}$ momenta were chosen to facilitate a comparison between the two sets of data from their respective reaction thresholds to excess energies of 40 MeV above these thresholds. The status of the near-threshold data evaluation, final results for an excess energy of 14.8 MeV above threshold, and theoretical models which compare the reactions $\bar{p}p \to \bar{\Lambda}\Sigma$ and $\bar{p}p \to \bar{\Lambda}\Lambda$ will be discussed.

*Carnegie-Mellon, Erlangen-Nürnberg, Freiburg, Illinois, KFA Jülich, Rice, Uppsala, Vienna.
‡Research supported in part by the National Science Foundation.
[1]P.D. Barnes et al., Phys Rev. B 189, (1987) 249,
[2]P.D. Barnes et al., Phys Rev. B 199, (1987) 147,
[3]P.D. Barnes et al., Phys Rev. B 229, (1989) 432, and
[4]P.D. Barnes et al., CERN-EP/90-40, Phys Rev. B, in press.

SESSION DC: WEAK INTERACTIONS, FUNDAMENTAL SYMMETRIES, AND NOVEL NUCLEAR PHENOMENA

Saturday morning, 27 October 1990
Room 144, Loomis Laboratory at 9:00
D. Beck, presiding

9:00
DC 1 Angular Correlation Test of CP-Invariance Using Polarized Positronium.* M. Skalsey and J. Van House, U. of Mich.-- We have recently completed a preliminary search for the new CP-violating angular correlation[1] $(\hat{S}\cdot\hat{k}_1)(\hat{S}\cdot\hat{k}_1\times\hat{k}_2)$ in the three photon decay of triplet positronium (o-Ps→3γ), where $\hat{S}$ is spin of o-Ps and $\hat{k}_i$ are the γ-momenta, with $|\vec{k}_1|>|\vec{k}_2|>|\vec{k}_3|$. Spin-aligned o-Ps is obtained by magnetic quenching of the m=0 triplet state, γ-momenta are determined with NaI detectors. Asymmetries of the number of events with $\hat{k}_1\times\hat{k}_2$ up and $\hat{k}_1\times\hat{k}_2$ down are measured to the level of 10^{-3}. The amplitude of this correlation is determined from the measured asymmetry and has been found to be zero at about the 1% level of uncertainty, consistent with CP-invariance.

* Work supported by NSF under Grant No. PHY-8803718.

[1] B. K. Arbic, et al., Phys. Rev. A37, 3189(1988).

9:12

DC 2 Δ Contributions to the Parity-Violating Nuclear Interaction G. B. Feldman, G. A. CRAWFORD, J. DUBACH, and B. R. Holstein, University of Massachusetts.* -- Most theoretical descriptions of parity violation in low- and intermediate-energy nuclear physics have been based on effective one-meson-exchange weak interactions between nucleons. In that case, one nucleon-nucleon-meson vertex is a parity-conserving strong vertex and the other is a parity-violating weak vertex. Recent studies of parity-violating proton-proton scattering at intermediate energies suggest that virtual Δ's may have a significant effect, especially since the parity-violating s-wave pion exchange between protons is forbidden by Barton's theorem. We therefore calculate an effective Hamiltonian for weak s-wave coupling of nucleons and/or Δ's with π, ρ, and ω mesons. These calculations are based on a simple quark description and an effective Weinberg-Salam model of the weak interaction which take into account gluon-exchange renormalizations.
*Supported in part by DOE Contract DE-FG02-88ER40415.

9:24

DC 3 The Measurement of Doppler Shifts in Gamma Rays Due to Nuclear Recoil Following Beta Decay.* M. B. SCHNEIDER, A. B. CRAFT, N. K. GREGORY, K. A. NASSIFF, and J. A. PATMON, Grinnell College. --- The beta decay of light radioisotopes causes a recoil of the daughter nucleus with a kinetic energy of typically several hundred electron volts. If this recoiling nucleus gamma decays in flight, the subsequent gamma ray is Doppler shifted by typically several hundred electron volts. Large shifts of this type have been used before for measuring the beta neutrino angular correlation.[1] This energy shift can be measured through coincident beta-gamma detection using conventional high purity germanium detectors and associated electronics. We have developed methods to measure the energy shift to an accuracy of one electron volt or better. We consider the application of these techniques to the study of angular correlations in nuclear beta decay; application to the beta neutrino angular correlation is discussed in detail.

*Supported in part by the National Science Foundation through Grant PHY-8907645, and by the Iowa Science Foundation through Grant ISF-88-47.
[1] Warburton, E. K., D. E. Alburger, and D. H. Wilkinson, Phys. Rev. C26,1186 (1982).

9:36

DC 4 Nuclear Structure Effects in Atomic Parity Nonconservation. E. N. FORTSON, Y. PANG and L. WILETS, University of Washington, Seattle, WA 98195 — We systematically study various effects of nuclear structure on atomic parity nonconservation (PNC). Experiments that measure atomic PNC on strings of isotopes of the same element and then take ratios of observables can cancel complicated dependence on electronic structure. We find that nuclear structure effects play a significant role in interpreting these experiments and in extracting weak interaction parameters from them. The uncertainties in the nuclear structure, especially the uncertainties in the neutron distribution, severely limit the precision of measuring the weak interaction parameters. On the other hand, the sensitivity to the neutron distribution could provide a unique method of making accurate determinations of RMS radii of neutron distributions.

9:48

DC 5 Neutron Beta Decay in the Skyrme Model for the Nucleon* G. J. Mathews, and N. J. Snyderman, LLNL-- We compute the neutron half life in the context of the Skyrme model. This model is an approximation to the large-N_c expansion of QCD in which baryons emerge as solitons in an effective field theory of mesons. We introduce local weak-interaction gauge symmetry to the Skyrme Lagrangian and compute the neutron half life as a test of the applicability of this model to describe nucleon structure.

*Work performed under the auspicies of the U.S. Department of Energy at Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

10:00

DC 6 A Search for Fusion Neutron Emission from a Thermally Cycled, Deuterated Titanium Source.[a] M J DUEWEKE, D A ROBERTS, K ASHKTORAB, F.D. BECCHETTI and R GUSTAFSON, Univ Michigan - Titanium sponge loaded with deuterium gas under high pressure at liquid nitrogen temperature was examined for evidence of fusion neutron emission using a special deuterated scintillator (NE230) neutron spectrometer. An upper limit of 0.0361 n/s per gram titanium was obtained, corresponding to 2.87×10^{-24} fusions/s per d-d pair.

a) Work supported in part by the National Science Foundation.

10:12

DC 7 The Effect of Electron Screening and Velocity Distribution on Hydrogen Fusion in Physical Processes. ROBERT A. RICE, YEONG E KIM, AND GARY S CHULICK, Purdue U —The electron screening effect, in conjunction with a particle velocity distribution, greatly enhances the cross sections and reaction rates (often by fifty orders of magnitude or more) for the fusion of hydrogen isotopic pairs for kinetic energies $E \lesssim 20$ eV in the center of mass (CM) frame. This helps to explain the observed fusion reaction rates from recent electrolysis and cluster fusion experiments, and indicates that these fusion reactions may play an important role in various geophysical and astrophysical processes (e g , p-) fusion as a source of internal energy for planetary bodies) It is demonstrated that the electron screening effect (which has been observed in low energy p and D projectile fusion reactions with He and Li targets[1,2]) may already be observable in the lowest energy (2keV < E(CM) < 4 keV)[3] measured D-D fusion cross sections, and it is emphasized that there is a need for new, precise, accurate measurements at even lower energies of hydrogen isotope fusion cross sections to further investigate this effect.

[1] S. Engstler, et al., Phys. Lett. B202, 179 (1988).
[2] U Schröder, et al., Nucl. Inst. Meth. B40/41, 466 (1989).
[3] A von Engel and C.C. Goodyear, Proc. Roy. Soc. A264, 445 (1961); A Krauss, et al., Nucl Phys. A465, 150 (1987).

10:24

DC 8 Natural Low-Energy Proton-Deuteron Fusion Processes GARY S. CHULICK, YEONG E. KIM, and ROBERT A. RICE, Purdue U.—The recent observation of high deuteron-deuteron fusion reaction rates from low-energy electrolysis and cluster fusion experiments leads to the intriguing supposition that proton-deuteron (p-D) reaction rates are similarly enhanced. Therefore, p-D fusion may then be expected to play an important role in various geophysical and astrophysical processes such as the production of abnormalous $^3He/^4He$ ratios from volcanic emissions and as an energy balance to the excess heat radiation from the outer planets. We present here a p-D fusion calculation that includes the effect of electron screening and particle velocity distribution for an energy balance to the excess heat generation of the planets.

10:36

DC 9 The Physics of Cluster Impact Fusion and Low-Energy Deuteron-Deuteron Fusion . YEONG E. KIM, GARY S. CHULICK,

and ROBERT A. RICE, Purdue U, and M. RABINOWITZ, EPRI– The results of recent experiments[1] involving the scattering of clusters of D_20 molecules on deuterated targets indicate an extra-ordinarily high deuteron-deuteron (D-D) fusion rate. These results are examined in terms of the electron screening effect and particle velocity distributions as well as other effects such as high energy D^+ contamination, surface layer penetration and reaction region compression.

[1]R.J. Beuhler, et al., Phys. Rev. Lett. 63, 1292 (1989), R J. Beuhler, et al., submitted to J. Phys. Chem.

10:48

DC 10 High-Efficiency Neutron Spectrometers an Detectors.* J. BART CZIRR and GARY L. JENSEN. -- series of efficient, low-background neutron detector has been designed and built at Brigham Youn University. These detectors are based upon coincidence-calorimeter principle and are suitable fo measurements of weak sources of MeV neutrons in whic the neutrons are emitted singly or in bursts. A low efficiency spectrometer of this type was utilized fo the initial cold fusion experiments at BYU.[1] Mor recent detectors have greatly improved efficiency an also permit measurements of bursts of neutrons. The burst-mode detector has an efficiency of approx 20% for 2.5 MeV neutrons, with a background level o 20 neutrons per hour. The high efficiency is achieve mainly by providing a 1 1/2 inch diameter cavity in th detector body. Another detector in the series is combination spectrometer/burst mode detector wit efficiency of 10-20%, depending upon the type o organic scintillator employed. The spectrometer mod is useful for detecting single neutrons in the 1-10 Me range. The burst mode feature, which may be use concurrently with the spectrometer function, is usefu in detecting bursts of two or more neutrons and has lo background rates.
1. J.B. Czirr and G.L. Jensen, Nuclear Instruments an Methods in Physics Research, v.A284, p.365 (1989).
*Submitted by S.E. Jones.

11:00

DC 11 Recent Results in Cold Fusion Experiments.*S.E JONES, D.B. BUEHLER, J.B. CZIRR, G.L. JENSEN, E.P PALMER, J.M. THORNE, S.F. TAYLOR, J.C. WANG, Brigha Young University; H.O. MENLOVE, Los Alamos Nationa Laboratory; and A.N. ANDERSON, Boise Research.--We hav observed anomalous neutron emission from metal containing deuterium, suggesting the occurrence o nuclear fusion at low rates under unusual conditions Neutron bursts of up to 450 neutrons within a 128 μ gate have been registered in two independent rings o ^{3}He gas tubes in CH, moderator. The detector i segmented, high-efficiency (44% for ^{252}Cf neutrons) noise resistant and has very low background in th inner ring (97 singles counts/h, 0.7 coincidenc counts/h). Low-multiplicity neutron burst emission (2-10n) are frequently seen above the low background in metal + deuterium systems.[1] Another detecto involves a plastic scintillator surrounding the sampl for prompt neutron information, while moderate neutrons are captured in ^{6}Li-doped glass. Pulses ar digitized yielding data on pulse heights (energies) shapes and times between detected neutrons.
*Supported by Advanced Energy Projects Division, U DOE, and Electric Power Research Inst., Palo Alto, CA
1. H.O. Menlove and M.C. Miller, "Neutron Burs Detectors for Cold Fusion Experiments," Seventh Symp on Radiation Measurements and Applications, Ann Arbor Michigan, 21-24 May 1990, LA-UR 90-1722.

Supplementary paper

DC 12 Cluster Impact Fusion by the Formation of Compact Electron-Deuteron Resonances.CJ Benesh, J.R. Spence and J.P. Vary. Physics Department*, Iowa State University. -- We speculate that the anomalously large cluster fusion yields measured at Brookhaven[1] may be explained in terms of the formation of compact electron deuteron resonance states with energies of the order of electron volts above threshhold. Similar states have been predicted to exist in the electron-proton system[2], and their geometrical sizes have been estimated to be of order fermis. We argue that these states, once formed, will screen the Coulomb repulsion between deuterons in a manner analogous to muon catalysed fusion, allowing fusion rates much higher than what one would ordinarily expect. Using a thermodynamic model for the cluster impact, we calculate the yield of resonance... produced per cluster incident on the target. If we assume that each resonance formed produces one fusion event, we obtain a reasonable quantitative description of both the cluster size and energy dependence of the observed fusion yields.

*Supported by the USDOE under Grant No. DE-FG02-87ER40371 and Contract No. W-7405-ENG-82.
[1]R.G. Beuhler, G. Friedlander, and L. Friedman, Phys. Rev. Lett. 63, 1292(1989).
[2]J.R. Spence and J.P. Vary, to be published

SESSION DD: NUCLEAR ASTROPHYSICS AND RADIOACTIVE BEAMS

Saturday morning, 27 October 1990
Room 136, Loomis Laboratory at 9:00
J. W. Truran, presiding

9:00

DD 1 The Alpha capture on ^{14}C and Nonstandard Big Bang Nucleosynthesis* M. WIESCHER, J. GÖRRES, S. GRAFF, Univ. of Notre Dame, R.E. AZUMA, University of Toronto, C.A. BARNES, T.R. WANG, CalTech.-- Reaction network calculation for a nonstandard Big Bang nucleosynthesis scenario[1] indicated a sufficient reaction flow from mass A = 12 towards heavier masses A ≥ 20 via the ^{14}C(α,γ)^{18}O reaction link. The rate of this reaction is partly based on theoretical alpha cluster model studies of the ^{18}O nucleus[2]. We measured the reaction the the range between 1 MeV and 2 MeV alpha energy. The resonance strengths of the two observed resonances were determined and agreed with the results of previous work[3]. Indications of a nonresonant reaction component were found and will be discussed. The implications of the results on the reaction rate and the reaction flow at big bang conditions will be shown.
* supported by the National Science Foundation.
1 J.H. Applegate et al., Ap.J. 329, 572 (1988).
2 C. Funck, L. Langanke, Ap.J. 344, 46 (1989).
3 M. Gai et al., Phys. Rev. C36, 1256 (1987).

9:12

DD 2 Observation of Beryllium 7 in LEO Atmosphere. S.E.KING, G.W.PHILLIPS, R.A.AUGUST & J.C.RITTER, NRL, J.H.CUTCHIN, Schs/Freeman, P.S.HASKINS, U. Fla., J.E.MCKISSON, J.W.ELY & A.G. WEISENBERGER, Inst. for Space Sci. and Tech., R.B. PIERCEY & T.DYHLER, Miss. State U.— We report the discovery of the accretion of ^{7}Be onto the Long Duration Exposure Facility (LDEF). This is the first known evidence for deposition of a cosmogenic isotope onto a spacecraft. The ^{7}Be was observed during the first γ-ray survey a large spacecraft using an array of germanium detectors from NRL and detectors from ISST. Selected individual experimental trays were also measured as they were removed. The most striking feature of the γ-ray data was the unexpected spatial distribution of ^{7}Be which was predominately observed on the leading edges of the spacecraft with a maximum surface density of 130,000 atoms/cm^2. The ^{7}Be deposited onto the surface of LDEF while in low earth orbit (LEO) is apparently produced via spallation by cosmic rays of nitrogen and oxygen in the mesosphere and/or stratosphere.

9:24

DD 3 The Influence of Low Energy Resonances in ^{31}P(p,γ)^{32}S* C. ILIADIS, U. GIESEN, J. GÖRRES, L. VAN WORMER, M. WIESCHER, Univ. of Notre Dame, R.E. AZUMA, J. KING, M. BUCKBY, University of Toronto, C.A. BARNES, T.R WANG.

CalTech.-- The understanding of the rp-process nucleosynthesis in the Si-P-S region is of particular interest for the interpretation of the recently observed high Si and S abundances in nova ejecta[1]. The reaction branch between $^{31}P(p,\gamma)$ and $^{31}P(p,\alpha)$ determines whether the material is processed further towards the Fe-Ni region, or whether it is stored in a SiPS-cycle[2] which would lead to an enrichment in the abundances of these isotopes. We therefore measured the $^{31}P(p,\gamma)^{32}S$ and the $^{31}P(p,\alpha)^{28}Si$ reactions in the proton energy range of $280 \leq E \leq 830$ keV in search for resonances in the two reaction channels. The experiments were performed at the JN Van de Graaff at the University of Toronto and at the 3MV Pelletron at CalTech. Six resonances were observed in the (p,γ)-channel. Resonance strengths were obtained for all observed levels. The influence of these resonances on the $^{31}P(p,\gamma)$ and $^{31}P(p,\alpha)$ reaction rates as well as the possibility of a SiPS-cycle at nova conditions will be discussed.

* supported by the National Science Foundation.

1 M. Wiescher et al., Astron. Astrophys. 160, 56 (1986).
2 M. Wiescher, J. Görres, Radioactive Nuclear Beams, eds. W.D. Myers, J.M. Nitschke, E.B. Norman, World Scientific, Singapore, p.229. (1990).

9:36

DD 4 The Influence of Low Energy Resonances in $^{22}Ne(\alpha,n)^{25}Mg$* -- U. GIESEN, S.M. GRAFF, J. GÖRRES, M. WIESCHER, Univ. of Notre Dame, R.E. AZUMA, J. KING, University of Toronto, V. HARMS, K.-L. KRATZ, Universität Mainz.-- The $^{22}Ne(\alpha,n)$ reaction is considered as an important neutron source for the s-process in stellar He-burning. However, a recent investigation of $^{22}Ne(\alpha,\gamma)$, (α,n) at bombarding energies of 0.8 - 2.2 MeV[1] indicates that the ratio of the reaction rates for (α,n) and (α,γ) is significantly smaller than the previously adopted values, mainly due to a strong resonance at 0.83 MeV, which was only observed in the (α,γ) reaction. We investigated the $^{22}Ne(\alpha,n)$ reaction in the energy range of 0.6 - 0.9 MeV at the JN Van de Graaff at the University of Toronto and measured the neutron yield of the 0.83 MeV resonance. The results will be presented and the impact on the stellar reaction rates discussed.

* supported by the National Science Foundation.

1 K. Wolke, V. Harms, H.W. Becker, J.W. Hammer, K.-L. Kratz, C. Rolfs, U. Schroeder, H.P. Trautvetter, M. Wiescher, and A. Wöhr, Z. Phys. A334 (1989).

9:48

DD 5 Study of $^{8}Li(\alpha,n)^{11}B$. T. Kubo, N. Inabe, T. Nakagawa, T. Suzuki, I. Tanihata, RIKEN, Wako, Saitama, Japan; X.X. Bai, Inst. At. Energy, Beijing; R.N. Boyd, Depts. Phys. Astron., Ohio State Univ.; K. Kimura, Dept. Phys., Kyushu Univ.; S. Kubono, Inst. Nuclear Science, Univ. Tokyo; and H.S. Xu, Inst. Modern Phys., Lanzhou--$^{8}Li(\alpha,n)^{11}B$, which makes ^{11}B and heavier nuclei in the inhomogeneous primordial nucleosynthesis model, has been studied with ^{8}Li beams produced by fragmentation reactions on ^{14}N beams from the RIKEN ring cyclotron. The RIken Projectile fragment Separator (RIPS) produced 10^3 s^{-1} ^{8}Li ions at from 6 to 15 MeV. Each ion passed through a time-of-flight system which determined its energy, then into the MUltiSampling Ionization Chamber (MUSIC), which mapped out its trajectory and energy losses. The ^{4}He in MUSIC served as both target and detector gas. The incident ^{8}Li energy spread together with the energy loss of the ions in traversing MUSIC determined the excitation function of interest in a single beam energy setting. Reaction events were identified by their change in dE/dx.

*Work supported in part by NSF grant PHY89-20606.

10:00

DD 6 Elastic Scattering of ^{6}He, ^{7}Be and ^{8}Li Radioactive Nuclear Beams.[a] R. J. SMITH, J. J. KOLATA, K. LAMKIN, A. MORSAD[b], Univ. Notre Dame, K. ASHKTORAB, F. D. BECCHETTI, J. BROWN, J. W. JANECKE, W. Z LIU[c] and D. A. ROBERTS, Univ. Michigan. - The first systematic study of the elastic scattering of the short-lived radioactive beams of ^{6}He, ^{7}Be and ^{8}Li has been performed at bombarding energies of 8-22 MeV from a number of targets. The results have been analyzed via optical model calculations and compared with the parameters derived from elastic scattering of stable nuclei. The scattering of these unstable nuclei exhibit some anomolous features when compared to adjacent stable nuclei.

a) Work supported in part by the National Science Foundation.
b) Present address: Centre Nationale de Recherches Scientifique, Groupe PNIN, 23 Rue du Loess, 67037 Strasbourg, FRANCE.
c) Present address: Cyclotron Institute, Texas A&M University, College Station, TX 77843.

10:12

DD 7 Inelastic Scattering of Short-lived Radioactive Beams: ^{8}Li.[a] J. BROWN, F.D. BECCHETTI, W.Z. LIU,[b] J.W. JANECKE AND D.A. ROBERTS, Univ. Michigan, J.J. KOLATA, R.J. SMITH, K. LAMKIN AND A. MORSAD,[c] Univ. Notre Dame, R.E. WARNER, Oberlin College. - Elastic and inelastic scattering of ^{8}Li ions have been observed on several targets at E ≈ 14 MeV using the University of Michigan - University of Notre Dame radioactive nuclear beam facility. The elastic scattering suggests that in some respects ^{8}Li is less absorbed than are ^{6}Li and ^{7}Li. Analysis of the inelastic data using a deformed ^{8}Li optical-model potential has been used to deduce $BE2\uparrow$ for $^{8}Li^{*}_{0.98}$. The relevance of the ^{8}Li projectile-excitation spectrum to predicted low-lying (soft) components of E1 giant-dipole resonances in exotic nuclei is discussed and limits on $BE1\uparrow$ to such levels in ^{8}Li at $E_x \leq 2$ Mev are deduced.

a) Work supported in part by the National Science Foundation.
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c) Present address: Centre Nationale de Recherches, Scientifique, Groupe PNIN, 23 rue du Loess, 67000 Strasbourg FRANCE

10:24

DD 8 Production of an Isomeric, Excited Radioactive Nuclear Beam.[a] F.D. BECCHETTI, K. ASHKTORAB, J. BROWN, J.W. JANECKE, D.A. ROBERTS, J. VAN KLINKEN[b] AND W.Z. LIU,[c] Univ. Michigan, J.J. KOLATA, K. LAMKIN AND R.J. SMITH, Univ. Notre Dame, R.E. WARNER, Oberlin College. - A momentum-analyzed, isomeric, radioactive $^{18}F^{m}$ beam (E_x = 1.1 MeV, $T_{1/2}$ = 163 ns) has been produced with the reaction $^{12}C(^{17}O, ^{18}F^{m})^{11}B$ at $E(^{17}O)$ = 70 MeV. The $^{18}F^{m}$ ions were focussed onto a secondary target using a compact superconducting solenoid lens and scattering of $^{18}F^{m}$ from Au and carbon targets was observed. A conversion efficiency of ca. 10^3 $^{18}F^{m}$/s per 100 particle nanoampe of ^{17}O was obtained using a 1.1 mg/cm^2 natural carbon production target.

a) Work supported in part by the National Science Foundation.
b) Permanent address: KVI, U. Groningen, The Netherlands
c) Present address: Cyclotron Institute, Texas A&M University, College Station, TX 77843

10:36

DD 9 The TISOL Radioactive Beams Facility at TRIUMF: A Progress Report. JOHN M. D'AURIA, Dept. of Chem., SFU, Burnaby, Canada. — The thick target on-line isotope separator (TISOL) located at the 500 MEV proton facility, TRIUMF, in Vancouver, Canada is in the process of converting from a test facility dedicated to the development of systems for an accelerated radioactive beams facility to a production facility at which studies of the properties of nuclides far from stability can be pursued. The only electron cyclotron resonance (ECR) ion source at such a facility in the world is used routinely for the efficient production of radioactive

ion beams of gaseous species and several experiments are in progress based upon its performance. A description of the separator will be presented along with a progress report on the expansion of the experimental area. Production yields for over 100 isotopes using both the ECR and heated surface ion source have been measured using TISOL, these will also be discussed. A review of the experiments approved to receive beam will be given along with initial results. A status of the proposed ISAC (Accelerated Radioactive Beams) facility will also be given.

10:48
DD 10 Direct Mass Determinations of Neutron-Deficient Nuclei Close to ^{100}Sn. G.R. DYCK, E. HAGBERG, V.T. KOSLOWSKY, J.C. HARDY, H. SCHMING, Atomic Energy of Canada Limited. K.S. SHARMA and R.C. BARBER, University of Manitoba. --- Atomic-mass ratios of radioactive isotopes have been measured directly with the Chalk River on-line isotope separator. Several improvements have recently been made to the mass-measurement procedure resulting in a reduction of our systematic errors. A precision of 1 ppm in the determination of unknown masses is now routinely achieved.

Our technique does not rely on the direct counting of the ions whose masses are to be compared, but on the observation of the specific radioactive-decay signature of those ions. Consequently, naturally occurring stable beams will not disturb or bias our results. Contaminations from unwanted isobars or even isomers, to the extent that they have a different decay signature, do not affect the determination of peak centroids.

We have determined several mass ratios for isotopes close to the proposed doubly magic nucleus ^{100}Sn. Systematic trends in the two-neutron separation energies of nuclides in this region will be discussed.

SESSION DE: THEORY III: HIGH ENERGY
Saturday morning, 27 October 1990
Room 158, Loomis Laboratory at 9:00
J. M. Lattimer, presiding

9:00
DE 1 Deuteron Production and Flow in Energetic Heavy-Ion Collisions.* P. Danielewicz, NSCL, Michigan State U. -- Coupled transport equations for nucleons and deuterons are derived from nonequilibrium many-body theory. Equations obey conservation laws and yield the proper thermal particle distributions in the static limit. Deuterons are produced in triple nucleon collisions, in a process that is an inverse of the deuteron breakup. The matrix element squared for the process can be in principle taken from the data on the breakup. When a modified impulse approximation is used for the element, then the calculational procedure may be arranged in such a manner that it becomes similar to the one in the approach to production by Remler et al'.

* Work supported in part by the National Science Foundation under Grant No. PHY-8905933.
1. M. Gyulassy, K. Frankel, E. A. Remler, Nucl. Phys. A402, 596 (1983); J. Aichelin, E. A. Remler, Phys. Rev. C 35, 1291 (1987).

9:12
DE 2 Experimental Constraints on In-Medium Effects in VUU* J JIANG, J COGAR, G FAI, AND D. KEANE, Kent State University, C HARTNACK and H STÖCKER, U. of Frankfurt—The interpretation of many heavy-ion experiments, and particularly the inference of properties of the nuclear equation of state, relies heavily on comparisons with nuclear transport theories such as the Vlasov-Uehling-Uhlenbeck (VUU) model.[1] Such models are based on assumptions about the modification of free nucleon-nucleon scattering cross sections in the nuclear medium. These assumptions have been tested through comparisons of VUU predictions with inclusive fragment momentum spectra for collisions of C, Ne, Ar and La projectiles at bombarding energies between 0.4 and 2.1 GeV/nucleon.[2] Good agreement is found within experimental uncertainties, although these uncertainties are generally too large to adequately constrain the models. *Supported by US DOE Grants DE-FG02-86ER40251 and DE-FG02-89ER40531 and by NSF Grant INT-8813351
[1]H. Kruse, B.V. Jacak and H. Stöcker, Phys. Rev. Lett. 54, 289 (1985).
[2]S. Nagamiya *et al.*, Phys. Rev. C24, 971 (1981); D. Keane *et al.*, Phys. Rev. C37, 1447 (1988); S. Hayashi *et al.*, Phys. Rev. C38, 1229 (1988).

9:24
DE 3 Charge Dependence of Electromagnetic Cross Sections for Single Nucleon Removal in Nucleus-Nucleus Collisions* John W. Norbury, Rider College.—Single nucleon removal in relativistic and intermediate energy nucleus-nucleus collisions is studied using a *generalization* of Weizsacker-Williams (WW) theory that treats each electromagnetic (EM) multipole separately. Calculations are presented for electric dipole (E1) and quadrupole (E2) excitations and incorporate a realistic minimum impact parameter and low energy Coulomb recoil correction. An analysis of the charge dependence of the EM cross sections from 200 GeV/N all the way down to 100 MeV/N is made showing that a plot of charge dependence versus energy does *not* follow a single universal curve. Even though the WW formalism should not be applied to lower energies, nevertheless it has been found that the charge dependence of WW theory is *exactly* the same as the generalized theory for all energies studied. *Supported by NASA Grant NAG-1-1134

9:36
DE 4 **Statistical Model Calculations in Highly Excited Compound Nuclei with PACEX.*** N.G. NICOLIS, Washington University and J.R. BEENE, Oak Ridge National Laboratory. – The need for statistical model calculations in highly excited compound nuclear systems has prompted the development of a high excitation energy version of the Monte-Carlo code PACE[1]. Features of the upgraded version, called PACEX, include: (1) Extension of the allowed particle decay modes to n, p, α, d, t, ^{3}He and ^{6}Li emission, (2) An improved treatment of the transmission coefficients for charged particle emission, (3) The ability of simulating decays from deformed emitting systems[2], (4) An improved treatment of the nuclear level densities, and (5) A weighted Monte-Carlo option for the treatment of high energy γ-ray emission. Applications of the code in different reaction systems will be discussed.

* Work supported by the U. S. Department of Energy.
1. A. Gavron, Phys. Rev. C21, 230(1980).
2. N.G. Nicolis et al., Phys. Rev. C41, 2118(1990).

9:48
DE 5 Direct Pions in Heavy Ion Collisions, B.A. LI and W. BAUER, MSU-NSCL* – We present a study of pion production in heavy ion collisions of beam energies around 1 GeV/nucleon. This is accomplished with a new heavy ion transport computer program based on the Boltzmann-Uehling-Uhlenbeck formalism. We

incorporate the resonant production of pions through Δ and N* resonances as well as the direct pion production process in nucleon nucleon collisions. The question if direct pions can be responsible for the second "temperature" component observed in pion spectra is investigated.

* Work supported by the National Science Foundation under Grant PHY-8906116.

10.00

DE 6 Critical Pion Opacity, W. BAUER, MSU-NSCL* - The new effect of critical pion opacity is proposed. It is a reduction of the emission probability for central-rapidity pions in the vicinity of the critical point of the nuclear "liquid-gas" phase diagram. We show in a strongly simplified model how this effect can arise, and we discuss how it could be measured in central symmetric heavy ion collisions at beam energies of around 100 MeV per nucleon.

* Work supported by the National Science Foundation under Grant PHY-8906116.

10:12

DE 7 Pion Double Charge Exchange from the Pion Cloud in Nuclei. M. B. JOHNSON, Los Alamos Nat. Lab., E OSET, Univ. of Valencia, H. SARAFIAN, Penn. State Univ. at York, E. F. SICILIANO, Los Alamos Nat. Lab., and M VICENTE-VACAS, Univ. of Regensburg.-- We have made an effort to assess the importance of pion double charge exchange (DCX) from the pion cloud in nuclei with low-energy incident pions. Our model includes sequential scattering and the delta-nucleon interaction mechanisms using the results of Ref. 1. Scattering from the pion cloud is calculated using the model of Ref. 2., in which the pion-pion scattering amplitude and its corresponding contact term are taken from the Weinberg Lagrangian. We will compare our results to experiments from ^{14}C, ^{42}Ca, ^{44}Ca, and ^{48}Ca targets, using realistic shell-model descriptions of the ground state.

[1]E. R. Siciliano, M. B. Johnson, and H. Sarafian, Ann. of Phys.(N.Y.) to be published.
[2]E. Oset, D. Strottman, M. Vicente-Vacas, and W.-S. Ma, Nucl. Phys. A. 408, 461 (1983).

10:24

DE 8 Spectator Recoil and the Nuclear Matter Equation of State* Y SHAO, G FAI, AND D KEANE, Kent State University—Attempts to extract the equation of state of nuclear matter from nuclear collision data typically rely on complicated measurements and sophisticated models.[1] In contrast, we investigate the sensitivity of a simple particle-inclusive observable, the momentum downshift of spectator fragments, to the equation of state in the framework of a geometrical model. For simplicity, we assume the momentum-independent parametrization of the nuclear mean field.[2] We study the propagation of the equation-of-state information from the participant region to the spectators via the nuclear mean field. The spectator downshift is connected to the *bounce-off* phenomenon.[3] The model can be extended to accommodate more complicated (momentum-dependent) potentials. Results will be compared to available data.

*Supported by US DOE Grants DE-FG02-86ER40251 and DE-FG02-89ER40531 and by NSF Grant INT-8813351

[1]H. Stöcker and W. Greiner, Phys. Rep. 137, 77 (1986).
[2]G. F. Bertsch and S. Das Gupta, Phys. Rep. 160, 189 (1988).
[3]H. Å. Gustafsson *et al.*, Phys. Rev. Lett. 52, 1590 (1984).

10:36

DE 9 **Bound States, Resonances, and Poles in $\overline{K}N$ Interactions with Nucleons and Nuclei.** R.H. LANDAU, G. HE, P.J. FINK, and J. SCHNICK, Oregon State University*.— The locations of the dynamic poles in the complex energy planes of the T matrix for the coupled $(\overline{K}N, \Sigma\pi, \Lambda\pi)$ system are calculated for the cloudy bag model (CBM) and several potential models. Each potential model is found to produce either one or no poles, while the CBM is found to support two — thus explaining the unusual behavior of the T matrices for the CBM. In all cases, the poles' energies are different from the energies of the $\Lambda^*(1405)$ determined by phenomenological analyses along the real energy axis.

These models are also used to construct microscopic, momentum space, optical potentilas including complete Fermi averaging, three body dynamics, nonlocalities, and the exclusion principle. Nuclear bound states are found at the complex energy zeros of the Fredholm determinant. The elementary interaction which provided agreement with the energy shift in kaonic hydrogen is also found to provide agreement with strong interaction shift in carbon. A hypernuclear state bound by 46 MeV with a width of 18 MeV is predicted.

*Research supported in part by the U.S. Department of Energy.

10.48

DE 10 Lattice calculation of muon pair production with capture at RHIC energies. A.S. UMAR, V.E. OBERACKER, J.C. WELLS, Vanderbilt Univ., J. WU, M.R. STRAYER, C. BOTTCHER, ORNL.* -- Heavy-ion beams in a relativistic collider generate very strong transient EM fields (E_{max} = 10^{25} V/m for U+U at 100 GeV/n) which produce lepton pairs in large numbers. Dilepton production followed by capture of the negatively charged lepton into an atomic bound state is one of the most serious beam-loss mechanisms for RHIC. Because the effective QED coupling constant Za is of order 0.5 for heavy nuclei, perturbation theory is not applicable. We utilize a novel lattice technique (Basis-Spline collocation method) for the solution of the Dirac equation in the presence of strong time-dependent external EM fields. Numerical results for the impact parameter and beam energy dependence of the pair production probability will be presented for Ca+Ca, Zr+Zr and Au+Au.

* Supported by grants from DOE and the National Center for Supercomputing Applications (NCSA)

INVITED SESSION EA: EXPLORING THE NUCLEUS WITH HEAVY IONS

Saturday afternoon, 27 October 1990; Room 141, Loomis Laboratory at 14:00; C. Gossett, presiding

14:00

EA 1 Gamma-Ray Induced Doppler Broadening. S. J. ROBINSON, *Institut Laue-Langevin, France.*

A technique[1] has recently been developed at the ILL Grenoble whereby nuclear excited level lifetimes can be measured by observation of the Doppler broadening of depopulating transitions. Unlike standard heavy ion techniques (eg DSAM), where the recoil velocity is a significant

fraction of c, this recoil is induced by preceding gamma emission and is only 10^{-4} to 10^{-5}c, with a subsequent Doppler shift of only a few eV. This is observed with a two axis flat crystal spectrometer[2] with ultra high resolution. By comparing the measured line shapes with those calculated using a model of the slowing down, level lifetimes can be extracted. The technique is sensitive to lifetimes below a few ps. In conjunction with the neutron capture reaction (which is non structure selective) this method offers a unique opportunity to measure the lifetimes of low spin states at relatively high excitation energy (up to 3MeV) and thus provides stringent tests for many nuclear models. Further, the resolution of the spectrometer is such that even the Doppler broadening of recoils below the atomic displacement threshold energy can be observed.

[1]H.G. Borner et al, Phys. Lett. B215, 45 (1988).
[2]M.S. Dewey et al, Nucl. Inst. Meth A284, 151 (1989).

14:36

EA 2 Angular Momentum and Cross Section in Subbarrier Fusion.† D. E. DiGregorio, *Lawrence Berkeley Laboratory.*

Recently, we observed a finite lower limit for the average angular momentum, $\langle \ell \rangle$, in a heavy-ion reaction, $^{12}C + ^{128}Te$, at energies far below the barrier.[1,2] This phenomenon is fundamental in that it is a feature of all models for barrier penetration, but it occurs at energies where the cross sections are very small. The experimental technique we used was to measure the ratio of the population of a high spin isomer to that of a low spin ground state in the heavy residual nucleus ^{137}Ce. Absolute values of $\langle \ell \rangle$ deduced from the isomer ratios and the fusion cross sections, $\sigma_{fus}(E)$, are also of interest because they provide an independent experimental approach to the problem that the theoretical values of $\langle \ell \rangle$ disagree with those deduced from fission fragment angular distributions and, sometimes, from gamma-ray multiplicities. This discrepancy has been an important and perhaps the central problem in studies of subbarrier fusion for several years. The double requirement of reproducing both the $\sigma_{fus}(E)$ and the $\langle \ell \rangle$ places a strong constraint on a model because, within a given model, the average angular momentum and the energy dependence of the cross section are intimately related. We compare all available data on the first or second moments of the spin distributions and the corresponding σ_{fus}(. with theory. The results of this systematic analysis will be presented and discussed.

†Supported by U.S. Department of Energy under Contract No. DE-AC03-76SF00098.
[1]R.G. Stokstad et al, Phys. Rev. Lett. 62, 399 (1989).
[2]D.E. DiGregorio et al, submitted to Phys. Rev. C.

15:12

EA 3 The Rainbow-Shift Mechanism Behind Discrete Optical Potential Ambiguities.* K. W. McVOY, *University of Wisconsin–Madison.*

We present a discussion of the physical significance of optical-potential ambiguities, motivated by recent successes in determining unambiguous potentials for certain "transparent" light-ion systems like $^{12}C + ^{12}C$. These ambiguities turn out to be a direct consequence of the occurrence of nuclear rainbows, whose signature is a series of broad Airy maxima and minima in the farside component of the corresponding scattering amplitude. In most heavy-ion angular distributions measured so far, these maxima are badly obscured by superimposed higher-frequency Fraunhofer oscillations; consequently rainbows in general, and their role in discrete ambiguities in particular, have frequently gone unnoticed. A study of several recent cases shows the nearside component of the elastic scattering amplitude to be essentially independent of V_o, the depth of the real part of the optical potential, while the entire farside Airy pattern shifts to larger angles with increasing V_o. The discrete potential ambiguities occur simply because appropriate increases in V_o can shift Airy minimum n to position n + 1, n + 2 , etc., bringing the farside back in phase with itself and so restoring the forward section of the angular distribution. This occurs even when these minima are "lost" under Fraunhofer fringes which obscure the underlying rainbow phenomenon. This rainbow mechanism is found to be equivalent to the increment of π in low-ℓ phase shifts noted long ago by Drisko, Satchler and Bassel; physically, it unambiguously signals deep interpenetration of the two nuclei during the scattering.

*Supported in part by the National Science Foundation

15:48

EA 4 Resonances in the Electron-Positron System. J. P. VARY, *Iowa State University.*

Exceedingly narrow resonances in the electron-positron system are obtained in scattering solutions to three different relativistic two body wave equations which are developed from various approximations to QED[1]. Complete treatment of the transverse photon exchange contributions is essential. The corresponding R-matrices are solved in the $J^{\pi}=0^{+}$,

L=1, S=1 channel and the same six resonances are obtained between 1.25 and 2.25 MeV in all three cases. The resonant energies are 1.351, 1.498, 1.659, 1.830, 2.009, and 2.195 MeV. Analysis of the interaction reveals that the resonances are short-distance phenomena occurring on a length scale of 30 fm. The close spacings of the resonances are attributable to a strong momentum dependence of the interaction.The widths are calculated to be so narrow as to be consistent with zero. Since the scale is radically different from the positronium scale and the widths are small for decay to the elastic channel, these resonances are quasi-bound states of a system labelled "photonium". These *parameter-free* results for photonium generate a provocative basis for the interpretation of the e^+e^- coincidence peaks from heavy ion scattering experiments. A comparison of the theoretical spectra of photonium with these e^+e^- coincidence spectra and a discussion of the conflicting Bhabha scattering experiments will be presented.

*Supported in part by the USDOE under Grant No. DE-FG02-87ER40371.

[1]J.R. Spence and J.P. Vary, "Resonances in e^+e^- Scattering", preprint. The results reported in this talk were achieved in a set of collaborations with John R. Spence.

SESSION EB: ELECTRON SCATTERING

Saturday afternoon, 27 October 1990
Room 151, Loomis Laboratory at 14:00
M. K. Brussel, presiding

14:00
EB 1 Compton Scattering from the Proton from 140 to 280 MeV. B. MACGIBBON, F. FEDERSPIEL, A. NATHAN, U. of Illinois;* D AMENDT, J BERGSTROM, H. CAPLAN, E. HALLIN, R IGARASHI, D SKOPIK, Saskatchewan Accelerator Laboratory; E. BOOTH, D. DELLI CARPINI, J. MILLER, Boston U.*; D. MACK, TRIUMF–Angular distributions for Compton scattering have been measured for the proton at mean photon energies of 146, 183, 225, and 281 MeV using the bremsstrahlung endpoint technique. Scattered photons were detected in a large-volume NaI spectrometer, which had sufficient energy resolution to distinguish the Compton photons from the neutral pion decay photons. Data were taken at CM scattering angles between 31° and 142°. The cross sections generally increase from pion threshold as the Δ resonance is approached, while the angular distributions evolve from an extreme backward peaking near pion threshold to a shape more symmetric about 90° near the Δ. The data will be compared to previous scattering data as well as to calculations based on dispersion relations.

*Supported by the National Science Foundation.

14:12
EB 2 Elastic Photon Scattering from ^{4}He between 24 and 72 MeV. D.P. WELLS U. of Washington, D.S. DALE, R.A. EISENSTEIN, F.J. FEDERSPIEL, M. LUCAS, K. MELLENDORF, A.M. NATHAN, A.E. O'NEILL U. of Illinois*–Elastic photon scattering differential cross sections from ^{4}He have been measured between 24 and 72 MeV at two angles using tagged monochromatic photons. At the higher energies a significant contribution to the process originates with scattering from the individual nucleons and nucleon pairs We therefore expect the measurement to be sensitive to the combined effects of nucleon substructure, specifically the electromagnetic polarizability of the bound nucleon, and meson exchange currents. In addition, at energies above the giant dipole resonance, the isovector giant quadrupole resonance contributes to the scattering. Our purpose is to provide data of sufficient quality to allow meaningful tests of present descriptions of such effects. Final results will be presented.

*Supported by the National Science Foundation.

14:24
EB 3 ELASTIC ELECTRON AND POSITRON SCATTERING FROM ^{12}C AND ^{208}Pb *, *A.J. Linzey[2], V. Breton[5], P. Bricault[5], L.S. Cardman[2], B. Frois[5], D. Goutte[5], D.B. Isabelle[5], L.C. Maximon[4], E.A.J.M. Offermann[2,3], X.H. Phan[5], S.K. Platchkov[5], I. Sick[1], S.E. Williamson[2],* [1]Univ. of Basel; [2]Nucl. Phys. Lab, Univ. of Illinois, [3]Inst. für Kernphysik, Mainz, [4]NIST, Washington, DC; [5]DPhN/SPE Saclay. Nuclear structure information is extracted from electron scattering data in a one-photon exchange approximation, modified to account for the distortion of the electron wave function and radiative effects. The validity of this approximation can be tested by comparing the scattering of electrons and positrons from nuclei. We have measured elastic scattering cross sections for both positrons and electrons from lead for momentum transfers between 1 and 2 fm^{-1} and from carbon between 1 and 1.4 fm^{-1}. The modest deviations of these data from the predictions of phase shift calculations set limits on the presence of higher-order effects in the scattering.

*Supported in part by NSF grant PHY-86-10493.

14:36
EB 4 Low Energy 180° Scattering from the 110 keV $1/2^-$ State in ^{19}F*, J.P. Connelly, H. Crannell, L.W. Fagg, J.T. O'Brien, M. Petraitis, D.I. Sober, Catholic University of America, J.R. Deininger, S.E. Williamson, Univ. of Illinois — Low momentum transfer ($q < 0.9 fm^{-1}$) electron scattering transverse cross sections have been measured on the 110 keV $1/2^-$ excitation in ^{19}F. The data was taken at the University of Illinois microtron using the Catholic University 180° system with electron beam energies between 24 MeV and 90 MeV. The E1 transition rate from the $1/2^+$ ground state to the $1/2^-$ excitation is of interest since these states constitute a parity-mixed doublet. This doublet has been the subject of a search for parity non-conservation in order to determine the weak component of the nucleon-nucleon interaction[1] Although both the longitudinal and transverse form factors have been mapped at higher momentum transfer ($q \geq 1 fm^{-1}$), no previous electron scattering data have been measured at lower momentum transfer. The extension of the data to low momentum transfer permits a more accurate determination of the $1/2^- \rightarrow 1/2^+$ transiton rate.

1.)E.G. Adelberger and W.C.Haxton, Ann. Rev. Nucl. Phys. 35, 501(1985).

* Supported in part by the National Science Foundation

14:48
EB 5 "Electroexcitation of Low-Multipolarity Transitions in ^{30}Si." M. PETRAITIS, J. CONNELLY, H. CRANNELL, L. FAGG, J. O'BRIEN, and D. SOBER,

CATHOLIC UNIVERSITY, R. LINDGREN, U. VA., and R. DEININGER, and S. WILLIAMSON, UIUC--A study of M1 and M2 transitions in ^{30}Si has been conducted using the CUA-UIUC 180° electron scattering system. This work complements the resonance fluorescence measurement[1] of M1 transitions in this nucleus below the particle emission threshold. Preliminary energy and multipolarity assignments and reduced transition matrix elements will be presented.

*Work supported in part by NSF under Grant NO. PHY8820654

[1]U.E.P. Berg, et al., Phys. Lett. 140B, 191(1984)

15:00

EB 6 Quasielastic R_L,T Response Functions of ^{3}He and ^{4}He at $Q^2 = 1(GeV/c)^2$.* Z. MEZIANI, G. DODGE, T. KOH, Stanford U., J. CHEN, L. CHINITZ, D. DAY, K. GIOVANETTI, J. McCARTHY, R. MINEHART, O. RONDON ARAMAYO, R. SEALOCK, C. SMITH S. THORNTON, U. Virginia, D. BECK, G. BOYD, B. FILLIPONE, J. JOURDAN, R. McKEOWN, R. MILNER, D. POTTERVELD, R. WALKER, C. WOODWARD, Caltech, L. DENNIS, K. KEMPER, Florida State U., J. MORGENSTERN, Saclay, I. SICK, W. LORENZON, U. Basel--Inclusive electron cross sections of ^{3}He and ^{4}He have been measured at SLAC (NPAS). The data cover the quasielastic and Δ region at incident energies ranging from 0.9 to 4.3 GeV and two scattering angles 15° and 85°. The transverse and longitudinal response functions of ^{3}He and ^{4}He have been extracted using the Rosenbluth technique at $Q^2 = 1(GeV/c)^2$. An analysis in terms of scaling properties reveals a new behavior of the data when compared to low momentum transfer results. The Coulomb sum rule is also investigated in these light nuclei.

*Supported by the U.S. Department of Energy under contract DE-FG03-88ER 40439.

15:12

EB 7 Off-shell Nucleon Form Factors and Off-shell Electron Nucleon Scattering. X. SONG, J. P. CHEN, J. S. MCCARTHY INPP, Univ. of Virginia, - - A relativistic gauge invariant γNN vertex has been discussed when the initial nucleon is off mass shell. Using the Ward identity, several model independent relations obeyed by the off-shell form factors are derived and verified in a simple dynamical model. The off-shell behaviour of the form factors, electron nucleon cross sections and quasielastic electron nucleus scattering cross sections are also discussed.

* Supported in part by the DOE and the Virginia Commonwealth Center for Nuclear and Particle Physics.

15:24

EB 8 Parity Violation in Elastic Electron-^{12}C Scattering. CUNY[a] – Harvard[b] – MIT[c] – Missouri-Rolla[d] – Princeton[e] – Syracuse[f] – Yale[g] Collaboration.* K. Isakovich,[c] J. Bellanca,[b] G. D. Cates,[e,g] G. W. Dodson,[c] K. A. Dow,[c] M. Farkhondeh,[c] R. Holmes,[f] V. W. Hughes,[g] T. J. Gay,[d] D.-H. Kim,[f] S. Kowalski,[c] K. S. Kumar,[f] M. S. Lubell,[a] R. Michaels,[g] J. S. Patch,[b] H. R. Schaefer,[g] M. E. Schulze,[f] P. A. Souder,[f] R. Wilson.[b] — At the MIT Bates Linear Accelerator Center we have measured the parity-violating electroweak asymmetry in the elastic scattering of polarized electrons from ^{12}C nuclei.[1] A source based on photoemission from a GaAs crystal provided a polarized beam with an intensity typically between 30 and 60 μA. Scattered electrons with a momentum transfer Q of 150 MeV/c were detected with a pair of quadrupole spectrometers. Our result is $A_{exp} = 0.60 \pm 0.14 \pm 0.02$ ppm, where the first error is statistical and the second is systematic. With a beam polarization of 0.37, we compute the isoscalar,vector hadronic coupling constant $\tilde{\gamma}$ to be $0.136 \pm 0.032 \pm 0.009$. The Standard Model predicts $\tilde{\gamma} = 0.155$ at the tree level, in agreement with our data.

*Research supported in part by the U. S. Department of Energy.

[1]G. Feinberg, Phys. Rev. D 12, 3575 (1975).

15:36

EB 9 ETA Photoproduction From the Proton Near Threshold*, S.A. DYTMAN, C.W. ALCORN, W.W. DAEHNICK, J. HARDIE, M. YAMAZAKI, University of Pittsburgh; E. BOOTH, J. MILLER; Boston University; M.J. LEITCH, S.MISHRA and J.C. PENG; Los Alamos National Laboratory; D. TIEGER and K. F.von REDEN; MIT-Bates Laboratory Differential cross sections have been measured for production of eta mesonsfrom a liquid hydrogen target. We hope to learn more about photon coupling ofthe proton to T=1/2 resonances. From previous data of 20 years ago, thereaction is felt to be dominated by intermediate states involving the $S_{11}(1535)N^*$ resonance. The purpose of this experiment was to investigate this dominance further with an emphasis on the region near threshold where there is no previous data and any competing reaction mechanisms will be most easily seen. The experiment was done with a Bremsstrahlung beam at the MIT-Bates Laboratory. Etas were detected via the 39% decay branch to 2 photons, using two towers of Pb-glass blocks. Angular distributions will be presented for photon beam energies of 720 and 750 MeV. We are also generating a multipole fit to all the eta photoproduction data assuming resonance dominance and a background of Born terms.

*Work supported by the National Science Foundation.

15:48

EB 10 Measurement of Inclusive Quasielastic Scattering of Polarized Electrons from Polarized ^{3}He. W.LORENZON, E.BEISE, E.BELZ, R.CARR, B.FILIPPONE, R.McKEOWN, B.MUELLER, T.O'NEILL and C.WOODWARD, Caltech.* G.DODSON, K.DOW, M.FARKHONDEH, S.KOWALSKI, K.LEE, N.MAKINS, R.MILNER, A.THOMPSON, D.TIEGER, J.VAN DEN BRAND, A.YOUNG, X.YU and J.ZUMBRO, MIT. ---We report a measurement of the asymmetry in spin-dependent quasielastic scattering of longitudinally polarized electrons from a polarized ^{3}He gas target. This measurement represents the first experimental separation of electromagnetic nuclear response functions by using a polarized beam and a polarized target. The measured asymmetry is in good agreement with a Faddeev calculation and supports the picture of spin-dependent quasielastic scattering from polarized ^{3}He as predominantly scattering from a polarized neutron.

* Supported by the National Science Foundation.

SESSION EC: GIANT RESONANCES

Saturday afternoon, 27 October 1990
Room 144, Loomis Laboratory at 14:00
S. Williamson, presiding

14:00

FC 1 A Coincidence Measurement of ^{6}Li(γ,np) for E_γ=55–100 MeV* B. B. RITCHIE, M. K. BRUSSEL, N. R. KOLB, J. H. SMITH, U. of Illinois*—Bremsstrahlung photons with endpoint energies from 55 to 100 MeV were used to photodisintegrate ^{6}Li. Emitted neutron/proton pairs were observed in coincidence, and cross sections in terms of their opening angles and transverse momenta were measured. Comparisons are made with previous work by Wade[1] (which this experiment continues) and Vogt[2], and with

the quasideuteron model of Levinger[3].

*Research supported in part by the National Science Foundation.
[1]M. W. Wade, M. K. Brussel, L. J. Koester, Jr. and J. H. Smith, Phys. Rev. Lett. 53, 2540 (1984).
[2]J M. Vogt, Ph.D. thesis, Johannes Gutenburg Univ., Mainz (1987).
[3]J. S. Levinger, Phys. Rev. 84, 43 (1951), Phys. Lett. 82B, 181 (1979).

14:12
EC 2 Investigation of the Giant Dipole Resonance of ^{12}C with $(e,e'\gamma)$. E. Ammons, R. Deininger, S. Dolfini, A. Linzey, J. Mandeville, P. Mueller, E. Offermann, C. Papanicolas, A. Serdarevic, and S. Williamson, Univ. of Illinois at Urbana-Champaign, J. Connelly, Catholic Univ of America- The $(e,e'\gamma)$ method is a relatively new technique in the field of electron scattering, widely accepted as a precision tool for the study of narrow states below particle emission threshold. We report on progress towards utilization of the $(e,e'\gamma)$ reaction to probe the giant resonance region of the ^{12}C nucleus. Due to the small photon emission probability of the giant resonances and their broad nature, combined with the competition from bremsstrahlung photons, previous theoretical analysis suggested that the use of the $(e,e'\gamma)$ reaction in the study of the giant resonances would be problematic. In a new approach, we look for decay of the giant resonances to low lying excited states rather than to the ground state. By forming missing energy spectra, $(e,e'\gamma)$ cross sections, integrated over the resonance, can be obtained for decay of the giant dipole resonance of ^{12}C to the 2^+ first excited state at 4.44 MeV and the 0^+ second excited state at 7.65 MeV.

14:24
EC 3 Elastic Photon Scattering above the GDR of ^{16}O. K. MELLENDORF, D. DALE, R. EISENSTEIN, F. FEDERSPIEL, M. LUCAS, B. MACGIBBON, A. NATHAN, U. of Illinois.*- Differential cross sections for the elastic scattering of photons from ^{16}O have been measured at scattering angles of 45° and 135° between the energies of 27 and 68 MeV. Beams of incident photons were provided by the Illinois tagged photon facility and the scattered photons were detected in a pair of large NaI spectrometers. The motivation for this experiment was to search for quadrupole strength above the GDR. The signature for such strength is a fore-aft asymmetry in the cross section due to the interference of the quadrupole with the high energy tail of the GDR. RPA calculations predict that most of the isovector quadrupole strength lies in the region we have investigated. Previous photoneutron and photon scattering experiments provide conflicting evidence as to the amount of E2 strength in this region. A preliminary analysis of the data, along with an interpretation of the data in terms of E1-E2 interference, will be presented.

*Supported by the National Science Foundation.

14:36
EC 4 Gamow-Teller Resonance Strength in $^{54}Fe(n,p)$ and $^{56}Fe(n,p)$ at 65 MeV*. B. McEACHERN, F.P. BRADY, J.R. DRUMMOND, G.P. GRIM, E.J. HJORT**, J.H. OSBORNE, M.D. PARTLAN, J.L. ROMERO, Physics Dept. and Crocker Nuclear Laboratory, U.C. Davis, CA 95616 - To determine the amount of missing GT strength, one compares with the non-energy-weighted sum rule, $S_- - S_+ = 3(N-Z)$, where S_- is the GT strength in the τ_- (β_-) direction and S_+ is in the τ_+ (β_+) direction. Large uncertainties in measured S values impact sum rule verification and hinder answers about GT quenching due to RPA correlations[1]. Recent measurement[2] of $^{54}Fe(p,n)$ yields an improved S_- value, providing motivation to better determine S_+ using a more precise measurement of $^{54}Fe(n,p)$. In addition, the GT matrix elements from $^{54}Fe(n,p)$, coupled with those from $^{54}Cr(p,n)$, are important in calculations involving $\beta\beta$-decay: processes significant in the late stages of stellar evolution[3]. The CNL (n,p) detector facility was used to measure ^{54}Fe and $^{56}Fe(n,px)$, $0 \le \varepsilon < 45$MeV, $0 \le \alpha < 60°$; differential cross-sections for the Gamow-Teller giant resonance have been extracted and will be presented.

*Supported in part by NSF Grant PHY87-22008
**Associated Western Universities Graduate Fellow
[1]N. Auerbach, Phys. Rev. C36 (1987) 2694
[2]B.D. Anderson, Phys. Rev. C41 (1990) 1474-1485
[3]H.A. Bethe, et al., Nucl. Phys. A234 (1978) 487

14:48
EC 5
Isoscalar Character of the GQR in ^{118}Sn. D.J. HOREN, F.E. BERTRAND, J.R. BEENE, Oak Ridge National Lab.*; W. MITTIG, A.C.C.VILLARI, Y. SCHUTZ, ZEN WENLONG, E. PLAGNOL, GANIL; and A. GILLIBERT, SACLAY--Final analysis of our $^{118}Sn(^{17}O,^{17}O')$ measurements at 84 MeV/nucleon in the giant resonance region indicate that the differential cross section for excitation of the GQR is well represented by a DW calculation using the deformed potential model assuming the resonance is isoscalar (i.e., $M_n/M_p \approx N/Z$). The data do not reproduce a minimum near $\theta_{cm} = 1.9°$ predicted by a similar calculation using the %EWSR and B(E2)↑ reported[1] from π^+/π^- scattering.

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*Operated by Martin Marietta Energy Systems, Inc. under contract DE-AC05-84OR21400 with the U.S. Dept. of Energy.
[1]J.L. Ullman *et al.*, Phys. Rev. C 35, 1099 (1987).

15:00
EC 6
Internal Pair Decay of Giant Resonances in ^{142}Nd.*
C.P.Montoya, S.Adami, I.Dioszegi, D.J.Hofman, P.Paul and P.H.Zhang, SUNY-STONY BROOK. The radiative capture reaction $^{141}Pr(p,e^+e^-)^{142}Nd$ was used to search for internal pair conversion from the Giant Dipole and the Isoscalar Giant Monopole Resonance based on excited states between 1.57 and 3.8 MeV. A plastic phoswich array was mounted with its center at 180° relative to the beam axis in order to de-emphasize the GDR relative to the GMR. Proton beams from the Stony Brook tandem-linac with energies from 11 to 14 MeV were used to trace out the GDR region that had previously been reported [1] in high energy γ decay. From α- scattering systematics the GMR is expected in the same energy region, although the degree of GMR collectivity is in question. This experiment attempts to separate the E0 from the E1 transition by a measurement of the e^+-e^- angular correlation. The data are presently under analysis and cleanly show the conversion of the GDR. The results on the GMR will be reported.
[1] M. Hasinoff et al., Nucl.Phys. A105 (1972) 78.
* Supported in part by the National Science Foundation.

15:12
EC 7 A Measurement of the Giant Electric Isovector Quadrupole Resonance in ^{208}Pb Using Polarized Photon Scattering. D.S. DALE, R.M. LASZEWSKI, R. ALARCON

U. of Illinois* Highly polarized tagged photons were used to measure the polarization asymmetries for elastic scattering in the energy region of the giant electric isovector quadrupole resonance in ^{208}Pb. Preliminary data analysis clearly demonstrates the interference between the isovector E2 resonance and the underlying electric dipole strength. It will be shown that the gross features of the isovector E2 resonance can be extracted from the polarization asymmetries in a relatively model independent manner. Our experimental results will be discussed.

*Research supported in part by the National Science Foundation.

SESSION ED: THEORY IV: GENERAL
Saturday afternoon, 27 October 1990
Room 136, Loomis Laboratory at 14:00
D. G. Ravenhall, presiding

14:00

ED 1 The Effect of Solar Density Fluctuations on Neutrino Flux A. B. Balantekin, and F. N. Loreti*, U. of Wisconsin Madison Solar density fluctuations[1,2] are studied in the context of spin-flavor precession of solar neutrinos. The effect on the electron neutrino flux of both holes and bumps in the standard solar model density is calculated for a variety of densities.

*Research supported in part by the University of Wisconsin Research Committee with funds granted by the Wisconsin Alumni Research Foundation and in part by the National Science Foundation.

1. A. Schäfer and S. E. Koonin, Phys. Lett. 185B, 417 (1987)
2. A. Yu. Smirnov, "Thirteenth International Conference on Neutrino Physics and Astrophysics", J. Schneps, T. Kafka, and W. A. Mann Eds., pg.123 World Scientific (1989)

14:12

FD 2 Electron Anti Neutrino Signal from Spin Flavor Precession of Majorana Solar Neutrinos F. N. Loreti, and A. B. Balantekin*, U. of Wisconsin Madison Spin flavor precession of Majorana neutrinos is studied[1,2]. For the range of parameters $\delta m^2 \leq 1 \times 10^{-6}$ and $\sin^2 2\theta \geq 1 \times 10^{-1}$, a significant flux of electron anti-neutrinos can be obtained using the standard solar model with a magnetic field confined to the convective zone, and a magnetic moment of $1 \times 10^{-11}\ \mu_B$. This signal should correlate with sunspot activity. Counting rates for the Borex experiment are calculated.

*Research supported in part by the University of Wisconsin Research Committee with funds granted by the Wisconsin Alumni Research Foundation and in part by the National Science Foundation.

1. A. B. Balantekin, P. J. Hatchell, and F. Loreti, Phys. Rev. D41, (1990).
2. A. B. Balantekin, F. N. Loreti, S. Pakvasa, and R. Raghavan (to be published).

14:24

ED 3 Multisoliton Solutions in the Skyrme Model. L. CARSON, Dept. of Physics and Astronomy, Univ. of Alabama, Tuscaloosa, AL 35487.— The static hamiltonian of the SU(2) Skyrme model with massive pions is formulated on a three dimensional cubic lattice and used to determine multisoliton solutions of the model. Besides reproducing known solutions corresponding to baryon numbers $B = 1$ and 2, new, classically stable, localized solutions corresponding to $B = 3$, 4, 5 and 6 are found. Although the new solutions do not share any of the continuous symmetries of the $B = 1$ and 2 solitons, the pion fields describing the solitons with $B = 3$ and 4 are found to possess tetrahedral ($\bar{4}3m$) and octahedral ($m3m$) symmetry, respectively. Implications of these discrete symmetries for the spectrum of states in the semiclassically-quantized theory are also worked out.

14:36

ED 4 Dirac eigenstates for valence quarks with self-confinement and nonlocal meson coupling*, M.R. FRANK and P.C. TANDY, Kent State Univ.--In a generalized nontopological soliton formalism[1] the effective meson fields are generated solely from $q\bar{q}$ composites. This leads, at the mean field level, to a Dirac equation for valence quarks having a translationally invariant dynamical mass and a nonlocal quark-meson coupling. In the circumstance where the dynamical mass is absolutely confining, the meson fields provide a finite region in which quark propagation is restored allowing formation of solitons. This mechanism is investigated numerically for several models of the dynamical mass and the nonlocal quark-meson interaction. The resulting eigenvalues and eigenfunctions will be presented along with a discussion of the transition to confinement, and the possible implications for nucleon structure and the nucleon meson vertex.

1. R.T. Cahill and C.D. Roberts, Phy. Rev. D32, 2419 (1985); M.R. Frank, P.C. Tandy and G. Fai, KSU preprint, KSUCNR 012-90, submitted for publication, 1990.

*Work supported in part through NSF grant No. PHY 88-05633.

14:48

ED 5 Electromagnetic Moments of $\Delta(1232)$ in Nonrelativistic Quark Model and Skyrme Model*. LISHENG ZHANG and NIMAI C. MUKHOPADHYAY, Rensselaer Polytechnic Institute, Troy, NY 12180-3590.— The nonrelativistic quark model[1] (NQM) and Skyrme model[2] (SM) are among the most successful hadron models stimulated by quantum chromodynamics. Here we discuss the important differences between their predictions on electromagnetic moments of various charge states of $\Delta(1232)$. NQM predicts nonzero values for magnetic dipole moments μ_Δ, electric quadrupole electric moments Q_Δ and magnetic octopole moments O_Δ, all of which are proportional to e_Δ. On the other hand, SM[2] generally gives these moments without factorization of e_Δ. We shall discuss the relevance of these results to recent experiments[3].

[1] N. Isgur and G. Karl, Phys. Rev. D19, 2653 (79), D20, 1191 (79) R. Koniuk and N. Isgur, Phys. Rev. D21, 1868 (80). S.S. Gershtein and G.V. Dzhikiya, Sov. J. Nucl. Phys. 34 (6) 870 (81). [2] G.S. Adkins, in "Chiral Solitons" edited by K.F. Liu, World Scientific Singapore, 1987. [3] A. Bossherd, et al., Phys. Rev. Lett. 64, 2619 (90).

*Work supported by U.S. Department of Energy.

15:00

ED 6 Calculation of Electromagnetic Pion Form Factor in a Non-local Nambu-Jona-Lasinio Model.* C. D. ROBERTS, Argonne National Laboratory--A model of QCD with a four fermion current-current interaction mediated by vector boson exchange is employed to calculate $F_\pi(q^2)$ for spacelike momenta. The vector boson propagator is the phenomenological input in the model, constructed to manifest asymptotic freedom and to ensure quark confinement in the sense that the quark propagator has no poles at timelike momenta. Electromagnetism is introduced through minimal substitution. The model is analyzed in Euclidean metric and the Schwinger-Dyson

and Bethe-Salpeter equations that arise in the model are solved numerically. The dressed quark propagator and meson Bethe-Salpeter amplitudes thus obtained are used to evaluate the Feynman diagrams relevant to $F_\pi(q^2)$. There are two contributions: a direct (or contact) $\gamma\pi\pi$ term and a ρ pole term. The direct term is the most important at small q^2 providing most of the contribution to the charge radius. The contribution of the pole term becomes relevant at larger q^2.

*Supported by the U.S. Department of Energy, Nuclear Physics Division, under contract W-31-10[illegible]-ENG-38.

15:12
ED 7 Use of Retarded Greens functions in Finite Temperature Quantum Field Theories* J.E. Davis The Ohio State University– As is well known[1], use of the Feynman propagator alone in real time finite temperature field theories leads to pathologies in the form of ill defined products of distributions. Such pathologies are avoided when the theory is expressed in terms of the retarded propagator. In addition, we expect the retarded propagator is to play a fundamental role in doing non-perturbative calculations because of the fact that, unlike the Feynman propagator, the retarded propagator enjoys an analytic continuation into the complex energy plane. This can be decisive when dealing with the non trivial pole structure inherent in strong coupled field theories. It is the purpose of this work to investigate the role of the retarded propagator at finite temperature and study their use in non perturbative approximation schemes in a *fully relativistic* quantum field theory.

* Work supported by the NSF under grant PHY-8858250.
[1]N.P.Landsman and Ch.G.vanWeert, Phys.Rep.145,141(1987)

15:24
ED 8 A Sum Rule for the Spin-Dependent Structure Function $b_1(x)$ for Spin-One Hadrons.† S. KUMANO* and F.E. CLOSE**, * Nuclear Theory Center, Indiana U., ** Rutherford Appleton Lab., U. of Tennessee, Oak Ridge Natl. Lab.— The recent experimental finding (new EMC effect) by the EMC group on the spin-dependent structure function of the proton has stimulated intense interest in the details of spin structures in the proton and neutron. The measurement for the neutron requires a polarized deuteron, which is interesting in its own right, because there is a new structure function, $b_1(x)$. We investigate a sum rule for $b_1(x)$. We show[(1)] that it is related to the electric quadrupole moment of the target and obtain $\int dx b_1(x) \lim_{t\to 0} \frac{5}{3}\frac{t}{4M^2}F_Q(t) - 0$ for isoscalar targets if the sea of quarks and anti quarks is unpolarized.
† Researc[illegible] supported by U.S. D.O.E. under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems Inc. and No. DE-FG02-87ER40365 and the Tennessee Science Alliance Center.
(1) F. E. Close and S. Kumano, submitted for publication.

15:36
ED 9
Semiclassical Model for Electron-Positron Resonances. A. Sommerer, C.J. Benesh, J.R. Spence, J.P. Vary, Physics Department*-Iowa State University.-- Motivated by the desire to have a simple, physically intuitive, treatment of the narrow e^+e^- resonances recently predicted from solutions of relativistic two-body wave equations (RTBWE)[1] we develop a semi-classical treatment to obtain the same resonances. A Hamiltonian obtained from Darwin's Lagrangian[2] is used to obtain an infra-atomic scale circular orbit (diameter ~ 30fm). A WKB treatment is then used to explore for the L=1 states corresponding to those of the RTBWE. A procedure is invoked to regularize the interaction at short distances and at high momenta. For certain choices of the regularization parameters a spectrum of states with energies corresponding to those of the RTWBE can be obtained. Some of these states correspond to peaks in the e^+e^- coincidence spectra from the GSI heavy ion experiments. The importance of momentum dependence in the e^+e^- interaction is clearly evident and the distance scale of the resonance phenomena is the same as that found in the RTWBE treatment[1]. The utility of this model for other applications will be discussed.
*Supported by the USDOE under Grant No. DE-FG02-87ER40371 and Contract No. W-7405-ENG-82.
[1]J.R. Spence and J.P. Vary, to be published
[2]C.G. Darwin, Phil. Mag. 39, 537(1920).

15:48
ED 10 Pair Production of Particles in Strong Electric Fields. J.E. SEGER and A.B. BALANTEKIN*, U. Wisconsin Madison, and S.H. FRICKE, U. of Dallas - We discuss non perturbative effects in pair production from classical electric fields. We point out a formal connection between fermion pair production in an external field and supersymmetric quantum mechanics. Pair production probabilities are calculated in a uniform semiclassical approximation. We also discuss the effects on the probability of pair production from the presence of a dynamical photon.
*Research supported in part by the University of Wisconsin Research Committee with funds granted by the Wisconsin Alumni Research Foundation and in part by the National Science Foundation.
1. J. Schwinger, Phys. Rev.82 (1951), 664;93 (1954), 615.
2. A.B. Balantekin, J.E. Seger, and S.H. Fricke, Int. J. Mod. Phys. A, in print.

16:00
ED 11
Two-photon Intermediate State Processes in Electron-Positron Scattering. Xizhi Zhang*, C.J. Benesh, J.R. Spence, J.P. Vary, Physics Department**-Iowa State University.-- Relativistic two-body wave equations have been solved to obtain e^+e^- resonances at energies close to the observed e^+e^- coincidence peaks in heavy ion scattering[1] In order to extend the Fock space used to describe e^+e^- scattering and to examine the sensitivity of the calculated scattering resonances to the level of model-space truncation, we have evaluated the analytical expressions for the two-photon intermediate state processes. The results of this analysis will be presented. In addition, we will describe the efforts underway to include these processes in the scattering calculations. It is expected that the addition of these scattering contributions will shift the resonances and contribute to their widths.

*Supported by the People's Republic of China, on leave from Zhengzhou Univ.
**Supported by the USDOE under Grant No. DE-FG02-87ER40371 and Contract No. W-7405-ENG-82.
[1]J.R. Spence and J.P. Vary, to be published.

16:12
ED 12 Informational Aspects of Isotopic Quantum Hopping - A.A.PEREZIN - *McMaster U.(Canada)* - - Isotopic diversity of natural nuclei deliveres specific and multifaced "degree of freedom" in matter.It has implications for physics[1], technology[2], biology[3], medicine[4],

etc. Recently we discussed isotopic models of interactive memories in crystals[3]. Here I add on possible features of quantum hopping (QH) tunneling transitions of isotopes in crystals. Microscopically, elementary steps of isotopic ordering include "ring" exchanges of different isotopes between lattice sites in isotopic sublattices. Quantum mechanical probability of such processes is usually quite low because of the tunneling through high barriers. However, rate of an actual move *when it occures* is defined by quantum delocalization velocity ($V \sim \hbar/Ma$, $a \sim 5$ Å), e.g. typical time is $\sim 10^{-11}$ sec. Under "informationally-driven resonance conditions" (IDRC) a multiplicity of QHs can lead to fast isotopic positional rearrangements of the whole crystal. In context of ref.[3], IDRC can admit teleological interpretation in terms of "goal attractors", similar to a "holistic state" of a neural network. Also, QH under IDRC can be linked to a (reversed) quantum Zeno effect[6] and to a way to "get around" the smallness of tunneling factors in cold fusion-type effects[7]. Such QH may involve local moves, rather than unlimited diffusion.

1. A.A.Berezin, *Physics Letters A*, 138, 447 (1989).
2. A.A.Berezin, *J.Phys.Chem.Solids*, 50, 5 (1989).
3. A.A.Berezin, *Biol.J.Linnean Soc.*, 35, 199 (1988).
4. A.A.Berezin, *Medical Hypotheses*, 31, 43 (1990).
5. A.A.Berezin, K.A.Williams, *Bull.APS*, 35, 1177 (1990).
6. W.M.Itano, et al., *Phys.Rev. A*, 41, 2295 (1990).
7. A.A.Berezin, *Bull.APS*, 35, 980 (1990).

AUTHOR INDEX

ELEVENTH INTERNATIONAL CONFERENCE
ON THE APPLICATION OF ACCELERATORS IN RESEARCH AND INDUSTRY

REGISTRATION AND INFORMATION DESK

Sunday, 4 November: 3:00 P.M. - 10:00 P.M., Sheraton Hotel
Monday, 5 November: 7:45 A.M. - 4:00 P.M., UNT University Union Building (Lyceum)
Tuesday, 6 November: 7:45 A.M. - 4:00 P.M., UNT University Union Building (Lyceum)
Wednesday, 7 November: 7:45 A.M. - 4:00 P.M., UNT University Union Building (Lyceum)
Thursday, 8 November: 7:45 A.M. - 4:00 P.M., UNT University Union Building (Lyceum)

REGISTRATION FEES

University Participants: $150.00 in advance**; $175.00 upon arrival. Industrial, Government or National Laboratory Participants: $225.00 in advance**; $250.00 upon arrival.

Although there is no registration fee, students are required to complete the registration form to assist in conference planning. **Advance registration checks (US Currency only) must be received prior to 1 October 1988 in order to receive the advance registration price.

REGISTRATION FORM BELOW

REGISTRATION FORM (please print) for the Eleventh International Accelerator Conference 11/5 - 8/90

NAME _____
Last First/M.I. Position/Title

INSTITUTION _____

ADDRESS _____
Street and/or P.O. Box and Mail Stop/Mail Zone

_____
City State/Province Zip Code/Postal Code Country

Business Telephone ( ) FAX # ( ) Home # ( )
Area Code & Number Area Code & Number Bitnet Area Code & Number

PARTICIPANTS:

University	Industrial Government or National Labs	Students
$150 in Advance*	$225 in Advance*	No Charge
$175 upon Arrival	$250 upon Arrival	

*Advance Registration Checks must be received prior to October 1, 1990, in order to receive the Advance Registration Price.
Send form to Accelerator Conference, Physics Department, University of North Texas, P.O. Box 5368, Denton, TX 76203-5368 U.S A.

BANQUET - UNT Coliseum

The Banquet is set for Wednesday evening, November 7, 1990, from 6:30 to 9:00 p.m. in the UNT Coliseum. The charge is $15.00 per person. This may be paid at Registration or sent in with your registration payment.

SOCIAL HOURS - University Union Building, Second (2nd) Floor

Sunday, November 04, 1990:	19:00 - 21:30
Monday, November 05, 1990:	17:00 - 18:30 & 21:00 - 22:30
Tuesday, November 06, 1990:	17:00 - 18:30 & 21:00 - 22:30
Wednesday, November 07, 1990	17:00 - 18:30 & 21:00 - 22:30

HOUSING

Motel/Hotel/Dormitories	Single	Double (2 persons unless stated otherwise	Telephone	Telephone Toll Free #
Sheraton, Denton	53.00	58.00	817-565-8499	USA:
Convention Headquarters				800-325-3535
2211 I-35E North, Denton, TX 76205				
Best Western, Denton	$23.00	$26.00	817-383-1681	800-528-1234
3116 Bandera (I-35E @ University Drive) Denton, TX 76201				
Delux Inn, Denton	21.00	26.00	817-566-1990	none
Refrigerator & Microwave is $2.00 extra; each additional person is $3.00				
601 Highway I-35E, Denton, TX 76201				
Exel Inn, Denton	24.95 (1 or 2 persons)	29.95 (up to 5 persons)	817-383-1471	800-356-8013
4211 Highway I-35E, Denton, TX 76201				
Holiday Inn, Denton	45.00 for up to 5 persons		817-387-3511	800-465-4329
Highway I-35E @ Dallas Drive: Teasley Lane Exit (north) to Dallas Drive (south), Denton,TX 76201				
La Quinta, Denton	31.00	35.00	817-387-5840	800-531-5900
Highway I-35E @ Fort Worth Drive, Denton, TX 76201				
Motel 6, Denton	21.95, $6.00 each additional person		817-387-0571	none
Highway I-35E @ University Drive Exit, travel west access road north, Denton, TX 76201				
Auburn Inn, Denton	37.00	37.00	817-387-0591	800-955-7829
Breakfast included				
Highway 1-35E @ Teasley Lane, Denton, TX 76201				
Royal Hotel Suites, Denton	22.00	34.00	817-383-2007	none
1210 I-35E @ McCormick Road, Denton, TX 76201				
				TEXAS:
Hampton Inn, Lewisville	37.00	37.00	214-434-1000	800-HAMPTON
200 N. Stemmons (I-35), Lewisville, TX				
Holiday Inn, Lewisville	42.50	49.00	214-462-1122	800-325-3535
2398 S. Stemmons (I-35), Lewisville, TX				
LaQuinta Inn, Lewisville	30.00	34.00	214-221-7525	800-531-5900
1657 Stemmons Fwy (I-35), Lewisville, TX				
Ramada Inn, Lewisville	39.95	39.95	214-221-2121	800-221-2121
Continental Breakfast included				
1102 Texas (I-35 & Hwy 121), Lewisville, TX				

FURTHER INFORMATION

For further information in regard to the Accelerator Conference contact:

Dr. Jerome L. Duggan
The University of North Texas
Department of Physics
P. O. Box 5368
Denton, TX 76203-5368
Work Phone: (817) 565-3252
Home Phone: (817) 382-1983
FAX: (817) 565-2227

For Overnight Delivery:
Physics Building
Avenue A & Mulberry
Denton, TX 76203-5368

Program of the Eleventh International Conference on the Application of Accelerators in Research and Industry

Denton, Texas; 5–8 November 1990

PREAMBLE

The Eleventh International Conference on the Application of Accelerators in Research and Industry will be held in the University Union Building on the campus of the University of North Texas (UNT) in Denton, Texas. The dates of the conference are 5–8 November 1990. Denton is located in the the Dallas/Fort Worth (DFW) Metroplex, 27 miles from the DFW International Airport. There also will be a one-day workshop, Sunday, 4 November 1990, on small tandem accelerators. This workshop will be at the Sheraton Hotel, which is located on the campus of the University of North Texas. Registration for the workshop will be limited to eighty participants. The registration fee for the workshop is $30.00 and can be paid upon arrival at the workshop registration desk in the Sheraton. This registration fee is separate and apart from the accelerator conference registration. The workshop runs from 14:00–19:00 on Sunday, 4 November 1990. Registration for the workshops is limited to 100 participants.

AIR TRAVEL AND CAR RENTAL

American Airlines and Avis Rent-A-Car are the official travel companies for this conference. For discounted domestic or international air fare and car rental information/reservations, call American's Meeting Services Desk at 800-433-1790 or your travel agent and give American's Star File #S-02N04G. For detailed information write to the Accelerator Conference Office listed below or call 817-565-3250.

TRANSPORTATION

Between Denton and DFW Airport:
Sunday, 4 November—Dallas Area Rapid Transit (DART) buses will depart American Airlines Terminal 3 E, B1 Doorway (near Gate 32), Upper Level, every hour beginning at 12.00 through 22.00. If you come into DFW International Airport at a terminal other than American, your should ride the Air Trans train to American Terminal 3 E, B1 Doorway (near Gate 32), Upper Level. There will be a fee of $15 (one way), $25 (round trip) for the service between DFW Airport and the conference. Please pay in American currency. Participants who do not rent cars are urged to ride the official accelerator conference bus (marked Accelerator Conference). Financially, it is difficult for us to manage this bus service unless our participants use it.

Thursday, 8 November—Return to DFW Airport every 2½ hours beginning at 12:00 through 19:30.

Friday, 9 November—Return to DFW Airport every hour beginning at 7:00 through 12:00.

Taxi service is available to and from DFW Airport but arrangements need to be made at least 24 hours in advance: Phone Denton Cab Company 817-382-2544.

Airport Shuttle also runs a shuttle service between Denton and DFW Airport. For reservations call 817-565-9936, 1 to 5 days in advance.

If you rent a car at the DFW Airport, there are now plenty of parking areas for visitors at UNT near the conference. A parking garage is available at the intersection of Welch and Prairie Streets, one block from the University Union Building. Parking stickers and information can be obtained at the Sullivant Information Center at UNT. This center can be reached by taking the Avenue D exit from Highway I-35 North. After you exit, stay on the northbound service road for one block. The Sullivant Visitor's Center will be on your right.

UNT Shuttle Service: For your convenience, the UNT Shuttle Service will be operating to transport the participants back and forth to the hotels and campus conference facilities.

This *Bulletin of the American Physical Society* contains the complete program for the conference. Participants who are members of the American Physical Society should bring this *Bulletin* with them to the meeting. A limited number of copies of this *Bulletin* will be passed out at the conference to non-APS members.

The conference is being supported by the DOE, NSF, NBS, SDIO, The Oak Ridge Associated Universities, and UNT. It will consist of two symposia which essentially run in parallel. These are the "Symposium on the Use of Accelerators in Research" and the "Symposium on Industrial Applications of Accelerators." Sessions are arranged in such a manner that participants can easily interchange between the symposia.

The conference is composed of 362 invited papers and 158 contributed presentations. The invited papers are divided between the following groupings. Those papers concerning industrial applications (30 sessions) and those related to research activities with accelerators (23 sessions). Most contributed papers will be presented in the poster sessions. These are poster session PA, which will take place Monday evening, 5 November in the hallways and classrooms of the Physics Building from 19:00–21:00, and poster session PB, which will take place Thursday afternoon, 8 No-

vember in the Silver Eagle Suite of the University Union Building from 14:00–16:00. Participants in session PA may set up their posters starting at 16:00 on Monday, 5 November. They should be removed by 22:00 that evening. Participants in poster session PB may set up their posters anytime after 10:00 on Thursday, 8 November. They should be removed by 18:00 on that day. Each poster paper will be mounted on a poster board that is 160-cm wide by 120-cm high. A complete set of instructions for displaying poster material at APS conferences can be found in the back of most issues of the APS *Bulletin*. Your assigned poster station can be found in the room. You should be at your poster station for at least the first hour during this session.

POSTDEADLINE ABSTRACTS

Postdeadline abstracts will be accepted for this meeting. These papers will be presented as poster papers in either poster session PA or PB. The format for this presentation is exactly the same as for a regular poster paper. We will accept postdeadline poster papers until 1 November 1990. A limited number of these papers will be published in the conference proceedings. Participants who give postdeadline poster papers must be registered for the conference.

The proceedings of the conference will be published by Elsevier Science Publishers B.V. They are scheduled to appear in the April 1991 issue of *Nuclear Instruments and Methods*. In the instructions that you will receive, detailed information is provided for preparing the paper. Since the manuscripts will be typeset by the staff at Elsevier Science Publishers B.V., camera-ready papers are not necessary. However, the figures and the appropriate size lettering on the figures must be camera-ready. The instructions that you will receive spell out all the dos and don'ts with respect to manuscript preparation. The complete manuscripts for both the invited and contributed papers must arrive in the conference office at UNT prior to 1 October 1990. These papers will be refereed prior to the conference and sent to Amsterdam immediately after the conclusion of the conference.

Important Notice: Because of the size of this conference, it will be impossible for us to publish in the proceedings papers that arrive after our 1 October 1990 deadline. In the past this deadline has been somewhat flexible. This year *no papers can be accepted for publication after the 1 October 1990 deadline.*

The proceedings of this conference will be provided to all paying participants. For those who do not attend the conference, copies may be obtained by writing North-Holland Publishing Co. or the organizers of this conference.

The twelfth conference in this series is being planned by the Organizational Committee. It will take place in Denton, Texas in November 1992.

Jerome L. Duggan
I. Lon Morgan
Conference Chairmen
University of North Texas

EPITOME

SUNDAY EVENING

19:00 Opening Reception. University Union Building, Second Floor.

MONDAY MORNING

8.45 Welcome. English Building, Auditorium. Duggan, Morgan, Chairman of the Department of Physics West, Associate Vice-President for Research and Graduate Dean Schafer, and President Hurley.

9.00 AA General Session. English Building, Main Auditorium. Grodzins, Briggs, Weinberg.

MONDAY AFTERNOON

14:00 BA Ion-Beam Analysis. Union Building, Golden Eagle Suite A. Tesmer, Bozoian, Leavitt, Rauhala, Dobeli, Ziegler, Gossett.

14:00 BB Commemorative Session for Dr. Paul A. Treado. Physics Building, Room 102. Slaus, Brown, Lightbody, Howell, Lehman, Cranell, Roos, Rolfs, Rodney.

14:00 BC Accelerator Technology. Union Building, Golden Eagle Suites B and C. Gilman, Jameson, Rhoades-Brown, Iwata, MacGowan.

14.15 BD Government Funding for Research. Union Building, Lyceum. Schoen, Berlincourt, Stephens, Cooper.

14.00 BE Activation Analysis and Nuclear Reaction Analysis. Union Building, Room 410. McKlveen, Supernau, Weinlein, Rauch, Qiu, Forster, Debrun, Bethge, Rickards.

14.00 BF Atomic Physics and Related Phenomena. Union Building, Room 412. Zouros, Reinhold, Olson, Ullrich, Schneider, Chabot, DePaola.

14:00 BG Ion Sources and Control Systems. Union Building, Room 418. Stockli, Berry, May, Myers, Rathmell, Clegg, Korschinek.

MONDAY EVENING

17:00 Social Hour. Union Building, Second Floor.

19:00 CA Accelerator Technology. Art Building, Room 223. Debiak, D. A. Swenson, Schempp, Fink, Little, Hamm.

19:00 CB Accelerator Targetry. Union Building, Room 411. Greene, Maier, Maier-Komor, Pauwels, Pengo, Thomas.

19.00 CC Ion Implantation. Union Building, Room 410. Andreadis, Ensinger, Earwaker, Williamson, Bridwell, Nielsen, Dearnaley.

19:00 CD Accelerator Technology. Union Building, Room 412. Frawley, Whitlow, Walton,

Johnson, Botwin, Correll.

19:00 CE Single-Event Upsets. Union Building, Golden Eagle Suite A. Pickel, Knudson, Murray, Thieberger, Sexton, Letaw.

19:00 PA Poster Session: Atomic Physics and Related Phenomena, Energy Loss, Nuclear Physics. Phys. Bldg., 1st & 2nd Flrs.

21:00 Social Hour. Union Building, Second Floor.

TUESDAY MORNING

9:00 DA Radioactive Beam Experiments I. Union Building, Room 410. Rolfs, Malaney, Kajino, Nagai, Paradellis, Görres, Galster, Becchetti, Cormier, Sherrill.

9:00 DB Ion Implantation. Union Building, Room 412. Neri, Culbertson, McCafferty, Cheung, Herbots, Volkert, Nielsen.

9:00 DC Photon-Ion Interaction Using Fast Beams. Physics Building, Room 102. Rau, Quick, Thompson, Lineberger, Walter, Dinneen, Johnson, Larson.

9:00 DD Positron Beam Experiments and Facilities I. Union Building, Golden Eagle Suite A. Canter, Cowan, Diana, Howell, Lynn, Okada, Schaefer, Hulett.

9:00 DE Atomic Physics and Related Phenomena. Physics Building, Room 104. Schwab, Mansour, Leventhal, Kádár, Ezell, Ford, Elkomoss.

9:00 DF Accelerator Technology. Union Building, Room 418. Jackson, Moser, Mosko, Newman, Newnam, Young.

9:00 DG Atomic Physics and Related Phenomena. Union Building, Golden Eagle Suites B and C. Church, Giese, Clark, Dunford, Salin, Ricz.

TUESDAY AFTEROON

14:00 EA Positron Beam Experiments and Facilities II. Union Building, Golden Eagle Suite A. Shaw, Schneider, Segers, Stoll, Sharma, Weiss, Hulett, Jean, Jones.

14:00 EB Radioactive Beam Experiments. Union Building, Room 410. Mueller, Buchman, Stokstad, D'Auria, Walker, Ryckewaert, Feinberg, Hass, Boyd.

14:00 EC Nonlinear Effects in ECR-Generated Plasmas. Union Building, Room 412. Wollnik, Reiser, O'Shea, Whealton, Antaya, Petty.

14:00 ED Nuclear Physics. Union Building, Golden Eagle Suites B and C. Mitchell, Becker, Madey, Mougey, Holbrow, Riedinger, Tribble.

14:00 EE Atomic Physics and Related Phenomena. Physics Building, Room 102. Rothard, Briand, Andersson, Grandin, Furst, MacAdam.

14:00 EF Accelerator Mass Spectrometry. Biology Building, Room 200. Anthony, Davis, Houzhi, Suter, Tuniz, Kubik, Kieser.

TUESDAY EVENING

17:00 Social Hour. Union Building, Second Floor.

19:00 FA Synchrotron Radiation I. Physics Building, Room 102. Johnson, Siddons, O'Brien, Morgan, Southworth, Kravis, Levin, Meron, Robinson, Lindle, Caldwell, Azuma.

19:00 FB Ion Implantation. Union Building, Room 411. Torp, Stephens, McKee, Marshall.

19:00 FC Nuclear Microprobes. Union Building, Room 412. Saint, Pallon, Sie, Lindh, Pontau, Kubena, Cholewa.

19:00 FD Accelerator Technology. Union Building, Golden Eagle Suites B and C. Oberschachtsiek, Prasad, Price, Lin, Jones, Liu, Lawrence.

19:00 FE Selected Topics: Ion Sources, Rail Guns, Explosive Detection. Union Building, Room 418. Tsai, Habiger, Whitham, Zhao, Harriman, Hayes, Krasnov.

21:00 Social Hour. Union Building, Second Floor.

WEDNESDAY MORNING

9:00 GA RBS, Channeling, and ERDA. Union Building, Room 410. Xiong, Bakhru, Robertson, Tirira, Keenan.

9:00 GB Cluster Impacts. Union Building, Room 412. Tombrello, Schweikert, Shapiro, Della-Negra.

9:00 GC Medical Applications of Accelerators. Union Building, Room 411. Valkovic, Votaw, Mallory, Lennox, Lambrecht, Jongen.

9:00 GD PIXE. Union Building, Golden Eagle Suite A. Vis, Maenhaut, Kusko, Swann, Ghermandi, Thompson, Thomson, Wätjen, Zanini.

9:00 GE Atomic Physics and Related Phenomena. Union Building, Room 418. Schulz, Schmidt-Böcking, Phaneuf, Beiersdorfer, Biedermann, Waggoner, Cheng, Kamber, Schoene.

WEDNESDAY AFTEROON

14.15 HA Superconducting Super Collider. Union Building, Lyceum. Trilling, Dibitonto, Brau, Sulak, Cox, Lockyer.

14:00 HB Accelerator Technology. Union Building, Room 410. Youngblood, Miller, Fox, McKenzie-Wilson, Schroeder, Hakamata,

Zinkann.

14:00 HC Radiation Processing. Union Building, Room 412. Sadat, Nablo, Stirling, Cleland, Smittle, Blind.

14:00 HD Accelerator Production of Medical Radioisotopes. Union Building, Room 411. Michaels, Hichwa, Sharp, Lagunas-Solar, Boothe, Schlyer.

14:00 HE Atomic Physics and Related Phenomena. Union Building, Golden Eagle Suite A. Heber, Kimura, Knystautas, Mannami, Powers, Musket, Vane.

14:00 HF Atomic Physics and Related Phenomena (Storage Rings). Union Building, Golden Eagle Suites B and C. Wolf, Kristensen, Tanis, Kühl, Schuch, Poulsen.

WEDNESDAY EVENING

17:00 Social Hour. Union Building, Second Floor.

18:30 Banquet. University of North Texas Coliseum.

21:00 Social Hour. Union Building, Second Floor.

21.00 Traveling Physics Circus. Physics Building, Room 102. Karl Trappe, Rory Coker and The Physics Demonstration Group, Physics Department, University of Texas, Austin.

THURSDAY MORNING

9:00 IA Synchrotron Radiation II. Union Building, Room 410. Huber, Schlachter, Rowe, Craft, Keller, Sah, Jones.

9:00 IB Atomic Physics. Union Building, Golden Eagle Suite A. Watson, Straton, McGuire, Rudd, Richard, Zoran, Wanser.

9:00 IC Atomic Physics and Related Phenomena. Union Building, Golden Eagle Suites B and C. Graham, Chen, Kanter, Benhenni, Bhalla, Hahn, Anthony, J. K. Swenson, Reeves, Bissinger, Cisneros.

9:00 ID Surface Analysis with Ion Beams. Union Building, Room 418. Tolk, Heiland, Strathman, Li-Scholz, Smith, Qiu.

9:00 IE Tomography--Radiography and Intense Sources. Union Building, Room 411. Hopkins, Agee, Antolak, Dance, Davanloo, Dilmanian, Hurley, Zeman.

9:00 IF Nuclear Physics. Union Building, Room 412. Toth, Spooner, Bhatia, Nelson, Trautvetter, Nagame, Iwata, Miljanić.

THURSDAY AFTERNOON

14:00 JA Atomic Physics and Related Phenomena. Union Building, Room 412. Fuelling, Echenique, Heil, Flores, Sabin, Smith, Weathers.

14:00 JB Selected Topics. Union Building, Golden Eagle Suite A. Vourvopoulos, Langanke, Summers, Kim, Wustenbecker, Fischbeck.

14:00 JC Atomic Physics and Related Phenomena. Union Building, Golden Eagle Suites B and C. Zeijlmans van Emmichoven, Träbert, Stolterfoht, Stöhlker, Shingal, Shafroth, Quarles.

14:00 JD Atomic Physics and Related Phenomena. Union Building, Room 410. Dietrich, Brun, Havener, Guardala, Del Grande, Fou.

14:00 JE Ion Microbeams. Union Building, Room 418. Campbell, Jakšić, Yang, Grime, Doyle, Klody, Staffan Tapper.

14:00 PB Poster Session: Particle Induced X-Ray Emission (PIXE), Rutherford Backscattering and Channeling (RBS), Nuclear Reaction Analysis, Neutron Activation Analysis, Ion Implantation, Medical Applications, Accelerator Technology, Targets, Accelerator Mass Spectrometry, Detectors, and Spectrometers. Union Building, Silver Eagle Suites A, B, and C. (The Poster Session is split as PB and PB' for indexing purposes only. This is all one session.)

14:00 PB' See Session PB.

MAIN TEXT

WELCOME.
Monday morning, 5 November 1990; English Building, Auditorium at 8:45;
Duggan, Morgan, West (Chairman of the Department of Physics),
Schafer (Associate Vice-President for Research and Graduate Dean),
and Hurley (President of The University of North Texas, Denton)

SESSION AA: GENERAL
Monday morning, 5 November 1990; English Building, Main Auditorium at 9:00;
J. M. Lambert, Georgetown University, presiding

AA 1 Nuclear Probes for Detecting Chemical Explosives. L. GRODZINS, *Massachusetts Institute of Technology.* (30 min.)

More than a dozen nuclear-based techniques have been proposed for rapidly scanning airport luggage to find hidden explosives by measuring their elemental distributions. In almost every scheme, the technological challenge is the accelerator, which must produce its intense beams of neutrons or photons -- whether pulsed or D.C. -- in an airport environment, perhaps even in an airport concourse. The accelerator must be small, well-shielded, and cost-effective. It must be operable by nominally-trained personnel, with minimum unscheduled downtime for repairs or service. The paper will summarize the physics and technology of the most promising of the imaging schemes, with special emphasis on the accelerator requirements.

AA 2 An Overview of the SSC Project. R. J. BRIGGS, *Superconducting Supercollider Laboratory.* (40 min.)

The technical objectives, milestones, and current status of the Superconducting Super Collider project are described. The accelerator consists of an injector complex with a linear accelerator and three booster synchotrons, and two 54 mile circumference collider rings where oppositely directed proton beams are accelerated to 20 TeV per beam and the superconducting dipole magnet is a key technology element that comprises about 1/3 of the machine cost. The paper will summarize the current status of the development of the magnets and other key technology elements. The implementation of this scientific mega-project relies heavily on partnerships between the SSC Laboratory and industry, and these relationships should facilitate industrial applications of the SSC technology developments.

AA 3 Physics with the SSC. S. WEINBERG (Nobel Laureate), *University of Texas at Austin.* (50 min.)

SESSION BA: ION-BEAM ANALYSIS
Monday afternoon, 5 November 1990; Union Building, Golden Eagle Suite A at 14:00;
J. F. Ziegler, IBM Corporation, presiding

BA 1 Identification and Compilation of High-Energy Nuclear Reaction Cross Sections for Ion-Beam Analysis.*
J. R. TESMER, *Los Alamos National Laboratory.* (20 min.)

There has recently been an increased interest among materials scientists in higher-energy nuclear reactions for ion-beam analysis. These reactions include both non-Rutherford elastic cross sections for backscattering analysis as well as nuclear reactions with higher-mass projectiles such as 3He and Li. Increased energies makes available a wealth of nuclear structure data. Unfortunately, there is an immense amount of data published, with only a small part useful to materials scientists. The problem becomes one of efficiently sorting through the data. One approach is to take a problem and search the literature for a better solution. The opposite is to search the literature to identify, within constraints, all the useful data, as well as data that is missing. Both of these methods will be discussed in the context of formulating a compilation of useful nuclear structure data for inclusion in a new handbook for materials scientists. Examples will be given of how and where to search for the data as well as constraints that can be placed on the data set.

* Supported under the auspices of the U.S. Department of Energy.

BA 2 Thresholds of Non-Rutherford Nuclear Cross Sections for Ion-Beam Analysis.
M. BOZOIAN, *Los Alamos National Laboratory.* (20 min.)

A recently developed theoretical model,[1] based upon classical scattering from a Coulomb field in the presence of a weakly perturbing Yukawa-like nuclear field, predicts the incident ion energy at which elastic backscattering cross sections begin to deviate from their Rutherford values. The model, parameterized with two nuclear constants, a potential and a length, is in good agreement with experimental data for proton and helium ion beams. Using the little backscattering data available and several low-energy optical models, the model has been augmented to include ^{2}H, ^{3}He, ^{6}Li, ^{7}Li, and ^{10}B ion beams by simply

accounting for projectile mass and isotopic differences between low Z projectiles, especially Z = 1 and Z = 2. The original form of the model is retained, including the values of the two nuclear constants, however, now the nuclear potential includes a simple factor involving projectile Z and A numbers. The revised model is in good agreement with available data and optical model calculations. New experimental results for ^{6}Li and ^{7}Li ion beams compared with the revised model are presented elsewhere at this conference.[2]

[1]M. Bozoian *et al.*, accepted for publication in Nucl. Instr. Meth. B (1990).
[2]K. M. Hubbard *et al.*, proceedings of this conference.

BA 3 Non-Rutherford ^{4}He Cross Sections for Ion-Beam Analysis.* J. A. LEAVITT, *University of Arizona.* (20 min.)

creasing use of ^{4}He analysis beams with energies between 3 and 10MeV for depth profiling d backscattering analysis of thin films and near-surface materials requires accurate measured values of non-Rutherford cross sections for scattering of ^{4}He by the lighter elements. Cross sections for scattering of ^{4}He through large angles deviate from Rutherford at ^{4}He laboratory energy = 2.2MeV for target nuclei ^{12}C and ^{16}O; deviations for target atomic number Z = 20 and 40 occur at ^{4}He energies of about 5 and 10MeV, respectively. We review the experimental cross section data currently available for large angle scattering of ^{4}He from the light elements ($4 \leq Z \leq 20$) for incident ^{4}He laboratory energies 1.5 to 10MeV. For each target element, we indicate energy regions with smooth cross section variation suitable for use for simple backscattering analysis as well as strong narrow resonances that may be used for depth profiling light elements in heavy-element matrices. We discuss experimental problems related to measurement of cross sections including target design, energy calibration, interference from nuclear reaction products and the effect of inelastic scattering.

*Supported in part by the Arizona Research Laboratories, the Optical Data Storage Center and the Air Force Office of Scientific Research (University Research Initiative Program).

BA 4 Protons, Helium, and Heavy Ions in Backscattering Analysis of High-T_c Superconductors.*
E. RAUHALA, *Accelerator Laboratory, University of Helsinki, Finland.* (20 min.)

Ion backscattering spectra for ^{1}H, ^{4}He, ^{7}Li, ^{12}C, ^{16}O, and ^{28}Si ions incident on thin and thick superconductor samples in the energy range 2-28 MeV have been measured. The spectra are analyzed by using a computer program package for ion backscattering data analysis. The general characteristics of the ion beams for the backscattering analysis of superconductors both in the Rutherford and Non-Rutherford energy regime are discussed. The advantages and disadvantages of using proton and heavy ion beams are compared to those of ^{4}He ion backscattering.

* Collaboration with N. NATH, *Physics Department, Kurukshetra University, Kurukshetra-132119, India* and J. SAARILAHTI, *Semiconductor Laboratory, Technical Research Centre of Finland, Otakaari 7 B, SF-02150 Espoo, Finland* is gratefully acknowledged.

BA 5 A Time-of-Flight Detector for Heavy Ion RBS.[1,2] M. DOBELI,[1,4] *California Institute of Technology.* (20 min.)

We describe the details and performance of a time-of flight spectrometer for application in heavy ion RBS. An energy resolution of better than 1% is achieved for ^{16}O and ^{35}Cl ions in the energy range between 3 and 15 MeV. Using ^{35}Cl ions for RBS a mass resolution between 1 and 2 amu is obtained over the whole periodic table. At the sample surface a depth resolution of approximately 1 $\mu g/cm^2$ can be achieved. The technique has been used to measure indium profiles in InGaAs/GaAs quantum well samples with a depth resolution of 30 Å, as well as to determine the arsenic loss in annealed GaAs samples. Further applications and improvements of the spectrometer will be discussed.

[1] Work supported in part by the National Science Foundation [DMR86-15641 and DMR88-11795].
[2] Collaborators: P.C. Haubert, R.P. Livi, S.J. Spicklemire, D.L. Weathers, and T.A. Tombrello
[3] Supported in part by a fellowship from the Swiss National Science Foundation.
[4] Permanent address: Paul Scherrer Institut c/o ETH Zürich, Switzerland.

BA 6 TRIM-90, The Transport of Ions in Matter.
J. ZIEGLER, *IBM Thomas J. Watson Research Cen..r.* (20 min.)

TRIM is a Monte Carlo program for the penetration of ions into solids. It calculates ion energy loss, ranges, damage, sputtering, backscattering and transmission averages for compl.. targets of many elements and of several layers. The program originated in 1980 (1), and was converted to a PC version with animated graphics in 1985 (2). This talk will cover new aspects of the program, including the use of high resolution graphics to show the 3-dimensional calculations. Programs are now included to calc..late stopping powers in

compounds, including chemical binding effects. A variety of comparisons will be shown between published experimental results and TRIM calculations.

(1) J. P. Biersack and L. G. Haggmark, NIM, 174, 257 (1980).

(2) J. F. Ziegler, J. P. Biersack and U. Littmark, "The Stopping and Range of Ions in Solids", Pergamon Press (1985).

BA 7 The Application of High-Energy Backscattering to High-Temperature Superconductors.
C. R. GOSSETT, *U.S. Naval Laboratory.* (20 min.)

SESSION BB: COMMEMORATIVE SESSION FOR DR. PAUL A. TREADO
Monday afternoon, 5 November 1990; Physics Building, Room 102 at 14:00;
J. M. Lambert, Georgetown University, and R. L. Walters, Duke University, presiding

BB 1 Quark Mass Difference and the Origin of Charge Symmetry Breaking. I. SLAUS, *Georgetown University.* (20 min.)

BB 2 Antimatter Gravity Experiment.* RONALD E. BROWN, *Los Alamos National Laboratory.* (20 min.)

An experiment is being developed to measure the acceleration of the antiproton in the gravitational field of the earth. Antiprotons of a few MeV from the LEAR facility at CERN will be slowed to tens of keV in an energy degrading foil, caught in a large electromagnetic trap, and cooled to tens of eV. These antiprotons will then be transferred to a second trap where they will be cooled to a temperature of about 10 K and subsequently launched a few at a time into a drift tube where the effect of gravity on their motion will be determined by a time-of-flight method. Development of the experiment is proceeding at Los Alamos using normal matter. The fabrication of a drift tube that will produce a region of space in which gravity is the dominant force on moving ions is of major difficulty. This involves a study of the electric fields produced by spatially varying work functions on metallic surfaces. Progress in all these areas will be mentioned, with stress on the drift-tube development.

*Work supported by the U.S. Department of Energy under Contract No. W7405 ENG-36.

BB 3 Multinucleon Knockout Experiments at CEBAF. J. LIGHTBODY, *National Science Foundation.* (20 min.)

BB 4 Neutron-Diffraction Elastic Scattering and Breakup Reactions Below 20 MeV. C. R. HOWELL, *Duke University.** (20 min.)

We are conducting a series of high-accuracy measurements at TUNL at incident neutron energies below 20 MeV on the n-d scattering system. These measurements are designed to address the following questions: (1) can three-nucleon (3N) scattering observables be used to refine our knowledge of the N-N force, (2) how well do we understand the dynamics of the breakup reaction in 3N systems, and (3) what is the influence of the three-nucleon-force (3NF) and off-shell effects on 3N scattering observables? We have measured vector analyzing powers $A_y(\theta)$ for n-d elastic scattering[1] and the breakup reaction[2] to an accuracy better than ±0.005 and ±0.020, respectively. The new insight on questions (1) and (2) gained by comparing our data to exact 3N calculations which use the Paris and new Bonn N-N potentials as input will be presented. The sensitivity of cross section data for different kinematic configurations of the nucleons in the exit channel of the n-d breakup reaction to the 3NF will be presented[3] along with recent results.[4]

*Work supported in part by the US Department of Energy, Contract No. DE-AC05-76ER01067.
[1]C. R. Howell *et al.*, Few-Body Systems 2, 19 (1987).
[2]C. R. Howell *et al.*, Phys. Rev. Lett. 61, 1565 (1988).
[3]W. Meier and W. Glöckle, Phys. Lett. 138B, 329 (1984).
[4]J. Strate *et al.*, J. Phys. G: Nucl. Phys. 14, L229 ('988).

BB 5 *D*-State Properties of ^{6}Li.*,† D. R. LEHMAN, *George Washington University.* (5 min.)
(Invited Poster Paper: See Poster Display PA 74).

The D-state structure of ^{6}Li is examined within the context of three-body models (alpha-particle, neutron, proton). The underlying alpha-nucleon interactions are represented by separable interactions in the $S_{1/2}$, $P_{1/2}$, and $P_{3/2}$ partial waves fitted to the low-energy phase shifts, while the nucleon-nucleon interaction is that of the Paris interaction as given by the PEST expansion.[1] A ^{6}Li wave function is obtained by solution of the three-body Schrodinger equation. From this wave function, the following D-wave quantities are calculated: D-wave asymptotic normalizaton constant, D-wave ^{6}Li → alpha + deuteron momentum distribution amplitude, D-wave DWBA parameter, D_2, and the alpha-deuteron contribution to the full ^{6}Li quadrupole moment. The connection

of the D-wave asymptotic normalization constant and the alpha-deuteron component of the ^{6}Li quadrupole moment will be discussed, especially with regard to signs.

*Work supported in part by The U.S. Department of Energy: DE-FG06-86-ER40270.
†In collaboration with J.P. Woloschek.
[1]J. Haidenbauer and W. Plessas, Phys. Rev. C30,1822(1984); C32,1424(1985).

BB 6 Preliminary Results of a New Determination of the RMS Charge Radius of the Proton*
HALL CRANELL, *The Catholic University of America.* (5 min.) (Invited Poster Paper. See Poster Display PA 23).

Preliminary Results of a New Determination of the RMS Charge Radius of the Proton* HALL CRANNELL, The Catholic Uuiversity of America -- New absolute and relative cross sections for elastic scattering of electrons from the proton have been measured using the linac facilities at NIST. The data were obtained by using a high-pressure, flowing-gas target cell alternately filled with pure H_2 and CH_4 gas. The measurements span a momentum transfer range from 0.22 to 0.73 fm^{-1}. These new results have been combined with an extensive set of existing elastic electron scattering data in a Fourier-Bessel analysis to obtain the charge density parameters and the rms radius of the proton. Some selection among the available data was necessary because of inconsistencies between published data sets. We obtain an rms charge radius of 0.865 ± 0.020 fm.

*Work supported in part by NSF Grant No. PHY8820654

BB 7 Pion Absorption on Nuclei. P. ROOS, *University of British Columbia, Canada.* (5 min.)
(Invited Poster Paper: See Poster Display PA 76).

BB 8 Novel Applications of Narrow Nuclear Resonances.* K. ROLFS,** *North Carolina State University.* (5 min.)
(Invited Poster Paper: See Poster Display PA 75).

Improvements in the energy resolution of ion beams and the quality of targets are valuable for the study of a wide range of phenomena in pure and applied physics with narrow nuclear resonances. An ultra high vacuum system has been developed which permits the fabrication of very pure targets and the energy spread in the ion beam from the 400 kV Münster cascade accelerator has been reduced to about 10 eV.[1] With this system we have observed a very strong Lewis effect for resonances in the ^{23}Na, ^{26}Mg and ^{27}Al (p,γ) reactions. (The Lewis effect is a manifestation of the quantum nature of the energy loss process. Its signature is a peak in the thick target yield slightly above the resonance energy, followed by the usual plateau.) Doppler widths also have been extracted from these resonance data. Preliminary measurements of the temperature dependence of the Doppler width have been used to extract a "surface" Debye temperature.[2] These measurements show great promise for novel methods of determining surface characteristics.

*Work supported by Deutsche Forschungsgemeinschaft (Ro429/16-1), US Department of Energy, Office of High Energy and Nuclear Physics (Grant No. DE-FG05-88ER40441), NATO Scientific Affairs Division (Grant No. 86-0485), Minister für Wissenschaft und Forschung des Landes NRW (IVA1-80098389), NC Board of Science and Technology, and Friedrich-Flick Förderungsstiftung.
**Now at: Ruhr-Universität Bochum, Bochum, Germany
[1]S. Wüstenbecker *et al.*, Nucl. Instrum. Methods A279, 448 (1989).
[2]H. G. Reusch, K. Langanke and C. Rolfs (to be published).

BB 9 Radioactive Beams in Astrophysics. W. RODNEY, *Georgetown University.* (5 min.)
(Invited Poster Paper: See Poster Display PA 80).

SESSION BC: ACCELERATOR TECHNOLOGY

**Monday afternoon, 5 November 1990; Union Building, Golden Eagle Suites B and C at 14:00;
M. Suter, PSI, Institut für Mittelenergiephysik, Zurich, Switzerland, presiding**

BC 1 Scientific Program at the SSC. F. J. GILMAN, *SSC Laboratory.* (25 min.)

BC 2 Accelerators for Materials Development.* R. A. JAMESON, *Los Alamos National Laboratory.* (25 min.)

Particle accelerators are important tools for materials research and production. Advances in high-intensity linear accelerator technology make it possible to consider enhanced neutron sources for fusion material studies (e.g. using the D-Li reaction) or as a source of spallation neutrons. Energy variability, uniformity of target dose distribution, target bombardment from multiple directions, time-scheduled dose patterns, and other features can be provided, opening new experimental opportunities. New designs have also been used to ensure hands-on maintenance on the accelerator in these factory type facilities. Designs suitable for proposals such as the Japanese Energy-Selective Intense Neutron Source (ESNIT) (20-40 mA cw deuteron beam), the International Fusion Materials Irradiation Facility (IFMIF) (250 mA cw deuteron beam modules), and a 1.6 GeV spallation neutron source are discussed.
*Supported by the Los Alamos National Laboratory, University of California, for the Department of Energy.

BC 3 Strong Field Effects and the Luminosity Lifetime of a Heavy-Ion Collider.*
M. J. RHOADES-BROWN, *Brookhaven National Laboratory.* (25 min.)

The Relativistic Heavy Ion Collider (RHIC) will accelerate fully stripped ions to beam kinetic energies of 250 (Z/A) GeV/u. For the heaviest nuclei, i.e., $^{197}Au^{79+}$, 10^9 ions per bunch will circulate in 57 bunches at a kinetic energy of 100 GeV/u. During bunch crossing, the peripheral collisions of the heavy ions generate a sufficiently large electromagnetic field that spontaneous e^+e^- pair creations will occur. Up to 10^7 pairs per second are expected at RHIC luminosity values (2×10^{26} cm^{-2} sec^{-1}). In addition, a produced electron may be captured by a heavy ion. The strong field pair creation and capture process will be discussed, including its effect on the luminosity lifetime of a heavy ion collider.

*Work performed under the auspices of the U.S. Department of Energy.

BC 4 Status of the JAERI Tandem Accelerator. T. IWATA, *Japan Atomic Energy Research Institute, Japan.* (25 min.)

The JAERI tandem accelerator has been operated for research works since 1982. Various ions of 43 elements ranging from hydrogen to bismuth have been accelerated with a terminal voltage of up to 18 MV. Thirteen beam lines from the accelerator are placed in five target rooms. The subjects of research activities are atomic physics and chemistry, solid state physics and radiation effects in materials, nuclear chemistry, nuclear physics, and neutron physics. Main facilities installed are magnetic spectrograph for heavy ion reactions, on-line isotope separator, TOF spectrometer for neutron physics and so on. A project of constructing a superconducting post accelerator to boost the energy of the heavy ion beams is in progress. The goal of our project is to obtain a 30 MV of accelerating voltage. The beam acceleration is scheduled to start in early 1993.

BC 5 X-Ray Laser Sources.* B. J. MacGOWAN, *Lawrence Livermore National Laboratory.* (25 min.)

X-ray lasers have been developed since 1984 as sources of high brightness x-rays. Early work achieved powers of up to 5 MW at wavelengths near 200 Å (60eV). Recent work at LLNL has concentrated on the development of the nickel-like tantalum amplifier at 44.83-Å. Amplification occurs in a laser produced plasma created by irradiating a thin foil of Ta with two beams of the Nova laser. It is hoped to saturate this system at output power levels of 10 MW. The wavelength of 44.83-Å (277eV) is close to optimal for holographic imaging of live cells and it remains to optimize the coherent output power of this amplifier to use it as a source for future x-ray holography experiments.

* This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

SESSION BD: GOVERNMENT FUNDING FOR RESEARCH

Monday afternoon, 5 November 1990; Union Building, Lyceum at 14:15;
G. M. Thomson, U.S. Army Ballistic Research Laboratory, presiding

BD 1 An Overview of NSF Today and Through the Crystal Ball. R. I. SCHOEN, *National Science Foundation.* (30 min.)

A general overview of the National Science Foundation will be presented. This will be followed with a discussion of budgetary trends and the 1991 budget. Certain new programs will be explored in more detail with special emphasis on applied research.

BD 2 Research Opportunities with the Department of Defense. T. BERLINCOURT, *U.S. Department of Defense.* (30 min.)

BD 3 Future Science Education Initiatives at the Department of Energy. R. STEPHENS, *U.S. Department of Energy.* (30 min.)

BD 4 Federal Basic Research: A Legislative Perspective. B. COOPER, *U.S. Senate.* (30 min.)

SESSION BE: ACTIVATION ANALYSIS AND NUCLEAR REACTION ANALYSIS
Monday afternoon, 5 November 1990; Union Building, Room 410 at 14:00;
B. E. Gnade, Texas Instruments Incorporated, presiding

BE 1 Neutron Generators Used for Undergraduate Teaching. J. W. McKLVEEN, *Arizona State University.* (15 min.)

For the past twelve years our undergraduate laboratory has used a Kaman A-711, 14.3 MeV neutron generator to provide students with a wide variety of teaching and research opportunities. The facility was easy to license, operates on a low budget (except for accelerator head replacement), and does not require extra radiation protection staff. Representative experiments include the buildup and decay of radionuclides, FNAA, measurement of protein in the student's favorite food, and the use of delayed neutrons to determine the uranium concentration in ore samples collected during field trips to uranium mines at the Grand Canyon.[1] Delayed neutron detectors and gamma spectrometers are coupled to the traditional counting modules and to PCs with multichannel analyzer capability. A book was prepared which lists the characteristic decays of all non-gaseous elements, and is used to facilitate the identification of unknown samples.[2] This paper will describe the typical experiments, the detection systems used, and the benefits and liabilities associated with the use of fast neutron generators as a teaching "tool" for undergraduate students.

[1] J.W. McKlveen, Laboratory manual for NUC/EEE-464, Nuclear Engineering Laboratory Experiments.
[2] J.W. McKlveen, FAST NEUTRON ACTIVATION ANALYSIS: Elemental Data Base, Ann Arbor Science, 1981.

BE 2 The Oxygen Activation Log in Underground Injection Control. I. SUPERNAU, *Texaco USA.* (20 min.)

The petroleum industry routinely injects saline waters into lithologic formations deep in the earth using some 170,000 injection wells scattered around the country. The oil companies and environmental regulation agencies alike are concerned about the possibility of these brines inadvertently finding their way into the shallow underground source drinking waters. (USDW's). Toward the aim of preventing such an occurrence, the industry, in general, and Texaco in particular has developed an oxygen activation logging system which incorporates a pulsed accelerator to produce fast neutrons which activate the oxygen present in any flowing water near the wellbore. The device's dual spaced detectors allow the detection of flowing water inside or outside the downhole tubulars and permit a calculation of the flow rate.

BE 3 A Pulsed Neutron Generator for *in vivo* Body Composition Studies.*
J. H. WEINLEIN, *Sandia National Laboratories, Albuquerque.* (15 min.)

A neutron generator system utilizing two zetatron[1] neutron tubes has been designed and delivered to the U.S. Department of Agriculture Human Nutrition Research Center on Aging at Tufts University for use in clinical measurements of body carbon by neutron inelastic scattering.[2] Each neutron tube is capable of delivering 10^3 - 10^4 14 MeV neutrons in a 7 μs pulse at rep rates of 4 or 8 MHz, and can be operated independently as well as in a master-slave mode. The neutron tubes are gas filled with a mixture of deuterium and tritium; the target of the tube is operated at -25 to -60 kVdc and the ion source is operated with a 2.5 kV, 7 μs pulse. The tube gas pressure is monitored and controlled by measuring the total current in the high voltage circuit which is fed back to the gas reservoir drive circuit. Neutrons were measured with a plastic scintillator and PMT detector.

* Supported by U.S. Department of Agriculture under contract No. 40-ILAN-8-098, and by U.S. Department of Energy under contract No. DE-AC04-76DP00789.
1. L. A. Shope, R. S. Berg, M. L. O'Neal and B. E. Barnaby, IEEE Trans. Nucl. Sci. NS-26, 1696 (1981).
2. J. J. Kehayias, K. J. Ellis, S. H. Cohn, and J. H. Weinlein, Nucl. Instrum. and Methods in Phys. Res. B 24/25, 1006 (1987).

BE 4 NRA Studies of Hydrogen in Metal-Oxide Films. F. RAUCH, *J. W. Goethe-Universität, Federal Republic of Germany* (20 min.)

Films and film combinations of metal oxides (SiO_2, TiO_2, Ta_2O_5, WO_3, ...) are widely used as coatings on glasses, for modifying the reflectance, absorbance or transmittance in certain spectral regions for mirrors, filters, windows, etc. Hydrogen is a common constituent of such films. Its eminent role for different film properties has been elucidated by NRA studies utilizing the resonant reaction $^1H(^{15}N, \alpha\gamma)^{12}C$. This talk reviews observations on H contents and depth distributions for various film systems, the influence of deposition methods, long-term changes and experimentally induced alterations. The unique properties

of the ^{15}N technique have enabled also the in-situ analysis of hydrogen transport within multilayer systems having electrically switchable optical properties.

Collaborators: W. Wagner, M. Laube, K. Bange and C. Ottermann.
Research supported by AIF 7434 and in part by BMFT 13 N 5476.

BE 5 Study of Deuterium Diffusion Behavior in SiO_2 by means of $D(^3He,p)^4He$ Reaction.*
Q. QIU, *Fraunhofer-Arbeitsgruppe für Integrierte Schaltungen, Federal Republic of Germany.* (5 min.)
(Invited Poster Paper: See Poster Display PB' 56)

Deuterium with concentration of 10^{16} - 10^{19} at./cm^3 has been measured quantitatively by using of $D(^3He,p)^4He$ reaction and a plastic-scintillator detector with large solid detection angle.[1] Thermal behavior of deuterium in SiO_2 has been studied in the temperature range of 200°C to 1000°C. Measurement shows that (1) deuterium concentration in SiO_2 depends on the solubility of SiOD[2] in temperature rigion of 200 to 700°C, and (2) water(D_2O) diffusion[3] is the donimative mechanism for hydrogen diffusion in temperature region of 700°C to 1000°C. Considering results from ESR and normal electrical methods, the behaviors of deuterium diffused in SiO_2 have been clarified.[4]

Collaborators: E.Arai+, Y.Ohji++
*This reaserch has been taken place in Tokyo Institute of Technology+,152 Tokyo/Japan, and co-laborated with Central Reserch Laboratory, HITACHI Ltd.++ Kokubunji 185 Tokyo/Japan.
[1]Q.Qiu, E.Arai, M.Aratani, M.Yanokura, T. Nozaki, Y. Ohji, and R. Imura; Nucl. Instr. and Meth. B44(1989)179
[2]F.J.Feigle, D.R.Young, D.J.DiMaria, S.Lai and J.Calise; J.Appl.Phys.,52,5665(1981)
[3]D.L.Wolters, Inst.Phys.ConfSer.No.50, The Institute of Physics,p.18(1979)
[4]Y.Ohji, Y.Nishioka, K. Yokokawa, Qi Qiu, E. Arai and T.Sugano; Solid-State Electronics,Vol.33Supplement,pp.383-388,1990

BE 6 *In Situ* NRA Studies of Hydrogen Ingress into Zr-2.5 wt. % Nb at the Liquid-Solid Interface.
J. S. FORSTER *Atomic Energy of Canada, Limited, Canada.* (15 min.)

Deuterium ingress into thin (3-5 μm) foils of Zr-2.5wt%Nb has been studied with the $^2D(^3He,p)^4He$ nuclear reaction. The foils were mounted in a compact cell[1]) placed in a scattering chamber. A ^3He beam bombarded the foil and liquid in the cell. We introduced substantial concentrations of D into the foil by removing the native oxide layer with a solution of 0.1 wt% NH_4HF_2 in D_2O and then cathodically charged the foil using a 0.1 M H_2SO_4 in D_2O solution. We anodically oxidized these foils, as well as unetched ones, using the 0.1 M H_2SO_4 in D_2O solution, and then measured the deuterium content in situ using the $^2D(^3He,p)^4He$ reaction.

[1]J.S. Forster, D. Phillips, T.K. Alexander, R.L. Tapping, T. Laursen and J.R. Leslie, NIM B48, 489 (1990).

BE 7 Study of the Lattice Location of Oxygen in Semiconductors by Combining Channeling and Charged Particle Activation.
J. L. DEBRUN,* *CNRS-CERI, France.* (20 min.)

The influence of oxygen on the electronic properties of semiconductors is not well known. This is in part due to the fact that the analysis of this element at low concentrations is difficult; the determination of the lattice location is difficult as well. Using charged particle activation (CPA), we were able to analyze oxygen accurately below the ppm level. By combining CPA with channeling, it was also possible to obtain information on the lattice position(s) occupied by the oxygen atoms. The methods will be described and discussed Recent work on $Ga_{1-x}Al_xAs$ prepared by MOVPE with organometallic compounds will be presented as an example. It is shown in this work that oxygen can occupy at least two different sites. tetrahedral interstitial and substitutional. The number of atoms on each site is governed by the number of arsenic vacancies and by the total oxygen concentration, which are both governed by the growth conditions.

*In collaboration with G. Blondiaux, G. Ducouret, E. Hanna Bakraji

BE 8 Analysis of GaAs by different Ion-Beam Methods.*
K. BETHGE, *University of Frankfurt, Federal Republic of Germany.* (20 min.)

Impurities in GaAs have been determined using different nuclear particle reactions. Particular interest is focussed on the carbon content because carbon affects the electrical behaviour, if incorporated in the lattice, whereas the role of interstitial carbon is not fully explored. The position of carbon was measured by channeled RBS and NRA using the ^{12}C (d,p)^{13}C reaction. Similar measurements on implanted carbon show different positioning in the lattice after tempering, indicating a mobility of the carbon atoms.

Variant surface contaminations have been observed after tempering under different gases. Particular nitrogen plays an important role.

*Supported by BMFT

BE 9 Fluorine Studies with a Small Accelerator. J. RICKARDS, *Universidad Nacional Autonoma de México, Mexico.* (15 min.)

A small (700 kV) accelerator has been used for studying fluorine in various solids and thin films, via the resonant nuclear reaction (RNR) technique. The strong and relatively thin resonance in the $^{19}F(p,\alpha\gamma)^{16}O$ reaction at 340 keV proton energy turns out to be the most convenient way of determining this element with a high sensitivity at low proton energies. With a typical beam resolution of 1 keV and a resonance width of 2.4 keV, a depth resolution of fluorine in most materials is in the .01 mg/cm^2 range. A computer program for a PC that calculates the excitation curve, given a certain F profile, has been developed and applied to various cases. The proton energy distribution is assumed to be Gaussian; straggling is considered. The F profile may be entered point by point or with any given function. By comparing the calculated and measured F excitation functions, a sensitivity of 10^{19} atoms/cm3 is estimated.

SESSION BF: ATOMIC PHYSICS AND RELATED PHENOMENA

Monday afternoon, 5 November 1990; Union Building, Room 412 at 14:00, P. Richard, Kansas State University, presiding

BF 1 Effect of Electron-Electron Interaction on Projectile K-Shell Ionization in Energetic Ion-Atom Collisions Studied by Zero Degree Auger Electron Spectroscopy. T. J. M. ZOUROS, *J. R. Macdonald Laboratory, Kansas State University and University of Crete, Greece.* (20 min.)

Cross sections for 1s ionization of the ground state of O^{4+} ($1s^2\,2s^2$) were obtained in 5-25MeV collisions of O^{4+} with He and H_2 targets. These cross sections were determined by measuring with high resolution the electron emitted at zero degrees with respect to the beam direction, from the Auger decay of O^{5+} ($1s2s^2$) → O^{6+} ($1s^2$) + e^- following 1s ionization of the O^{4+} ions. An increase of the ionization cross section above the electron impact ionization threshold for 1s ionization of O^{4+} by free electrons was found to be consistent with an impulse approximation treatment of this process. Recent calculations[1] of 1s ionization due to both electron-nucleus and electron-electron interaction were also found to be in agreement with the data clearly showing that ionization due to electron-electron interactions can be significant. K-shell ionization of the metastable O^{4+} ($1s^22s2p^3P$) component of the beam is also reported.

Our results are in general agreement with recent ionization studies[2] of hydrogenic ions in which the ensuing number of bare ions were directly determined by particle counting.

[1] Y. WANG AND J. Mc GUIRE private communications
[2] H.P. HÜLSKÖTTER et al PRL 63, 1938 (1990).

BF 2 On the Description of Classical Trajectory Methods in a Quantum-Mechanical Language.* C. O. REINHOLD,+ *University of Missouri-Rolla.* (20 min.)

Formally, quantum collision theory can be exactly formulated in terms of real phase-space distributions. This type of approach provides an intuitive picture of complex scattering problems which has proved very useful in different disciplines such as nuclear physics, chemical physics and quantum field theory. In this work, the classical trajectory Monte Carlo (CTMC) method, which is a well known technique in ion-atom collisions, is put into context with these more general phase-space approaches. It is found that the main approximation made in this model consists of evaluating the evolution of the phase-space distributions by using classical mechanics. In other words, the quantum Liouville equation is approximated by the classical Liouville equation. The CTMC wavefunction is defined in configuration space and its equation of motion is compared to the Schroedinger equation. As with any theoretical model, the CTMC method is found to have inherent limitations which will be discussed.

* Supported by the Office of Fusion Energy, U.S. Department of Energy.
+ New address: Department of Physics, University of Tennessee Knoxville.

BF 3 Electron Emission in U^{q+}+Ar Collisions.* R. OLSON,+ *University of Missouri-Rolla.* (20 min.)

Ionized electron spectra have been calculated for 1.4 MeV/u collisions of U^{q+} on Ar, with charge states q from 11 to 92. The classical trajectory Monte Carlo method has been utilized with Hartree-Fock model potentials to represent the U^{q+} ion's 4f-shell, and the L- and M-shells of Ar. Singly and doubly differential cross sections in ionized electron energy and angle are used to illustrate the various collision dynamics. Projectile electron-loss and charge-transfer-to-the-continuum cross sections near 0° are analyzed and compared to one another. Electrons ionized from

the L-shell are found to be more narrowly peaked in angle than those from the M-shell of Ar, giving raise to a slight "ridge" in the differential cross sections near 0°. The Ar electron binary peak $v_e = 2v_p\cos\theta$ is investigated as a function of projectile charge and angle and at 0° the magnitude does not scale with q. Anomalously large cross sections for "hot" electrons from the U^{q+} ion are found at velocities significantly above that for projectile binary peak electrons of $v_e=v_p$.

*Work supported by the Office of Fusion Research of the U.S. Department of Energy.

†Work in collaboration with C. O. Reinhold and D. R. Schultz.

BF 4 Recoil-Ion Momentum Spectroscopy.*
J. ULLRICH, *Gesellschaft für Reaktorsicherheit Darmstadt, Federal Republic of Germany.* (20 min.)

Within the last years the spectroscopy of the target recoil momentum[1] in distant ion-atom collisions has been established as a third, independent and valuable method of target spectroscopy besides the classical measurement of ejected electrons and x-rays. For a large set of collision systems e.g. for fast and heavy projectiles as delivered by the new SIS/ESR facilities at GSI impinging on gaseous targets, the determination of the recoil-ion transverse momentum provides the only possibility to obtain differential excitation or ionisation cross sections. Moreover, since the requirements on the ion beam (emittance, focussing) are comparably low even for high precision measurements, experiments using exotic beams like antiprotons can be envisaged. The present stage of development of the recoil-ion momentum spectroscopy is illustrated, its special ability to obtain information on many-body interactions in an ion-atom collision is demonstrated[2] and the future potential of the method as to the momentum resolution, the solid angle and possible applications in many particle coincidence measurement is outlined.

* supported by GSI, Darmstadt and Bundesministerium für Forschung und Technologie (BMFT), FRG
[1] Ullrich J, Schmidt-Böcking H, Kelbch C, 1988 Nucl. Instr. Meth. A268 216
[2] Olson R E, Ullrich J and Schmidt-Böcking H 1989 Phys. Rev. A 39 5572

BF 5 δ-Ray and Auger Electron Spectroscopy Following Heavy-Ion Collisions.
D. SCHNEIDER,* *Lawrence Livermore National Laboratory, Livermore.* (20 min.)

Recent results from secondary electron spectroscopy, including high resolution Auger electron spectroscopy, performed at the SuperHILAC and the ECR source at Lawrence Berkeley Laboratory and at EBIT at Lawrence Livermore National Laboratory are presented. Doubly differential cross sections and yields for continuum electron emission following collisions of MeV/u U-ion impact on gases and foils are shown. Data from high resolution Auger electron spectroscopy following the formation of Auger states via multi-electron capture in slow ion-atom collisions are discussed. First attempts to measure electron emission following the impact of very slow highly charged ions on surfaces are demonstrated.

*Work performed under the auspices of the U. S. Department of Energy at Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

BF 6 Single and Double Excitation of Two-Electron Ions. M. CHABOT, *Institute Curie, France.* (20 min.)

BF 7 RTE Studied in Electron Emission.* B. D. DEPAOLA, *J. R. Macdonald Laboratory, Kansas State University.* (20 min.)

Resonant Transfer with Excitation (RTE) is currently of great interest both because of its apparent similarity to dielectronic recombination, and because, being at least a four body problem, serves as a proving ground for few body atomic theories. Recent advances in the study of RTEA, RTE relaxing through Auger emission, will be discussed.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

SESSION BG: ION SOURCES AND CONTROL SYSTEMS

Monday afternoon, 5 November 1990; Union Building, Room 418 at 14:00;
J. M. Anthony, Texas Instruments Incorporated, presiding

BG 1 The Physics of Electron Beam Ion Sources.* MARTIN STÖCKLI,
J. R. Macdonald Laboratory, Kansas State University,. (20 min.)

The typical Electron Beam Ion Source uses a high field solenoid to compress and confine the electron beam which transverses the solenoid on its axis. Atoms crossing the electron beam are easily ionized and become trapped inside the source. Step-by-step ionization by the electron beam increases the charge state of the trapped ions during their confinement, which normally is controlled with electrostatic potentials at both ends. Therefore, the resulting average charge state increases with the product of the electron beam density and the confinement time, but is limited by the rate of electron capture from the residual gas. However, experience with the operational Electron Beam Ion Sources over the last few years has shown the importance of other processes such as dielectronic recombination or ion

heating. With the recognition of ion heating and ion-ion cooling, the maximum achieved charge states were pushed to even higher limits, which now include bare Krypton and hydrogen-like Xenon.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

BG 2 Characteristics of ECR Plasmas for Advanced Deposition and Etch Technology.* L. A. BERRY, *Oak Ridge Laboratory.* (20 min.)

Plasmas created by microwave absorption at the electron cyclotron resonance (ECR) are increasingly used for a variety of plasma processes, including both etching and deposition. ECR sources efficiently couple energy to electrons and use magnetic confinement to maximize the possibility of creating an ion or free radical. The characteristics of ECR sources include: capability of operating over a wide pressure range (from below 10^{-5} Torr to over 10 mTorr), intrinsic ion energies as low as 10–20 eV; high gas efficiency, and electrodeless operation. As a result, processing can occur with minimal ion energy and directionality, which in turn leads to finer control over etch kinetics (or nucleation and growth kinetics) and minimal radiation damage. The lack of electrodes allows for infrequent source maintenance and reduces the possibility of electrode contamination. Etching applications include Si and GaAs devices. Materials successfully formed include cubic boron nitride, diamond, and SiO_XN_y.

*Research sponsored by the U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.
**In collaboration with S. M. Gorbatkin.

BG 3 The TAMU ECR Ion Source: K500+ECR Performance.* D. P. MAY,** *Texas A&M Univer.* (20 min.)

The Texas A&M ECR ion source produced its first plasma in August 1989, and by October it was capable of producing a variety of high-charge-state ion beams. In November the source began supplying beams for the K500 superconducting cyclotron so that source development was cut back considerably. The initial performance has been excellent. Beams such as $^{129}Xe^{17+}$, $^{84}Kr^{19+}$, $^{63}Cu^{17+}$, $^{40}Ar^{14+}$, $^{32}S^{11+}$, $^{16}O^{7+}$, and HD^{+} have been supplied to the cyclotron. Experiments have been run using beams with energy/nucleon ranging from 2.42 MeV/n to 40 MeV/n, with total energy ranging from 60 MeV to 1.26 GeV, and with mass ranging from 4 to 129. Future development includes ovens and/or rod drives for the production of beams from solid materials and the conditioning of the source with silane gas.

*Supported in part by the U.S. Department of Energy under Grant DE-FG05-86ER40256, The Robert A. Welch Foundation and TAMRP.
**G. Mouzinty, P. Smelser, R. C. Rogers and D. H. Youngblood, Collaborators.

BG 4 The FSU Optically Pumped Polarized Lithium Ion Source.* E. G. MYERS, *Florida State University.* (20 min.)

A laser-optically-pumped polarized lithium ion source is being developed to provide beams of nuclear polarized $^{6,7}Li^{-}$ for injection into the F.S.U. tandem Van de Graaff-Linac accelerator. The source is largely based on developments of the polarized alkali source at the Heidelberg M.P. tandem [1,2]. Electro-optically modulated, circularly polarized, light optically pumps a lithium atomic beam into a single magnetic substate, M_I=I, M_J=1/2 [3]. No inhomogeneous magnetic field (sextupole or quadrupole) is needed. Adiabatic R.F. transitions enable the polarization to be changed by transferring the population into different magnetic substates. Using a second electro-optic to modulate a second beam from the same laser, and Zeeman tuning, the polarization of the atomic beam is obtained from laser induced fluorescence.

*Supported by the National Science Foundation and the State of Florida.
1. D. Krämer et al., Nucl. Inst. and Meth. 220 (1984) 123.
2. H. Jänsch et al., Nucl. Inst. and Meth. A254 (1987) 7.
3. H. Reich, Diplomarbeit, Heidelberg (1987).

BG 5 Automated Accelerator Controls for a 3 MV Tandem Pelletron. R. D. RATHMELL, *National Electrostatics Corporation.* (20 min.)

A new accelerator control system has been developed using a real-time, multi-tasking operating system running on a Motorola 68030 based microcomputer. The system includes multiple graphics and text displays and provides communication for the operator via these displays to the accelerator which is interfaced to CAMAC. Most accelerator parameters can be controlled using a mouse in conjunction with a single graphic display eliminating the need to change CRT pages to control parameters from the source to the target. A touch screen is also available to permit a number of parameters to be at the operator's finger tips at all times. Operating parameters for a new beam and energy can be automatically set by scaling from a previous set of data. The program and database are structured to facilitate interlocking and closed loop control of parameters. The hardware configuration, structure and features of the software will be reviewed.

BG 6 Prospects for Single State High Charge State ECR Ion Sources. T. CLEGG, *University of North Carolina, Chapel Hill.* (20 min.)

BG 7 The Munich Laser-Ion Source: Research Results. G. KORSCHINEK, *Technische Universität München, West Germany.* (20 min.)

SESSION CA: ACCELERATOR TECHNOLOGY

Monday evening, 5 November 1990; Art Building, Room 223 at 19:00;
R. W. Hamm, AccSys Technology, Incorporated, presiding

CA 1 Cesium-Enhanced H^- and D^- Beam Characteristics from a High-Brightness Volume Source.*
T. W. DEBIAK, *Grumman Corporation.* (20 min.)

Previous experiments have demonstrated that the H^- beam extracted from a volume source may increase by a factor of four or more when cesium vapor is introduced into the arc discharge chamber. This is accompanied by a dramatic reduction in extracted electron current and a small increase in RMS emittance. We have extended these experiments to higher H^- current enhancement and to D^- beams obtained at the same energy (20 KeV) and in the same extraction configuration. The D^- results show similar characteristics to that obtained with H^- beams. In particular, a current enhancement of a factor of five was obtained compared with noncesiated results and the extracted electron current is dramatically reduced. A study of the beam divergence of Cs-enhanced beams as a function of extracted equivalent current produced unexpected results. The minimum beam divergence appeared to occur at a different equivalent current than the uncesiated results. In addition, the minimum beam divergence of the H^- beams appeared to occur at a lower equivalent current than the D^- beams.

*Supported by Grumman IRAD Contract 7222-3002

CA 2 A ^{3}He RFQ Linac for PET Isotope Production.*
D. A. SWENSON, *Science Applications International Corporation, San Diego.* (20 min.)

An isotope production facility, based on an 8-MeV ^{3}He RFQ Linac, is under development to fulfill the needs of the medical community for hospital-based sources of short-lived, positron-emitting radioisotopes for positron emission tomography (PET). The short-lived nature of these isotopes (2 minutes for ^{15}O) necessitates that these ions be produced at the location where they are used. This gives rise to a need for economical sources of these isotopes that are suitable for installation in both new and existing medical research and treatment facilities. The isotope production cross sections for ^{3}He projectiles re adequate at an ion energy of 8 MeV. These ions, which have the same velocity as 2.66-MeV protons, lie within the velocity range for efficient acceleration in RFQ linacs. The choice an RFQ linac as the accelerator and ^{3}He++ as the projectile leads to a very favorable configuration for the production of these isotopes. The single linear accelerating structure makes for simple operation and easy maintenance. The double charge state of the projectile makes for efficient acceleration and effective focusing. The neutron-poor nature of the projectile leads to very low activation of the accelerator and target systems and minimizes the required radiation shielding. The electrical power, cooling and floor loading requirements are well within the capabilities of normal hospital and laboratory facilities. A description of the isotope production facility under development will be given.

*Supported by the SDIO Office of Technology Applications.

CA 3 Recent Applications of RFQ Linacs in Research and Industry. A. SCHEMPP, *Universität Frankfurt, West Germany.* (20 min.)

CA 4 A 3-MeV Accelerator Test Stand.* C. L. FINK, *Argonne National Laboratory.* (20 min.)

The Applied Accelerator Programs Section of the Engineering Physics Division at Argonne National Laboratory is collaborating in the development and testing of high-current hydrogen and deuterium accelerators for potential applications in fusion material testing, plasma injection heating, accelerator production of tritium, and space-based accelerator systems. A 3-MeV accelerator system has been assembled to study key issues, components, and diagnostics in these high-current devices in an offline environment. Modular design of the source, extractor, accelerator column, low-energy beam transport, and radio frequency quadrupole allow maximum flexibility in performing tests of system components and new accelerator concepts. The initial system consists of a H_2^+ volume source, a 140-kV accelerator column, a cryogenic radio frequency quadrupole, and 480 kW power supply. The radio frequency quadrupole and radio frequency power systems were designed by AccSys Technology. Design parameters are a current of 100 mA, an emittance of 0.02 π-cm-mr, an output energy of 3 MeV, a pulse width of 100 μs, and a 0.1 percent duty factor. Initial operation of this system will be to test beam diagnostics being developed for the Continuous Wave Deuterium Demonstrator. Ideas for future activities include testing longitudinal emittance diagnostics, low-energy beam transport systems, new superconducting radio frequency cavity designs, and computer control systems. Future system upgrades may extend the pulse width to several seconds to test continuous wave superconducting radio frequency quadrupole designs and provide the option of using other sources

such as H^+, D^+, and D. Modifications of the low-energy beam transport to an electrostatic system that does not require charge neutralization is also being considered. The source, extractor, and accelerator columns are being assembled currently, and the radio frequency quadrupole fields have been characterized and compared to previous measurements made by others.

*Work supported by the U.S. Department of Energy under Contract W-31-109-ENG-38 and by the U.S. Army Strategic Defense Command.

[1]Work described was performed in collaboration with A. Taylor and L. Sagalovsky.

CA 5 Initial Operation of the LLUMC Accelerator and Beam Transport.
R. LITTLE, *Science Applications International Corporation, Princeton.* (20 min.)

The first proton synchrotron system built specifically for cancer treatment is in the early stages of operation at Loma Linda University Medical Center (LLUMC). The accelerator, a 250 MeV proton synchrotron, was designed, built, and tested by Fermi National Accelerator Laboratory and was moved to Loma Linda late in 1989. Commissioning and initial operation at Loma Linda is described. A complete beam transport system to the treatment rooms has been installed including 360° beam rotation to permit isocentric treatment. This commissioning and operation is being performed by SAIC for LLUMC.

CA 6 The TRILAC—A New Company Linac for Analytical Analysis. R. W. HAMM, *AccSys Technology, Incorporated.* (20 min.)

Since the development of the Radio Frequency Quadrupole (RFQ) structure, the ion linear accelerator (linac) has been accepted as a useful tool in research, industrial, medical and military applications. The small size and high efficiency achievable with the RFQ has made it ideally suited for applications which require a portable accelerator. This characteristic has been exploited in a new portable system for analytical analysis. A small RFQ linac that can be configured to produce either 1 MeV protons, 900 keV deuterons, or 1.8 MeV ^{4}He ions has been packaged in a self-contained unit mounted in a portable cabinet. The current available from this system varies from less than one microampere to more than 100 microamperes, depending on the application. This small unit can be easily transported or moved about a plant or laboratory for application in PIXIE, neutron activation analysis, or RBS. The system and its features will be described, along with the results from a prototype unit for deuterons.

SESSION CB: ACCELERATOR TARGETRY

Monday evening, 5 November 1990; Union Building, Room 411 at 19:00;
J. Pauwels, Commission of the European Communities, Center for Nuclear Measurements,
and G. E. Thomas, Argonne National Laboratory, presiding

CB 1 Reduction of Rare-Earth Isotopes. J. P. GREENE, *Argonne National Laboratory.* (25 min.)

CB 2 Radioactive Targets for Heavy-Ion Experiments.
H. J. MAIER, *Universität München, Federal Republic of Germany.* (25 min.)

The quality of a nuclear accelerator target is assessed in terms of its purity, mechanical strength, thickness uniformity and microstructure. High vacuum thin film condensation is the preferred production method, because it results in microscopically smooth targets of high purity. Special variants of this technique are used in our hot laboratory to prepare radioactive targets of good macroscopic and microscopic homogeneity while keeping the consumption of isotopic material on a low level. New equipment including modern production plants as well as gloveboxes and hotcell facilities permits to maintain the service for a long period.
Radioactive targets prepared in our laboratory do not differ in morphology or other properties from stable isotope targets. Their mechanical strength is mainly determined by the backing, whereas the degradation under heavy ion bombardment is governed by the chemical and physical behaviour of the target material. The inherent radioactivity has virtually no influence on the lifetime of such a target.

CB 3 A Review of Laser Ablation Techniques for the Preparation of Vacuum-Deposited Isotope Targets.
P. MAIER-KOMOR, *Technische Universität München, Federal Republic of Germany.* (25 min.)

Laser ablation techniques are used for the preparation of accelerator targets at our laboratory since 1978. For refractory materials, where the evaporation out of a collimating crucible is not possible, laser ablation is the most efficient method, because all other procedures cannot cover such a big solid angle for the substrates.

Evaporation of isotopic refractory materials at a controlled partial pressure of an oxidizing or reducing gas can be performed only with laser ablation techniques. Procedures for target preparation are described using different Nd:YAG laser systems, optically coupled to a vacuum chamber with a base vacuum of 10^{-5}Pa. Differences in the results depending mainly on the time structure of the laser beam are discussed for lasers with up to 100 W cw-power and pulsed lasers with a peak pulse power of 0.1 MW for 120 ns and 30 MW for 10 ns pulses.

CB 4 Specific Nuclear Target Preparation and Characterization Techniques Used at CBNM.
J. PAUWELS, *Commission of the European Communities, Joint Research Centre, Central Bureau for Nuclear Measurements, Belgium.* (25 min.)

CBNM's nuclear target preparation activity is conceived as a public service towards neutron physicists not only from CBNM, but also from universities, nuclear centres, industry, etc.
Besides more classical techniques like electrospraying, spray painting and electrolysis, high quality actinide deposits are prepared by vacuum deposition of actinide fluorides. These evaporate at approximately 1000°C lower temperatures as oxides do. The possibility to do so is however dependent on the possibility to prepare high quality actinide fluoride powders without water residue. This technique is used to prepare targets used for cross section measurements, for fission fragment studies and also for targets used as fission foils. In this case high accuracy characterization is obtained by low geometry α-counting and IDMS calibration.
Similar techniques were also used to prepare certified reference deposits of ^{6}LiF and ^{10}B for absolute neutron flux measurements.
Finally, it must be mentioned that many deposit requests are carried our on thin foils. Therefore, important development work was carried out to prepare very thin (< 25 μg·cm^{-2}) polyimide foils.

CB 5 Experimental Requirements for Accelerator Targets. R. PENGO, *INFN-Laboratori Nazional di Legnaro, Italy.* (25 min.)

The successful conclusion of a nuclear physics experiment very often depends on the quality and characteristics of the target used for the nuclear reaction. A target is normally a thin film, composite or not, of an isotope-enriched material. Various techniques have been developed (vapour condensation, rolling, sputtering, electrochemical deposition, etc.) in order to meet both the experimenter's requirements and the cost of the preparation itself. The former depends on the type of experiment to be carried out; while, for instance, to detect the gamma-rays of the de-excitation of a nucleus produced after a nuclear reaction, a thick target can be used (up to few mg/cm^2), whereas for a reaction mechanism study or a lifetime measurements a thin target must be used (a few tens of mg/cm^2). The latter problem, i.e. the total cost, is mainly related to the necessity of using materials which are isotopically enriched and sometimes radioactive in order to obtain the desired reaction and also to the efficiency of production. E.g. rolled targets have to be preferred to vapour condensed ones, where possible. The experimenter's requirements related to reactions induced both by light- and heavy ions will be reviewed and discussed.

CB 6 Description of the Argonne National Laboratory Target Making Facility. G. E. THOMAS, *Argonne National Laboratory.* (25 min.)

SESSION CC: ION IMPLANTATION

Monday evening, 5 November 1990; Union Building, Room 410 at 19:00;
G. M. Klody, National Electrostatics Corporation, presiding

CC 1 Void Volume Reduction in Surface Films During Ion-Beam Assisted Deposition.
T. D. ANDREADIS,* *Naval Research Laboratory.* (20 min.)

A collision cascade model is presented of the reduction of void volume by incident energetic ions during Ion Beam Assisted Deposition (IBAD)of thin films. Reduction of void volume is of interest since it is accompanied by increased stability of the deposited film. Simulations were made for Ge deposition under Ar ion bombardment using the binary collision cascade code MARLOWE with realistic void-size distributions. MARLOWE is used to obtain void volume loss as a function of void depth in the deposited film. This information is used to analytically obtain the ratio of ion beam to vapor atom arrival ratio that yields full densification. The fate of residual interstitials and vacancies has been taken into account.

*Co-author: Mervine Rosen, Naval Research Laboratory, Washington, DC, 20375-5000.

CC 2 Corrosion Protection by Ion-Beam Assisted Coatings.
W. ENSINGER, *University of Heidelberg, Federal Republic of Germany.* (20 min.)

Coatings prepared using ions with high energies are becoming increasing interesting for application in the field of corrosion. Irradiation with ions with energies up to some ten keV combined

with evaporation or sputter deposition leads to coatings with special properties which are often superior to those obtained by other techniques. High adhesion and low microporosity are of particular importance for prevention of corrosive attack. Ion beam assisted deposition offers some further advantages such as the low process temperature (typically below 200° C) which is important for substrates which undergo undesired phase changes at high temperatures or the high flexibility of the process which permits deposition of multilayers and tailoring the interface between coating and substrate. Elemental coatings such as Al, Ti, Ta and i-C and compound coatings such as nitrides and carbides of Ti and Cr were deposited on iron and steel substrates. Results of electrochemical and immersion corrosion tests in aqueous media like seawater, acetate buffer and dilute acids will be presented and discussed in terms of coating process parameters.

CC 3 Analysis of Porous Silicon-on-Insulator Material.* L. G. EARWAKER, *University of Birmingham, England.* (20 min.)

Silicon-on-Insulator materials are being used in the development of radiation hard VLSI circuits and one promising route is the use of porous silicon. Porous silicon is produced by electrochemically etching selected regions of silicon wafers to produce volumes of highly reactive porous silicon which can easily be converted to dielectric oxide or conducting metal or silicide. This is a collaborative programme involving also the Royal Signals and Radar Establishment, Imperial College, Queen Mary and Westfield College and Liverpool University. We have used accelerator-based techniques to study the behaviour of porous silicon under a range of conditions. Results will be presentded on the pick-up and removal on annealing of carbon and of methods of minimising carbon inclusion during transport. Oxidation behaviour as a function of temperature and different annealing conditions will be presented. Fluorine, which has been reported to improve radiation hardness, has been implanted into porous silicon and is seen to be very mobile even at low temperatures. Finally, preliminary results on metallisation of porous silicon will be presented.

*Supported by IED1625 through the Science and Engineering Research Council.
Associated workers, M C ,Briggs, J P G Farr, J M Keen and M I Nasir.

CC 4 Effects of Rapid, High-Dose, Elevated Temperature Ion Implantation on the Microstructure and Tribology of Ferrous Surfaces.* D. L. WILLIAMSON, *Colorado School of Mines.* (5 min.) (Invited Poster Paper. See Poster Display PB' 6)

High current density, broad-beam ion implantation[1] at 60 keV produces elevated target temperatures that can be controlled by shuttering and variations in thermal contact resistance. Target temperatures near 400 C and above yield unusual near-surface microstructures for nitrogen ion implantation into ferrite (pure iron) and austenite (AISI 304 and 310 stainless steels) as determined by conversion electron Mossbauer spectroscopy, x-ray diffraction and Auger electron depth profiling[2,3]. Appropriate microstructures produce dramatic improvements in sliding wear as characterized by an oscillating pin-on-disc tribo-tester[4,5]. Oxygen and carbon ion implantation under similar conditions is also under investigation.

*Supported by the National Science Foundation.
1. P.J. Wilbur, R. Wei and W.S. Sampath, Mater. Sci. Engr. A116, 215 (1989).
2. D.L. Williamson, Yi Qu, R. Wei, W.S. Sampath and P.J. Wilbur, Mater. Res. Soc. Symp. Proc. 128, 409 (1989).
3. D.L. Williamson, Li Wang, R. Wei and P.J. Wilbur, Mater. Lett. (in press).
4. R. Wei, P.J. Wilbur, W.S. Sampath, D.L. Williamson, Yi Qu and Li Wang, J. Tribology 112, 27 (1990).
5. R. Wei, P.J. Wilbur, W.S. Sampath, D.L. Williamson and Li Wang, J. Lubr. Technol. (in press).

CC 5 Ion Implantation of Polymers for Electrical Conductivity Enhancement.
L. B. BRIDWELL, *Southwest Missouri State University, Springfield.* (20 min.)

CC 6 Metal Ion Implantation into M50 and Tl Bearing Steels for Improved Corrosion Resistance.
B. R. NIELSEN, *Danfysik A/S, Denmark.* (20 min.)

CC 7 The Performance of Ion-Assisted Diamondlike Carbon Coatings. G. DEARNALEY, *Harwell Laboratory, England.* (20 min.)

SESSION CD: ACCELERATOR TECHNOLOGY
Monday evening, 5 November 1990; Union Building, Room 412 at 19:00;
J. W. Butler, Naval Research Laboratory, presiding

CD 1 A High Stopping Power, Segmented Bragg Curve Spectrometer for Heavy-Ion Detection.*
A. D. FRAWLEY, *Florida State University.* (20 min.)

A large acceptance, high stopping power, Bragg curve spectrometer has been developed for use in coincidence experiments with heavy ions. The electron collection fields are radial and position information is obtained from a resistive anode. The detector is 60 cm deep and operates at pressures of up to 2.5 atm of P-10 gas, giving it the ability to stop 12 MeV/u ^{4}He ions. The maximun acceptance is 77 msr. The radial electron collection fields allow a segmented anode to be used, so that multiple hits from the same nuclear reaction can be separated. The detector is mated to a scattering chamber which allows it to cover all angles within a 60° half-angle cone centered on the beam axis. Considerable experience has been accumulated with an unsegmented anode, and the construction of an anode segmented into nine strips is underway. Factors limiting the performance of the detector will be discussed, and results presented.

*Supported by the National Science Foundation.

CD 2 Application of Mass and Energy Dispersive Recoil Spectrometry in Some Industry Related Studies: Oil Additive Tribology and Optical Coating Diagnostics. H. J. WHITLOW, *The Royal Institute of Technology, Sweden.* (20 min.)

CD 3 Some Recent Silicon Detector Spectroscopy Applications at LBL. J. T. WALTON, *Lawrence Berkeley Laboratory.* (20 min.)

The development and fabrication of specialized silicon detectors have long been an integral part of the LBL experimental capabilities. This silicon detector expertise utilizes two technologies, oxide-passivated diffused junction and lithium-ion compensation. These technologies are complementary, with detectors of 10 μm to 500 μm thick fabricated using the diffused-junction process and detectors 500 μm to 10,000 μm using the lithium-ion technique. Particle spectroscopy applications at LBL typically employ a thin diffused, ΔE, detector followed by a thick lithium compensated, E, detector. Novel position-sensitive ΔE and E detectors recently employed in two separate experiments conducted at LBL are described. In addition the requirements for employing thick lithium-compensated detectors in an ongoing LBL double beta decay experiment and a proposed LBL dark matter search are also presented. Future expectations for silicon detector capabilities are briefly outlined.

CD 4 Heavy-Ion Storage Ring for Atomic Physics Vacuum Test Stand for Pressures of 10^{-12} Torr.*
J. W. JOHNSON,[1] *Oak Ridge National Laboratory.* (20 min.)

A vacuum test stand has been constructed and operated to test components and procedures to achieve pressures of 10^{-12} Torr. The 3.5 m-long test stand fabricated from 10-cm-diam components, with 316 LN stainless-steel flanges, approximately models 1/16 of the vacuum chamber for HISTRAP (Heavy Ion Storage Ring for Atomic Physics), a proposed synchrotron/cooler/storage ring accelerator optimized for advanced atomic physics research. The storage ring requires a vacuum of 10^{-12} Torr to minimize losses of highly charged, very heavy ions decelerated to low energies. Prior to assembly, the components were vacuum fired at 950°C at $<10^{-4}$ Torr. The test stand is bakable *in situ* at 300°C. Pressure is measured with two extractor ion gauges and a 10^{-14} partial pressure residual gas analyzer. Rough pumping is by cryosorption pumps followed by a cryopump. Final pumping is by two 750ℓ/s titanium sublimation pumps and one 60ℓ/s ion pump. A pressure of $4X10^{-12}$ Torr has been achieved.

*This research was sponsored by the U.S Department of Energy under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.
[1]Co Investigators are W. H. Atkins, D. T. Dowling, J. W. McConnell, W. T. Milner, and D. K. Olsen.

CD 5 Accelerator Development and New Ventures for Grumman. R. BOTWIN, *Grumman Space Systems.* (20 min.)

Grumman is preparing for tomorrow's world of accelerators. Significant opportunities are forseen for particle accelerators in military scientific and industrial applications. Our work encompasses accelerator design, manufacture of components, and the design of construction of major test facilities for military space accelerators.

In the field of military accelerators Grumman is the principal industrial contractor for development of the U.S. Army's neutral particle beam accelerator for the Strategic Defense Initiative (SDI) program. In civilian applications our interests include high-energy physics research accelerators such as the Superconducting Supercollier (SSC) and Relativistic Heavy Ion Collider (RHIC), accelerators for medical diagnosis and therapy, and accelerators for materials production and lithography.

At Grumman's accelerator technology laboratory in Bethpage, New York, wide-ranging development is in progress on such areas as: Automatic control of ion sources of high brightness; High-precision emittance measurements; High-power continuous wave (CW), radio frequency (RF) drive looops and cavities (RF Quadrupoles, Drift Tube Linacs, and Coupled-Cavity Linacs); RF Quadrupole stabilization techniques; and High-gradient accelerators.

Much of this work is being done in collaboration with the national laboratories. For example, the world's first space-qualified accelerator, successfully operated in space in 1989, was jointly designed by the Los Alamos National Laboratory and Grumman engineers and fabricated by Grumman.

Looking toward the future, we are convinced that the compact, high-power accelerator will continue to evolve into a scientific/medical tool as significant as the laser has proved to be. Grumman's objective is to be a leader in the development and production of the accelerators that will serve these anticipated needs.

CD 6 Undergraduate Research and Teaching with a Small Tandem Accelerator. F. D. CORRELL, *U.S. Naval Academy.** (20 min.)

The U.S. Naval Academy has recently installed an NEC model 5SDH tandem accelerator, primarily to support undergraduate student independent research and several laboratory courses. The accelerator system presently includes the 1.7-MV accelerator, an NEC Alphatross ion source, and one locally constructed, oil-pumped beamline with a general-purpose scattering chamber and an external beam ion milliprobe. The milliprobe was designed and constructed as part of one student honors research project, and will be used in another to study archeological samples by in air PIXE. The laboratory was first used this Spring in a senior-level nuclear physics course to demonstrate inelastic scattering of protons from ^{12}C, further experiments on Rutherford scattering, with emphasis on both the basic principles and on applications to materials analysis, are planned. This Fall, the laboratory will be used in a junior-level modern physics course to demonstrate Moseley's Law and the principles of PIXE analysis.

*James R. Huddle, Jeff Vanhoy, and J.M. Anthony have also made essential contributions to the development of the accelerator laboratory and of the projects described herein.

SESSION CE: SINGLE-EVENT UPSETS

Monday evening, 5 November 1990; Union Building, Golden Eagle Suite A at 19:00;
W. J. Stapor, Naval Research Laboratory, presiding

CE 1 History and Overview of Microelectronic Single-Event Upset in Space. J. C. PICKEL, *S-CUBED.* (25 min.)

As microelectronic feature size continued to decrease in the mid-seventies to allow for higher circuit density, a threshold was passed for a new radiation effect that of single event upset (SEU). The effect is a consequence of the smaller quantity of electronic charge used to represent information in digital circuitry. When this charge became comparable to the charge that could be generated by a single energetic ion in the cosmic ray environment of space, the era of SEU concern began. The predominant effect of SEU is loss of information stored in a memory cell, with no permanent damage. Nonetheless, the scrambling of data in space-borne computer memories continues to be cause for concern among space system designers and users, with problems ranging from nuisance levels of memory reset by ground control to loss of mission due to faulty instructions from a corrupted space computer memory. To a lesser extent, permanent damage effects can occur, such as transistor burnout due to a single ion. Such permanent damage is intolerable to space systems. An overview of single event phenomena and a historical perspective of the developments in single event radiation effects research will be given. Speculation will be made on future trends.

CE 2 Charge Collection in Semiconductors—A Fundamental Process for Single Events.
A. R. KNUDSON, *Naval Research Laboratory.* (25 min.)

Charge from the ionization track of an energetic ion penetrating a semiconductor device can be collected at sensitive nodes by drift, diffusion, and funneling processes and may result in a change of state of a memory cell or logic latch. This review will describe measurements of both the total amount of charge collected and the time dependence of the charge collection process in various test devices and in both bipolar and field effect transistors. Ions (Z=2 to 35) in the energy range form 1 to 70 MeV as well as focussed light from pulsed picosecond lasers have been used to produce charge in these devices. The results of computer simulations of the charge collection process will also be presented.

CE 3 A Proton Beam Facility for Single-Event Research.* K. M. MURRAY, *KM Sciences.* (25 min.)

We describe a charged particle (Z=1 or 2) radiation system developed jointly by KM Sciences, The Naval Research Laboratory, and The Crocker Nuclear Laboratory. The system is used primarily to simulate the space environmental protons and other charged particles with energies from 10 to 70 MeV. These particles in turn produce single events in devices being tested. The system provides a highly reproducible beam combined with precise dosimetric measurement and control to better than 2% for fluxes from 1e8 to 1e12 particles per square cm. The system can also provide chopped single pulses with durations from 0.1 to 10 seconds at intensities up to 3e13 particles per square cm per second.

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Additional contributors to this work are:
C. CASTENEDA, Crocker Nuclear Laboratory, University of California, Davis, CA.
W. STAPOR, U. S. Naval Research Laboratory, Washington, DC.

CE 4 Heavy-Ion Beams for Single-Event Research at Brookhaven—Present and Future.*
P. THIEBERGER, *Brookhaven National Laboratory.* (25 min.)

Since low energy nuclear physics research was discontinued at Brookhaven and replaced by a relativistic heavy ion program, large blocks of time became available at the Tandem Van de Graaff Facility for technological applications and for research in other areas. The main technological application has been the single event upset (SEU) testing of microelectronic devices and this activity has been steadily increasing over the last few years. The ion beam requirements for this type of work are discussed and a description is given of methods used for satisfying these requirements at the Brookhaven facility. Available ion species, energies, ranges, LETs and beam intensities, purity and uniformity are discussed in detail. Characteristics are summarized of a sophisticated and extremely user friendly test chamber and associated hardware and software installed at Brookhaven by a coalition of government agencies and made available for general use. The possibility is mentioned of extending SEU testing to higher energies by using heavy ion beams from a Booster synchrotron now under construction and/or from the existing large alternating gradient synchrotron (AGS). Finally a brief discussion is given of compatibility with other programs and of future availability of low and high energy heavy ions for SEU testing at Brookhaven.

*Supported by the U.S. Department of Energy under Contract #DE-AC02-76CH00016, and an interagency agreement with NASA-Goddard Space Flight Center (GSFC), Naval Research Laboratory (NRL), National Security Agency (NSA), United States Army Strategic Defense Command (USASDC).

CE 5 Single-Event Effects Experiments Using Heavy-Ion Accelerators.*
F. W. SEXTON, *Sandia National Laboratories, Albuquerque.* (25 min.)

Electronics incorporated into spacecraft subsystems encounter a hostile environment that can threaten spacecraft survival. In particular, heavy-ion strikes from galactic cosmic rays, solar flares, and the earth's radiation belts can alter critical data or destroy key components, resulting in loss of mission. This paper will address several specific topics in single event effects, SEE. First, a discussion of how heavy-ion strikes effect integrated circuits will be presented with examples of specific failure mechanisms such as soft and hard errors, power transistor burnout, and latchup. This will be followed by a discussion of how SEE experiments are performed and requisite accelerator characteristics. Energies in the 1 to 10 MeV per nucleon are typically required. However, relativistic beams with GeV/nucleon energies are required for edge-on strikes, characterization of space-based sensors, and the study of dE/dx films. Finally, the application of ion microprobes for detailed analysis of IC response will be discussed.

* This work supported by the U.S. Department of Energy through contract number DE-AC04-76DP00789.

CE 6 Single-Event Effects Rate Predictions in Space. JOHN R. LETAW, *Severn Communications Corporation.* (25 min.)

Computational methods for estimating single event error rates in space are reviewed. Single event effects are a source of error in spacecraft microelectronics caused by the passage of high-energy charged particles such as cosmic rays. These one- or few-bit errors may cause data loss or system malfunctions without any permanent damage to the device. Designers must be assured that errors fall below tolerable limits for their mission. Susceptibility of microelectronic devices is characterized by exposure to proton and heavy ion beams in laboratory facilities. The behavior of devices in space is generally estimated using computational models in conjunction with the accelerator data. Models of the space radiation environment include the CREME (Cosmic Ray Effects on Microelectronics) model of the galactic cosmic ray environment, the AP-8 trapped proton model, and various models of solar flare events. Radiation transport codes determine changes in the radiation environment after passage through the Earth's magnetic field and spacecraft structural materials. Semiconductor device models are used to convert particle fluxes into error rates.

SESSION PA: POSTER SESSION: ATOMIC PHYSICS AND RELATED PHENOMENA, ENERGY LOSS, NUCLEAR PHYSICS

Monday evening, 5 November 1990
Physics Bldg., 1st and 2nd Flrs., at 19:00

PA 1 Reduced Error in σ_{xx} via Nuclear-Coulomb Excited Absolute Detector Efficiency Normalization for Targets with Z=29-79. R.MEHTA*, G.BISSINGER and J.JOYCE, East Carolina U. - Incident proton (1-3 MeV) and helium ion (2-4.5 MeV) excited K x-rays in targets of copper, silver, gold, and dysprosium (natural Dy and isotopic ^{161}Dy enriched) were measured with a HpGe detector (3-200 keV range). The largest error in σ_{xx} was in determining the absolute detector efficiency. The 43.8 keV gamma ray from nuclear-coulomb-excited ^{161}Dy, in combination with an RDE curve, provided absolute detection efficiency for the entire photon energy range. The absolute production cross section were determined by normalizing the K x-ray yields to the integrated incident beam flux, Rutherford scattered ions and 43.8 keV gamma ray yield in the case of Dy targets. The multiple normalization technique reduced the overall errors and allowed for checking the consistency among the various normalization methods.

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PA 2 Angular Dependence of Thick-Target Bremsstrahlung, RAJ AMBROSE, D.L. KAHLER, H.E. LEHTIHET and C.A. QUARLES, Texas Christian U.* Bremsstrahlung spectra are obtained for thick targets of various Z values using a monoenergetic electron beam. Comparisons will be made between experiment and theory for the yields of the spectra collected. The theory

is determined by using a simple model which employs a theoretical bremsstrahlung cross section integrated over the target thickness. The model takes into account electron energy losses and photon attenuation within the target material using tabulated coefficients. It is also intended to investigate the angular dependence of the bremsstrahlung energy distribution focusing on a comparison of this dependence between thin and thick targets. The bremsstrahlung produced at various angles to the incident electron beam is collimated and detected by two hpGe detectors. Results will be presented for incident electron energies from 50 to 100 keV.
* Supported by the Welch Foundation.

PA 3 Atomic-field Bremsstrahlung at Zero Degrees, RAJ AMBROSE, D.L. KAHLER, H.E. LEHTIHET and C.A. QUARLES, Texas Christian U.*-- Bremsstrahlung spectra have been measured for the elements Ag, Te, Tb, Au and U at zero degree photon emission angle with a 100 keV electron beam. The beam was deflected away from the detector by a magnet; however, the dispersion of the electron beam in the target created a background that cannot be subtracted out easily. Hence an alternate approach to magnetic deflection is to stop the beam completely by adding a carbon backing to the thin-film target. The thick-target bremsstrahlung from the low-Z backing, which decreases linearly to zero at the end point, can be subtracted out, and reliable estimates of the cross section can be made. Preliminary investigations show that this method can be used to study a region of about 10 to 15 keV near the endpoint. Results will be presented for various elements from Ag to U for 50-100 keV incident electron energies.
*Supported by the Welch Foundation.

PA 4 Design of a Versatile Pressure Control System for Gas Targets in Ion-Atom Collision Studies, S. FUELLING and R. BRUCH, University of Nevada, Reno. -- For absolute cross section measurements, the gas pressure inside a differentially pumped target cell or jet has to be known accurately and kept constant during the collision experiment. Therefore, a sophisticated electronic feed-back control system has been developed, which consists of a time response optimized feed-back controller which uses the output of an electronic manometer. As pressure sensor a Datametrics absolute Barocel was used. The gas flow was regulated via a Veeco PV10 piezo electric valve. A typical pressure range is 1 mTorr - 10 Torr, depending on type of sensor and application.
*Work supported in part by Hewlett Packard, Xerox Corp. and Bentley Nevada Corp.

PA 5 Absolute State Selective Cross Sections for Ionization-Excitation of Helium in fast H^+ + He and C^{6+} + He Collisions: Z_p-Dependence, S. FUELLING, G. LIU, R. BRUCH, University of Nevada, Reno, E. TRÄBERT, Harvard Smithsonian Center for Astrophysics, P. H. HECKMANN, University of Bochum, Germany. -- We report high resolution EUV measurements of absolute ionization-excitation emission cross sections in the He^+ Lyman series (np -> 1s) for n=2 to 5 following 0.83-2.3 MeV/u H^+ and C^{6+} impact on He gas[1]. The experiment was performed at the Bochum Dynamitron Tandem Laboratory (DTL). These cross sections were placed on an absolute scale by additional studies of electron and proton impact cross sections carried out at the University of Nevada, Reno. Simultaneous ionization plus excitation of He ($1s^2$) is of fundamental importance because it reveals the dynamic aspect of electron correlation due to the Coulomb interaction between the two target electrons and the fast moving projectile ion. It appears that the projectile charge state dependence of the derived cross sections is proportional to Z_p^3 in the energy range used.
[1] E. Träbert, P. H. Heckmann, R. Bruch and S. Fuelling, Nucl. Instr. Meth. B23, 151 (1987)

PA 6 Absolute State Selective Cross Sections for Excitation and Ionization plus Excitation of Helium in H^+ + He, H_2^+ + He and H_3^+ + He Collisions, S. FUELLING, R. BRUCH, University of Nevada, Reno, E. TRÄBERT, Harvard Smithsonian Center for Astrophysics, P. H. HECKMANN, University of Bochum, Germany. -- We present absolute photon emission cross sections for the production of $He^+(np)$ and He $(1snp)\,^1P^o$ states following 50 keV/u to 500 keV/u H^+, H_2^+ and H_3^+ ion impact on He. Experimentally we have measured the extreme ultraviolet (EUV) spectra associated with the HeI $(1snp)\,^1P^o$ -> $(1s^2)\,^1S$ + hv and the HeII $(np)\,^2P^o$ -> $(1s)\,^2S$ + hv electric dipole transitions by means of a 1.5 m grazing incidence monochromator. This study has been performed using the Reno 2 MV Van de Graaff accelerator. The present results have been placed on an absolute scale by HeII L_α produced in 300 eV e^- + He collisions. Furthermore the detection efficiency of our monochromator has been determined by comparing 1 MeV C^+ + Ne spectra from Reno and Bochum[1].
[1] E. Träbert, P. H. Heckmann, R. Bruch and S. Fuelling, Nucl. Instr. Meth. B23, 151 (1987)

PA 7 Detection of Long-Lived Highly Excited Ions by Means of Charge-Stripping Processes.
E. KAMBER, Western Michigan University, Kalamazoo, MI, USA.

See Session Number: GE 8

PA 8 Ion Trap Measurement of U^{64+} X-Ray Transition Spectra.
N.K. DEL GRANDE, Lawrence Livermore National Laboratory, Livermore, England.

See Session Number: JD 5

PA 9 A High Resolution Study of the Extreme Ultraviolet Spectrum of N_2 by Fast Proton and Electron Impact, M. BAILEY, S. FUELLING, R. BRUCH, University of Nevada, Reno. -- High resolution EUV spectra induced by 100 - 1500 keV proton and 100 - 1000 eV electron impact on molecular nitrogen were studied in the spectral region from 20 to 90 nm. A mass and momentum analyzed proton beam from the University of Nevada, Reno 2 MV Van de Graaff accelerator was collimated and passed through a differentially pumped gas cell. The radia-

tion resulting from H^+ impact was observed at an angle of 90° to the beam direction and wavelength dispersion was accomplished through a 1.5 m grazing incidence monochromator. The present work includes EUV emission studies of atomic and molecular nitrogen as well as e^- + He data to place our emission yields on an absolute scale.

*Work supported by Research Corporation, Edwards High Vacuum International, Kinetic-Systems and Acton Research Corporation.

PA 10 Angular Distribution of Decay Products in Resonant Processes.
Y. HAHN, University of Connecticut, Storrs, CT.

See Session Number: IC 6

PA 11 Total Charge Transfer Cross Sections for 100-1500 keV Multiply Charged Carbon, Nitrogen, and Oxygen Ions in Collisions with Gaseous He, Ne, and H_2O Targets. M. ROTTMANN, R. BRUCH, University of Nevada, Reno, R. D. DuBOIS, L. H. TOBUREN, Pacific Northwest Laboratory. -- Absolute measurements of charge transfer cross sections for C^{q+}, N^{q+} and O^{q+} (q = 1-3) ion impact on He, Ne and H_2O are presented as a function of the projectile energy, mass and charge state. The experimental results are compared with earlier work.

*This work was supported in part by the Office of Health and Environmental Research, U.S. Department of Energy Contract No. DE-AC06-76RLO 1830.

PA 12 The Intensity Distribution of Ion-Induced $K\alpha L^n$ X-R Satellites and the Geometrical Model. B. SULIK and I. TÖRÖ Institute of Nuclear Research of the Hungarian Academy of Scien Debrecen, Hungary*, A. ÁGOSTON, BIOGAL Pharmaceuti Works, Debrecen, Hungary - - Light element (Mg, Al, Si, Ca, $K\alpha L^n$ x-ray satellites have been measured by a crystal spectro ter. The x-rays were induced by p and He^+ bombardment at sev energies. Additional data have been collected from the literature c ering a wide energy range and also for other bombarding particles some cases more than two orders of magnitude of projectile energ covered. Using the experimental data diagrams were constructe show, how the different satellite lines shared in the total Kα inten The predictions of the geometrical model[1] are compared to these agrams. These comparisons help to improve the model calculatio

* Supported by OTKA-grant No. 1184-1185.

[1] B. Sulik, I. Kádár, S. Ricz, D. Varga, J. Végh, G. Hock and D. Berényi, Nucl Instrum. Meth. B28,509(1987).

PA 13 MULTIPLE COLLISION ANALYSIS OF CHARACTERISTIC X-RAYS FROM 50-600 keV ARGON STOPPING IN Mg, Al, and Si.* Sam J. Cipolla, Creighton U. --- Thick target analysis has been used to obtain Ar-L x-ray and target K-vacancy production cross sections for these collision systems. Assuming Ar L vacancy equilibrium, the data have been rendered to yield information on the L-vacancy lifetime and fluorescence yield. The results will be compared and discussed in relation to the dependence on projectile energy and target atomic number.

*Work performed at the U. of Nebraska-Lincoln and supported by NSF Grant PHY-8401328.

PA 14

K-x-ray cross sections by proton bombardment E.ROSATO, Phys. Dept., Un. of Napoli (Italy)---Proton-induced K-x-ray cross sections (σ_{KX}) are presented for all Z=4÷92 elements over a wide bombarding energy range. The σ_{KX} values are derived by performing fit in terms of weighted orthonormal polynomials to almost all the measurements available from the literature (at present the data base includes more than 4500 points). Original σ_{KX} points are carefully screened to ascertain their precisioin and accuracy and to check statistical compatibility among measurements from various authors and/or different techniques. Experimental data are also grouped in intervals of suitable width for reducing bias in favour of mostly measured elements and washing out unavoidable fluctuations. Several methods are discussed for combining incompatible σ_{KX} and removing statistical inconsistencies both on a local and a global basis. The σ_{KX} estimates are precise and accurate and their uncertainties are noticeably smaller than the errors of any single measurements. Therefore, they could be profitably used for PIXE analysis, calibrating x-ray detectors and testing theoretical models of inner-shell ionization. Present results are compared to empirical and analytical cross section formulae.

PA 15 Increased Binding Effects in L-Subshell Ionization of Nd, Gd, and Er Charged Particles. L.A. Rayburn*, Department Physics, University of Texas at Arlingt L-subshell x-ray production cross sections Nd, Gd, and Er for incident deuterons (0.40 2.00 MeV) and alpha particles (0.60 to 2 MeV) were measured using standard techniqu It is possible to isolate two effec Coulomb-deflection and increased-binding (wh are part of the Perturbed Stationary Sta (PSS) theoretical treatment of this phenomen by forming ratios of the production cr sections for equal velocity pairs of particl The PSS theory provides a good fit to experimental results for the Coulomb-deflect effect for all three subshells for these s three elements[2]; however, it does not provid good fit for the increased-binding effect.

[1] W. Brandt and G. Lapicki, Phys. Rev. A 465(1979).

[2] L.A. Rayburn, Nucl.Instr. and Me B40/41(1989)113.

*Retired:Present address:231 Whittier La Oliver Springs,TN 37840,USA.

PA 16 K-Shell X-Ray Production Cross Sections in $_6$C, $_8$O, $_9$F, $_{11}$Na, $_{12}$Mg, and $_{13}$Al for 0.75 to 5 MeV H and Li Ions. Y.C. YU, M.R. MCNEIR, D.L. WEATHERS, J.L. DUGGAN, AND F.D. MCDANIEL, *Dept. of Physics, University of North Texas, Denton, TX 76203, USA*, and G. LAPICKI, *Dept. of Physics, East Carolina University, Greenville, NC 27858, USA.*--K-shell x-ray production cross sections are reported for elements with K-shell x-ray energies between 282 eV (C) and 1487 eV (Al). X-ray measurements were made with a Link Analytical windowless Si(Li) x-ray detector. The Si(Li) detector was calibrated for efficiency by comparing atomic-field bremsstrahlung spectra from electron bombardment of thin foils with true bremsstrahlung spectral distributions which are known to 5%.[1] X-ray production cross sections are compared to first Born[2] and ECPSSR[3] theories for direct ionization (DI) and electron capture (EC).

*Work supported in part by the State of Texas Coordinating Board, the Robert A Welch Foundation, the NSF, the ONR, Texas Instruments Inc., Texas Utilities Electric Co., and International Digital Modeling Corp.

[1] L Kessel, C A Quarles, and R H. Pratt, At. Data Nucl. Data Tables 28, 381 (1983).

[2] PWBA for DI and OBK for EC.

[3] W. Brandt and G. Lapicki, Phys. Rev. A23, 1717 (1981) for DI and G. Lapicki and F.D. McDaniel, Phys. Rev. A22, 1896 (1980), A23, 975 (1981) for EC. ECPSSR = Energy loss and Coulomb deflection effects, Perturbed Stationary State approximation with Relativistic effects.

PA 17 Measurement of the Ratio of L_{III}/L_I Ionization by Fast Heavy Projectiles.* TOM J. GRAY and NABIL MALHI, James R. Macdonald Lab, Kansas State University, Manhattan, KS--We have measured the ratio of the X-ray production cross sections for the $L\alpha_{1,2}$ (L III subshell) and $L\gamma_{2,3,(6)}$ (L I subshell) for H, Li, Be, B, C, N, O, F and Si ions over an incident velocity range of 0.5 to 3.0 MeV/amu. Our results strongly suggest that distortion effects in the entrance channel should be considered in describing inner shell ionization by heavy projectiles. Specifically, the ratio, $\sigma_{L\alpha_{1,2}}/\sigma_{L\gamma_{2,3,(6)}}$, is a strong function of the projectile, Z_1. Multiple ionization effects cannot explain the measured variations in this ratio as a function of Z_1. Current theoretical descriptions such as the ECPSSR[1] model are not in agreement with our measurements.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.
[1] W. Brandt and G. Lapicki, Phys. Rev. A 23, 1717 (1981).

PA 18 L-Shell X-Ray Production Cross Sections in $_{20}$Ca, $_{26}$Fe, $_{28}$Ni, $_{29}$ and $_{32}$Ge for 0.75 to 5 MeV H and Li Ions. M.R. MCNEIR, Y.C. YU, T WEATHERS, J.L. DUGGAN, AND F.D. MCDANIEL, *Dept of Phy University of North Texas, Denton, TX 76203, USA*, and G LAPICKI, *D of Physics, East Carolina University, Greenville, NC 27858, USA* --L-shel ray production cross sections are reported for elements with L-shell x- energies between 303 eV (Ca) and 1216 eV (Ge) X-ray measurements v made with a Link Analytical windowless Si(Li) x-ray detector The Si detector was calibrated for efficiency by comparing atomic-f bremsstrahlung spectra from electron bombardment of thin foils with t bremsstrahlung spectral distributions which are known to 5%.[1] X- production cross sections are compared to first Born[2] and ECPSSR[3] theo for direct ionization (DI) and electron capture (EC).
*Work supported in part by the State of Texas Coordinating Board, the Rob A. Welch Foundation, the NSF, the ONR, Texas Instruments Inc , Te Utilities Electric Co., and International Digital Modeling Corp.
[1] L. Kessel, C.A. Quarles, and R.H Pratt, At. Data Nucl. Data Tables 28, (1983).
[2] PWBA for DI and OBK for EC.
[3] W. Brandt and G. Lapicki, Phys. Rev. A23, 1717 (1981) for DI and Lapicki and F.D. McDaniel, Phys. Rev. A22, 1896 (1980), A23, 975 (1981) EC. ECPSSR = Energy loss and Coulomb deflection effects, Perturl Stationary State approximation with Relativistic effects.

PA 19 High-Resolution Heavy-Ion-Induced X-ray Satellite Emission Study of Implanted Sulfur as a Probe of Co-Implanted Oxygen in an Oxide Matrix.* T. M. Rosseel, J. P. Young, C. R. Vane., R. A. Zuhr, Oak Ridge National Laboratory and R. S. Peterson, Department of Physics, University of the South.-- A series of quartz glass targets have been implanted to a depth of 90 nm with approximately equal doses of 70 keV sulfur and 35 keV oxygen ions ranging from 0.5 to 10 x 10^{16}/cm^2 at the ORNL Surface Modification and Characterization Facility. Using high-resolution measurements, the relative fluorescence yields of the sulfur KL^n X-ray satellite lines, produced by the excitation with 24 MeV Si ions extracted from the ORNL EN-Tandem, have been determined and compared to a series of quartz glass targets implanted with sulfur only. The data exhibit lower yields for the co-implanted oxygen samples but similar dose dependent curves. These results are consistent with oxygen increasing the valence electron density of the local sulfur environment. It also suggests that, with the appropriate choice of a probe ion, HIXSE may be capable of detecting a wide range of impurity ions including even oxygen in oxide substrates.

*Research sponsored by the U. S. Department of Energy, Office of Energy Research, under contract DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

PA 20 Z-Dependence of K-Shell Ionization at 30 MeV/amu.* V HORVAT, R L. WATSON, G. SAMPOLL, and T. LOTZE, Texas A&M University. -- The projectile and target Z-dependences of K-shell ionization by fast projectiles are being investigated via K x-ray measurements. Thin targets of elements ranging from Al to Zn are bombarded with a variety of 30 MeV/amu ion beams ranging from protons to Ar and the spectra of target K x-rays are observed with an Si(Li) detector. Absolute cross section measurements are performed for Cu by detecting the projectile ions directly in a surface barrier or microchannel plate detector placed immediately behind the target and recording the x-rays in coincidence with the particles. Cross sections for the other elements are made relative to those determined for Cu. One of the main objectives of these experiments is to test the projectile Z-dependence of K-shell ionization for projectile to K-electron velocity ratios spanning the region from 1.31 to 3.25.

*Work supported by the Division of Chemical Sciences of the U.S. Department of Energy and the Robert A. Welch Foundation.

PA 21 The availability of the $L_2L_3M_4$ Coster-Kronig Transition at Z = 93. P.N. JOHNSTON, Royal Melbourne Institute of Technology --- The availability of $L_2L_3M_4$ at Z=93 is of interest as a test of relativistic calculations of Coster-Kronig electron energies. In addition, the low energy photon intensity standard, ^{241}Am, decays to ^{237}Np producing neptunium L X-rays. This decay is complex and atomic branching processes play an important part in final balancing of the decay scheme. In the present work, using proton ionisation of ^{234}U and ^{237}Np targets, systematic behaviour of ionisation cross-sections and atomic branching ratios indicate $L_2L_3M_4$ is energetically available, contrary to relativistic theory.

PA 22 Photoion Auger-Electron Coincidence Measurements Near Threshold
J.C. LEVIN, University of Tennessee, Knoxville and Oak Ridge National Laboratory, Knoxville, TN.

See Session Number: FA 7

PA 23 Low Momentum Electron Scattering from Protons
H. CRANELL, California Institute of Technology, Pasadena, CA, USA.

See Session Number: BB 6

PA 24 Electron Energy Distributions in Multiply Ionizing Collisions, Differential in Recoil Charge States.
H. SCHOENE, Oak Ridge National Laboratory, Oak Ridge, TN, USA.

See Session Number: GE 9

PA 25 Evidence for Two Path Interference of Coulomb Focussed Electrons in Low Energy He^+ + He Collisions.
J.K. SWENSON, SAIC, San Diego, CA, USA.

See Session Number: IC 8

PA 26 Study of the Line Shape of Auger Electrons Excited Direct Ionization and Electron Capture. T. VAJNAI*, L. SARKA Á. KÖVÉR and J. VÉGH, Institute of Nuclear Research of t Hungarian Academy of Sciences, Debrecen, Hungary - - The exc tion of Auger electrons by electron capture (in contrast to direct i ization) in collisions of atoms with singly charged ions is not influen by post collision interaction (PCI) effects in lack of charged out ing particles. The detection of the Auger electrons following capt thereby represents a unique method to establish a reference line sh

which is free of PCI distortions. In the present work we have stud the shape of the L_3-$M^2_{2,3}(^1S_0)$ Auger line of argon excited by 0.7 M protons detecting the electrons in coincidence with the neutrali outgoing H^0 atoms and without it. The non-coincidence spectr (originating dominantly from direct ionization) shows a considera shift and asymmetry of the peak compared to the peak of the coi dence spectrum.

*On leave from Technical University for Heavy Industry, Misk Hungary

PA 27 Double Differential Cross Sections for Electron Capture to the Continuum of Bare H and He Projectiles in Noble Gases and Hydrocarbons.
G. BISSINGER, East Carolina University, Greenville, NC, USA.

See Session Number: IC 10

PA 28 Angular Distribution for Electron Capture From He By Low Velocity Ar^{6+} Ions.
W. WAGGONER, Hastings College, Hastings, NE, USA.

See Session Number: GE 6

PA 29 Electron Capture by O^{8+} from Aligned Molecular Deuterium.
S. CHENG, J.R. Macdonald Lab, Kansas State University, Manhattan, KS, USA.

See Session Number: GE 7

PA 30
Two electron capture in collisions of fully stripped ions with Helium* Z. Chen, R. Shingal and C.D.Lin, Department of Physics, Kansas State University, Manhattan, KS 66506 Adopting an independent electron approximation, the double capture cross sections to individual doubly excited states for bare ions colliding with Helium in the keV/amu range are calculated. The double capture amplitudes are obtained by properly weighting with the configuration interaction coefficients the single capture amplitudes which are calculated using the two-center atomic orbital close coupling method. The calculated cross sections are compared with recent high resolution electron spectroscopy experiments. The dominant states populated in the collision are generally well predicted.

* Work supported by the Division of Chemical Sciences, Office of Basic Energy Science, Office of Energy Research, U.S. Department of Energy.

PA 31 Direct Ionization and Electron Capture in K-Shell X-Ray Product in Fluorine by Highly-Charged Boron, Carbon, and Oxygen Ion D.K.MARBLE, F.D. MCDANIEL, J.L. DUGGAN, M.R. MCNEIR, Y.C. Z Y ZHAO, D.L. WEATHERS, AND P.S. ELLIOTT, *Dept. of Phys University of North Texas, Denton, TX 76203, USA.* R.M. WHEELER A R.P. CHATURVEDI, *Dept. of Physics, State University of New York Colle Cortland, NY 13045, USA,* G. LAPICKI, *Dept. of Physics, East Carol University, Greenville, NC 27858, USA*--Measurements of fluorine K-sl x-ray production cross sections are reported for thin solid targets of YF a function of ion charge state, q. To determine target thickne corresponding to near single-collision conditions, x-ray measurements w made for targets of thickness 2 - 66 micrograms/cm^2 deposited o micrograms/cm^2 carbon backings. Cross sections for electron capture to K-shell of the ion and the sum of cross sections for direct ionization to continuum and electron capture to the L, M, N, etc. shells are inferred fr the charge-state dependence of the data. Experimental procedures discussed as well as comparisons to theory.

*Work supported in part by the NSF, the ONR, Texas Instruments, Inc., State of Texas Coordinating Board, and the Robert A. Welch Foundation

PA 32 RTE Interference Calculations.
T. REEVES, Coastal Carolina College, Conway, SC.

See Session Number: IC 9

PA 33 Single Electron Capture by High Velocity Bare and One-Electron Projectiles in Collisions with Molecular Hydrogen.* J.M. SANDERS, TRACY N. TIPPING, JAMES HALL,† J.L SHINPAUGH, D.H. LEE, and PATRICK RICHARD, J.R. Macdonald Lab, Kansas State Univ., Manhattan, KS 66506--Total cross-sections for single electron capture by 0.5-2.5 MeV/A bare and hydrogen-like F and O projectiles on molecular hydrogen have been measured. The measured cross sections are compared with empirical, semi-empirical, and theoretical calculations.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Science, Office of Energy Research, U.S. Department of Energy.
† Permanent Address: Lawrence Livermore National Laboratory, Livermore, CA

PA 34 Electron Capture and Excitation Studied by State-Resolved *KLL* Auger Measurements in 0.25-2 MeV/u $F^{7+}(1s^2\ ^1S, 1s2s\ ^3S)$ + H_2/He Collisions.* D.H. LEE, P. RICHARD, T.J.M. ZOUROS,† J.M. SANDERS, J.L. SHINPAUGH, and S.L. VARGHESE,‡ J.R. Macdonald Lab, Kansas St. U.--State-resolved *KLL* Auger cross sections were measured for collisions of 0.25-2 MeV/u $F^{7+}(1s^2\ ^1S, 1s2s\ ^3S)$ with H_2 and He targets at 0°. The mechanisms for forming the $1s2\ell2\ell'$ and $2s2p\ ^{2S+1}L$ Auger states were identified to be single electron capture, $1s \rightarrow 2p$ excitation, and nonresonant and resonant transfer excitation (RTE) by the $1s^2\ ^1S$ ground or $1s2s\ ^3S$ metastable states of the incoming projectile ions. Using known metastable beam fractions,[1] the cross sections for the formation of the excited states were extracted and compared with theory. The $1s2s2p\ ^4P$ state showed a projectile energy dependence of E_P^{-n} (n=~4.2 for He and ~5.2 for H_2 targets) in electron capture. The other $1s2\ell2\ell'\ ^{2S+1}L$ states exhibit RTE.
* Supported by the Div. of Chemical Sciences, Office of Basic Energy Sciences, Off. of Energy Research, U.S. Dept. of Energy.
† Physics Dept., Univ. of Crete, Iraklion, Crete, Greece.
‡ Physics Dept., Univ. of S. Alabama, Mobile, AL 36688, USA.
[1] T.R. Dillingham *et al.*, Phys. Rev. A 29, 3029 (1984).

PA 35 Satellite and Hypersatellite Structure in the K-Auger Spectrum of Carbon Following Collisions of C^{6+} with He.
J.M. ANTHONY, U.S. Naval Academy, Annapolis, MD.

See Session Number: IC 7

PA 36 Transition from the Quantum to a Classical Limit on the Atomic Scale.* J.H. MCGUIRE, JACK C. STRATON, Y.D. WANG, and L.O. WEAVER, J.R. Macdonald Lab, Kansas State U.--A projectile of charge Z carrying N electrons may be described at high collision velocities in the Born approximation by an effective charge $Z_{eff}^2(Q)$, which varies with the momentum transfer, Q, of the projectile. At small Q, Z_{eff}^2 goes to $(Z-N)^2$ corresponding to coherent quantum amplitudes. At large Q, Z_{eff}^2 goes to Z^2+N corresponding to incoherent scattering by all of the constituent particles of the projectile. This incoherent

limit corresponds to the free collision model of Bohr. We discuss the transition from coherence to incoherence and suggest experiments to observe this transition which is related to the so called "measurement problem" of quantum mechanics.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

PA 37 Anisotropy of Polarized X-Ray Emission from Free Molecules
S.H. SOUTHWORTH, National Inst. of Standards and Technology, Gaithersburg, MD.

See Session Number: FA 5

PA 38 Angular Distribution and Linear Polarization in Dielectronic Recombination of Lithiumlike Nickel.* C.P. BHALLA, Physics Dept., Kansas State U., K.R. KARIM, Physics Dept., Illinois State U., and M WILSON, Physics Dept., Royal Holloway and New Bedford College (U. of London).--Recent experiments[1] with LLNL EBIT (electron-beam ion trap) and KSU EBIS (electron-beam ion source) have made it possible to measure the differential dielectronic recombination (DR) cross sections as a function of electron energy. The doubly excited states produced in DR are collisionally aligned[2] and the stabilizing x-rays in DR have characteristic angular distributions. In addition these x-rays are, in general, linearly polarized. We present here the results of our calculations.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U S. Department of Energy, and in part by the SERC Rutherford Appleton Laboratory.

[1]D.A. Knapp, *et al* , Phys. Rev. Lett. 62, 2104 (1989); C.L. Cocke, *et al.*, Bull. Am. Phys. Soc. 35, 1155 (1990).
[2]C.P. Bhalla, Phys. Rev. Lett. 64, 1103 (1990).

PA 39 Vibrational Excitation Effects on Core Exciton Spectra
W.L. O'BRIEN, University of Tennessee, Knoxville, TN, USA.

See Session Number: FA 3

PA 40 Test System for Creation and Trapping of Low Energy H^- Ions.* KI KI HOSEA and R.A. KENEFICK, Texas A&M University.--- An apparatus for *in situ* production of a small number ($<10^4$) of calibration H^- for the cooling and launching region of the LANL antproton gravity experiment has been developed. Hydrogen ions are detected at high sensitivity in an ICR (flat rectangular electrode structure) trap by a marginal oscillator. It is operated with synthetic Q chosen at 2000-4000 which is possible with very low-level RF injection at the selected cyclotron resonance frequency in the 2 to 4 MHz range. Resonance scanning and signal averaging are achieved by magnetic field modulation at very low frequency. Differences in ion signal with sign of dB/dt due to Faraday e.m.f. are observed and analyzed. These differences can be a useful technique to distinguish H^- from H^+ ions. Resonance spectra of H^+, H_2^+, and H_3^+ are analyzed for optimization of the detection sensitivity for the H^- ions. An interesting and useful ion signal response when the marginal oscillator is driven slightly off resonance is analyzed. The capture mechanism for H^- using swept trap electrode potentials is described and results for this method are discussed.

* Work supported by the Department of Energy under contract No. W7405 ENG-36

PA 41 Atomic Physics Research with 2nd and 3rd Generation Synchrotron Light Sources
B. M. JOHNSON, Brookhaven National Laboratory, Upton, NY, USA.

See Session Number: FA 1

PA 42 Theoretical description of the anomalous q-dependence of the zero degree binary peak in F^{q+} + H_2 collisions.
C.O. REINHOLD+, D.R. SCHULTZ and R.E. OLSON
Department of Physics, University of Missouri-Rolla.*
The anomalous q-dependence of the zero degree binary peak recently observed by Richard et al. [1] is explained in terms of the differences between scattering of target electrons by either a bare or clothed projectile. Calculations have been performed using the impulse approximation. That is, the convolution of the quantum mechanical elastic cross sections and the target momentum distribution were calculated. The non-Coulomb phase shifts due to the screened projectile - electron interaction were obtained by direct integration of the radial Schroedinger equation and using Hartree-Fock model potentials. Excellent agreement is obtained between theory and experiment.

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* Supported by the Office of Fusion Energy of the U.S. D.O.E.
1. P. Richard, D.H. Lee, T.J.M. Zouros, J.M. Sanders and J.L. Shingpaugh, J. Phys. B 23, L213 (1990).

PA 43 Excitation of the Na 3p Level by Light Ions in the Intermediate Energy Range, A. SEN, H. S. KINDLE, and X. LI, University of Toledo--An ion-atom collision apparatus has been built for the measurement of excitation processes in the energy range 30-300 keV. The light ions (H^+, H_2^+, H_3^+) produced in a Danfysik accelerator system are intersected with a sodium beam from an effusive source. The excitation of the Na(3p) level is measured by recording the 3p→3s resonance emission in a photomultiplier tube with a narrow band filter. The measured cross sections are normalized with respect to the calculations made by Theodosiou[1].

[1] C.E. Theodosiou, Phys. Rev. A 36, 3067 (1987)

PA 44 Molecular Studies Using Imaging Time-of-Flight Techniques
M. MERON, Brookhaven National Laboratory, Upton, NY, USA.

See Session Number: FA 8

PA 45 Collisional Dissociation of HD_2^+ Molecular Ions in H_2 in the Energy Range 1.5 - 5.0.
C. CISNEROS, Instituto de Fisica, UNAM, Cuernavaca, Mor., Mexico.

See Session Number: IC 11

PA 46 2- and 3-Electron Processes in H_3^+-He Collisions.* O. Yenen, B.W. Moudry, D.H. Jaecks, and M.E. Rudd, University of Nebraska-Lincoln-- Most collision studies to date, involving many-electron processes, are confined to highly charged atomic ions at high velocities. To expand the measurements to molecular ions and velocities of the order of 1 a.u., we have measured the energy spectra of electrons resulting from collisions of 30-120 keV H_3^+ with He. The spectra show the well-known autoionizing states of He and the $He^-(1s2s^2)$ Feshbach resonance. The latter is produced by a transfer and excitation mechanism, a 2-electron process. The singlet autoionizing states of He are also formed by a 2-electron process whereas the triplet autoionizing states result from 3-electron processes. The energy dependence of these 2- and 3-electron processes will be discussed and a molecular orbital (MO) model will be used to explain our observations.

* Work supported by the National Science Foundation under Grant PHY-8701905.

PA 47 Angular distributions of H^- fragment fror H_2^+ on Mg at low keV collisions.* C. Cisneros, I. Alvarez, J. de Urquijo, and H. Martinez. Instituto de Fisica, UNAM, Cuernavaca, Mor., 62191 Mexico. Differential cross sections are presented for the production of H^- fragment produced in co--llisions of H_2^+ with Mg at collision energies 1.0, 2.0, 3.0, 4.0, and 5.0 keV. The measured angular distributions fit a scaling law[1] $(1/E_{inc})d\sigma/d\Omega = f(E_{inc}\ \theta^2)$. Three interesting structures are observed at 13 keV-deg², 23.6 keV-deg² and 40 keV-deg². The peaks suggest that the mechanism for producing the H^- fragment is a two step process, that is, $H_2^+ + Mg \rightarrow H_2 + Mg^+ \rightarrow H + H + Mg^+$, and $H + Mg \rightarrow H^- + Mg^+$.

*Research partially supported by CONACyT and DGAPA.
[1]C. Cisneros, I. Alvarez, C. F. Barnett, J. A. Ray, and A. Russek, Phys. Rev. A14, 88 (1976).

PA 48 Angle-differential cross sections for collisions of H^- with He. V. MA, C. E. THEODOSIOU, and T. J. KVALE,* Univ. of Toledo-- The angle-differential cross sections for the elastic scattering of H^- by He have been calculated within the unitarized Born approximation for various impact energies. Our calculations verify previous predictions by Theodosiou,[1] based on a simple Born approximation, of the existence of a sharp minimum in the cross sections at small scattering angles due to the internal structure of H^-. Our data will be compared with the available experimental data.[2,3]

* Supported by US DOE Grant DE-FG05-88ER13971
[1] C. E. Theodosiou, Bull. Am. Phys. Soc. 34, 1358 (1989); Phys. Rev. Lett. (submitted)
[2] M. P. McCaughey and J. A. Bednar, Phys. Rev. Lett. 28, 1011 (1972)
[3] V. Esaulov, D. Dhuicq, and J. P. Gauyacq, J. Phys. B 11, 1049 (1978)

PA 49 Analysis of Emittance Growth in an H^- Beam with Xenon Gas Neutralization,* T. W. Debiak, G. Gammel, Y. C. Ng, and J. Sredniawski, Grumman Corporation --- Introduction of a gas, like xenon or argon, into the transport channel of an ion beam may be used to reduce the emittance growth due to nonuniform beam density. Measurements of beam emittance of an H- beam with and without gas neutralization will be presented at various perveance values and drift space distances. Preliminary analysis of these results indicates that the fractional reduction of emittance growth is greater as the length of the drift space increases. Results of a computer simulation that uses the electron loss cross-sections for H^- and Xenon to model the amount of space-charge neutralization will be presented. The purpose of this model is to obtain a theoretical basis for quantitatively understanding these results.

*Work supported by Grumman IRAD contract 7222-3002

PA 50 Measurements and Simulations of Emittance Growth of an H^- Beam from an LBL Volume Source,* G. Gammel, T. W. Debiak, Y. C. Ng, and J. Sredniawski, Grumman Corporation --- Measurements of emittance and emittance growth in an H^- beam extracted from an LBL volume source will be presented. Effects of introducing cesium into the arc chamber will be shown. Some differences are noted, depending on whether cesium is actively entering the chamber or whether the source is running on residual cesium. Also, the effect of beam perveance will be shown. At a fixed location, the dependence of emittance on perveance is similar to the dependence of beam width on perveance, as if emittance is proportional to beam divergence. This data will be compared with WOLF simulations of emittance growth at different currents, with a non-uniform initial current density distribution.

*Work supported by Grumman IRAD contract 7222-3002

PA 51
Measurements of the post collisional interaction and Stark effect in Auger decays from He^+ on He. ROBERT DESERIO, University of Tennessee and Oak Ridge National Laboratory. Measurements of the cross section, doubly differential in energy and emission angle, have been made of Auger electrons produced in He^+ on He collisions at beam energies of 15, 35, 50 and 65 keV. Both target and projectile Auger electrons have been observed. Target electrons experience a strong "Coulomb focussing" affect — enhancing the cross section as much as an order of magnitude within a few degrees of the forward direction. The unfocussed, forward-directed projectile Augers provide a sensitive test of apparatus effects that can be used in the analysis. The measurements also provide an opportunity to test other theoretical predictions. The detailed energy and angular distributions are a sensitive probe of the precursor excited states formed in the collision. Recent calculations indicate that the strong Stark fields of the ions in the ion-atom complex are expected to produce observable effects. *Work supported in part by the National Science Foundation and by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Chemical Sciences, under Contract No. DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

PA 52
Measurements of two-center electrons from low-energy H^+ on He collisions. ROBERT DESRIO, University of Tennessee and Oak Ridge National Laboratory. For electron capture to the continuum in ion-atom collisions, it is well known that the Coulomb interaction produces a "1/v" or "cusp" singularity in the electron velocity distribution at the projectile velocity. Measured distributions at high collision energies have been used to test predictions of the multipole content of the density matrix describing the captured electron. For the present measurements at 10-70 keV, the larger range of electron velocities measured make multipole expansions of limited value. Only a complete description of the production and emission process

in the fields of both the residual target ion and the projectile ion is expected to compare well with the data. Indeed, recent classical trajectory Monte-Carlo and CDW-EIS calculations which both include two-center effects appear promising, though not completely satisfying. The present measurements show peaked angular distributions at electron velocities where the effect of both ions should be comparable. *Work supported in part by the National Science Foundation and by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Chemical Sciences, under Contract No. DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

PA 53

In-beam Study of Spin Density Oscillations in Ferromagnetic Fe-based Alloys using ^{67,69}Ge isomers. C.S.LEE, P.RAGHAVAN*, Rutgers Univ.+ and R.S.RAGHAVAN, AT&T Bell Lab. Since the first in-beam observation[1] of spin density oscillations(SDO) of conduction electrons in $Fe_{1-x}Ge_x$ alloys using a ^{67}Ge isomer was reported, we have continued the measurement of SDO using a microsecond isomer, ^{69}Ge. The isomeric state in ^{69}Ge was populated in the ^{56}Fe(^{16}O,2pn) reaction with the pulsed ^{16}O beam at the energy of 56 MeV, and the magnetic hyperfine fields at the Ge-nucleus site were measured via the TDPAD technique. The observed set of multiple precession frequencies proves constant, independent of the solute concentration, and the deduced spin density manifests itself the oscillatory nature as a function of interatomic distance. The radial dependence of SDO is extracted up to the third nearest neighbor and the combined works using both ^{67,69}Ge isomers will be discussed in the framework of the Ruderman-Kittel-Kasuya-Yosida interaction.

* Present address: AT&T Bell Laboratories, Murray Hill, NJ.
+ Supported in part by the National Science Foundation.
1) C.S. Lee, *et al.*, Bull. Am. Phys. Soc. 30(1985)741.

PA 54

Test System for Trapping and Resistively Cooling H⁻ to Cryogenic Temperatures* S. Cornford and R. A. Kenefick, Texas A&M University--- A Penning Trap held at 4 K which is suitable for demonstration of resistive cooling of H⁻ ions, or antiprotons in the LANL antiproton gravity experiment, is described. Circuit Q in the range 3500-12000 is achieved using opposed superconducting solenoids which resonate with two of the four-quadrant ring electrodes. A Q of 600 is achieved using an identical copper solenoid pair. The normal-mode trap resonances are driven and detected during optimization of the system performance. Current lifetime and cooling results are presented and discussed.

* Work supported by the Department of Energy under contract No. W7405 ENG-36

PA 55 Radiative Lifetime Measurements Using an Argon Ion-Beam. SCOTT A. YOUNG and CHARLES E. HEAD, Univ. of New Orleans -- Using an Ar+ ion beam in the 30 to 35 keV energy range, we have obtained several radiative decay curves for the upper levels of the 407.2-nm, 434.8-nm and 454.5-nm transitions of Ar+. All curves were subjected to a systematic deletion-of-points curve fitting routine to assess the effects of cascades. Based on fits to the decay curves we estimate these lifetimes to be about 8.0 ns, 7.0 ns, and 9.5 ns, respectively. Uncertainties in the first two values are estimated to be about 0.5 ns; and in the third value, about 1.0 ns.

PA 56 Injection and Confinement of Beam Ions* **Lisheng Yang and D. A. Church**, Texas A&M University Ions from a 2keV Ar^+ beam (a few nA current) were captured into an electro-static ion trap (Kingdon Trap) and stored for as long as 100 msec. The containment time was limited by the chamber pressure of 2×10^{-7} Torr. The trap is made of an Al cylinder, 4" in diameter by 6" long, with a central tungsten wire of diameter 0.0025". Fast (100 ns fall time), high voltage pulses (1.9kV→0V) with various durations of up to 100 ms were fed to the wire to turn the trap on and off. The cylinder was held at a constant potential ≈1.9kV. The ions were dumped at the end of each storage interval and a fraction of them was measured by a microchannel plate. A signal to background ratio of 10 was achieved. The number of ions was found to decrease exponentially with a time constant of 60 ms due to collsions with the residual gas. The technique is being extended to slow, highly-charged ions and lower pressures.

* Research supported by the Robert A. Welch Foundation, The National Science Foundation and Texas A&M University.

PA 57

Detection of two electrons in low lying continuum states of the same projectile ion.* J.D. RICHARDS, M. BREINIG, C.C. GAITHER, III AND T.A. UNDERWOOD, University of Tennessee and Oak Ridge National Laboratory. A 30 deg parallel plate spectrometer with a large channel plate in its focal plane and an anode consisting of discrete stripes has been used in preliminary experiments to detect two electrons in low-lying continnum states just above the ionization limit of the same projectile ion. Collisions between 0.1 - 0.3 MeV/u O^{2+} and Ag^{5+} projectiles and Ar target atoms have been investigated. Work is continuing to investigate in detail the energy and angular correlations between the two electrons near the threshold for double escape. *Work supported in part by the National Science Foundation and by the U.S. Dept. of Energy, Off. of Basic Energy Sciences, Div. of Chemical Sciences, under Contract No. DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

PA 58 A study of scattered ion charge states for Kr^{n+} - Kr collisions (n = 1,2,3,4 and 5). E. F. DEVENEY, MICHAEL H. RAPPOSCH, and QUENTIN C. KESSEL, *University of Connecticut.*--The final ionization states have been measured for Kr ions scattered to 1, 2, and 4 degrees from Kr targets for selected ion energies from 0.4 to 1.4 MeV. For projectile ionization states ranging from 1 to 5 the average final scattered charge state is observed to have only a weak dependence on the initial charge state. For example, for 1.4 MeV, 4 degree scattering the average final charge state for Kr^+-Kr collisions was 10.2 and for Kr^{5+} collisions it was 10.3. For 0.7 MeV, 1 degree scattering the final charge states ranged from 4.8 to 5.3 for incident charge states from 1 to 4. This relative independence of the final charge state with respect to the initial charge state is surprising. While one would not expect the full increase in projectile charge state to be reflected in the final charge state (sharing of the electrons surrounding both nuclei might be expected to occur in the short-lived collisional molecule), the observed independence shows the ionization and charge transfer processes do interact in a specific way. It is not clear, for these very

heavy ion-atom collisions, that existing models provide an appropriate description of the multielectron processes that give rise to the observed ionization states.

*Supported by National Science Foundation grant number PHY-8818347.

PA 59 Energy Dependence of the Alignment of Ne^{7+}.* C.J. LIU, R.W. DUNFORD, H.G. BERRY AND D.A. CHURCH† Argonne National Laboratory--The uncertainty due to anisotropic emission and polarization correction contributes the largest error in the determination of subshell selective electron-capture cross sections. We report on a study of the alignment of excited Ne^{7+} ions produced in collisions of Ne^{8+} ions on a sodium beam target at beam energies from 4.8 keV/amu to 32.8 keV/amu. The main capture channels are in high Rydberg states (n=9 and n=8) with high orbital angular momentum. The linear polarization of the 434.2 nm (n=9 to n=8) and 297.7 nm (n=8 to n=7) emission lines of Ne^{7+} ions have been studied using a recoil ion source[1] in the energy region between 0.025 keV/amu and 0.4 keV/amu. The work reported here extends the previous work[1] from low energies to higher energies where the atomic state expansion method or AO-MO matching method has to be employed to calculate the magnetic substate distribution.

*Supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under contract W-31-109-ENG-38.

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[1]L. J. Lembo, Ph.D. thesis, Stanford University, Stanford, CA, unpublished (1987).

PA 60 Calibration of a Two-photon Coincidence Experiment Using 133Ba. DAVID J. LAWRENCE and C.A. QUARLES, Texas Christian U.*-Accelerators are increasingly being used in the measurement of coincident two-photon processes. The measurement of the cross section of such processes using a coincidence technique requires the determination of the efficiency/solid angle product. Since the geometries for accelerator set-ups are usually quite complicated, the most accurate way to determine the calibration product is by measuring a well-known two-photon process. A calibrated 133Ba source is well suited for calibrating a coincidence system. This is because its decay produces a high rate of coincident photons in the wide energy range from 31 to 383 keV. In this paper various two-photon coincidence probabilities for 133Ba are computed from tabulated transition values. Examples will be given to illustrate the use and accuracy of this calibration technique.

*Supported by the Welch Foundation.

PA 61 Radiative and nonradiative branching ratios of double-Rydberg states of Ba.* K.R. Karim, Physics Department, Illinois State U., C.P. Bhalla, Physics Department, Kansas State U., and M. Wilson, Physics Department, Royal Holloway and New Bedford College (U. of London).-- We report here the radiative and nonradiative branching ratios for a few selected double-Rydberg states of barium atom to different final states. The calculation has been performed using Hartree-Fock Atomic model in the intermediate coupling scheme including the effects of configuration mixing.

* Supported by Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

PA 62 Lifetime Measurements on Nitrogen Ion Beams from a Low-Energy Accelerator. M.E.M. HEAD, C.E. HEAD, Univ. of New Orleans, and J.L. DEAN, LSU Medical Center --- Experimental lifetimes for the 2p3p ^3D laser level of N^+ differ by an order of magnitude and indicate the need for further study. High-statistics decay curves for the 2p3p ^3D levels obtained in the current investigation show clear evidence of a short-lived, growing-in cascade and support the longer value. Decay curves for two of the important cascade levels were also measured directly, along with decay curves for the 3p ^1D laser levels. These curves were subjected to a systematic deletion-of-points curve-fitting routine which was evaluated using Monte-Carlo generated decay curves. Mean lifetimes (in ns) and their associated statistical errors obtained from decay curves to date are: 2p3p ^3D, 18.50±0.72; 2p3d $^3F^o$, 8.23±0.28; 2p4f ^3G, 2.93±0.18; 2p3p ^1D, 6.42±0.13. Systematic and curve-fitting uncertainties vary with the particular level, and are included in total uncertainties in the full paper. These experimental lifetimes are in excellent agreement with theoretical transition probabilities tabulated by NIST.

PA 63 Integrated Accelerator-Monochromator Apparatus for Time-Resolved Vacuum-Ultraviolet Spectroscopy. D.F. HASENKAMPF and C.E. HEAD, Univ. of New Orleans -- A computer controlled vuv monochromator and scanning mirror were integrated into a low-energy accelerator for measurements of radiative lifetimes of vuv transitions with the beam-gas method. This method is a time-of-flight technique in which the decay time is related to the distance from a target cell by t=x/v (v = speed of the ions in the beam). Radiation from position x is collected by the scanning mirror and directed through the entrance slit of the monochromator, which contains a 1200-g/mm concave grating in a Seya-Namioka mount. The stepping increment along the beam is (8.476 ± 0.002) x 10^{-3} cm per step of the scanning mirror drive motor. The monochromator was calibrated for expected operational slit widths and used to measure the wavelengths and instrumental linewidths of the 102.5- and 121.6-nm lines of atomic hydrogen and a number of Hg lines. Application of the apparatus for determination of radiative lifetimes of vuv transitions will be discussed.

PA 64 **Efficiency Determination for a Windowless Si(Li) X-Ray Detector for Photon Energies Below 5 keV Using Atomic-Field Bremsstrahlung.*** D. L. WEATHERS, J. L. DUGGAN, M. R. MCNEIR, Y. C. YU, and F. D. MCDANIEL, *Dept. of Physics, University of North Texas, Denton, TX 76203*; C. A. QUARLES, H. LEHTIHET, and D. KAHLER, *Physics Dept., Texas Christian University, Fort Worth, TX 76129*—The efficiency of a Link Analytical windowless Si(Li) X-ray detector has been determined experimentally for photon energies down to 600 eV. Thin foil targets were bombarded with 66.5 keV electrons, and the resulting atomic-field bremsstrahlung spectra were measured with the detector. The detector's relative efficiency as a function of photon energy was obtained by comparing these measured distributions with the true spectral distributions for the bremsstrahlung, which are well known to ~5% [1]. By matching the relative efficiency determined in this manner to absolute efficiencies determined with calibrated radioactive photon sources at energies above 5 keV, a continuous, absolute efficiency curve has been obtained. The efficiency data have been fit with a simple model, allowing extension to the lowest photon energies discernable with the instrument (~200 eV) The general applicability of the calibration technique, its limitations, and proposals for further refinement are discussed.

* Work supported in part by the State of Texas Coordinating Board, Texas Instruments Inc., NSF, ONR, and the Robert A. Welch Foundation.

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PA 65 Stopping Powers for 400 to 2400 keV N Ions in He Ar. JACK L. PRICE, STANLEY H. STERN, DONALD G. SIMONS*, I J. LAND, JAMES G. BRENNAN*, Naval Surface Warfare Center White Oak, MD - The stopping powers for 400 to 2400 keV N in He and Ar gas targets were measured using time-of-fligl techniques. The stopping power was directly determined fi the change in ion time of flight over a fixed distance af passing through a differentially-pumped, windowless gas c Start and stop pulses, derived from secondary electrons produced by passing the ion through thin C foils and dete by microchannel plates, are used to trigger a TAC spectro The measured stopping power values are analyzed as a func of their linearity with projectile velocity and are compa with those compiled by Ziegler et al.[1] and with predictio the Firsov-Land-Brennan (FLB) Theory.[2] In general, the measured values agree with FLB but are consistently lower those of Ziegler. Comparison of results obtained with ^{14} ^{15}N and with N^+ and N^{++} projectiles will be presented. D of the measurement and detection systems will also be giv

* Also at The Catholic University of America, Washington,
1 J. Ziegler, J. P. Biersack, and U. Littmark, Stopping Range of Ions in Solids, Pergamon Press, NY (1955).
2 D. J. Land and J. G. Brennan, Atomic Data and Nuclear I Tables 22, 235 (1978).

PA 66 Corrections to Ion Energy Determinations in Tandem Accelerato. A.M. ARRALE, S. MATTESON, F.D. McDANIEL, and J.L. DUGGA *Dept. of Physics and Center for Materials Characterization, University North Texas, Denton, TX 76203*--Ion energy loss occurs during pass through the stripping gas or foil in the terminal of a tandem accelerator energy loss is usually small and is ignored in most experiments. accelerator mass spectrometry (AMS),[1] the energy loss may result non-detection of the ion. We have obtained an approximate expression the energy loss of 1 to 4 MeV ions in nitrogen gas and carbon foils. By us the scaling theory of Lindhard, Scharff, and Schiott (LSS),[2] a semi-empir formula is found for the energy loss as a function of a dimensionless redu energy. Calculated energy losses of all ions as a function of atomic mas plotted for each energy, and the result is compared to experimental d measured in an AMS system.
*Work supported in part by the State of Texas Coordinating Board, Te Instruments Inc., the NSF, the ONR, the Robert A. Welch Foundation, Te Utilities Electric Co., International Digital Modeling Corp., and University of North Texas Organized Research Fund.
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PA 67
M.PEÑALBA, A.ARNAU, P.M.ECHENIQUE, Departamento de Fisica de Materiales, Universidad del Pais Vasco, Facultad de Quimica, San Sebastián 20080, Spain.

A charge state approach is used to calculate the electronic stopping power of carbon for a beam of He ions at intermediate energies. The contribution to stopping power from the different charge states and that of the charge exchange processes are evaluated separately. Several approximations to treat the C-target are used to study the difference between diamond, graphite and amorphous carbon. Comparison with some experimental data is done.

PA 68 A Possible Search for Doubly-Charged Negative Ions. ĐURO MILJANIĆ, Ruđer Bošković Institute, Zagreb, Yugoslavia. --- Reports on the observation of doubly-charged negative ions are inconclusive. Searches via accelerator mass spectrometry (AMS) gave very low limits (10^{-14}-10^{-16}) for the ratio of doubly-charged to singly-charged ions. However, since one is probably dealing with very loosely bound ions, the AMS as used in the searches may not be suitable for this purpose. It is proposed to use singly-charged negative ions of positron emitters (e.g. $^{18}F^-$) as parents of doubly-charged negative ions. Different approaches to the search will be discussed.

PA 69 Scattering of Molecular Hydrogen at Fixed Orientation.* Y.D. WANG AND J H MCGUIRE, J.R. Macdonald Lab, Kansas State Univ.--Within a first Born theory, we have studied collisions with H_2 by fast projectiles (bare nuclei and projectiles carrying electrons). Because of the relative short collision time, electronic transitions occur at a fixed orientation of the molecular axis. We first consider orientation dependence in ionization of H_2 by fast protons. The orientation dependences in cross sections generally tend to be less pronounced than those found in charge transfer processes. The total cross sections are compared with experiments. Our calculations suggest that a constructive interference between the two atomic centers may explain the observed "equality" between H_2 and 2H at high velocities. We then isolate the role of the molecular two-center effects and apply this result to recoil distribution from Coulomb explosions. This is done by using an effective charge involving a molecular form factor at a fixed orientation. We show that, in general, use of an orientation averaged form factor is not always justified.
* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

PA 70 Dissociation of Multicharged Molecular Ions Produced in Collisions with 97 MeV Ar^{14+}.* G. SAMPOLL, R. L. WATSON, O HEBER, and V. HORVAT, Texas A&M University. -- Transient molecular ions of O_2, N_2, and CO having charge n to $10+$ were produced by single collisions of 97 MeV Ar^{14+} projectiles. The resulting dissociation products were identified by coincidence time-of-flight spectroscopy. The differences in the times of flight of the two ions formed in these binary dissociation events were used to deduce the average total kinetic energies for the various charge division pathways In some cases, it was possible to transform the time difference distribution into kinetic energy distribution by employing a Monte Carlo trajectory simulation procedure.

*Work supported by the Division of Chemical Sciences of the U.S. Department of Energy and the Robert A. Welch Foundation.

PA 71 Multicharged Recoil-Ion Production by ^{252}Cf Fission Fragments.* B. HILL, R. L. WATSON, B. B. BANDONG, and G. SAMPOLL, Texas A&M University. -- Charge state distributions of He, Ne, Ar, Kr, and Xe ions produced by bombardment with highly-charged heavy ions from the spontaneous fission of ^{252}Cf have been measured using time-of-flight spectroscopy. The measurements reveal that as many as 10 electrons are removed from Ar in a single collision. The spectra and the cross sections obtained for the various target gases will be presented and compared with the results of experiments utilizing lower Z projectile ions from a particle accelerator.

*Work supported by the Division of Chemical Sciences of the U.S. Department of Energy and the Robert A. Welch Foundation.

PA 72 Recoil-Ion Kinetic Energies for Collisions of 96 MeV Ar.* O. HEBER, R. L. WATSON, G. SAMPOLL, and B. B. BANDONG, Texas A&M University -- The kinetic energies of He, Ne, and Ar recoil-ions produced in single collisions with 96 MeV Ar^{4+} and Ar^{15+} projectiles have been determined from high resolution time-of-flight measurements. They were found to vary from ≈kT for charge 1 recoil-ions to 6 eV for Ar^{11+} recoil-ions. For the higher charged recoil-ions, the kinetic energy increases faster than q^2. Average impact parameters are deduced from these results and compared with those obtained by Levin et al.[1] for 25 MeV $Cl^{8+,10+}$ on Ar.

*Work supported by the Division of Chemical Sciences of the U.S. Department of Energy and the Robert A. Welch Foundation.

[1]J. C. Levin, R. T. Short, C.-S. O, H. Cederquist, S. B. Elston, J. P. Gibbons, I. A. Sellin, and H. Schmidt-Bocking, Phys. Rev. A36, 1649 (1987).

PA 73 KLn (n=2,3,4) RTEA Cross Sections for $C^{5+} + H_2$.* R. PARAMESWARAN, B.P. WALCH, and B.D. DePAOLA, J.R. Macdonald Lab, Kansas State Univ.--Cross sections for RTEA with 4-12 MeV C^{5+} projectiles incident on a H_2 target were obtained. The measured cross sections were then compared with theory to obtain the first experimental confirmation of the theoretical prediction of the n-dependence (n = principal quantum number) of the RTEA cross sections.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

PA 74 D State Components of Li
D. LEHMAN, George Washington University, Washington, DC, USA.

See Session Number: BB 5

PA 75 Novel Applications of Narrow Nuclear Resonances
K. ROLFS, North Carolina State University, Raleigh, NC, USA.

See Session Number: BB 8

PA 76 Pion Absorption on Nuclei
P. ROOS, University of British Columbia Campus, Vancouver, B.C. Canada.

See Session Number: BB 7

PA 77
Gamma Radiation from 3.4-6.4 MeV α-Particles bombarding on ^{27}Al, C. W. Wang, E. K. Lin, S. W. Hsu and Y. C. Hsu, Institute of Physics, Academia Sinica, Taipei, Taiwan, Republic of China
The gamma-radiation following the reactions $^{27}Al(\alpha, \gamma)^{31}P$, $^{27}Al(\alpha, p\gamma)^{30}Si$, $^{27}Al(\alpha, \alpha'\gamma)^{27}Al$ and $^{27}Al(\alpha, n\gamma)^{30}P$ have been measured. Excitation functions were obtained at 90° in the energy range E_α = 3.4 - 6.4 MeV for selected regions of γ-ray energies with a high resolution HpGe detector and a large volume NaI(Tl) scintillator. In All, about 300 resonances were observed and the corresponding excitation energies (Ex = 12 - 15 MeV) of the compound system ^{31}P were determined. The obtained level density in this region was compared with the calculation of statistical compound nucleus theory.

PA 78 In Beam Spectroscopy And Microscopic Calculations In The A = 60-80 Region. L. Chaturvedi*, J. H. Hamilton, A. V. Ramayya, X. Zhao, Vanderbilt University. -- In recent years our understanding of the mean field in nuclei has greatly expanded with the discovery of new regions of deformations. Earlier, the nuclei in this mass region were thought to be quasi-vibrational. Since the discovery of shape coexistence in ^{72}Se (Ref. 1), experimental and theoretical studies of nuclei in this region have shown that their spectra are quite complex and exhibit coexistence of bands of quite different deformations. Sharp changes in nuclear structure with small changes in neutron or proton numbers have been observed through the influence of competing gaps in the Nilsson single-particle levels at different deformation. Unusually large ground state deformations, $\beta \sim 0.4$, observed in this region are the result of a reinforcing effect of the shell gaps in the single particle levels for both Z,N ~ 38. The remarkable agreement of recent microscopic calculations[2] (Tübingen) and studies[2] of ^{68}Ge and ^{72}Se with 19 and 20 Compton suppressed Ge detectors at HHIRF will be reviewed.

*Physics Dept., Banaras Hindu U., Varanasi-221005, India.

1.J. H. Hamilton et al., Phys. Rev. Lett. 32, 239 (1974).
2.L. Chaturvedi et al., to be published.

PA 79 Nuclear Level Studies in I-127
T.S. CHEEMA, D. MEHTA, AND B.K. ARORA
Panjab U. -- Different nuclear levels in I-12 have been populated via Coulomb Excitatio process using low energy proton beam.. Angula correlation studies of the de-excitation gamm rays were carried out using two 64.1 cm^3 HPG detectors placed at 0° and 90° respectively wit respect to the incident proton beam. The Iodin target was prepared by pressing KI into a thic pallet. The proton beam of 3.57 MeV energy wa used to excite the levels at 202.8, 375.0, 418.0 628.6 and 745.0 keV in I-127. The multipol mixing ratios and A2 coefficients for variou gamma ray transitions have been extracted an compared with those given by Ward et al.1 an Renwick et al.2 The ambiguity in the spi assignment to the level at 628.6 keV is discusse in the light of present measurements.

1D. Ward et al. Phys. Lett. 29B, 487 (1969).
2B. B.W. Renwick et al. NPA 208, 574 (1973).

PA 80 Radioactive Beams in Astrophysics
W. RODNEY, Georgetown University, Washington, DC.

See Session Number: BB 9

PA 81 States in Ne^{20} through the $^{19}F(p,\alpha)$ reaction. Y. AZZOUZ and N. BENDJABALLAH, USTHB, Institut de Physique, B.P.32 Babezzouar, Alger, (ALGERIA). We have studied the excited states in Ne^{20} around 14.5 MeV excitation energy through the $^{19}F(p,\alpha)$ reaction at proton energies between 1.55 MeV and 1.64 MeV by 5 keV steps.Gas target and differential pumping are utilized.Excitation functions at several angles have been obtained for the 5 first α groups.The data show clearly 2 resonances at 1575 keV and at 1605 keV with 35 keV and 6 keV width respectively.The analysis of the data are performed in the frame of the R-Matrix formalism.Taking into account also all the resonances in the same energy range compiled (1983) by F.Ajzenberg-Selove, we deduced the partial widths wich give the best fits to the data and the most probable spin parity assignment 0^-, 1^- and 1^- to the 14.27 MeV, 14.34 MeV and 14.37 MeV in Ne^{20} respectively.

PA 82 Trends in (n,α) cross-sections at 14,5 MeV
H.ATASOY,S.DÖKMEN, Y.ÖZBİR, Dept. of Physics Cekmece Nucle Research and Training Center, İSTANBUL, TURKEY
The available information on the neutron induced (n,α) re as well as the reaction cross sections are reviewed for th interval of $9 \leq Z \leq 92$ at 14.5 MeV neutron energy, the choi this energy being mainly due to the availability of inten neutron beams using SAMES T-400 low energy ion accelerato the Cekmece Nuclear Research and Traing Center.
In this study, it was found that the ratio of $\sigma^{exp}/(14.5-$ shows an exponential form as a function of (N-Z) where E_{th} the (n,α) threshold energy and (N-Z) is the neutron excess the target nucleus. This realationship can be expressed by following empirical equation

$$\sigma = a\, e^{-b(N-Z)}(14.5-E_{th})^{1/3} \text{ mb} \begin{cases} a=65.034 & b=0.34 \quad 0 < N-Z \\ a=12.1 & b=0.089 \quad 9 \leq N-Z \end{cases}$$

where E_{th} is in MeV. The good fit of this empirical formu the experimental cross sections for $9 \leq Z \leq 92$ can be use quick estimation of the unknown cross sections.

PA 83 Dependence of Knock-on Collision Electron Emission on the Orientation of Swift Diclusters in Solids.* J.M. PITARKE, Fisika Teorikoa Saila, Euskal Herriko Univertsitatea, Spain and P.M. ECHENIQUE, Materialen Fisika Saila, Euskal Herriko Univertsitatea, Spain, and R.H. RITCHIE, Oak Ridge National Laboratory.--- Calculations of the cluster-orientation dependence of the emitted knock-on collision electron distributions when fast diclusters interact with the condensed matter are presented. The scattering by each centre of the dicluster is described by means of the phase shifts of a velocity dependent Yukawa potential describing the dynamic screening, and the interference effects are approximated within the second Born approximation. The applicability of this approximation as the charges and velocities of the diclusters are changed is also discussed.

* Research sponsored by the Eusko Jaurlaritza and by the office of Health and Environmental Research, U.S. Department of Energy, under contract DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

PA 84 Multiple Scattering Effects on Electron Emission by Swift Diclusters in Solids.* J.M. PITARKE, Fisika Teorikoa Saila, Euskal Herriko Univertsitatea, Spain and P.M. ECHENIQUE, Materialen Fisika Saila, Euskal Herriko Univertsitatea, Spain.--- Multiple scattering effects on the cluster-orientation dependence of the knock-on collision electrons emitted when fast diclusters penetrate the condensed matter are studied using methods developed in the Theory of Low Energy Electron Diffraction (LEED). The dynamic screening of the Coulomb potential is described by means of a Yukawa potential with an electron-density and velocity dependence of the screening parameter. Numerical comparisons of our results with experiment are made.

* Research sponsored by the Eusko Jaurlaritza.

PA 85
Slowing down of heavy ions in solids near the stopping power maximum. A. ABDESSELAM, J.P. STOQUERT, G. GUILLAUME, M. HAGE-ALI, J.J. GROB and P. SIFFERT, Centre de Recherches Nucléaires (IN2P3), Laboratoire PHASE (UPR du CNRS n°292), BP 20, F-67037 Strasbourg Cedex, France --- Accuracy in the Rutherford backscattering technique, which is extensively used in material analysis, has been largely improved by systematic measurements of the stopping power for the light ions used as projectiles, and precise compilation of data are available[1]. More recently, the Elastic Recoil Detection method with heavy incident ions has been introduced[2], but until now this technique suffers from a lack of precision in the stopping power data. We have measured energy losses of C, Al, Cu, Ti, I, Ag and Au ions in various absorbers of C, Al, Cu, Ag, Ta and Au in the region of the stopping power maximum by using secondary ions produced by primary incident beams of ^{127}I (240 MeV) and ^{197}Au (200 MeV). The data are of practical interest as they correspond to the maximum depth resolution. From a theoretical point of view, calculations assume the energy loss of fast projectiles to be proportional to $Z_1^2 L_0$, where Z_1 is the charge and L_0 the stopping function. We have discussed different corrections due to the effective charge and to the high order Barkas and Bloch terms and compared them with the experimental data.

1 The Stopping and Ranges of Ions in Matter - Vol. 3 and 4 - Organized by J.F. Ziegler, Pergamon Press, 1977, 1980.
2. J. L'Ecuyer et al , J. Appl. Phys. 47 (1976) 381.

PA 86 Far uv Spectroscopy of Highly Ionized Argon Using Complementary Techniques.
E. KNYSTAUTAS, Department de Physique, Universite Laval, Quebec, Canada.

See Session Number: HE 3

PA 87 Electron-Atom Collisions in a Laser Field.
P.H.G. SMITH, Georgia Institute of Technology, Atlanta, GA.

See Session Number: JA 6

PA 88 Potential Applications of a New Microwave ECR Multicusp Plasma Ion Source.
C.C. TSAI, Oak Ridge National Laboratory, Oak Ridge, TN.

See Session Number: FF 1

PA 89 Molecular Orientation Dependence for Projectile - H_2 Collisions.
R.L. EZELL, Augusta College, Augusta, Georgia.

See Session Number: DE 5

PA 90 Electronic Stopping-Power Calculations for Heavy Ions in Semiconductors.
S.G. ELKOMOSS, Centre de Recherches Nucleaires, Strasbourg, France.

See Session Number: DE 7

PA 91 Transitions in Highly Charged Ions of Heavy Atoms.
D.D. DIETRICH, Lawrence Livermore National Laboratory, Livermore, England.

See Session Number: JD 1

SESSION DA: RADIOACTIVE BEAM EXPERIMENTS I
Tuesday morning, 6 November 1990; Union Building, Room 410 at 9:00; W. S. Rodney, Georgetown University, presiding

DA 1 General Introduction to the Radioactive Beams. C. ROLFS, *Westfälische Wilhelms Universität, West Germany.* (15 min.)

DA 2 RIB and Studies of the Early Universe. R. MALANEY, *Lawrence Livermore National Laboratory.* (15 min.)

DA 3 Primordial Nucleosynthesis and Radioactive Beam. T. KAJINO, *Tokyo Metropolitan University, Japan.* (20 min.)

DA 4 Neutron Capture Cross Sections of Light Nuclei in Primordial Nucleosynthesis.
Y. NAGAI, *Tokyo Institute of Technology, Japan.* (15 min.)

The baryonic density fluctuations caused by the phase transition from the quark-gluon plasma to the hadronic phase will form high density proton-rich and low density neutron rich regions.[1] In the latter regions a primordial r-process will produce heavy elements(A>12).[2] Consequently it is important to measure neutron capture cross sections of light elements for the quantitative discussion on the production rate of heavy elements. The measurement was carried out by using pulsed neutrons with the energy of 30 keV and detecting prompt γ-rays from the captured state. The pulsed neutrons were provided by the 3.2 MV Pelletron Accelerator of the Research Laboratory for Nuclear Reactor at the Tokyo Institute of Technology. Captured γ-rays were detected by a 7.6 cm^{ϕ} × 15.2 cm NaI(Tl) detector, surrounded by an annular NaI(Tl) detector with the size of 25.4 cm^{ϕ} × 28.0 cm. The absolute capture cross section of light nuclei was determined by comparing the prompt γ-ray yield with that of ^{197}Au. Capture cross sections of ^{7}Li and ^{12}C will be discussed.

[1]J.H. Applegate and C. Hogan, Phys. Rev. D31 (1985) 3037.
[2]J.H. Applegate, C. Hogan and R.J. Schener, Phys. Rev. D35 (1987) 1151.
T. Kajino, G.J. Mathews and G.M. Fuller, to be appeared in Astrophs. J. 1990.

DA 5 Reaction Rate for $^{8}Li(\alpha,n_0)^{11}B$. T. PARADELLIS, *NCSR Demokritos, Greece.* (15 min.)

DA 6 Radioactive Ion Beams and Explosive Nucleosynthesis.* J. GÖRRES, *University of Notre Dame.* (15 min.)

Nuclear reaction sequences in explosive hydrogen burning are determined by proton capture reactions on proton rich nuclei far off stability (rp-process). These reactions will process light mass CNO material, produced in previous stages of nucleosynthesis, into the intermediate mass Fe-Ni region[1]. Because of the small Q-values for (p,γ)-reactions on nuclei close to the proton drip line ($Q \leq 3$ MeV), the stellar reaction rates will be in most cases determined by 1 or 2 resonances as well as the nonresonant direct capture to bound states. The rates for strong reactions such as $^{13}N(p,\gamma)^{14}O$ can be measured directly, if high intensity ($I = 10^{10}$/sec) radioactive ion beams are available. For considerably weaker reactions an indirect determination of the reaction rates will be necessary. While reactions with stable ion beams and targets allow the measurement of the excitation energies of states close to the proton threshold, the measurement of proton spectroscopic factors necessitates the use of radioactive ion beams. As an example, the reaction $^{19}Ne(p,\gamma)^{20}Na$ [2] will be discussed and depending on the available ^{19}Ne beam intensity, several experimental approaches to determine the reaction rate will be discussed.

* Supported by the National Science Foundation
[1] R.K. Wallace, S.E. Woosley, Ap.J. Supp. 45 (1981) 389
[2] L.O. Lamm et al., Nucl. Phys. A510 (1990) 503

DA 7 Status Report on RIP Project in Louvain-la-Neuve, Belgium.* W. GALSTER, *Catholic University of Louvain, Belgium.* (15 min.)

At present two cyclotrons are used to produce and accelerate radioactive ion beams (RIB). In the first step the primary (p,n) reaction delivers the radioactive species, which is extracted from the target in gaseous form. Ionization takes place in an Electron Cyclotron Resonance source (ECR) and the positive ions are injected into and accelerated by a second cyclotron. The two cyclotron concept has provided first encouraging results, 0.7 MeV/u $^{13}N^{+}$ beams of 1.5 * 10^{8} particles per second are now available on target. These intensities can be enhanced by at least one order of magnitude through various improvements. Particular attention is paid to the problem of purifying the RIB from isobaric contaminants. First experiments will be dedicated to the study of nuclear reactions of astrophysical interest. Future developments will be discussed.

*** In collaboration with D. Darquennes, P. Decrock, Th. Delbar, M. Huyse, Y. Jongen, M. Lacroix, P. Leleux, I. Licot, E. Liénard, P. Lipnik, M. Loiselet, G. Ryckewaert, Sindano Wa Kitwanga, P. Van Duppen, J. Vanhorenbeeck, J. Vervier and S. Zaremba.**

DA 8 Production and Use of ^{6}He, ^{7}Be, ^{8}Li, and Metastable Nuclear Beams.*
F. D. BECCHETTI, *University of Michigan, Ann Arbor.* (15 min.)

A variety of energy-resolved short-lived radioactive nuclear beams (RNB), E = 8 to 60 MeV, have been developed at the University of Michigan - University of Notre Dame RNB facility[1,2] and used in nuclear reaction studies. Recent improvements in the accelerator, negative ion source, RNB production targets and RNB ion optics have

resulted in substantial increases in the intensity (to 10^7/s), purity, and energy (E>20 MeV) of the secondary RNBs. This has permitted observation and measurements of RNB induced one and two-nucleon transfers, RNB projectile excitation and RNB elastic scattering. An effective method of producing usable quantities ($\geq 10^3$/s) of excited, isomeric nuclear beams, such as $^{18}F^m$ ($J^\pi = 5^+$, $E_x = 1.1$ MeV) has also been developed.[3]

*Supported in part by the National Science Foundation.

[1]R.L. Stern *et al.*, Rev. Sci. Instr. 58, 1682 (1987).
[2]J.J. Kolata *et al.*, Nucl. Instrum. Meth. B40/41, 503 (1989).
[3]F.D. Becchetti *et al.*, Phys. Rev. CR (in press).

DA 9 Possibilities for Radioactive and Isomeric Beams from the New Generation of Recoil Mass Spectrometers.
T. M. CORMIER, *Texas A&M University.* (15 min.)

DA 10 The A1200 Mass Separator. B. M. SHERRILL, *National Superconducting Cyclotron Laboratory.* (15 min.)

At the National Superconducting Cyclotron Laboratory a section of beamline, called the A1200, has been constructed between the K1200 cyclotron and the transfer beamlines to the experimental devices. The A1200 will be used as a projectile fragment separator for making radioactive beams with energies between 30 and 200 MeV/nucleon. The fragments are formed at a production target at the start of the A1200. A 45 degree bend is used to select those fragments with a desired mass-to-charge ratio, then the fragment beam can be purified by inserting a piece of degrading material at an intermediate image and using a second 45 degree bend to remove ions which did not have the correct energy loss in the degrader. Special profiles of the degrader can be used to minimize the final image size or to reduce the energy spread of the fragments, using the techniques developed at GSI and GANIL(1). A program has been written to evaluate the intensities and emittances of radioactive beams which can be produced with the A1200. The initial operating results will be compared to predictions and rates and purities will be presented, along with some details of the separation method and the ion-optical design. Experiments which are planned for the initial operation include decay studies, reaction mechanism studies, elastic scattering, and single nucleon transfer reactions with radioactive ions.

Construction supported by the National Science Foundation Grant PHY8215585.
(1) K.H. Schmidt et al., Nucl. Instr. and Methods A260, 287 (1987).

SESSION DB: ION IMPLANTATION

Tuesday morning, 6 November 1990; Union Building, Room 412 at 9:00; O. W. Holland, Oak Ridge National Laboratory, presiding

DB 1 Goals and Results of the AVSCOM Initiative on Ion Implantation of Engineering Components.
LEWIS NERI, *AVSCOM Depot Engineering and Reliability Centered Maintenance Office.* (20 min.)

The U.S. Army Aviation Systems Command (AVSCOM) is taking the initiative to apply ion implantation as an environmentally acceptable process to improve wear life, corrosion protection, and reliability of existing aircraft engineering components. This initiative has involved, first, thoroughly assessing the state of the art of ion implementation, both commercially and within the Army. Based on this assessment, a program strategy for application of ion implantation is being formulated. Aircraft parts have been selected for trial implantation and test protocols have been developed to evaluate implanted parts. Already a number of excellent cost avoiding applications for ion implantation at the Army aviation depot at Corpus Christi has been demonstrated and work is under way to transfer this manufacturing technology to the depot shops. This paper will provide an overview of the goals and current status of all these initiatives by AVSCOM's satellite organization, DERSO, at Corpus Christi, Texas.

DB 2 Applications of Ion Implantation to Maintenance of U.S. Army Helicopters.
ROBERT J. CULBERTSON, *U.S. Army Materials and Technology Laboratory.* (20 min.)

The maintenance and repair of helicopters involves rework of a wide range of high performance materials. Component wear and corrosion are the primary concerns in helicopter maintenance, and repair and/or replacement costs are substantial. Furthermore, tooling requirements are extremely severe due to the necessity of working with hardened exotic materials. Over the past several decades ion implantation has shown to be a beneficial surface modification technique for improving corrosion and wear resistance of bearing and tool materials. However, wide acceptance of ion implantation for these applications has been slow. The U.S. Army is presently taking aggressive steps towards the demonstration of ion implantation as a viable solution to some of the problems encountered in helicopter maintenance. Results from a collaboration of the Materials Technology Laboratory, Aviation Systems Command Depot Engineering and Reliability Centered Maintenance Support Office, and Corpus Christi Army Depot in the areas of ion implantation of both machine tools and helicopter components as well as the supporting technology will be reviewed.

DB 3 Ion Beam Processing of Metal Surfaces for Improved Corrosion Resistance.[1]
E. McCAFFFRTY,[2] *Naval Research Laboratory.* (20 min.)

Various ion beam techniques are being employed at the Naval Research Laboratory as methods of modifying the surfaces of metals to improve their corrosion resistance. These techniques include ion implantation, ion beam mixing, and ion beam assisted deposition of coatings. The advantages of each of these methods will be discussed, as well as the corrosion behavior of

various systems produced by these three techniques. Examples will include the corrosion behavior in acid solutions of ion implanted and ion beam mixed palladium into titanium, improvements in the pitting resistance of aluminum by ion implantation, and the corrosion behavior of various ion beam assisted deposited coatings. Where appropriate, the corrosion behavior will be interpreted in terms of a fundamental electrochemical approach, e. g., the pitting behavior of aluminum will be explained in terms of the recently developed pH of zero charge model of pitting.

[1] Supported by the Office of Naval Research.
[2] With P. M. Natishan and G. K. Hubler.

DB 4 Plamsa Immersion Ion Implantation for Semiconductor Processing. N. W. CHEUNG, *University of California, Berkeley.* (20 min.)

Using an electron cyclotron resonance (ECR) discharge for high ion density generation and by immersing a negatively biased target in the ECR plasma, the implantation dose rate can be increased by factors of hundreds over conventional ion implanters. With the high current capability of Plasma immersion ion implantation (PIII), the throughput of integrated circuit implantation steps can be substantially increased. The implantation depth profiles of PIII can be controlled by the substrate bias, gas pressure, and the duty cycle and frequency of the applied voltage pulses. Furthermore, the plasma constituents of PIII can be controlled independently by the ECR source to change the abundance of different ionic species. The PIII technique can also perform both ion implantation and thin-film deposition simultaneously, using a triode configuration, which is sell-suited for ion beam modification of solid surfaces. We have used PIII to demonstrate new VLSI processing technologies for sub-100nm pn junction formation[1], conformal doping of high aspect-ratio trenches[1], gettering of metallic impurities in Si2, and selective seeding for electroless plating of copper interconnects[1]. Performance of engineering PIII reactor capable of processing 10-inch diameter wafers will be described[3].

1 N.W. Cheung (in press), Presented at the VIII International Conference on Ion Implantation Technology, Surrey, 1990.
2 Olan et al (in press), Proceedings of the 176th Electrochemical Society Meetings, Fort L ·erdale, 1989.
3 Olan et al (in press), Presented at the VIII International Conference on Ion Implantation Technology, Surrey, 1990.

DB 5 Thin Film Growth Using Low-Energy Ions: Low-Temperature Kinetics for Epitaxy and Chemical Reactions.*
N. HERBOTS, *Massachusetts Institute of Technology.* (20 min.)

Low energy (< 1 keV) ions are presently used in a variety of thin film growth techniques. These techniques range from ion beam deposition (IBD) where the films are directly grown from an ion beam to Ion Assisted Deposition (IAD) where ionized species contribute to the growth process in combination with other particle beams or enhance growth without being directly incorporated to the material being deposited. Two important effects of low energy ion bombardment are the athermal enhancement of atomic mobility and the subsequent modification of growth kinetics this creates. Both can lead to a significant lowering of the temperature necessary to induce specific processes such as epitaxial growth and chemical reactions. We will review the present understanding of the atomistic mechanisms by which the temperature is lowered for semiconductor epitaxial growth and oxidation and how it can be applied to select deposition conditions for both IBD and IAD. We will also discuss our most recent results on room temperature Ion Beam Oxidation (IBO) of GaAs and demonstrate how the low temperature processing conditions enabled by the use of low energy ion beams render possible not only unique growth conditions but the formation of metastable phases that cannot be grown by purely thermal means.

* Supported by the IBM grant to MIT, the Carl Soderberg Professorship, and the Physical Electronics Division of Perkin-Elmer.

DB 6 An Investigation of Ion Implantation Damage in Silicon Using Wafer Curvature Measurements.
C. A. VOLKERT, *AT&T Bell Laboratories, Murray Hill.* (20 min.)

The damage produced by MeV ion implantation in silicon has been studied using wafer curvature measurements. These measurements are extremely sensitive to changes in the volume of the bombarded region, as well as to plastic flow in response to the stress imposed by the substrate, and are therefore ideally suited for investigating damage creation, motion and annihilation. Results will be presented from two sets of experiments. The first set measures the stresses created during amorphization of silicon by ion bombardment, in which plastic flow of amorphous silicon is observed while the ion beam is on. The second set of experiments involves a careful study of low dose damage in both crystalline and previously amorphized silicon. Values are obtained for the damage cascade diameter, density of the damaged regions, and the activation energy for damage annihilation. Distinct annealing regimes were observed during heating both the amorphous and crystalline silicon after implantation. The nature of the damage is discussed and compared for these two phases of silicon.

Collaboration with K. Allen and D. C. Jacobson is gratefully acknowledged.

DB 7 Defects in MeV Ion-Implanted Si Probed by Positrons.
B. NIELSEN, *Associated Universities, Incorporated, Brookhaven National Laboratory.* (20 min.)

SESSION DC: PHOTON-ION INTERACTION USING FAST BEAMS

Tuesday morning, 6 November 1990; Physics Building, Room 102 at 9:00; D. J. Pegg, University of Tennessee, presiding

DC 1 Study of Correlations with Ions (Theory).* A. R. P. RAU, *Louisiana State University, Baton Rouge.* (20 min.)

This talk will be primarily on two-electron states of the negative ions, H^- and He^-. Both doubly excited states, particularly at high excitation, and two-electron continuum states just above threshold are dominated by the correlations between the two electrons. The structure of these states, and the attendant implications for their excitation and decay, will be discussed. Similar states have also been observed, although less extensively, in positively-charged ions like C^{4+} and N^{5+} through ion-atom collisions. They shed light on the way correlations scale with the nuclear charge. The primary conclusion from all these studies is that to understand highly correlated states, it is best to view the (core + e + e) system as one whole, rather than split the pair of electrons according to any independent particle scheme.

*Supported by the National Science Foundation.

DC 2 Photodetachment of the H^- Ion.* C. R. QUICK, JR., *Los Alamos National Laboratory.*** (20 min.)

Recent results concerning electron detachment from the H- ion induced via 1) infrared multiphoton absorption near the one-electron detachment threshold (0.754 eV), and 2) single photon uv excitation of two-electron excited state resonances are presented and discussed. An H- beam moving at a relativistic velocity (2.5 x 10^{10} cm/sec) was intersected with the focused output from a pulsed, linearly polarized, CO_2 TEA laser with peak intensities on the order of a few GW/cm^2 to examine the multiphoton absorption process. The fourth harmonic (266 nm) of Nd:YAG laser was used to excite the doubly-excited state resonances in H^-. The Doppler effect was used to carry out a systematic variation of the center-of-mass (CM) photon energy, over a wide range by simply adjusting the angle between the ion and laser beams. In the multiphoton absorption work, electron detachment was observed at photon energies where as few as 2 and as many as 8 photons are required to get above the 1-electron detachment threshold (EDT) of H-. Electron yield vs. photon energy plots exhibit structure that is laser intensity dependent. Electron yield vs. laser pulse energy data was obtained at a few selected CM wavelengths and laser pulse energies. In the single-photon uv laser work, numerous resonances within the H^- continuum corresponding to two-electron excitation processes were observed. The doubly-excited resonances appear to be of the Feshbach type. A simple, semi-empirical recursion formula predicts the resonance energy levels. Some practical accelerator applications of this work will also be discussed.

*Research carried ut at the Los Alamos Meson Physics Facility (LAMPF) under the auspices of the US DOE, supported in part by the Office of Basic Energy Sciences.
**This work was carried out in collaboration with: H.C. Bryant, C.Y. Tang, P.G. Harris, A.H. Mohagheghi, R.A. Reeder, H. Tootoonchi (U. New Mexico), S. Cohen, J.B. Donahue (Los Alamos National Laboratory), W.W. Smith (U. Connecticut), J.E. Stewart (Western Washington U.), H. Sharifian (California State U.).

DC 3 Photodetachment of Metastable He^-.* J. S. THOMPSON,† *The University of Tennessee, Knoxville.* (20 min.)

A crossed-beams apparatus has been used to measure angular distributions and cross sections for photodetaching electrons from metastable He^-. Cross sections for photodetaching $He^-(2^4P)$ via the $He(2^3P)$ and $He(2^3S)$ exit channels were determined. The precision of the cross section measurements was enhanced by exploiting the kinematic effects associated with detachment from a fast beam source. Radiative attachment cross sections are derived from the photodetachment results using the principle of detailed balance.

*This work was performed in collaboration with D. J. Pegg, J. Dellwo, G. D. Alton, and R. N. Compton at the Univ. of Tennessee and Oak Ridge National Laboratory. Research supported by the Office of Basic Energy Sciences, Division of Chemical Sciences, U.S. DOE, under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.
†Present address: JILA, Univ. of Colorado and NIST, Boulder, CO 80309.

DC 4 High-Resolution Photodissociation Spectroscopy of Doubly Charged Positive Ions.*
W. C. LINEBERGER, *University of Colorado and JILA, Boulder.* (20 min.)

Doubly charged molecular positive ions are examined by a new high-resolution spectroscopic technique. The spectra yield information about the electronic structure, chemical bonding and geometry of the doubly charged molecular ions. Little spectroscopic data is available for these compounds because of the difficulty of performing such an experiment on very unstable molecular species. The doubly charged positive ions are formed by electron impact of the neutral precursor, mass selected and coaxially merged with a laser beam. The positive ions are electronically excited and photodissociated by either a visible (dye) or infra-red (titanium sapphire) tunable single-mode laser. Structural and potential energy curve information about the ground and excited electronic states are obtained from the photofragmentation spectrum. Additionally, the dynamics of the photodissociation can be elucidated by analyzing of the spectral linewidths of the individual rotational lines. Results on N_2^{++} and NO^{++} will be presented.

* Work supported in part by AFOSR High Energy Density Materials Program.

DC 5 Photodetachment of Molecular Negative Ions. C. W. WALTER, *SRI International.* (20 min.)

DC 6 Laser Measurements of QED Effects in Heliumlike Boron.* T. P. DINNEEN,† *Argonne National Laboratory.* (20 min.)

We have measured the wavelengths of the 1s2s ^3S - 1s2p $^3P^o$ transitions at 282 nm using laser induced fluorescence. These measurements are compared with the latest calculations which include electron correlation, relativistic and QED corrections. Ions in the 1s2s metastable state were extracted and accelerated from the ECR ion source injector of the Argonne ATLAS accelerator. The 30 keV B^{3+} beam was overlapped collinearly with the frequency doubled output of a Coherent 699 ring dye laser. The parallel and antiparallel laser measurements eliminated the Doppler shift from the results. The absolute wavelengths were measured relative to a standard iodine absorption cell using the fundamental of the laser at 564 nm. A comparison of the fine structure measurements with calculations of Drake[1] show significant discrepancies which are attributed to uncalculated relativistic terms of order $\alpha^4 Z^4$.

*Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under contract W-31-109-ENG-38.
†Work done in collaboration with N. Berrah Mansour, H. G. Berry, and L. Young.
[1]G. W. F. Drake, Can. J. Phys. 66, 586 (1988).

DC 7 Inner-Shell Photoionization Studies Using Ion Beams and Synchrotron Radiation.*
BRANT M. JOHNSON,† *Brookhaven National Laboratory.* (20 min.)

The inner-shell photoionization of ions is of both fundamental and applied interest. Theoretical studies have been in progress for years, but until recently, there were no experimental measurements. Applications abound in astrophysics and laboratory-plasma research, but many basic theoretical predictions remain untested. There are many open questions. For example, are total photoabsorption cross sections affected by the removal of a few outer-shell electrons; will additional Cooper minima be observed along isonuclear sequences as outer-shell electrons are removed; and can measurements of vacancy cascades following inner-shell electron removal be understood through theoretical modeling? While photodetachment, outer-shell photoionization, and multiphoton ionization can be studied with lasers, the removal of tightly-bound inner-shell electrons through single photon-ion interactions requires the use of hard x rays from facilties such as the x-ray ring of the National Synchrotron Light Source (NSLS). Recent experimental results from NSLS beam line X26C and future plans to further investigate the inner-shell photionization of ions will be presented.

*Research supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, US Department of Energy under Contract No. DE-AC02-76CH00016.

†In collaboration with K. W. Jones, M. Meron, M. Franklin, and R. Hedeman

DC 8 Photodetachment from Negative Ions in Strong Electromagnetic Fields.* D. J. LARSON, *University of Virginia.* (20 min.)

Photodetachment from negative ions near the single photon threshold has been studied in the presence of strong infrared and microwave fields. In the experiments using infrared fields an infrared beam of up to 10^{11} W/cm^2 overlaps a tunable ultraviolet probe beam in a Penning ion trap containing Cl^- ions. The experiments have been done at two wavelengths, 1.06 μm and 1.91 μm. The data are fitted to a model which includes a threshold shift and two-color, two-photon detachment. In the experiments using microwave fields, photodetachment from Cl^- and S^- was studied using ion beams. Detachment in a 2.6 GHz field with strengths of up to 3 KV/cm was measured using time-of-flight spectroscopy of the resulting neutrals. Below threshold detachment and oscillations on the cross section above threshold were observed, consistent with detachment in a static electric field. The experiments raise interesting questions about detachment or ionization in oscillating fields.

*Supported in part by the National Science Foundation.

SESSION DD: POSITRON BEAM EXPERIMENTS AND FACILITIES I

Tuesday morning, 6 November 1990; Union Building, Golden Eagle Suite A at 9:00;
L. D. Hulett, Oak Ridge National Laboratory, presiding

DD 1 Future Prospects of Linacs in Positron Microanalysis.* K. F. CANTER, *Brandeis University.* (20 min.)

Over the past 40 years, positron annihilation spectroscopy (PAS) has evolved into a powerful probe of the electronic and defect structure of solids. With the advent of slow positron beams over the last twenty years, PAS can also now be precisely targeted to study interfaces, surface and near-surface regions of a large range of systems.[1] The recent application of brightness enhancement[2] to positron beams enables one to efficiently focus positrons down to a few microns[3] and promises to make submicron resolution PAS studies a practical reality in the near future. Linacs have been used successfully to produce high fluxes of positrons but with insufficient brightness for purposes of microanalysis. This talk will deal with the benefits to be gained in using linac-produced positron beams for positron microanalysis as well as some of the considerations necessary to incorporate the positron microbeam technology with the linac.

*Work supported in part by NSF Grant DMR-8820345.
[1]P.J. Schultz and K.G. Lynn, Rev. Mod. Phys. 60, 701 (1988).
[2]A.P. Mills, Jr., Appl. Phys. 23, 189 (1980).
[3]G.R. Brandes, K.F. Canter, T.N. Horsky, P.H. Lippel, and A.P. Mills, Jr., Rev. Sci. Instrum. 59, 228 (1988).

DD 2 Search for Resonances in Electron-Positron Scattering Using a Cold Positron Gas Target.
T. E. COWAN,* *Lawrence Livermore National Laboratory.* (20 min.)

The recently discovered correlated positron-electron peaks[1] emitted from superheavy nuclear collisions may be signatures for previously undetected neutral particle-like objects having masses of 1-2 MeV/c^2. We have designed an experiment to *definitively* test this hypothesis by searching for resonant states formed directly in the scattering of monoenergetic electrons incident on a gas of cold positrons confined in a Malmberg-type Penning trap. This technique will provide an improvement in sensitivity for detecting new neutral particle-like objects of two orders of magnitude over that of present positron-beam, thin-foil scattering experiments[2], which are fundamentally limited by the momentum of the atomic electrons. Combined with a recoil-shadow technique, this experiment will explore the entire four decade range in possible neutral particles lifetimes (10^{-13}s to 10^{-9}s) which cannot be probed by other methods.

Work performed under the auspices of the U.S. Dept. of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

[1]T. Cowan *et al.*, Phys. Rev. Lett. 56 (1986) 444; and T.E. Cowan and J.S. Greenburg, *Physics of Strong Fields* (Plenum, New York, 1987), p. 111.
[2]K. Maier *et al.*, Z. Phys. A 330 (1988) 173; H. Tsertos *et al.*, Phys. Lett. B 207 (1988) 273.
[3]R.H. Howell *et al.*, NIM B10/11. 373 (1985)

*In Collaboration with R.H. Howell, and R. Rohatgi, Lawrence Livermore National Laboratory, Livermore, CA and J. Fajans, University of California at Berkeley, Berkeley, CA.

DD 3 Absolute Differential and/or Total Cross Sections for the Scattering of Positrons from Helium and Other Noble Gases.*
L. M. DIANA, *The University of Texas at Arlington.* (20 min.)

We have been using our 3m high resolution time-of-flight spectrometer to measure absolute differential and total elastic scattering cross sections and absolute total excitation and ionization cross sections for positrons incident on helium at energies up to 100 eV and our 2.3 m spectrometer to determine absolute total ionization and positronium formation cross sections for positrons colliding with helium and other noble gases at energies ranging from threshold to intermediate values. We shall present, discuss, and compare with theory some of our results for these cross sections and for the energy distributions of ionization electrons.[1]

*Supported in part by NSF Grant PHY-8506933.
[1]It is a pleasure to acknowledge the major contributions of R. L. Chaplin, D. L. Brooks and P. G. Coleman and the energetic efforts of our many student collaborators.

DD 4 Experiments in Atomic Interactions Using an Intense Positron Beam.
RICHARD H. HOWELL, *Lawrence Livermore National Laboratory.* (20 min.)

After the instillation of the first intense positron beam at the 100 MeV electron linac at Livermore the beam was used to study positron-surface interactions. More recently a series of experiments using the beam to study the properties of the electon-positron bound state, positronium, have been initiated. The results of measurements of the spectroscopy of high n states of positronium will be given and some potential future experiments will be described. Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Natl. Laboratory under contract N. W-7405-ENG-48.

DD 5 Interface Studies Using Positron. K. G. LYNN, *Brookhaven National Laboratory.* (20 min.)

DD 6 Design of an Intense Slow Positron Beam Production System Using a 100-kW Electron Linac for Positron Factory.
S. OKADA, *Takasaki Establishment, Japan Atomic Energy Research Institute, Japan.* (20 min.)

The JAERI has started drafting a construction plan of "Positron Factory", in which intense energy-tunable monoenergetic positron beams are produced by a high-power electron linac and are used for materials characterization and basic researches. A tentative goal of the slow positron beam intensity is 10^{10} s^{-1}. A rough and conservative estimation based on the empirical data has shown that the intensity can be attained with a linac of 100kW class whose beam energy is around 100MeV. We have estimated the optimal combination of the incident electron energy and the geometry of the electron/positron converter and the positron moderator by Monte Carlo calculations. The heat removal system of the converter, the shielding and the confinement/ventilation of the activated air have been also investigated in relation to the electron beam energy. In this article is presented a present status of the conceptual design.

DD 7 Positron Annihilation for Investigating Crystal Defects and the Structure of Disordered Media.*
H.-E. SCHAEFER, *University of Stuttgart, Federal Republic of Germany.* (20 min.)

Recent studies of defects in semiconductors and metal oxides will be overviewed with particular reference to positron lifetime measurements at hight temperatures. In addition, the potentials of positron annihilation for structural inves-

tigations of disordered media, e.g. nanocrystalline materials, will be demonstrated. Results from beam and ion-beam experiments will be presented.

*Supported by the Deutsche Forschungsgemeinschaft.

DD 8 A TOF Mass Spectrometer for Studies of Positron-Molecule Interactions.
L. D. HULETT, *Oak Ridge National Laboratory.* (5 min.) (Invited Poster Paper: See Poster Display PB' 43)

Slow positrons captured in a Penning trap are thermalized with a cooling gas and allowed to interact with large molecules. The Penning trap is required to have a large field-free central zone in order to contain the positrons and ions produced. Time-of-flight spectrometry is the more practical technique for studying the ions produced, but the large region from which the ions originate requires that the spectrometer resolution be insensitive to the starting position of the ions. A spectrometer has been designed in which the accelerating potential is proportional to the square of the distance from the detector. The equation of motion for the ions is the analogue of that for the mechanical oscillator moving under a Hook's law force:

$$X = X_o\mathrm{Cos}(gt) + (v/g)\mathrm{Sin}(gt)$$

X and t are the distance and time coordinates of the ion during its flight; X_o is the initial distance of the ion from the detector, and v is the initial velocity at the time of its creation; g is proportional to the reciprocal of the period. For small initial velocities the time of flight to the detector is insensitive to X_o. Performance of the spectrometer will be discussed.

SESSION DE: ATOMIC PHYSICS AND RELATED PHENOMENA

Tuesday morning, 6 November 1990; Physics Building, Room 104 at 9:00; C. A. Quarles, Texas Christian University, presiding

DE 1 Low-Energy Positron Scattering from Atomic Hydrogen.
A. SCHWAB, *University of Bielefeld, Federal Republic of Germany.* (20 min.)

The first and, so far, only experimental results on scattering of positrons from atomic hydrogen are reported. Total ionization cross sections as a function of energy have been measured at the University of Bielefeld (1) with a positron beam from a weak radioactive source. Due to the low beam intensity (10^4 e^+/sec) no other processes, as Positronium-formation or differential elastic scattering, could yet be investigated. In a collaboration with groups of the Brookhaven National Laboratory and the City College of New York these measurements will now be done using the high intensity (up to 10^9 e^+/sec) positron beam at BNL (2), the concept of which will also be briefly discussed.

*present address: Brookhaven National Laboratory, Department of Physics
(1) G. Spicher, B. Olsson, W. Raith, G. Sinapius, and W. Sperber;Phys. Rev. Lett. 64,9 (1990),1019
(2) K. Lynn, M. Weber, L.O. Roellig, A.P. Mills,Jr., and A.R. Moodenbaugh in:
Atomic physics with positrons, eds.: J.W. Humberston and E.A.G. Armour; NATO ASI series B Vol. 169 (Physics), 161

DE 2 First Measurement of Hyperfine Structure by Laser-rf Double Resonance in N_2^+.*
N. BERRAH MANSOUR,† *Argonne National Laboratory.* (20 min.)

The ion-beam laser-rf double resonance technique has been used to make high-precision measurements in the X $^2\Sigma$ (v^+=1) of N_2^+. Laser induced fluorescence was observed from a 25 keV ion beam which was superimposed with the output of an actively stabilized ring dye laser. Direct measurements of the spin-rotation and hyperfine splittings in the X $^2\Sigma$ (v^+=1) electronic ground state of N_2^+ were made. This technique has the advantage of breaking the correlation between upper and lower state hfs that often clouds interpretation of even very high resolution optical spectroscopic data. The magnetic hyperfine parameters were determined with better precision than earlier results using only optical spectroscopy and the electric-quadrupole hfs parameter eqQ was determined for the first time.

*Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under contract W-31-109-ENG-38.
†Work done in collaboration with T. P. Dinneen, C. Kurtz, and L. Young.

DE 3 Photoionization of Excited Atoms Using Synchrotron Radiation.*
J. J. LEVENTHAL,[1] *University of Missouri, St. Louis.* (20 min.)

Experimental studies of photoionization of atoms in low-lying excited states have received a great deal of attention in recent years. Largely ignored however have been experiments in which the energy dependence of the photoionization cross section near threshold is acquired for atoms in highly excited states. Because of the large spatial extent of these highly excited atoms such experiments can reveal atomic properties not usually observable with atoms in the ground or low-lying excited states. Specific experiments in which ir synchrotron radiation is to be used to photoionize highly excited atoms created by two-step laser excitation as well as pilot experiments with a CO_2 laser will be discussed.

* Work supported by the National Science Foundation.
1 In collaboration with C. E. Burkhardt, M. Ciocca and S. T. Manson.

DE 4 The Excitation of Sodiumlike Argon Ions by High-Energy Projectiles.
I. KÁDÁR, *Hahn-Meitner Institut, Berlin, Germany.* (20 min.)

The Auger electron spectrum emitted by singly excited sodium-like argon ions has been investigated by means of high resolution 0° projectile Auger spectroscopy at high impact energy. The lines found in the experimental spectrum were assigned to the corresponding Auger transitions by using the theoretical transition energies and their differences as well as the relative intensities (PWBA collision strengths) calculated using the configuration interaction Hartree-Fock code by Cowan[1]. The Auger electron spectrum is due to the decay of levels in the sodium-like Ar populated by single monopole, dipole and quadrupole excitation by He atoms. The intensities due to monopole excitation are significantly higher than the PWBA expectation. The structure of the emitted electron spectrum is found to be deeply influenced by configuration interaction. The screening effect of the target electrons seems to be responsible for the deviation of the ratio of the intensities due to monopole and dipole excitation from the PWBA estimate.

* on leave from Institute of Nuclear Research of the Hung. Acad. of Sci, Debrecen, Hungary
In collaboration with: H. Altevogt, R. Führbrück, V. Montemayor, A. Mattis, G. Schiwietz, B. Skogvall, K. Sommer, U. Stettner, and N. Stolterfoht, Hahn-Meitner Institut Berlin GmbH, Glienicker Straße 100, D-1000 Berlin 39

1. R.D. Cowan, The Theory of Atomic Structure and Spectra, University of California Press, Berkeley, 1981

DE 5 Molecular Orientation Dependence for Projectile-H_2 Collisions.*
R. L. EZELL,† *Augusta College.* (5 min.) (Invited Poster Paper: See Poster Display PA 89)

The cross sections for the ionization plus excitation and double excitation of H_2 have been measured for equivelocity electrons and protons on H_2 as a function of orientation of the internuclear axis. The projectile energies ranged from 0.5 to 3 MeV/u. The data can be fit to an expression of the form

$$\sigma(\theta) = \sigma_0(1 + A\cos^2\theta).$$

The excited states of H_2^+ included the $2p\sigma_u$, $2s\sigma_g$ and $2p\pi_u$.

* Supported by the National Science Foundation.

† Co–workers are A. K. Edwards, R. M. Wood, M. L. Dittmann, and J. F. Browning.

DE 6 Correlation in Ion-Atom Collisions.* A. L. FORD, *Texas A&M University.* (20 min.)

Due to the strong electron-nucleus force in the target atom, many atomic collision processes are well-described within the independent particle model. But in cases involving transitions of two or more electrons, dynamical correlation between the electrons during the collision can be important. One such example is the double ionization of helium, where one manifestation of the correlation is the large difference in double ionization produced by protons and antiprotons. Further work on double ionization of helium is reported, and the double ionization mechanism discussed. The related problems of double photoionization, of double excitation, and of excitation plus ionization are discussed and compared to double ionization.

*Work done in collaboration with J. F. Reading. Supported by the NSF under grant PHY-8707383.

DE 7 Electronic Stopping-Power Calculations for Heavy Ions in Semiconductors.
S. G. ELKOMOSS, *Centre de Recherches Nucléaires, France.* (5 min.) (Invited Poster Paper. See Poster Display PA 90)

A model for ion stopping in semiconductors, which considers separate stopping contributions from valence and core electrons and explicitly includes the effect of the gap, has been used to calculate the electronic stopping-power of energetic B, P and As in Si, Ge, GaAs and CdTe for projectile energies 10 keV - 100 MeV. Account was taken of the partially stripped incident ions by means of the effective charges. The proton effective charge has also been considered for the $0 < (V_1/V_0) \leq 3$ range where V_1 and V_0 are the projectile and Bohr velocities, respectively. There is good agreement at low ion velocity with Lindhard and Scharff's values, which for heavy ions do not depend on effective charge theory, as well as with the semiempirical curves at energies $E \geq 0.2$ MeV/nucleon where they can be compared.

SESSION DF: ACCELERATOR TECHNOLOGY

Tuesday morning, 6 November 1990; Union Building, Room 418 at 9:00;
R. D. Rathmell, National Electrostatics Corporation, presiding

DF 1 The Advanced Light Source at the Lawrence Berkeley Laboratory.* ALAN JACKSON, *Lawrence Berkeley Laboratory.* (25 min.)

The Advanced Light Source (ALS), a National facility currently under construction at the Lawrence Berkeley Laboratory (LBL), is a third-generation synchrotron light source designed to produce extremely bright beams of

synchrotron radiation, in the energy range from a few eV to 10 keV. The design is based on a 1 - 1.9 GeV electron storage ring (optimized at 1.5 GeV), and utilizes special magnets, known as undulators and wigglers (collectively referred to as insertion devices), to generate the radiation. In this paper we describe the main accelerator components of the ALS, the variety of insertion devices, the radiation spectra expected from these devices, and the complement of experiments that have been approved for initial operation, starting in April 1993.

*This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Material Sciences Division, U. S. Department of Energy, under Contract No. DE-AC03-76SF00098.

DF 2 General Purposes Compact Synchrotron Radiation Sources.
H. O. MOSER, *Institut fur Mikrostrukturtechnik, Kernsforschungszentrum Karlsruhe, Germany.* (20 min.)

Besides the development of synchrotron radiation sources of the 3rd generation it seems important to work also on general-purpose synchrotron radiation sources which are less expensive and offer easy access for a broad user community from research, industry, and the medical field. The radiation spectrum of these sources must extend into the hard X-ray range since most of the X-ray analytical methods and promising schemes in industrial production and medical diagnosis need this feature. Superconducting bending magnets are likely to play an important role in these machines, either to make the source compact or to ensure a hard spectrum at moderate beam energy, or both. Furthermore, some insertion devices will be included for higher brightness and brilliance requirements. Some of the design criteria for, a possible lay-out and the status of such sources are discussed.

DF 3 The Design of the rf Cavity for the Heavy Ion Storage Ring for Atomic Physics at Oak Ridge.*
S. W. MOSKO, *Oak Ridge National Laboratory.* (20 min.)

An rf cavity and drive system have been designed for the proposed "Heavy Ion Storage Ring for Atomic Physics," HISTRAP, at Oak Ridge. A peak accelerating voltage of 2.5 kV per turn is required, with a continuous tuning range of 200 kHz through 2.7 MHz. A single-gap, half-wave-resonant configuration is used with biased ferrite tuning. The cavity structure is completely outside of the beam line/vacuum enclosure, except for a single rf window that serves as an accelerating gap. Physical separation of the cavity and beam line permits in situ vacuum baking of the beam line components at 300°C. A prototype cavity was built and tested.[1] Development of frequency synthesizer and tuner control circuitry is under way.

*Research sponsored by the U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.
[1]S. W. Mosko, D. T. Dowling, and D.K. Olsen, Proc. of the 1989 IEEE Particle Accelerator Conference, pp. 193.

DF 4 Precision Calibration of the L3 and L* Electromagnetic Calorimeters with a Radiofrequency Quadrupole Accelerator.
H. NEWMAN, *California Institute of Technology.* (20 min.)

The L3 experiment, now in operation at the LEP e^+e^- collider at CERN, and the L^* experiment which has been proposed for the SSC, derive much of their physics discovery potential from the use of high precision electromagnetic calorimeters. The high resolution depends on accurate and frequent gain calibrations "in situ". Over the last 6 years, Caltech and AccSys Technology, Inc. have developed and tested precise, rapid calibration techniques, using a pulsed proton beam from a Radiofrequency Quadrupole (RFQ) accelerator. The RFQ beam bombards a Li or CaF_2 target permanently installed in the experiment. Radiative capture of the protons yields a high intensity flux of single 17.6 MeV photons (Li target) or short bursts of photons which simulate a high energy photon of up to 40 GeV (CaF_2 target). This pulsed photon source can calibrate the thousands of large crystals in the experiment with an absolute accuracy of 0.5% in a few hours, or with a relative accuracy of 0.4% in a few minutes, using the two types of targets.

DF 5 Potential Application of XUV Free-Electron Lasers in the Computer Chip Industry.*
BRIAN E. NEWNAM, *Los Alamos National Laboratory.* (25 min.)

Future free-electron lasers (FELs), when operation is extended into the extreme ultraviolet (XUV) from 4 to 20 nm, will be excellent exposure tools for extending the resolution limit of projection optical lithography to ≤0.1 μm while providing adequate total depth of focus (1 to 2 μm). The potential capability of FEL oscillators, in particular those driven by rf linacs, to produce high-average power (50-200 W) in the XUV will offset the inherently low throughput of the projection optics which will have about five reflections at ≤50% each. When operated at a moderate duty rate of ≥1%, one XUV FEL could supply sufficient average power to support high-volume chip production by multiple lithographic steppers operating simultaneously. Recent progress in attaining the very bright electron beam, short-period magnetic undulator, and high-reflectance resonator mirrors necessary for XUV operation is encouraging. Additionally, work is underway to develop the other XUV projection lithography components including the reflective projection optics, photoresists, and high-precision alignment techniques.

*Supported by Los Alamos Internal Program Development funds and conducted under the auspices of the U. S. Department of Energy.

DF 6 Compact Photoinjector Accelerators for FEL's.* L. M. YOUNG, *Los Alamos National Laboratory.* (20 min.)

A compact photoinjector accelerator has been built for the Los Alamos Free Electron Laser (FEL) Facility. This accelerator produces a very high quality beam at 6 MeV with a peak current of 300 A and an emittance <50 n mm mrad. Two more compact photoinjector accelerators are now being designed and built that will incorporate features which will eliminate some problems that affected the first photoinjector accelerator. One problem was multipacting in the coupling cells. This problem has been avoided in this accelerator but a design change for the coupling cell will eliminate multipacting in the new photoinjector accelerators being built. Another problem observed in this accelerator is a small quadrupole component in the accelerating field, which is caused by the coupling slots. The new design will reduce this effect also. This phenomenon was detectable only because the beam quality was excellent.

*Work supported and funded by the US Department of Defense, Army Strategic Defense Command, under the auspices of the U.S. Department of Energy.

SESSION DG: ATOMIC PHYSICS AND RELATED PHENOMENA

Tuesday morning, 6 November 1990; Union Building, Golden Eagle Suites B and C at 9:00;
J. F. Reading, Texas A&M University, presiding

DG 1 Collision Measurements Using Cold Ions Produced by Synchrotron Radiation.*
D. A. CHURCH, *Texas A&M University.* (20 min.)

The K-shell photoionization of light atoms such as Argon, and the L-shell photoionization of heavier atoms like Xenon, are followed by vacancy cascades leading to charge-state distributions of multi-charged ions. Since the recoil momentum is minimal, the ions have near-thermal energies, which can be preserved when they are confined in a Penning ion trap. Broadband bending magnet radiation was focussed with a cylindrical mirror through the center of the Penning trap to produce the ions from a static gas target. The charge-changing collisions of these ions with the parent gas, or with other targets such as H_2 or He, were studied by recording the rate of ion loss with storage time in the trap. Measurements of the rate coefficients for the collisions of Ar^{q+} ions ($3 \le q \le 6$) with argon and H_2 targets yield rates typically falling below Langevin theory. The data will be compared with trends from measurements at higher energies. Collision processes of particular multi-charged ions having similar energies occur in laboratory and astrophysical sources.

*This research was supported by the National Science Foundation and by the Division of Chemical Sciences, Office of Basic Energy Sciences, DOE.

DG 2 Electron-Electron Interactions in Two Electron Phenomena in Collisions of Fast Ions with He Atoms.
J. P. GIESE, *Kansas State University.* (20 min.)

Recent experiments and calculations have helped clarify the role of electron-electron interactions in two electron phenomena in fast ion-atom collisions. The goal of this work has been to find and explore collision systems where the independent electron approximation (IEA) DOES NOT model the data well. Deviations from the IEA predictions are often described as electron correlations. This paper reviews recent studies of double ionization, transfer ionization, ionization excitation, and double excitation following collisions of fast ions with He atoms. Clear indications of electron-electron interactions have been observed in each of these phenomena. The experimental and theoretical results will be compared with emphasis on the conceptual models of electron correlation.

Prepared in collaboration with J.O.P. Pedersen, University of Aarhus, Aarhus, Denmark.[2]
[1]Supported in part by the U.S. Department of Energy, Office of Basic Energy Sciences.
[2]Supported in part by the Carlsberg Foundation.

DG 3 First Ion Collision Experiments with Highly Charged Ions Extracted from an Electron Beam Ion Trap.
M. C. CLARK, *Lawrence Livermore National Laboratory.* (20 min.)

Highly charged Ar (up to 18^+), Xe (up to 48^+), and U (up to 71^+) ions produced through electron impact ionization and excitation in an electron beam ion trap (EBIT) have efficiently been extracted from the trap, and mass and charged analyzed.[1] Charge state distributions for Ar and Xe ions following electron impact ionization/excitation have been measured. Relative yields for the production of Ar^{16+} and Xe^{44+} ions have been deduced as a function of electron beam energies. The dielectronic recombination in H^-, He^- and Li-like Ar and Fe has been measured via charge state analysis of extracted ions as a function of electron beam energy. Ar K and Xe L x-ray emission following Ar^{17+}, Ar^{18+} and Xe^{44+}, Xe^{45+} and Xe^{48+} ion impact on a Cu surface was measured. The observed line positions demonstrate electron capture into high n states and a fast radiative decay in the neutralization process at the surface.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

+Kansas State University, Manhattan, Kansas
++Manne Siegbahn Institute, Stockholm, Sweden
+++Sandia Laboratories, Livermore, California

1. D. Schneider, D. Dewitt, M. C. Clark, R. Schuch, C. L. Cocke, R. Schmieder, K. J. Reed, M. H. Chen, R. Marrs, M. Levine, R. Fortner, to be published in Phys. Rev. A.

DG 4 Forbidden Transitions in One- and Two-Electron Ions. R. W. DUNFORD, *Argonne National Laboratory.* (20 min.)

DG 5 Projectile Scattering-Angle Dependence in Ionization of Helium by Ion Impact.
A. SALIN, *Universite de Bordeaux I, France.* (20 min.)

DG 6 Fast Multicharged Ion Induced Satellite Auger Electron Angular Distribution.
S. RICZ,* *Institute of Nuclear Research of The Hungarian Academy of Sciences, Hungary.* (20 min.)

The angular distribution of satellite Auger transitions of neon target atoms was investigated by fast heavy ion impact. The energy resolution of the electrostatic electron spectrometer was 1 eV for the diagram K-LL Auger lines of neon[1]. We found relatively high anizotropy parameters. The alignment parameter of O-like satellites shows a definite dependence on the projectile charge at a constant impact velocity. Analyzing the N-like satellite Auger lines determined from Ne^{3+}-Ne collisions we found that the angular distribution of several lines could be described only by using both A_2 and A_4 anisotropy parameters. The definite presence of A_4 may show the deficiency of the independent particle approximation in describing the multiple ionization process.

*In collaboration with: I. Kádár, J. Végh, B. Sulik, D. Varga and D. Berényi, Institute of Nuclear Research of the Hungarian Academy of Sciences
1. I. Kádár, S. Ricz, J. Végh, B. Suli , D. Varga and D. Berényi, Phys. Rev. **A41** (1990) 3518.

SESSION EA: POSITRON BEAM EXPERIMENTS AND FACILITIES II

Tuesday afternoon, 6 November 1990; Union Building, Golden Eagle Suite A at 14:00;
S. C. Sharma, University of Texas at Arlington, presiding

EA 1 The Microtron Accelerator Permits a Compact Positron Source. E. D. SHAW, *AT&T Bell Laboratories, Murray Hill.* (20 min.)

The microtron accelerator developed at AT&T Bell Laboratories currently produces macropulses with charge slightly greater than 1.0μC at energies of 19-20 MeV. The measured vertical emittance at the exit of the microtron is (8±4)π mm mrad while the horizontal emittance is much smaller. In normal operations, about 30μ amps cw current is delivered to a positron moderator in 16μsec pulses at 30Hz. The accelerator is being used to study stimulated emission in a helical undulator for a free electron laser and to make pulses of 10^5 positrons for various solid state experiments and for laser measurements on positronium atoms. Several important microtron improvements including a LaB_6 cathode, electron beam extraction, better vacuum, a new cavity design, and rf pulse envelope flattening will be discussed.

EA 2 New Results at the Giessen Positron Source TEPOS.+
H. SCHNEIDER,++ *Strahlenzentraum der Universität, Federal Republic of Germany.* (20 min.)

At the positron source TEPOS[1] on the Giessen 65 MeV electron linear accelerator (Strahlenzentrum) ratios of K- and L-shell ionization cross-sections by electron and positron impact, respectively, were measured on different Au-/Ag-foils as function of the incident projectile energies. Near threshold a departure of the corresponding ratios from unity is observed for K-shell ionization. To reduce the background we are testing a special coincidence facility. Results are discussed in detail.
To improve the beam quality of our positron source (smaller beam diameter, lower energy spread) we are optimizing remoderation facilities in transmission mode, specially. The extraction of the remoderated positrons is achieved electrostatically.
Further, a new additional bremstarget facility (Platinum target) with a shorter beam transporting system should provide e.g. a better transmission performance for the slow positrons.
Some experiments together with the scientific positron group of the University Mainz (G.Werth et al.) on excited states of positronium were performed.[2]

+ Supported by the Deutsche Forschungsgemeinschaft (DFG), Bonn-Bad Godesberg (Germany).
++ Group members: W.Faust, C.Hahn, M.Rückert, H.Schneider, A.Singe, and I.Tobehn.
1 F.Ebel, W.Faust, C.Hahn, M.Rückert, H.Schneider, A.Singe, and I.Tobehn, Nucl. Instr. a. Meth. B 50 (1990) 328
2 R.Ley, K.D.Niebling and G.Werth; C.Hahn, H.Schneider and I.Tobehn. J.of Phys., accepted.

EA 3 Creation of Slow Positrons at the Ghent 90-MeV LINAC. D. SEGERS,* *Rijksuniversiteit Gent, Belgium.* (20 min.)

At the 90 MeV electron LINAC of the Ghent State University a beam of low-energy positrons was constructed. The convertor-moderator set-up, the magnetic transport system and the experimentation chamber are described. Operating the LINAC at 45 MeV, at a maximum current of 85 μA and a repetition rate of 300 Hz, a positron yield of 2 10^7 e^+/s is obtained. Since these positrons are bunched with the same time-characteristics as the LINAC, it is necessary to spread them out, in order to avoid pile-up in the measuring

system. Therefore a Penning-trap was inserted in the transport system. The characteristics of the positron beam (energy distribution as a function of moderator bias and magnetic guiding field) are discussed. The properties of the Penning trap and the resulting characteristics of the slow positron beam after the Penning trap are described. As an example, the first measurements are illustrated.

*In collaboration with J.PARIDAENS, M.DORIKENS and L.DORIKENS-VANPRAET

EA 4 Positronium and Defect Characterization in Solids with a MeV positron (e^+) Beam.
H. STOLL, *Max-Planck-Institut für Metallforschung, Federal Republic of Germany.* (20 min.)

A monoenergetic positron beam ($6 \cdot 10^4 e^+/s$) in the energy range of 0.5 MeV $\leq E \leq$ 6.5 MeV ($\Delta E/E \approx 10^{-4}$ FWHM) has been installed at the Stuttgart Pelletron accelerator. Besides experiments on e^+e^- scattering (Bhabha scattering) and on e^+e^- annihilation- in-flight, $\beta^+\gamma$ positron-lifetime measurements in solids and melts have been performed. Among the advantages of the beam-based $\beta^+\gamma$ technique over the conventional $\gamma\gamma$ coincidence technique are substantially increased count rates and virtually eliminated statistical backgrounds, measurements under difficult conditions (e. g., in high-temperature melts) are simplified. Time resolved information on the evolution of the positron states (e. g., positron trapping at defects) and a sensitive detection of positronium formation are obtained by a triple coincidence method ($\beta^+\gamma E$ age-momentum correlation).

EA 5 Physisorption of Atoms on Internal Surfaces of Radiation-Induced Cavities in Metals. A Positron Annihilation Study.*
S. C. SHARMA, *The University of Texas at Arlington.* (20 min.)

Positron annihilation spectroscopy (PAS) and scanning electron microscopy (SEM) have been used to study helium bubbles in alpha irradiated samples. We present results from our recent PAS and SEM experiments conducted on single and polycrystalline samples irradiated under identical conditions. SEM reveals significant differences in surface morphology and PAS provides estimates for the size and concentration of the helium bubbles. We discuss the effects of the grain boundaries and impurities on bubble growth and review applications of PAS in the study of physisorption of simple atoms/molecules on surfaces. We also show that the recently observed temperature dependance of the positron lifetime data in alpha irradiated aluminum can be understood in terms of helium physisorption on the internal surfaces of the radiation-induced cavities.

*Supported by the Welch Foundation, Houston, Texas. Research conducted in collaboration with J. Ma, N. Hozhabri, S. V. Naidu, C. I. Eom, P. Sen, and G. Nambissan.

EA 6 Positron Annihilation-Induced Angular Electron Spectroscopy and Its Implementation at Accelerator-Based Low-Energy Positron Factories. ALEX WEISS, *The University of Texas at Arlington.* (20 min.)

Positron Annihilation Induced Auger Electron Spectroscopy (PAES) makes use of a beam of low energy positrons to excite Auger transitions by annihilating core electrons. Thus the large secondary electron background usually present in collisionally excited Auger spectra can be eliminated by setting the positron beam energy well below the Auger electron energy. This allows true Auger lineshapes to be obtained. Further, because the positron is localized just outside the surface before it annihilates, PAES is extremely sensitive to the topmost atomic layer. Recent PAES results obtained at the University of Texas at Arlington will be presented. In addition, the use of high resolution energy analyzers with multichannel particle detection schemes to prevent problems due to the high data rates associated with accelerator based positron beams will be discussed. This research supported by the Robert A. Welch Foundation.

EA 7 Slow Positron Beam Extraction and Manipulation Using a Pulsed Gap Accelerator Technique.
L. D. HULETT, *Oak Ridge National Laboratory.* (20 min.)

The generation of slow positrons by an electron LINAC source requires that the moderator be placed in close proximity to the electron target, in an environment of intense gamma, beta, and neutron flux, it must be cooled to remove the heat generated. The extraction of the positrons by raising the moderator to high potentials requires insulators that can withstand the high voltages in the presence of the radiation environments. Also, the cooling water lines must have special insulating breaks in them. An alternative extraction method is to use a pulsed gap accelerator technique that leaves the moderator at ground potential, eliminating the need for insulators. Such a method is being used at the ORNL facility. Results will be reported. Other applications of the method for positron beam manipulation will be discussed.

EA 8 Free-Volume Properties of Polymers Probed by Positrons.*
Y. C. JEAN, *University of Missouri–Kansas City.* (5 min.) (Invited Poster Paper. See Poster Display PB 36).

Positron annihilation spectroscopy(PAS) has been developed to characterize the microstructural properties of polymers[1,2]. Positron annihilation lifetime measurements give direct information about dimensions, contents and distributions of free-volume holes in amorphous polymers. Angular correlation of positron annihilation radiation measurements give additional information about the shape of holes in oriented polymeric materials. The unique capability of

PAS to probe free-volume properties is from the fact that positronium atom is found to be preferentially trapped in the atomic-scale holes which have a size ranging from 1 to 10 A. Theoretical aspects and experimental results along with examples in analyzing the free-volume hole structures of epoxy, PEEK, and PMMA will be presented.

*Supported by McDonnell Douglas Independent Research and Development Program and National Science Foundation.

1. Y. C. Jean et al, J. Polym. Sci. B, 24, 1247(1986)
2. H. Nakanishi et al, J. Polym. Sci. B, 27, 1419(1989)

EA 9 Materials Science Application with Positrons.
P. L. JONES, *Duke University.* (5 min.) (Invited Poster Paper: See Poster Display PB 35).

SESSION EB: RADIOACTIVE BEAM EXPERIMENTS

Tuesday afternoon, 6 November 1990; Union Building, Room 410 at 14:00;
C. ROLFS, Westfälische Wilhelms Universität, Federal Republic of Germany, presiding

EB 1 Production and Studies with Secondary RIB at LISE. A. MUELLER, *Orsay-Ganel, France.* (15 min.)

EB 2 Ion Source for RIB at TRIUMF. L. BUCHMAN, *TRIUMF, France.* (15 min.)

EB 3 Plans for Radioactive Beams at the LBL 88-Inch Cyclotron. R. STOKSTAD, *Lawrence Berkeley Laboratory.* (15 min.)

EB 4 Accelerated Radioactive Beams—A Status Report. JOHN M. D'AURIA, *Simon Fraser University, Canada.* (15 min.)
Over the last five years considerable interest has developed in the world in the use of accelerated radioactive beams for a variety of fundamental and applied nuclear science studies. It is now recognized that technology is in place to produce such exotic beams. Facilities exist in Europe, Japan and in the U.S. to produce energetic beams (50-500 MeV/u) using the Projectile Fragmentation Recoil Method while a number of proposals exist around the world including Canada and the U.S. to produce low energy (less than 10 MeV/u) beams using the ISOL/Post-Accelerator Approach. A Steering Committee has just been formed to coordinate the preparation of a proposal to install a major accelerated radioactive beams facility based upon the ISOL/Post-Accelerator approach somewhere in North America. In this presentation a review of this developing field will be given along with a summary of possible scientific programs, and details of some of the proposed or operating low energy beams facilities. The activities and the plans of the Steering Committee will also be presented.

EB 5 The Proposed Radioactive Nuclear Beam Facility at RAL.
T. G. WALKER, *Rutherford Appleton Laboratory, England.* (15 min.)
In the United Kingdom we are studying a Radioactive Nuclear Beam Facility which will have as its major experimental goal the extension of the study of the nucleus through spectroscopic studies at and near the neutron and proton drip lines and in the region of superheavy nuclei. This facility will separate and accelerate radioactive fragments with half-lives down to tens of milliseconds produced in spallation, fission and fragmentation processes using a primary beam of high intensity protons. A 100 microampere 800 MeV proton facility ISIS already exists at the Rutherford Appleton Laboratory for the production of neutrons for condensed matter research. The on-line isotope separation will follow the principles of the ISOLDE facility at CERN. Provision is provided for further acceleration up to energies of several MeV per nucleon using either a linear accelerator system or a linac plus race-track synchrotron.

EB 6 Low- and Medium-Energy Radioactive Ion Beams at Louvain-la-Neuve, Belgium.*
G. RYCHEWAERT, *Catholic University of Louvain, Belgium.* (15 min.)
This paper reviews the status and recent achievements of the Leuven Isotope Separator On Line where the low energy radioactive beams (50 KeV acceleration energy) are mainly used for nuclear physics experiments. Radioactive beams with masses ranging from A ≃ 8 up to A ≃ 240 are produced by light and heavy ion induced fusion and fission reactions. The second part describes a project for accelerating these beams to medium energy (~ 1.5 MeV/AMU) for use in nuclear, astrophysical and solid state studies (ARENAS[3]).

* In collaboration with P. Decrock, Th. Delbar, P. Den Dooven, W. Galster, M. Huyse, P. Leleux I. Licot, E. Liénard, P. Lipnik, M. Loiselet, G. Reusen, P. Van Duppen J. Vanhorenbeeck, J. Vervier and J. Wouters.

EB 7 Radioactive Ion Beams at the Bevalac: Greatly Enhanced Fragment Separation for High-Energy Beams.*
B. FEINBERG, *Lawrence Berkeley Laboratory.* (15 min.)
Radioactive beams are routinely produced at the Bevalac by the fragmentation process. High energy beams (energies ~ 800 MeV/u) produce fragments with nearly the original beam momentum, forming a radioactive ion beam. A new beamline is being constructed which will provide resolution for ions approaching the mass 100 region, compared to the present mass 20 capability, by strongly increasing the dispersion and also increasing the beam size for easier tuning and more effective collimation. In addition, the angular acceptance has been more than doubled. Details of the design will be presented.

*Work done in collaboration with J.G. Kalnins and G.F. Krebs, and supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Nuclear Physics Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

EB 8 Nuclear Polarization of Radioactive Beams by Tilted Foils.*
MICHAEL HASS, *NSRL, University of Rochester, and the Weizmann Institute, Israel.* (15 min.)

The atomic polarization present when ions traverse thin foils at an oblique angle (tilted-foil geometry) can be transferred to the nucleus via the hyperfine interaction of the electronic spin with the nuclear magnetic moment and hence produce nuclear polarization. This method has been used[1] successfully in the past few years to measure diverse nuclear electromagnetic properties such as signs of quadrupole moments of isomeric high-spin levels, parity violation effects and magnetic moments in ground states of mirror nuclei (using the β-NMR technique). Of particular importance is the use of this method in conjunction with facilities which produce separated reaction products ("radioactive beams"), allowing such measurements to be performed for nuclei in far-from-stability regions and under favorable conditions of good (radioactive) beam quality and no interference from the direct beam. A brief summary of the subject and of the present status of such efforts will be presented.

*Supported in part by the NSF and by the Israel-US BSF.
†Permanent address.
[1]G. Goldring, M. Hass and E. Dafni, Hyper. Interact. 33, 19 (1987).

EB 9 Synthesis of Light Elements. R. N. BOYD, *Ohio State University, Columbus.* (30 min.)

SESSION EC: NONLINEAR EFFECTS IN ECR-GENERATED PLASMAS

Tuesday afternoon, 6 November 1990; Union Building, Room 412 at 14:00; G. D. Alton, Oak Ridge National Laboratory, presiding

EC 1 The Design of Particle Spectrometers and Beam Guidance Systems with Reduced Image Aberrations.
H. WOLLNIK, *Justus Liebig Universität, West Germany.* (25 min.)

EC 2 Injection of High-Brightness H^- Beams into RFQ Accelerators. M. REISER, *University of Maryland.* (25 min.)

EC 3 Transport of High-Intensity H^- Ion Beams in the BEAR Accelerator. P. O'SHEA, *Los Alamos National Laboratory.* (25 min.)

EC 4 Aberration Production in Liquid Metal Ion Sources.* J. H. WHEALTON, *Oak Ridge National Laboratory.* (25 min.)

To model accurately the liquid metal ion source (LMIS), with the great disparity between the dimensions of its emitter and its expanded beam, a calculational technique has been devised and implemented that is a trillion times more expeditious than previous techniques [1]. Two independent approaches (the inverse Vlasov and the variable mesh) were first considered and subsequently rejected as unfeasible. A third approach, the Vlasov-Poisson-Oscillating Dirichlet Microscope, was therefore developed. This third approach has enabled accurate modeling over scale changes of 10^8 per dimension. An example is considered in Fig. 1 where several blowups (12 x 16 area magnification in each) are analyzed self-consistently near the space-charge limit, leading to fractional Å resolution in a cm-sized device as shown in in Fig. 2. The physical size represented by Fig. 1 is approximately 1 cm on a side. The physical region represented in Fig. 2 is a blowup of the needle tip shown in Fig. 1. The physical size is approximately 4 million time smaller in each dimension (40 A x 40 A). Boundary conditions on the edges of Fig. 2 are determined from the solution of the previous blowup. For finite space charge, as shown, this telescope-microscope procedure is repeated until converged. To get this resolution from the full device would require more than 10^{20} nodes for the finite difference solution to the Laplace equation (symmetry reduces it from 10^{30} nodes – numerologically equal to the age of the universe in picoseconds). Only 10^7 simple calculations are required as a result of the subject procedure.

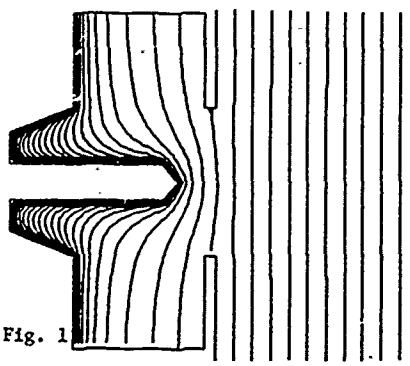

Fig. 1

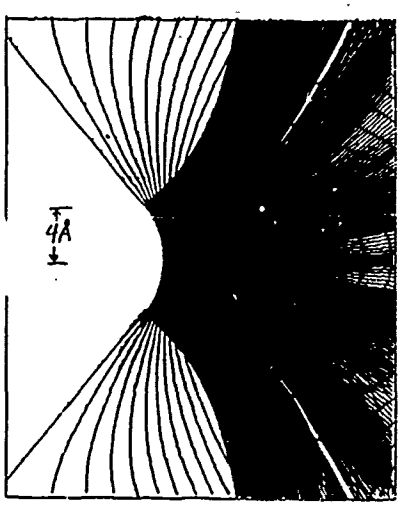

Fig. 2

*Research sponsored by the Exploratory Studies Program of the Oak Ridge National Laboratory, operated for the U.S. Department of Energy by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400.
[1]J. H. Whealton, P.S. Meszaros, K. E. Rothe, R. J. Raridon, and P. M. Ryan, "Beam Dynamics of a Liquid-Metal Ion Source," Rev. Sci. Instrum. 61 (1), 568 (1990).

EC 5 Factors Which Affect the Emittances in ECR Ion Sources. T. ANTAYA, *Michigan State University.* (25 min.)

EC 6 Gas Mixing Effects in ECR-Generated Plasmas.*
C. C. PETTY,† *Plasma Fusion Center, Massachusetts Institute of Technology.* (25 min.)

Operators of electron cyclotron resonance (ECR) ion sources have found that by mixing a lighter gas with a heavier gas, the extracted currents for high charge states of the heavier gas increase over what they would be if the lighter gas were not present. In order to learn more about this phenomenon, a case of gas mixing was studied in Constance B, a single-cell quadrupole mirror. The ion temperatures, densities, and end-loss fluxes as a function of charge state were measured for a pure oxygen and a oxygen and helium plasma. The end-loss flux of O^{6+} increased by 80% during gas mixing even though the total oxygen density decreased by half. The increased O^{6+} end-loss was mainly due to reduction of cross-field transport of ions. A significant amount of oxygen ion cooling by helium was also observed.

*Work supported by U.S. Department of Energy Contract DE-AC02-78ET51013.
†Current address: General Atomics, P.O. Box 85608, San Diego, CA.

SESSION ED: NUCLEAR PHYSICS
Tuesday afternoon, 6 November 1990; Union Building, Golden Eagle Suites B and C at 14:00;
R. L. Walter, Duke University, presiding

ED 1 Chaotic Behavior of Nuclear Spectra.*
G. E. MITCHELL, *North Carolina State University and Triangle Universities Nuclear Laboratory.* (20 min.)

The topic of quantum chaos and searches for quantum systems which display chaotic behavior have been the subject of much discussion recently. Bohigas *et al.* conjectured that quantum analogs of classically chaotic systems display level statistics which are consistent with the predictions of the Gaussian orthogonal ensemble (GOE) of random matrix theory.[1] This suggests that the fluctuation properties of nuclear levels may be used as a signature for chaos or regularity. High quality nuclear resonance data are known to display the long and short range order predicted by GOE.[2] In only one nucleus, ^{26}Al, are all levels known from the ground state to the resonance region. Analysis of the first 100 positive parity states suggests that the fluctuation properties lie between a GOE and a Poisson description and are independent of excitation energy.[3,4] There is no other available data which is of sufficient quality to permit such analysis in a single nuclide. However, there are many nuclides whose level schemes are complete over a more limited range of energies and spins.[5] We have analyzed a much expanded data set (168 sequences of levels in 60 nuclides). Our results show a strong dependence on the mass number A, with suggestions of effects due to spin and deformation.

*Supported in part by US Department of Energy, Office of High Energy and Nuclear Physics (Grant No. DE-FG05-88ER40441).
[1]O. Bohigas *et al.*, Phys. Rev. Lett. 52, 1 (1984).
[2]O. Bohigas *et al.*, Phys. Rev. Lett. 54, 1645 (1985).
[3]G. E. Mitchell *et al.*, Phys. Rev. Lett. 61, 1473 (1988).
[4]J. F. Shriner, Jr. *et al.*, Z. Phys. A 335, 393 (1990).
[5]T. von Egidy *et al.*, Nucl. Phys. A454, 109 (1986); Nucl. Phys. A481, 189 (1988).

ED 2 Discovery of Very Elongated Nuclei Near $A=190$. J. A. BECKER, *Lawrence Livermore National Laboratory.* (20 min.)

ED 3 Probing the Charge Structure of the Neutron.* R. MADEY, *Kent State University.* (25 min.)

Knowledge of the distribution of electric charge within the neutron is fundamental to understanding both nucleon and nuclear structure. Little is known at the present time because the theoretical description of the deuteron is model dependent. Experiments are planned at the Bates electron accelerator facility and at CEBAF to probe the charge structure of the neutron in a way that should circumvent these large uncertainties by scattering longitudinally-polarized electrons from deuterium quasielastically and measuring the transverse polarization component $P_{s'}$ of the recoil neutron. This polarization component $P_{s'}$, which lies in the scattering plane normal to the neutron momentum, is proportional to the electric form factor of the neutron, G_E^n, in the impulse approximation.[1] Theory indicates that $P_{s'}$ has almost no dependence on the deuteron model, and that it is insensitive to the influence of final-state interactions, meson-exchange currents, and isobar configurations.[2]

* Supported in part by the National Science Foundation.
1. R.G. Arnold, C.E. Carlson, and F. Gross, Phys Rev. C23, 363 (1981).
2. H. Arenhövel, Phys. Lett. B199, 13 (1987).

ED 4 Selected Studies of Electrodisintegration of ^{3}He and ^{4}He at CEBAF.
J. MOUGEY, *Continuous Electron Beam Accelerator Facility.* (20 min.)

ED 5 Nuclear Properties from Optical Spectroscopy of Radioactive Atoms Produced by Heavy-Ion Fusion.*
C. H. HOLBROW, *Colgate University.* (20 min.)

A gas filled cell has been developed to collect accelerator produced radioactive nuclei in order to study laser induced spectra of atoms formed from them. The apparatus can detect spectra even when the nuclides are being produced at less than 1000 s^{-1}. At this level of sensitivity heavy-ion fusion reactions become a useful source of very neutron deficient atoms, and we have measured isotope shifts of ytterbium out to ^{152}Yb, 18 neutrons away from the line of beta stability. The data imply a large jump in the rms nuclear charge radius of Yb surprisingly

near the N – 82 neutron shell closure. Heavy ion fusion can produce isotopes so selectively that isotope separation is not needed. As a result our apparatus permits optical spectroscopy of atoms too refractory or too short-lived to process in an isotope separator; studies of the refractory element hafnium are now under way.

*Supported by the National Science Foundation.

ED 6 The Dominant Role of Intruder States in the Structure of Ir and Au Nuclei.
L. L. RIEDINGER, *The University of Tennessee, Knoxville.* (20 min.)

ED 7 Momentum Achromat Recoil Spectrometer. R. TRIBBLE, *Texas A&M University.* (20 min.)

SESSION EE: ATOMIC PHYSICS AND RELATED PHENOMENA

Tuesday afternoon, 6 November 1990; Physics Building, Room 102 at 14:00;
I. A. Sellin, Oak Ridge National Laboratory, presiding

EE 1 Electron Emission Induced by Ion Bombardment of High-T_c Superconductors.[1,2]
HERMANN ROTHARD, *J. W. Goethe-Universität, Germany.* (25 min.)

The interaction of swift ions with solids causes a dynamical collective response of the electron plasma ("wake"). These conical electron density fluctuations show the charateristic behaviour of Mach shock waves and lead to the directed emission of shock electrons perpendicular to the wake shock front. Shock electrons have recently been detected by measuring angular distributions of heavy ion induced secondary electrons (SE) emitted from thin foils in the forward half cone[3]. Within the framework of a model for the refraction of low energy electrons at surfaces it has been predicted[4] that it should be possible to detect shock electrons from thick solid samples in backward direction. Also, the question has been raised whether SE emission[5] and in particular the collective emission of shock electrons[5] is influenced by the superconducting phase transition. To test these consi' rations, we have performed first studies of H^+- and C^+- (2 MeV) induced SE energy- and angular distributions from $YBa_2Cu_3O_7$ and $EuBa_2Cu_3O_7$ high Tc superconductors at sample temperatures above (T=300K) and below (T=35K) the superconducting transition temperature (Tc=90K).

[1] In collaboration with Karl-Ontjes Groeneveld, Markus Schosnig, Dominik Schlößer, Kurt Kroneberger, Enio da Silveira (Pontificia Universidade Católica, Rio de Janeiro, Brazil).
[2] This work has been funded by the German "Bundesminister für Forschung und Technologie", Bonn, FRG, Nr. 06OF173/Ti476
[3] Nucl.Instrum.Meth. B48(1990)616 [4] J.Physique(Paris) 50(1989)C2-105 [5] Phys.Rev. B38(1988)9224
[6] K.Griepenkerl,B.Müller,W.Greiner, Radiation Effects and Defects in Solids 110(1989)215

EE 2 Spectroscopy of Hydrogenlike and Heliumlike Uranium.
J. P. BRIAND, *Universite Pierre et Marie Curie, France.* (25 min.)

EE 3 Angular Scattering in Low-Energy Collisions Involving Multicharged Ions.*
L. R. ANDERSSON, *Manne Stegbahn Institute, Sweden.* (25 min.)

Calculations of the angular distribution of ions resulting from charge transfer in Ar^{6+} +He collisions at energies below 25 eV/ amu have been carried out. The calculations were performed both by a MCLZ model with classical nuclear trajectories[1] and by a fully quantal model-potential method. The results were compared to experimental results giving both the scattering angle and the energy-gain of the projectile ions[2]. After convolution with the experimental resolution, the two theoretical methods give essentially the same angular distributions. The principal features of the experimental angular and energy-gain distributions for one-electron transfer are reproduced. However, structures appearing in the experimental data at collision energies below about 13 eV/ amu can not be satisfactorily explained including only one-electron transfer channels in the calculations. The experiments[2] show that two-electron transfer into non-autoionizing states of Ar^{4+} occurs. The presence of such inelastic channels may offer an explaination of the angular distributions for one-electron transfer.

* Work supported in part by the Swedish Natural Science Research Council
In collaboration with A. Bárány, C. Biedermann, H. Cederquist, M. Gargaud, R.McCarroll and I.A. Sellin.
[1] L.R. Andersson, J.O.P Pedersen, A. Bárány, J.P. Bangsgaard and P.Hvelplund, J.Phys.B 22, 1603 (1989)
[2] C. Biedermann, this conference

EE 4 Overview of Atomic Physics Experiments at GANIL. J. P. GRANDIN, *GANIL/CIRIL, France.* (25 min.)

GANIL accelerator located at Caen (France) provides intense beams of Carbon to Uranium ions with energies ranging from 100 MeV/amu for the lightest elements to 20 MeV/amu for the heaviest (15 to 4 MeV/amu at the newly operated medium energy facility). The corresponding velocity range thus extends from neon K shell up to higher than xenon K shell electron velocity. Excellent optical quality beams of bare, or very few electron ions, may be prepared using the doubly achromatic magnetic spectrometer LISE (or an equivalent device at the medium energy line). Atomic Physics experiments performed so far includes:
- *Atomic Spectroscopy experiments* which mostly aim at testing relativistic and QED calculations.

- *Atomic Collision experiments* mainly dedicated to the very study of elementary collision processes or to the production of very low energy multicharged recoil ions.
- *Channeling experiments* which, under some drastic conditions, allow to study the interaction of the projectile ions with the slowest electrons of a solid target.

Atomic Physics experiments are furthermore closely related to condensed matter physics experiments which are devoted to the study of the consequences of the huge energy deposited in the targets as a result of the slowing down of the ions by electronic stopping power.

EE 5 A Study of the Polarization of Photons in Polarized Electron-Noble Gas Collisions.*,+
J. E. FURST, *University of Missouri—Rolla.* (20 min.)

It is possible to determine the importance of the spin-orbit interaction in electron-noble gas collisions by using polarized electrons and measuring the polarization of the radiation emitted in the collision. For example, a non-zero value of η_1, which is the linear polarization fraction obtained with a polarizer set at 45° and 135° with respect to the electron beam axis, indicates the presence of significant spin orbit effects in the collision[1]. A method for separating target and continuum electron spin orbit effects, using well L-S coupled excited states, will be discussed. We will present a comparison between scattering from He, where spin-orbit effects are not important and from Xe, where they may be, in the energy range from threshold to 200 eV. The polarization measurements take into account the effect of cascades from higher states and the influence of near threshold negative ion resonances.

*Supported by National Science Foundation Grant PHY 9007721 and the University of Missouri.
+Work performed in collaboration with T. J. Gay, J. A. Brand, and W. M. K. P. Wijayratna.
[1]K. Bartschat and K. Blum, Z. Phys. A 304, 85 (1982).

EE 6 How Does Rydberg Charge Transfer Vary Over the Intermediate Velocity Region?*
K. B. MACADAM, *University of Kentucky.* (25 min.)

The relative distribution of Rydberg final states populated in capture of highly excited electrons from Na Rydberg target atoms by singly charged ions has been measured throughout the range of reduced velocity $\tilde{v} = 0.2$ to 1.95. Laser-excited s and d target states n = 24 to 33 were studied at ion energies from 60 to 2100 eV. A consistent pattern of shifting, broadening and skewing has been observed in which the distributions are narrowest in n near $\tilde{v} = 0.7$. At this same velocity the most probable n of the smoothly peaked distributions is highest, generally about two to three units above the initial n. The ratio of orbital kinetic-energy spread after capture to initial rms kinetic energy in the projectile frame before capture shows a universal behavior. In the newest experimental work the velocity dependence of the total charge-transfer cross section, encompassing all final Rydberg states, has been measured for similar energies and quantum numbers, and consistent patterns of variation have been observed.[1]

*Supported in part by NSF Grant PHY-8808022.
[1]The contributions of coworkers L.G. Gray, R.G. Rolfes, S.B. Hansen and E. Horsdal-Pedersen are gratefully acknowledged.

SESSION EF: ACCELERATOR MASS SPECTROMETRY

Tuesday afternoon, 6 November 1990; Biology Building, Room 200 at 14:00; W. E. Kieser, University of Toronto, presiding

EF 1 Materials Characterization Using Accelerator Mass Spectrometry.
J. M. ANTHONY,* *Texas Instruments, Incorporated.* (20 min.)

Accelerator mass spectrometry (AMS) has become a mature technology for the detection of low level (10^7 at/cc) radioisotope concentrations in materials, and instruments devoted to the analysis of stable element impurities are under development[1]. In general, impurity analysis requires less sensitivity but a broader range of detectability than conventional AMS measurements. Several factors must be considered in any attempt to optimize the performance of an AMS system for full periodic table coverage in all solid materials, including efficient ionization of sputtered particles and a careful choice of isotope/charge state combinations to avoid kinematic interferences. Quantification, insulator analysis and sample contamination also pose practical problems which must be addressed. This paper discusses the techniques in use at the University of North Texas to optimize AMS for routine materials characterization of solid samples. This includes investigations of the relative ionization rates of various sputtered elemental and molecular ions in semiconductors and efficient algorithms for routine mass analysis of unknown samples. The design and

status of the ultra-clean ion source will be discussed, and detection limits of the AMS system will be presented.

[1]Proceedings of the Fifth International Conference on Accelerator Mass Spectrometry, Paris, April 23 - 27, 1990

* In Collaboration with: R.L. Beavers, T.J. Bennet, Texas Instruments, Dallas, Texas, and S. Matteson, D.J. Marble, D.L. Weathers, F.D. McDaniel, and J.L. Duggan, University of North Texas, Denton, Texas

EF 2 Biomedical and Clinical Applications of Accelerator Mass Spectrometry.*
J. C. DAVIS, *Lawrence Livermore National Laboratory.* (20 min.)

The very high sensitivity attainable and small sample size required in accelerator mass spectrometry assay of long-lived isotopes have made this nuclear technology an obvious candidate for extension to biomedical and clinical applications since its first demonstration. Using ^{14}C compounds, we have begun applying the technique to dosimetry of damage caused to DNA by mutagens and carcinogens at exposure levels representative of normal human diet and environment and have begun the study of very low probability biological events. With clinical collaborators, we are developing assays to determine drug efficacy and techniques to allow dose reduction in both research and clinical investigations. Spectrometer development for special clinical uses is in progress. The sensitivities obtained in the results obtained to date and the protocols developed to allow safe usage of the same spectrometer for natural abundance and labeled materials will be discussed.

*This work was performed under the auspices of the U. S. Department of Energy at the Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

EF 3 A Sputter Negative Ion Source for AMS.*
SI HOUZHI,** *Shanghai Institute of Nuclear Research, People's Republic of China.* (20 min.)

A high intensity Cs sputter negative ion source for AMS application has been constructed and tested. A heated spherical tungsten surface with an extraction hole of 5 mm in diameter acts as the Cs ionizer. A target wheel with 18 sample positions is seperated from the ionization region by a gate valve. The "cathode insulator",usually made of boron nitride in Model 860 ion sources, was removed and a metal-ceramic bonded ring is used to support the cathode potential. A specially designed shield structure arround the ionization region confines the Cs vapor,prevents it from condensing on the insulators and reduces the memory effect of the source at the same time. The source is being tested intensively at the ion source test stand. 10μA of BeO^- and more than 350μA of C^- beams have been delivered from this source. The emittance measurement of the beam is now under way.

*Supported by the National Natural Science Fundation of China
**In collaboration with ZHANG WEIZHONG,ZHU JINGHUA,DU GUANGTIAN,ZHANG TIAORONG

EF 4 Isobar Separation with Ionization Counters in AMS. M. SUTER,[1] *Paul Scherrer Institut, Switzerland.* (20 min.)

The sensitivity of accelerator mass spectrometrey (AMS) depends in many cases on isobaric interferences, and the techniques applied to separate the isobars. In this paper the potential and limitations of ionization counters for isobar separation are presented. As an initial approach, a model detector with two electrodes is discussed. The energy resolution of the ΔE-signal is primarily determined by the energy straggling caused by charge state fluctuations of the project[illegible]s in the counter gas (and entrance foil). With semi-empirical formulas this energy straggling can be calculat[illegible] function of the initial energy and the energy loss. Based on this information the best ratio for the energy lo[illegible]tribution between the two electrodes can be determined. Assuming gaussian shaped peaks, the suppression of isobars can be estimated for various energies and masses. The model calculations are compared with experimental results obtained on the ^{36}Cl-^{36}S system in the energy range between 32 and 48 MeV. At lower energies reasonable agreement has been found. The measurements show that gaussian shaped peaks can be assumed over the first 3 orders of magnitude. Below that, large angle scattering affects the peak shape dramatically. This would require a more detailed model to describe the suppression at higher energies, at which the peak separation is larger. Improvements with multielectrode arrangements and appropriate data analysing systems are also discussed.

The limitations given for ionization counters are compared with other methods used for isobar separation such as gas filled magnet, stripping to bare ions and absorber techniques.

[1] In collaboration with: G. Bonani, H.J. Hofmann, Th.R. Niklaus, H.A. Synal, W. Wölfli and U. Zoppi, ETH Zürich

EF 5 Probing the Environment with Accelerator-Based Techniques. C. TUNIZ,* *University of Trieste, Italy.* (20 min.)

Natural and anthropogenic events are deteriorating the terrestrial environment with global effects on the atmosphere, water and soil. Greenhouse effect, ozone layer depletion, acid rain, drought, desertification and heavy metal contamination are some of the plagues threatening our future. Records of the past

behaviour of the terrestrial environment, preserved in natural archives, such as marine sediments, ice cores and tree rings, provide useful clues to the interpretation of the symptoms preceding significant environmental modifications. In particular, antarctic ice is an archive recording climatic changes on temporal scales of hundreds of thousands of years. Modern analytical techniques based on particle accelerators, originally designed for fundamental physics experiments, can provide useful tools to assist in these studies. For example, Accelerator Mass Spectrometry (AMS) measures long-lived cosmogenic isotopes present in the environment, such as ^{14}C, ^{10}Be, ^{36}Cl and ^{129}I. This technique has been applied to investigate soil erosion and salinization, ground water management, nuclear waste disposal, dating of ancient earthquakes, etc. The AMS measurements of radioisotopes provide important chronological information. Another accelerator-based technique, Synchrotron-Radiation Induced X-ray Emission (SRIXE), can be used to study the distribution of heavy metals and other trace elements in the environment. SRIXE microprobes are being developed to map trace elements in micron-size particles and microorganisms of environmental interest. The utility of these advanced methods to understand the impact of natural phenomena and human activity on the ecological disequilibrium will be discussed.

* In collaboration with F. Zanini and R.K. Moniot

EF 6 A Dedicated Gas-Filled Magnet Isobar Separator for AMS Applications.[1] PETER W. KUBIK, *University of Rochester.* (20 min.)

The most difficult problem in many accelerator mass spectrometry (AMS) measurements is the rejection of background from stable isobars. With the use of high intensity ion sources the isobar intensity will increase. We have shown that the gas-filled magnet (GFM) technique can reduce the isobaric background in a 36Cl AMS system by at least two orders of magnitude (2). A dedicated GFM is currently being installed in our beamline. The magnet has been reconfigurated for transmission of ions with large mass-energy products. The pole face gap has been enlarged to accommodate the increased beam size in the low pressure gas region. The pole face angles can be adjusted to optimize the focussing properties. The new configuration of the University of Rochester AMS beam line will be described in detail.

1. Supported by NSF grant EAR-8803803 and EAR-8916359. In collaboration with R. Teng and S. Datar Nuclear Structure Research Laboratory, University of Rochester, Rochester, NY 14627, D. Elmore and T. Miller, Department of Physics, Purdue University, W. Lafayette, IN 47907

2. P.W. Kubik et al. Nucl. Instr. and Meth. B40/41 (1989) 741-744

EF 7 Recent Developments in AMS at the IsoTrace Laboratory. W. E. KIESER, *IsoTrace Laboratory, Canada.* (20 min.)

In the past year, two new analytical applications have become available at IsoTrace: the measurement of $^{129}I/^{127}I$ ratios in natural materials such as groundwater and marine organic materials, and the *in – situ* measurement of gold and platinum group elements in sulphide ores [1,2]. Procedures and detection limits for these applications will be described. Recent measurements of accuracy and sample preparation induced contamination in radiocarbon analysis will be reviewed [3] and progress in the electric field dissociation of negative ions as an isobar selection tool will be discussed [4].

[1] L. R. Kilius, M. A. Garwan, A. E. Litherland, M-J. Nadeau, J. C. Rucklidge and X-L Zhao, Nucl. Instr. and Methods B40/41 745-749 (1989).
[2] L. R. Kilius, N. Baba, M. A. Garwan, A. E. Litherland, M-J. Nadeau, J. C. Rucklidge and X-L Zhao, Proc. 5th Int. Symp. on AMS, Nucl. Instr. and Methods *(in press)* IsoTrace preprint #90.04
[3] R. P. Beukens, Radiocarbon 32 no. 3 *(in press)* IsoTrace preprint #89.04.
[4] M-J. Nadeau, A. E. Litherland and L. R. Kilius, Proc. 5th Int. Symp. on AMS, Nucl. Instr. and Methods *(in press)* IsoTrace preprint #90.06

SOCIAL HOUR
Tuesday evening, 6 November 1990; Union Building, Second Floor at 17:00

SESSION FA: SYNCHROTRON RADIATION I
Tuesday evening, 6 November 1990; Physics Building, Room 102 at 19:00; B. Johnson, Brookhaven National Laboratory, presiding

FA 1 Atomic Physics Research with Second and Third Generation Synchrotron Light Sources.*
BRANT M. JOHNSON, *Brookhaven National Laboratory.* (5 min.) (Invited Poster Paper: See Poster Display PA 41)

This brief talk and poster is intended to provide an introduction and overview for a collection of invited presentations on atomic (and related) physics research at existing and planned synchrotron light sources. The emphasis will be on research accomplishments and future opportunities, but a

comparison will be given of operating characteristics for first, second, and third generation machines. First generation light sources were built to do research with the primary electron and positron beams, rather than with the synchrotron radiation itself. Second generation machines were specifically designed to be dedicated synchrotron-radiation facilities, with an emphasis on the use of bending-magnet radiation. The new third generation light sources are being designed to optimize radiation from insertion devices, such as undulators and wigglers. Each generation of synchrotron light source offers useful capabilities for forefront research in atomic physics and many other disciplines.

*Research supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, US Department of Energy under Contract No. DE-ACO2-76CH00016.

FA 2 Nuclear Resonant Bragg Scattering. P. SIDDONS, *Brookhaven National Laboratory.* (20 min.)

FA 3 Vibrational Excitation Effects on Core Exciton Spectra.
W. L. O'BRIEN, *University of Tennessee, Knoxville.* (5 min.) (Invited Poster Paper: See Poster Display PA 39)

The effects of vibrational excitations on core spectra of solid state systems have been studied in a number of cases by comparing results from spectroscopies measuring the population and the decay of the core hole states. Core hole decay spectra are dependent on the rate at which the nuclei rearrange via phonon emission and the lifetime of the initial state. Core excitons, being well-defined discrete atomic-like excitations, are well suited for these studies. In cases where they can be resolved in both x-ray absorption and emission any discrepancy in shape and energy position can be related to the relaxation of the excited state. For example the two exciton peaks associated with the Al L_3 and L_2 excitations in Al_2O_3 have been found to shift 0.15 eV. Our results will be discussed in terms of phonon relaxation theory[1] and results in the literature.

[1]G. D. Mahan, Phys. Rev. **B15**, 4587 (1977).

J-E. Rubensson, D. R. Mueller and D. L. Ederer, NIST.
J. Jia, Q. Y. Dong, T. A. Callcott, University of Tennessee, Knoxville.

FA 4 Photoionization of Ions and Laser-Excited Atoms at Super ACO. T. J. MORGAN, *Wesleyan University.* (20 min.)

FA 5 Anisotropy of Polarized X-Ray Emission from Free Molecules.
S. H. SOUTHWORTH, *National Institute of Standards and Technology, Gaithersburg.* (5 min.)
(Invited Poster Paper: See Poster Display PA 37)

The previous observation[1] of polarized x-ray emission (fluorescence) from free molecules demonstrated that it is possible to create an ensemble of aligned (spatially anisotropic), core-excited molecules within a gas-phase target via energy and polarization selective excitation with x-rays. In the present work we have extended the previous studies[1] by demonstrating the anisotropy of polarized emission. These effects present an unprecedented opportunity for observing the x-radiation field pattern from free molecules. Specifically, CF_3Cl molecules were photoexcited at energies near the Cl K-edge, and the resulting Cl K-V emission was analyzed as a function of polarization and emission angle. The different symmetry types of the emission dipole moment for the different valence orbitals involved give rise to distinctively different polarizations and anisotropic emission patterns. The measured anisotropies are in good agreement with the theoretical formulation[2] when values for the alignment parameter and geometrical factors are taken in the classical limit.

[1]D. W. Lindle, P. L. Cowan, R. E. LaVilla, T. Jach, R. D. Deslattes, B. Karlin, J. A. Sheehy, T. J. Gil, and P. W. Langhoff, Phys. Rev. Lett. 60, 1010 (1988).
[2]C. H. Greene and R. N. Zare, Ann. Rev. Phys. Chem. 33, 119 (1982).

FA 6 K-Shell Photoionization of Argon Ions Using Synchrotron Radiation and a Penning Ion Trap.*
S. D. KRAVIS, *Texas A&M University.* (20 min.)

Argon gas was pulsed into an ultra-high vacuum environment of a Penning ion trap vacuum chamber. During the gas pulse, Ar^{2+} ions were produced by electron impact ionization from an electron beam directed through the trap end cap electrodes. The Ar^{2+} ions were then stored until the argon partial pressure dropped to background levels, after which focussed broadband synchrotron radiation with energy above the argon K-shell was pulsed through slots in the ion trap ring electrodes, ionizing the Ar^{2+} ions. The ions were detected on a m/q basis by resonance of the ion axial motion with a tuned circuit driven at resonance. Backgrounds due to possible photoionization of residual argon atoms and due to ions other than Ar^{2+} produced by the electron beam, were recorded and subtracted. The resulting charge state distribution probability following vacancy cascading will be compared with that of a neutral argon target and available theory.

*This research was supported by the National Science Foundation and the Department of Energy.

FA 7 Photoion Auger-Electron Coincidence Measurements Near Threshold.†
JON C. LEVIN, *University of Tennesssee, Knoxville and Oak Ridge National Laboratory.** (5 min.)
(Invited Poster Paper: See Poster Display PA 22)

The vacancy cascade which fills an atomic inner-shell hole is a complex process which can proceed by a variety of paths, often leading to a highly charged residual ion. We have measured simplified argon photoion charge distributions by requiring a coincidence with a K-LL or K-LM Auger electron, following K excitation with synchrotron radiation, as a function of photon energy. The distribution exhibit a much more pronounced photon-energy

dependence than do the more-complicated non-coincident spectra. In the near K-threshold region, shakeoff of np levels, populated by resonant excitation of K-electrons, occurs with significant probability, as do double-Auger processes and recapture of the K photoelectron through post-collision interaction.

†Work supported in part by the National Science Foundation and by the U.S. Department of Energy under contract No.DE-AC05-840R21400 with Martin Marietta Energy Systems Inc.

*In collaboration with C. Biedermann, N. Keller, R. T. Short, and I. A. Sellin (UTK/ORNL), L. Liljeby (MSI, Stockholm, Sweden), and D. W. Lindle (NIST).

FA 8 Molecular Studies Using Imaging Time-of-Flight Techniques.
M. MERON, *Brookhaven National Laboratory.* (5 min.) (Invited Poster Paper: See Poster Display PA 44)

FA 9 The Advanced Light Source at LBL.[1] A. L. ROBINSON, *Lawrence Berkeley Laboratory.*[2] (20 min.)

Construction of the Advanced Light Source (ALS) at the Lawrence Berkeley Laboratory recently passed the half-way point. Scheduled to begin operation as a U.S. Department of Energy national user facility in the spring of 1993, the ALS is a third-generation synchrotron source based on a low-emittance, 1.5-GeV electron storage ring with 10 long straight sections available for insertion devices and, initially, 24 bend-magnet ports. Undulators will provide high-brightness radiation to photon energies above 2 keV; wiggler and bend-magnet radiation will extend the spectral coverage with high fluxes to above 10 keV. The status of ALS construction, with an emphasis on experimental facilities, and progress toward establishment of the initial scientific program, including opportunities for industrial participation, will be reviewed.

[1]This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Division of Materials Sciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.
[2]In collaboration with A.S. Schlachter, Lawrence Berkeley Laboratory

FA 10 Atomic, Molecular, and Optical Physics with X Rays.
D. W. LINDLE, *National Institute of Standards and Technology, Gaithersburg.* (20 min.)

With the advent of new third-generation synchrotron-radiation sources now being built, research in the areas of atomic, molecular, and optical physics using x-rays from these insertion-device-based facilities is expected to experience a renaissance. Many of the most sought after experimental goals in these areas of research will become possible and/or routine. To highlight some of the exciting possibilities, some specific examples, such as the x-ray and Auger resonant-Raman effect and polarized molecular x-ray emission, are discussed. Finally, specific plans for implementation of an x-ray synchrotron-radiation beamline dedicated to atomic, molecular, and optical physics at the Advanced Light Source are presented, with emphasis on the enhanced capabilities that will be available at this state-of-the-art facility.

FA 11 Atomic Physics Experiments Using VUV and Soft X Radiation. D. CALDWELL, *University of Central Florida.* (20. min.)

FA 12 Atomic Physics at the Advanced Photon Source.* Y. AZUMA, *Argonne National Laboratory.* (20 min.)

Ground has been broken for the construction of the new 7-GeV synchrotron light source - the Advanced Photon Source (APS) - at Argonne National Laboratory, and the source will be ready for experiments in 1995. The unsurpassed brightness and photon energy of the APS in the hard X-ray region make possible a vast array of new research opportunities for the atomic physics community. A number of such possibilities were discussed at the Workshop on Atomic Physics at the Advanced Photon Source, held at ANL in March, 1990. A summary of this workshop, as well as the Argonne initiative to establish a dedicated atomic physics experimental station on an undulator beam-line, will be discussed.

*This research was supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under contract W-31-109-ENG-38.

SESSION FB: ION IMPLANTATION
Tuesday evening, 6 November 1990; Union Building, Room 411 at 19:00;
R. F. Pinizzotto, University of North Texas, presiding

FB 1 Metal Ion Implantation into M50 and T1 Bearing Steels for Improved Corrosion Resistance.*
B. TORP, *B. R. Nielsen Danfysik A/S, Denmark.* (25 min.)

In order to improve service life and reliability of rolling bearings in gas turbine engines a BRITE project has been started to improve the corrosion behavior of bearing components by ion implantation[1].
Prior to implanting into bearing components, test specimens of the main aero bearing steels M50 and T1 implanted with different species (Chromium, Tantalum and Yttrium + Nitrogen) and doses have been characterised by RBS and NRA techniques, to determine the implantation and purity by independent means. Systematic tests have been performed to measure the corrosion resistance of the treated surfaces in order to define the optimum treatment..

In order to be able to make implantations into bearing raceways and balls a manipulator dedicated for this purpose will be developed. Test bearings implanted with the optimum dose and ion species will be tested at high temperature and in corrosive environment before the ultimative test on implanted Rolls Royce GEM engine bearings.
The status and progress of the project will be reported, and results obtained so far will be discussed.

* This project is funded by the EEC under BRITE/EURAM contract no. RI1B-284.
1 Co-workers: C.M.Rangel, M.H.Simplicio, A.C.Consiglieri, M.F.DaSilva and F.Paszti, LNETI Portugal. J.C.Soares, University of Lisbon Portugal. A.Dodd and J.Kinder, RHP Bearings Ltd. Newark England.

FB 2 High-Energy Implantation at the University of Surrey. K. G. STEPHENS, *University of Surrey, England.* (25 min.)

The growing technical significance of the ability to implant ions at energies above 400 keV will be demonstrated by several quite different experiments.
In GaAs three examples are given. Firstly the use of selenium as a donor, instead of silicon, has some advantages, but necessitates the availability of Se ions at 1 MeV or more. Some good electrical profiles using Se^{++} at 500 KV will be shown. Secondly, to avoid channelling tails from implants, high energy, Ga^{+} and As^{+} ions were used to amorphise the substrate, prior to an implant of an active ion. Thirdly multiple quantum well structures of GaAs and $Al_{0.26}Ga_{0.74}As$ layers have been disordered by implanting either boron or fluorine ions in order to provide waveguides with a low loss. This impurity induced disordering process has also been applied to buried double quantum well waveguide structures and some recent results will be presented.
In silicon, samples were implanted at low energies with arsenic or antimony ions prior to 1 MeV implants of silicon ions. Rutherford backscattering was used to ascertain whether the arsenic or antimony atoms form precipitates or redistribute as a result of the high energy silicon implant. Much of this work has been carried out in implanters with a voltage limitation of 500 KV through the successful development of ion sources which produce usable beams of doubly and triply charged ions and these developments will be described. However in the near future a 2 MV implanter will be installed and future plans for the use of this machine will complete this survey.

FB 3 Investigation and Characterization of Space Materials.* J. S. C. McKEE, *University of Manitoba, Canada.* (25 min.)

The facilities of the Accelerator Centre at the University of Manitoba have been used recently in the study of materials of particular relevance to the aerospace industry and to the construction of space vehicles. Amorphous silicon, titanium carbide, composite and other materials have been studied by implantation and radiation damage techniques. Surfaces have been examined using the method of inelastic light (Raman) scattering, and attempts have been made to simulate exposure to the solar wind in the laboratory. Conclusions relating to the appropriateness of the use of certain refractory materials in the construction of space vehicles are reached, and the nature of damage to such materials discussed.

*Supported in part by the Natural Sciences and Engineering Research Council of Canada.

FB 4 Proton-Induced Displacement Damage Fluctuations in Silicon Micro-Volumes.
P. W. MARSHALL,# *Naval Research Laboratory.* (25 min.)

Particle-induced displacement damage degrades semiconductor properties by introducing localized energy states which increase generation dark current, recombination and charge trapping. Average proton-induced damage in bulk Si is proportional to the average nonionizing energy loss resulting from elastic and inelastic interactions. On a microvolume scale, however, average damage is a poor indicator of damage effects since fluctuations in energy deposition are unavoidable. Calculations of the first and second moments of damage energy distributions from coulombic collisions and from nuclear interactions at a given incident proton energy are incorporated into a model describing the probability of damage as a function of the proton fluence and the sensitive volume in Si. Comparisons between the predicted and measured leakage currents in Si imaging arrays illustrate how the Poisson distribution of higher energy nuclear reaction recoils affects the variance in the distribution of damage across the array.

#Also C.J.Dale, E.A.Burke and G.P.Summers.

SESSION FC: NUCLEAR MICROPROBES

Tuesday evening, 6 November 1990; Union Building, Room 412 at 19:00; B. L. Doyle, Sandia National Laboratory, presiding

FC 1 High-Resolution Techniques for the Scanning Proton Microprobe. A. SAINT, *The University of Melbourne, Australia.* (20 min.)

The technique of Scanning Transmission Ion Microscopy (STIM) will be discussed in the light of it's applica to high resolution imaging using a Scanning Proton Microprobe (SPM). This technique was first annou simultaneously by the Micranalytical Research Centre and the University of Oregon in 1983. Using the

bourne microprobe we have obtained STIM images of a silver grid indicating a resolution of 50nm. These im provide information on the areal density of the sample and can thus be used to provide a mass normalisa of PIXE images of the same region as well as a high resolution image of the sample.

The STIM technique can also be allied with Computer Aided Tomography (CAT) to provide high resolu 3-dimensional images. Recently we have also experimented with Channeled-STIM to provide crystallogra information on single-crystal samples. Other possible extensions to these techniques will also be discussed.

FC 2 Imaging of Thin Biological Sections Using STIM and Related Techniques—A Comparative Study.
J. PALLON, *Lund Institute of Technology, Sweden.* (20 min.)

When using the nuclear microprobe for elemental analysis, it can be a critical task to locate the areas of significance on the sample. Besides from using an optical microscope, information produced by the scanning beam is of interest. The aim of this study is to evaluate different imaging techniques with the purpose of obtaining as high resolution as possible on low-contrast samples like biological sections.
Besides from STIM, scanning transmission ion microscopy, detection of secondary electrons and forward/backward scattered particles is done. High resolution STIM is performed by closing down the objective slits and putting the detector at zero degrees, using a beam of only some 1000 ions/s. Images produced online from the energy loss information is used when selecting the area to irradiate. If combined with data from scattered particles, collected simultaneously with PIXE in a subsequent analysis on the same area, valuable information of beam induced irradiation losses can be obtained.

FC 3 Accelerators are Essential Tools in Minerals Research. S. H. SIE, *CSIRO Exploration Geoscience, Australia.* (20 min.)

Application of accelerator based analytical methods in minerals research has steadily crossed experimentation stages for a wide range of areas and become essential in a number of cases. The progress has been spearheaded mainly by PIXE with microbeams, but the other techniques (RBS, NRA) are rapidly gaining acceptance as well. The paper will review the state of art, and conditions conducive to wider acceptance, with illustrations drawn from applications in igneous mineralogy and petrology, and their implication in minerals exploration research.

FC 4 Medical Applications of Nuclear Microscopy. U. LINDH, *Uppsala University, Sweden.* (20 min.)

Nuclear microscopy is the use of a finely focussed beam of charged particles to extract structural information from a sample. In biomedicine, the samples may be individual cells or tissue sections. The increasing interest in trace elements has motivated nuclear microscopy of the islets of Langerhans and surrounding tissue in pancreas cryosections from experimental animals. The incitament of these investigations was the possible role of trace elements for insulin secretion and correlations with important elements such as calcium. The regulation of secretion has direct consequences for diabetes. The studies in Uppsala used non-inbred obese-hyperglycemic mice either fed ad lib. or starved overnight[1], normal and genetically diabetic hamsters[2] and diabetic (C57BL/KsJ-db/db) and normal (C57BL/KsJ-±/±) mice[3]. The results of these experiments illustrated with elemental maps and multivariate statistical analysis are presented and discussed. Some thoughts about the impact of nuclear microscopy in medicine and trace element biology will also be forwarded.

[1]U. Lindh, L. Juntti-Berggren, P.-O. Berggren and B. Hellman, Biomed. Biochim. Acta 44, 55 (1985).
[2]L. Juntti-Berggren, U. Lindh, P.-O. Berggren and B.J. Frankel, Biosci. Repts. 7, 33 (1987).
[3]L. Juntti-Berggren, U. Lindh, P.-O. Berggren, O. Berglund and B.J. Frankel, Biosci. Repts. 10, 217 (1990).

FC 5 Ion Microtomography Using Time-of-Flight Detection.* A. E. PONTAU, *Sandia National Laboratories, Livermore.*[1] (20 min.)

The practical application of Ion Microtomography (IMT) can be limited by data acquisition rate. To provide full 3-dimensional density distributions for extended objects with fine spatial resolution, IMT requires huge data sets. For example, a 512 x 512 x 512 volume element rendition requires over 200 million accurate density determinations, each derived from several to hundreds of individual ion energy loss measurements. In previous studies, we have described IMT based on transmitted ion energy losses measured using silicon surface barrier detectors. The detector and associated electronics have limited acquisition rates to less than about 20,000 ions per second. In this work, we describe our first studies using time of flight analysis to derive energy losses. Start and stop timing pulses come from secondary electrons produced as the transmitted ion passes through the specimen or through subsequent thin carbon films. We report improvements in data acquisition rate and evaluate limits for density sensitivity using this technique.

*This work supported by the U.S. Department of Energy under contracts DE-AC04-76P00789 and W-7405-Eng-48.
[1]Contributing authors: D. H. Morse, A. J. Antolak, and B. N. Handy, *Sandia National Laboratories, Livermore, CA,* M. Roberts and D. L. Weirup, *Lawrence Livermore National Laboratory, Livermore, CA.*

FC 6 Ultrahigh Resolution Focused Ion Beams in Semiconductor Device Research.
R. L. KUBENA, *Hughes Research Laboratories, Malibu.* (20 min.)

Recent advancements in our understanding of the ion optics of focused-ion-beam (FIB) systems using high brightness liquid metal sources have led to improved system resolution. Currently, we are able to form 50-keV focused Ga beams with 15nm spot diameters (FWHM) and 10pA target current. At these dimensions, such beams are proving to be useful tools for the study of nanofabrication and quantum effects in electronic materials. We have found, for example, that feature sizes in thin resist layers such as PMMA can be predicted fairly accurately using only beam profile and resist contrast data. Effects such as secondary electron range, ion scattering, and atomic recoil are apparently not predominant for feature sizes larger than about 10nm. In addition, the throughput can compete favorably with state-of-the-art electron beam systems. We will present several device applications for quantum electronics.

FC 7 Application of Channeling Scanning Transmission Ion Microscopy.
M. CHOLEWA, *The University of Melbourne, Australia.* (5 min.) (Invited Poster Paper. See Poster Display PB'44)

Scanning Transmission Ion Microscopy (STIM) has been used in conjunction with channeling, to explore tr mission channeling in thin epitaxially grown n type silicon crystal. Beams of 1 MeV and 3.9 MeV H^+ and of MeV α^+ were used with beam currents of 0.1 fA focussed to spot sizes of less than 200 nm. Part of the san was damaged in the channel direction with the same beam focussed to ~16 μm diameter spot size and cur up to 2 nA. Theoretical calculations predict the behaviour of collected energy spectra in both the random the channel direction.
The Channeling STIM (CSTIM) technique can be 100% efficient, the analysis is achieved in a short time v negligible damage, compared to backscattering Channeling Contrast Microscopy (CCM), and it is capabl very high resolution (50 nm). These features can be succesfully applied to the investigation of crystal dam and small size imperfections in samples transparent to the beam.

SESSION FD: ACCELERATORS TECHNOLOGY
Tuesday evening, 6 November 1990; Union Building, Golden Eagle Suites B and C at 19:00;
J. Lin, Hewlett Packard Labs and L. K. Farris, LTV Corporation, presiding

FD 1 A 3-MV Pelletron for Materials Research at Heidelberg.
P. OBERSCHACHTSIEK, *Max-Planck-Institut für Kernphysik, Federal Republic of Germany.* (20 min.)

This year, we have been reconstructing three beam lines for materials modification and analysis at a 3 MV tandem facility delivered by NEC/EII, Middleton, USA. The 0° beam line will be operated for nuclear reaction analysis, with particular emphasis for H profiling. An in-line-low-level γ-ray detection system together with an automatic energy scanning device will allow for both sensitive and fast impurity depth profiling. The 25° beam line has been outlayed for high energy Rutherford backscattering work mainly using α-particles in the energy range between 1-10 MeV. A 24-segment Si detector together with improved pile-up rejection electronics has been designed to yield a 100-fold enhancement in counting rate capability over the standard one-detector arrangement. The low energy backscattering facility, located at the 45° beam line, employs an electrostatic analyser for ultimate depth resolution in near-surface regions. Resolutions of about 1 nm have been obtained with α-particles of up to 1 MeV energy. In addition, a lab ion source type of implanter will be coupled to the target station in order to facilitate in-situ implantation analysis of shallow implants within about 100 nm depth. First results demonstrating the capability of our set-up will be reported including data on the Pelletron performance itself.

FD 2 Experience with 14-UD Pelletron at Tata Institute of Fundamental Research.
K. G. PRASAD, *Tata Institute of Fundamental Research, India.* (20 min.)

The 14UD Pelletron facility was set up at TIFR under a joint BARC-TIFR Project[1] and became operational in December 1988. Several experiments in various disciplines have been started with beams like ^{1}H, ^{4}He, $^{6,7}Li$, $^{10,11}B$, ^{12}C, ^{16}O, ^{19}F, ^{27}Al, ^{28}Si, $^{35,37}Cl$ etc. ions. The energy calibration of the accelerator for system was carried out using the $^{12}C(p,\gamma)^{13}N$ resonance reaction at proton energy of 14.231 MeV. There have been three chain breaks. We have encountered vacuum problems in the beam transport system. The installation of the double harmonic buncher for pulsing the ion beam necessiated the realignment of the injector beam line. The remedial measures taken to overcome the above and several other problems will be discussed.

[1] K.G. Prasad, Nucl. Inst. and Methods B 40/41 (1989) 916.

FD 3 An Overview of the Ion-Beam Analysis Laboratory at White Oak.
J. L. PRICE, *Naval Surface Warfare Center, White Oak.* (20 min.)

The Naval Surface Warfare Center (NSWC) at White Oak is completing a major upgrading of its positive-ion accelerator facilities dedicated to the study of ion-atom collisions and ion-beam analysis of materials. At the heart of the facility is a new National Electrostatics Corporation 3 MV tandem accelerator which replaced a 2.5 MV van de Graaff. There are two ion-sources available which will enable the accelerator to produce an ion from nearly any element in the periodic table. Mass-energy control is defined by a 90 degree analyzing magnet. A downstream switching magnet, allows for the establishment of five separate beam lines. Currently three beam lines are in operation: an RBS & PIXE analysis system, an NRA analysis system, and an experimental line for measuring the stopping powers of ions in gases. In addition to numerous PC's for data manipulation, a VAX computer system is being upgraded to perform computer controlled acquisition and analysis of spectral data. Details on the upgrade will be presented as well as recent results of ion-beam analysis.

FD 4 3-MV Pelletron Accelerator at IPAS. E. K. LIN, *Academia Sinica, Republic of China.* (5 min.)
(Invited Poster Paper: See Poster Display PB 58)

A new accelerator laboratory was established at the Institute of Physics, Academia Sinica (IPAS), in Taipei. We have installed a 3 MV 9SDH-2 Pelletron tandem system from ion sources to target chambers for basic and applied research. A wide range of ion beam species from proton to Zr have been acceleratord. The performance of the beam test is satisfactory. Three beam lines have been set up to be used for experiments in atomic physics, low-energy nuclear physics and applied technology. Brief description of ongoing experiments is presented.

= Visiting Professor, permanent address: Department of Physics, University of Delaware, Newark, Delaware.

FD 5 The Accelerator Installation at Union College. C. C. JONES, *Union College, Schenectady.* (20 min.)

A one million terminal volts tandem accelerator was installed in January 1990 replacing a 400 KeV Van de Graaff machine which has been in use since 1965. Research and laboratory experience is thus made available to undergraduates from Union and other area institutions using 2 MeV protons or 3 MeV alpha particles. We have done elastic scattering, charged particle nuclear reactions, channeling, R.B.S. (Rutherford back scattering) and PIXE (proton induced X-ray emission) experiments, sometimes as laboratory exercises with associated courses, and sometimes as undergraduate research projects.

FD 6 An Overview of the Ion Beam Laboratory at Beijing Institute of Physics.
J. LIU,* *Chinese Academy of Sciences, Beijing, People's Republic of China.* (20 min.)

A multi-user MeV ion beam system has been installed and has been operating since 1983. It has being used for research projects in different area such as solid state physics, material science and atomic physics. The operational characteristics and experiences, modifications and end-station developments are discussed. The system is based on 2x1.7 MV Tandetron small accelerator (General Ionex Corporation, USA) which has a negative sputtering ion source and a home-made cold cathode Penning ion source with a charge-exchanger. Almost All elements ions can be extracted in-to three low angle beam lines with a big switching magnet. There are five beam lines were installed. A summary of the beam lines that are being constructed for the activities of the laboratory will also be given. These include: Rutherford backscattering spectrometry (RBS), channeling analysis, particle-induced X-ray emission (PIXE), nuclear reaction analysis (NRA), elastic recoil detection analysis (ERDA), high-energy ion implantation (HEII), proton microprobe, atomic collision system with different optical measurements, and a cross-beam RBS-Implantation end-station coupled with a 200 keV implanter. The multi-charged ion beams are often used to get higher energy with sufficient particle beam current. Research activities in this ion beam laboratory include material modification and characterization, solid state physics, atomic physics, environmental science and proton microscopy for biomedical, archaeology and geoscience investigators. Some typical projects at this system are introduced and examples of current research results will also be presented.

* Present address: Texas Center for Superconductivity, University of Houston, Texas-77204-5506

FD 7 High-Power Linear Accelerators for Tritium Production and Transmutation of Nuclear Waste.*
G. P. LAWRENCE, *Los Alamos National Laboratory.* (20 min.)

High-power proton linear accelerators driving spallation neutron sources are being proposed for important nuclear process applications, including transmutation of nuclear waste and production of tritium. Recent advances in high-current linac technology have allowed the development of credible designs for the required class of accelerators, which have a nominal 1.6 GeV beam energy , and 250 mA peak current, with duty factors ranging from 12% to 100% (cw). A 250-mA, 1.6-GeV cw proton beam incident on a liquid lead/bismuth target generates 45-55 neutrons per proton, with a fission-like spectrum that is moderated to produce a thermal neutron flux of up to 5 x 10^{16} n/cm^2-s. This high flux permeates a cylindrical blanket

surrounding the spallation source, generating tritium through the $^{6}Li(n,T)^{3}He$ or $^{3}He(n,\gamma)T$ reactions, or burning long-lived actinides and fission products from nuclear waste through capture and fission processes. In some system scenarios, waste actinides and/or other fissile materials are inserted into the blanket, producing sufficient fission energy to power the accelerator.

* Work supported by the US Department of Energy, with Los Alamos National Laboratory Program Development funds.

SESSION FE: SELECTED TOPICS: ION SOURCES, RAIL GUNS, EXPLOSIVE DETECTION

Tuesday evening, 6 November 1990; Union Building, Room 418 at 19:00; F. Rauch, University of Frankfurt, presiding

FE 1 Potential Applications of a New Microwave ECR Multicusp Plasma Ion Source.*
C. C. TSAI, *Oak Ridge National Laboratory.* (5 min.) (Invited Poster Paper: See Poster Display PA 89)

A new microwave electron cyclotron resonance (ECR) multicusp plasma ion source has been developed at Oak Ridge National Laboratory using two ECR plasma production regions and multicusp plasma confinement. This source is capable of producing uniform and dense plasmas over large areas of 300 to 400 cm^2, and could be scaled up to produce uniform plasma over 700 cm^2 or larger. The plasma source has been operated with continuous argon gas feed and impulse microwave power. The discharge initiation phenomena and the plasma properties as functions of discharge parameters have been investigated. The observed discharge characteristics will be described, and a hypothetical discharge mechanism for this plasma source will be reported and discussed. Potential applications including uniform plasmas, ion beams for advanced microelectronics processing, and space electric propulsion will be discussed.

*Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

FE 2 EXDEP: Explosives Detection with Energetic Photons.[1] KERRY W. HABIGER,[2] *TITAN/Spectron Division, Albuquerque.* (20 min.)

TITAN has developed a new technique for detecting explosives using an RF LINAC. The patented EXDEP technique uses an intense 14-MeV x-ray beam to photoactivate the nitrogen comprising >18.5% of most explosives. Activated nitrogen ($t_{1/2}$ = 10 minutes) decays emitting a positron, which annihilates producing two 511-keV photons that are detected. The RF LINAC's electron energy is selected to optimize the nitrogen activation and minimize background. In a DARPA/SNL-sponsored countermine program, TITAN developed a model, benchmarked it with experiments, and used it to determine the parameters for a prototype system. Experiments at the Naval Research Laboratory verified that EXDEP could detect plastic and metal buried mines in sand and soil. An EXDEP system has been designed to screen luggage for concealed explosives. An RF LINAC illuminates the luggage, a detector array provides a 3-D image of the activity concentration within the luggage, and a 3-D computer tomography x-ray scanner maps the physical density of those areas. Calculations have shown that the probability of detection will be >99% with a false alarm probability of <1%.

[1]Supported jointly by Sandia National Laboratories and the Defense Advanced Research Projects Agency
[2]Collaborating Authors: Jerome R. Clifford, R. Bruce Miller, William F. McCullough

FE 3 Linear Accelerators for Explosive Detection. K. WHITHAM, *Beta Development Corporation, Dublin, California.* (20 min.)

A 14-MeV, S-band linear accelerator has been designed and built by Beta Development for use in an explosive detection program at TITAN/Spectron Division. The explosive detection technique utilizes photoneutron activation of the nitrogen which is an integral component in explosives.

The accelerator was designed to be a small, high-power, light-weight, and portable unit capable of operation from the bed of a moving vehicle. The accelerator produces 3 KW of beam power at an energy selectable between 12.5 and 14 MeV. The electron beam will strike a converter to give over 300 R/s bremsstrahlung radiation.

This paper describes the accelerator system and the associated control features.

This work was supported by DARPA and the Sandia National Laboratories.

FE 4 Induced Activity in Scintillation Detector in Space.* X. ZHAO, *Vanderbilt University, Nashville.* (20 min.)

An experimental system was flown on the Space Shuttle Columbia on August 8 13, 1989 as part of the Shuttle Activation Monitor (SAM) program[1]. Gamma ray spectra were collected both during flight and after landing from two 3"x3" scintillation detectors, NaI and BGO. The shuttle was in a high inclination(57°) orbit, at an altitude of 160 nautical miles which provided exposure to the trapped charged particles in the South Atlantic Anomaly (SAA) as well as the electrons in the Polar regions. The induced radiations observed by the detectors resulted from both external and internal sources activated by the interaction with the energetic charged particles. The flight data analysis indicates variations of the induced external radiation as a function of geomagnetic coordinates and amount of shielding, whereas the post-landing data exhibits induced

internal radiation from the two different types of detector materials. Based upon the data analysis and our own experiences, a new experiment has been proposed to measure both gamma-ray and charged particles in space.

* The SAM experiment is sponsored by the Strategic Defense Initiative Organization and flew under the management of the Department of Defense Space Test Program. This work is done with the collaboration of A.V. Ramayya, Vanderbilt University; P.S. Haskins, J.E. McKisson, D.W. Ely, A.G. Weisenberger, University of Florida, Gainesville FL 32609; R.B. Piercey, Mississippi State University, Mississippi State MS 39762.

1 P.S. Haskins *et al*, IEEE Transactions in Nuclear Science, June 1990

FE 5 Radiation Chemistry of Cyanine Dyes. ANTHONY HARRIMAN, *University of Texas at Austin.* (20 min.)

Cyanine dyes are finding increasing applications in biomedicine and merocyanine 540 (MC540), in particular, has been found to exhibit powerful antiviral activity. The mechanism of the in-vivo process is unknown but may involve electron transfer reactions. Under pulse radiolytic conditions, MC540 is reduced by solvated electrons and 2-hydroxypropyl radicals to form an unstable π-radical anion. This species undergoes rapid disproportionation, in which a carbonyl function is reduced to the corresponding alcohol, but it reduces oxygen to superoxide ions in aerated solution. Oxidation of MC540 can be achieved using trichloromethyl peroxyl radicals in aqueous 2-propanol solution. The initial product appears to be an adduct, which undergoes sub-millisecond rearrangement to a ring-closed structure. This latter species retains the cytotoxicity of native MC540 and seems to be the active reagent responsible for killing viruses.

FE 6 Railgun Experiments at The University of Texas, Center for Electromechanics.
R. J. HAYES, *University of Texas at Austin.* (20 min.)

The Center for Electromechanics at the University of Texas at Austin (CEM-UT) presently has five experimental electromagnetic (EM) launchers or railguns in operation. An additional ten, fully operational railguns are presently decommissioned and five new launchers are being fabricated. Several different parallel rail configurations and geometries are being studied as well as augmented rails and coaxial launchers. Recent tests utilizing the magnetic flux generated in a coil have produced promising results for work with coilgun launchers. CEM-UT's launchers have been used in a wide variety of experiments. Fifty to five hundred micron diameter particles have been accelerated up to 17 km/s to determine the effects of micro-meteorite impacts on materials used in space applications and 2.5-kg packages have been launched to 2.6 km/s (8.5 MJ muzzle energy) in ballistic tests. Paper studies on launching 100-kg payloads at 10 km/s have also been conducted to determine the feasibility of launching satellites with EM launchers.

FE 7 Application of Cyclotron for Radionuclide Production.
N. N. KRASNOV, *Institute of Physics and Power Engineering, Obnisk, U.S.S.R.* (25 min.)

SOCIAL HOUR
Tuesday evening, 6 November 1990; Union Building, Second Floor at 21:00

SESSION GA: RBS, CHANNELING, AND ERDA
Wednesday morning, 7 November 1990; Union Building, Room 410 at 9:00;
J. A. Keenan, Texas Instruments Incorporated, presiding

GA 1 *In Situ* RBS and Channeling Study of Epitaxial Growth of Semiconductors with Liquid Metal Media.
F. XIONG, *Harvard University.* (25 min.)

GA 2 Ion Beam Analysis Techniques at SUNY-Albany. H. BAKHRU, *State University of New York at Albany.* (25 min.)

The 4MeV Dynamitron Accelerator and a 3 MeV Tandem Accelerator are being utilized for the Ion Beam Analysis at SUNY-Albany. Various Ion Beam Analysis techniques set-up on eight beam-lines of accelerators and commonly used are: Rutherford backscattering spectroscopy (RBS); Channeling; Particle induced x-ray emission (PIXE); Nuclear reaction analysis (NRA) including Hydrogen, Lithium and Aluminum depth profiling; A microbeam scanning system with a spatial resolution of 2 μm in conjunction with RBS and PIXE. Studies on several Ion Beam Analysis Techniques will be presented. Several examples of chemical and microstructural analysis will be given.

GA 3 Ion Beam Analysis of Lithium-Ion Conducting Amorphous Electrolyte Films.*
J. D. ROBERTSON, *University of Kentucky.* (25 min.)

A new IBA facility capable of simultaneous PIXE, PIGE, and RBS analyses has been installed at the University of Kentucky 7.5 MV, Model CN Van de Graaff accelerator. The facility was initially used to determine the stoichiometry of 1 to 2 μm thick xLi2O:ySiO2:zP2O5 amorphous films by PIGE and RBS analyses. The nondestructive PIGE determination of the Li content of the films proved to be more reliable than SIMS analysis and more convenient than atomic absorption analysis. Deficiencies on the order of 20 to 50% in the Li2O content of the films prepared from sintered targets resulted in decreases in the conductivity by as much as six orders of magnitude at room temperature.

*Work done in collaboration with J.B. BATES, N.J. DUDNEY, and R.A. ZUHR, Oak Ridge National Laboratory.
^Supported by the National Science Foundation and the Kentucky EPSCoR program.

GA 4 Study of Hydrogen Content in Solids by ERDA and Radiation-Induced Damage.*
J. TIRIRA, *Laboratoire Pierre Sue, CEA/DSM/DPhG Cen de Saclay, France.* (25 min.)

A simulation-optimisation algorithm is described for hydrogen determination based on elastic recoil detection analysis induced by 1.8 - 3 MeV ^4He ions. The effect of straggling, multiple scattering and geometrical spread are taken into account in the simulation. The scattering cross section are taken from theoretical and experimental data[1,2]. Heterogeneous hydrogen concentration depth profile can be derived from experimental spectra in semi-automatic mode (Gaby Code)[3]. The capabilities of this absolute method are discussed in terms of sensitivity, probing depth, depth resolution and detection limit. The hydrogen measurements are interpreted in relation to the damage induced by the ^4He microbeam. It is shown that the hydrogen distribution can change during the ^4He irradiation, depending on the local structure of target material. In particular, the influence of the thermal gradient around the incident beam impact and of the energy loss along the helium beam track is discussed. This procedure is applied to study the hydrogen distribution in thin polymer films irradiated by high energy heavy ions (Kr 230 MeV), natural and synthetic glasses using a nuclear microprobe.

* Supported by the Fundamental Research Institute CEA/CEN Saclay
[1] R. Benenson, L. Wielunski and W. Lanford, Nucl. Instr. and Meth. B34 (1986) 453.
[2] J. Tirira, P. Trocellier, J.P. Frontier and P. Trouslard, Nucl. Instr. and Meth. B45 (1990) 203.
[3] J. Tirira, J.P. Frontier, P. Trocellier and P. Trouslard, (in press). Presented at the 2th Nuclear Microprobe Conference, Melbourne Australie, 1990. Nucl. Instr. and Meth. B°° (1990) °°°.

GA 5 Complex Depth Profiles Derived from Ion Backscattering. J. A. KEENAN, *Texas Instruments, Inc.* (25 min.)

Ion backscattering provides quantitative characterization of complex combinations of oxides, nitrides, silicides, metal conductors, and their related barrier layers which are key structures in silicon integrated circuit fabrication. Process development often requires an understanding of the interfaces between these layers. Ion backscattering is especially useful in this context since depth information is predicated upon stopping powers without liability to sputtering artifacts. The most common method of data reduction for ion backscattering is to use a postulated layered structure as input to a modeling program. The correctness of the structure is inferred from the quality of fit to the experimental data. Buried interfaces must be characterized by iterative fitting. The alternative presented here is to use interactively defined regions of interest from the backscattering spectrum to compute the depth profile. The resulting depth profiles reveal the nature of buried interfaces to the limits imposed by depth resolution. Comparison with depth profiles derived using Auger electron spectroscopy and Ar ion sputtering and with TEM cross sections confirms the quality of the ion backscattering depth profiles.

SESSION GB: CLUSTER IMPACTS

Wednesday morning, 7 November 1990; Union Building, Room 412 at 9:00;
T. A. Tombrello, California Institute of Technology, presiding

GB 1 Short Overview of Cluster Impacts. T. TOMBRELLO, *California Institute of Technology.* (20 min.)

GB 2 Surface Analysis with keV Polyatomic Projectiles.* E. A. SCHWEIKERT,** *Texas A&M University.* (40 min.)

Bombardment of solids with polyatomic projectiles (e.g., Cs_2I^+, CO_2^+) results in high secondary ion (SI) yields. For projectiles of 5 keV to 500 keV, SI yields as high as 10% have been observed; they are up to 50 times higher than those obtained with equal velocity monoatomic ions. Our data show that the SI yields increase with the mass of the projectile and its velocity. The SIs are identified by TOF-MS in an event-by-event counting mode, allowing the study of sputtering phenomena in the limit of a single projectile-target interaction. Moreover, the SIs emitted from a single primary ion impact can be acquired in a coincidence mode, i.e., we can determine which masses are desorbed together from a primary impact site. The analytical significance of these findings will be discussed, in particular the prospects for surface mapping with high planar resolution.

*Supported in part by NSF Grant INT-8801783 and by CNPq.
**In collaboration with M.A. Park,[a] E.F. da Silveira,[b] C.V. Barros Leite,[b] J.M.F. Jeronymo,[b]
[a]Texas A&M University, College Station, TX 77843-3144, USA.
[b]Pontificia Universidade Catolica, Rio de Janeiro, Brazil.

GB 3 Molecular Dynamics Simulations of Energetic Cluster Impacts on Metallic Surfaces.*
M. H. SHAPIRO,+ *California State University.* (40 min.)

A modified version of the multiple-interaction code SPUT2 has been used to simulate impacts of 32- and 63-atom metallic clusters (Al, Cu, and Au) on six and nine layer fcc metal surfaces (Al, Cu, and Au). Simulations were carried out with cutoff times of 100 and 500 fs for an incident cluster energy of 63 keV (1 keV/atom). Energy and angular distributions were computed for atoms ejected both from the target and the incident cluster. For light mass clusters incident on heavy targets (e.g. Al on Au) there is significant ejection of cluster material as well as target material. Total sputtering yields were found typically to be in the range of several hundred atoms per incident cluster for the systems studied. The implications of these results for the use of energetic cluster ion beams in the micromachining of surfaces will be discussed.

+In collaboration with T.A. Tombrello, *Caltech*
*Supported in part by NSF grant DMR86-15641 at Caltech.

GB 4 Desorption Induced by Cluster Bombardment. S. DELLA-NEGRA, *Instituto de Physique Nucleaire, France.* (40 min.)

SESSION GC: MEDICAL APPLICATIONS OF ACCELERATORS

Wednesday morning, 7 November 1990; Union Building, Room 411 at 9:00;
V. Valkovic, International Atomic Energy Agency, Austria, presiding

GC 1 Advances in Medical Applications of Low-Energy Accelerators.
V. VALKOVIC, *International Atomic Energy Agency, Austria.* (20 min.)

Medical applications of low energy accelerator include:
- radiotherapy with ions, based on improved understanding of interaction of charge particles with living tissues;
- radioisotope productions and their applications in radiopharmaceuticals as well as positron emission tomography;
- material productions and modifications to meet special requirements;
- the use of nuclear analytical methods and procedures for laboratory studies and routine measurements.

Recent advances in these fields are critically summarized. Plan for an improved charged particle facility in hospital environment dedicated to applications in biology and medicine is presented.

GC 2 Automatic, Sterile, and Apyrogenic Delivery of Pet Radiotracers from the Cyclotron to the Patient.
J. R. VOTAW,[1] *Vanderbilt University.* (20 min.)

The efficient delivery of sterile and pyrogen free tracers has been a limiting factor in performing multiple PET studies that use a small accelerator to produce the isotopes. Rapid delivery is required because of the short half-life (10 or 2 mins.) and the limited production capabilities of 11 MeV proton only cyclotrons. Remote administration is necessary in order to reduce the radiation exposure to the person administering the radiopharmaceutical. To increase the throughput and efficiency of the PET center, one technologist must be able to produce the tracer while concurrently preparing the patient for scanning. An automatic delivery, remote injection system has been developed to administer either ^{13}N labelled ammonia or ^{15}O labelled water to patients. Production of the tracer is initiated from the scanner room through a remote terminal connected to the cyclotron. In the case of ammonia, at EOB the aqueous ammonia is pumped into a teflon tube (1/16 in. OD, 0.030 in. ID) with an HPLC pump and then driven to the scanner (50 feet distant) with high pressure helium where it is collected in a vessel within a dose calibrator. Typically, 18 ± 1 mCi is delivered to the scanner 20 ± 0.25 minutes after requesting ammonia from the cyclotron. In the case of labelled water production, target gas containing ^{15}O is is kept at saturation in the target until it is transferred to the scanner where it is converted to water over a platinum catalyst then collected in the vessel in the dose calibrator. Typically, 260 ± 30 mCi is delivered 45 seconds after the technician requests delivery. The dose is injected using a syringe pump to withdraw the activity, a three-way valve is then switched and then the same syringe pump is used to infuse the tracer into the patient through preset IV lines. The whole system (excl. target material) is washed with 80% EtOH whenever any part is disassembled (e.g. installing a new target). The system is washed with 20 ml of sterile water twice at the beginning of each day and these washes are tested for pyrogens at 3 and 0.1 EU/ml thresholds. Since the tracer is delivered in approximately an 8 ml bolus of water, the next delivery through the system is considered safe for injection if pyrogens are not detected at the 3 EU/ml threshold in the second wash. In practice, it is rare that pyrogens are detected at the 0.1 EU/ml level. Time delayed tests show that the system may be left left unused for up to 6 hours before the daily washes must be repeated.

[1]The author acknowledges the contributions of JA Clanton and DB Cashion.

GC 3 A Comprehensive Cyclotron Program at a Medical Facility.* M. L. MALLORY, *University of Texas.* (20 min.)

Cyclotrons are being installed at medical facilities at an increasing rate. At these facilities, the prime consideration for use of these cyclotrons are for medical applications. Secondarily, the cyclotron may be used for basic research and commercial isotope production. At the M.D. Anderson Cancer Center (MDACC) the cyclotron facility is utilized for all three applications. The cyclotron is used for neutron therapy of patients during the working hours of 8:00 AM to 5:00 PM. The cyclotron also produces short-lived positron emitting isotopes for a hospital based

PET imaging program for cancer during the early morning hours. The challenges are to develop cyclotron research and industry programs that effectively utilize the remaining time. We find that the flexibility of our cyclotron, multiple extraction ports and different vaults, are important parameters in establishing the multiple applications and this paper will contain examples of our ongoing and planned usage.

*Supported in part by the National Cancer Institute No1-CH-57775

GC 4 Hospital-Based Proton Linac for Particle Theory and Radioisotope Production.
A. J. LENNOX, *Fermi National Accelerator Laboratory.* (20 min.)

Taking advantage of recent advances in linear accelerator technology it is possible for a hospital to use a 70 MeV proton linac for fast neutron therapy, boron neutron capture therapy, proton therapy for ocular melanomas, and production of radiopharmaceuticals. The linac can also inject protons into a synchrotron for proton therapy of deep-seated tumors. With a 180 microampere average current a single linac can support all of the above-mentioned applications. This paper presents a conceptual design for a medical proton linac, switchyard, treatment rooms, and isotope production rooms. Special requirements for each application are outlined and a method for sharing beam among the applications is suggested.

GC 5 Cyclotron Production of Medical Radionuclides.
RICHARD M. LAMBRECHT, *King Faisal Specialist Hospital and Research Centre, Saudi Arabia.* (5 min.)
(Invited Poster Paper: See Poster Display PB' 55)

Accelerators with energies of 45 MeV and less are experiencing an increasing role for production of medical radionuclides required for improved health care delivery. Advances in gas, liquid and solid targetry that have occurred since Sajjad's review at the 10th Denton Conference[1] will be the focal point of discussion. The excitation functions for proton induced reactions on 99.9% enrichment ^{124}Xe resulting in formation of ^{123}Cs-^{123}Xe-^{123}I will be illustrated to show the ^{123}I thick target yields obtainable (ie 24.5, 16.5, and 10.5 mCi/uAh) with cyclotron energies of 40, 30 and 26 MeV, respectively[2]. The Kernforschungszentrum Karlsruhe has demonstrated that the method permits production of 1-3 Ci of ultra high purity ^{123}I in 4-6 hr irradiations at using a 50 uA beam. The ^{122}Xe-^{122}I generator could be developed with a production rate of 3.5 mCi/uAh using 42-35 MeV protons on 99.9% ^{124}Xe. Alternatively the ^{122}Xe-^{122}I generator is attainable using 30 MeV alphas on isotopically enriched ^{120}Te targets. There has been resurgent interest in ^{67}Cu, ^{73}Se and ^{124}I. Emphasis will be placed upon the design, fabrication of targetry and other relevant parameters using expensive isotopically enriched target matrices.

1 M. Sajjad and R. M. Lambrecht. Nucl. Instrum. Meth. Phys. Res. B49/41 (1988) 1100-1104.
2 F. Tarkanyi, S. M. Qaim, G. Stocklin, M. Sajjad, R. M. Lambrecht and H. Schweickert. Int. J. Appl. Radiat. Instrum. Part A (submitted).

GC 6 Preliminary Design of a Reduced-Cost Proton Therapy Facility Using a Compact, High-Field Isochronous Cyclotron.
Y. JONGEN, *Ion Beam Applications SA, Belgium.* (20 min.)

It is generally agreed that, among the different kinds of radiations usable for radiotherapy, high energy proton beams exhibit the best ballistic specificity However, the development of proton therapy has been hindered by the size, cost and complexity of high energy accelerators. We have therefore tried to design a complete proton therapy facility where the size, the investment, the complexity and the cost of operation would be minimized.
To optimize the simplicity reliability of the system we selected a non superconducting isochronous cyclotron as accelerator. The magnet is a high field (3.09 Tesla peak field, 2.165 Tesla average field at extraction) deep valley design, using 190 kW in conventional coils. The complete cyclotron is split in two parts at the median plane. The upper half can be quickly raised by one meter, using hydraulic jacks allowing an unrestricted access to all cyclotron elements.
The cyclotron would then feed two or three isocentric gantries. IBA has developed a new concept leading to isocentric gantries of reduced size and cost This new gantry design allows to reach infinite "source to patient distance" with a gantry not exceeding 2.5 m total maximum radius.
The dose delivery system has been reviewed to optimize dose accuracy, uniformity and speed of delivery. In the axial motion , the magnet sweep is controlled by a dose integrator, guaranteeing an uniform dose irrespectively of minor intensity fluctuations.

SESSION GD: PIXE

Wednesday morning, 7 November 1990; Union Building, Golden Eagle Suite A at 9:00;
H. A. Van Rinsvelt, University of Florida, presiding

GD 1 The Analysis of Surface Layers with PIXE. R. D. VIS, *Free University, The Netherlands.* (20 min.)

GD 2 On the Use of a Modern Low-Energy Germanium Detector for PIXE.
WILLY MAENHAUT, *University of Gent, Belgium.* (20 min.)

Recent progress in low-energy Ge (LEGe) detectors has for effect that such detectors are increasingly considered as a viable alternative to Si(Li) detectors for energy-dispersive X-ray spectrometry in a variety of applications, including PIXE. In the first part of our study, the performance of a current LEGe detector was compared to that of a top-quality Si(Li) detector through measurements with X-ray sources. Long

and short peak tails, and energy resolution and detection efficiency as a function of energy were examined. Both detectors were subsequently used for PIXE measurements on atmospheric aerosol filters and biological samples, which are typical study objects for PIXE analysis. All PIXE bombardments were done with a 2.4 MeV proton beam, and the X-ray signals of the 1 to 25 keV energy region were collected in the PIXE spectrum. The results of the various experiments are discussed, and our conclusions with regard to the applicability of LEGe's for PIXE are presented.

GD 3 Accelerator Analysis of Museum Objects at the Louvre.
B. KUSKO, *Accelerateur Grand Louvre d'Analyse Elementaire, France.* (20 min.)

GD 4 Application of PIXE in the Study of Shell Fish. C. P. SWANN, *Bartol Research Institute.* (20 min.)

The Bartol in-air PIXE system has been used to study the elemental composition of many varieties of sea life; the sensitivity for the elements from Na to Sr is good, a reasonable spatial resolution is attainable and little preparation of the samples is required. Two examples are cited. First, the composition of the interior nacreous and calcitic regions of mussels (Mytilus edulis) taken monthly (1981-1982) from the Damariscotta River, Maine, has been measured and, second, the shell and soft tissue of oysters (Crassotrea virginica) grown under laboratory conditions on substrata of compacted residues from coal-fired power plants have been analysed. The mussel study shows a rather large anomaly in the Sr/Ca ratio for the nacreous region for May which suggests a possible connection with the reproduction cycle. The oyster study demonstrates that power plant residues provide a good substrata for the growth of healthy, non-toxic oysters.

GD 5 Trace Metal Distribution in Aquatic Systems as Studied by PIXE Analysis of Water and Sediment.
G. GHERMANDI, *Istituto Osservatorio Geofisico, Italy.* (20 min.)

The PIXE technique is used to measure trace metal concentrations (Ti, V, Cr, Mn, Fe, Cu, Pb) in water and sediment samples collected in a shallow water area (Venice Lagoon - Nothern Adriatic Sea, Italy). The objective is to investigate pollution progress in this aquatic system and to understand the mechanisms of pollutant distribution, in order to know their final fate. A test area at the main land - lagoon interface is constantly monitored with survey of chemical-physical-hydrodynamical parameters; the metal distribution in its surface sediments has also been mapped. Under comparable weather conditions, sampling campaigns have been performed at the mouths of a polluted channel discharging in this area. During the time period of one tide half-cycle, water samples have been collected long the vertical stream profile, in order to test the effect of salt and fresh water mixing on metal distribution. Sample filtration in field allows analysis of soluted and suspended matter.

GD 6 Trace Element Analysis with Synchrotron X-Ray Beams.* A. C. THOMPSON, *Lawrence Berkeley Laboratory.* (20 min.)

We have developed a hard x-ray (6-15 keV) microprobe that uses a pair of multilayer coated x-ray mirrors to focus a white radiation synchrotron beam. The x-ray microprobe can detect femtogram amounts of trace elements within a counting time of 60 sec. A major advantage of the x-ray microprobe is that the specimen does not have to be placed in a vacuum or to undergo special contrast-enhancing preparation. An inherent characteristic of these x-ray mirrors is that they act as a broadband monochromator which reduces the background underneath the fluorescent x-rays. A spot size of 2 um x 2 um has been achieved. Sample applications of this microprobe to geophysical, materials science and biology problems will be presented.

* Supported by the U.S. Department of Energy under Contract DE-AC03-76SF0098.

GD 7 X-ray Fluorescence for Heavy Metal Dust Alarms in the Industrial Workplace.
G. M. THOMSON, *U. S. Army Ballistic Research Laboratory, Aberdeen Proving Ground.* (20 min.)

Two x-ray fluorescence (XRF) devices for the analysis of particle-bearing aerosols at the worksite have been developed. They provide values of the mass concentration M for each element Z>22 in the aerosol in minutes - in time for corrective action before harm to workers or the environment takes place. The two devices separately span different regimes of M, one at "smokestack" levels (milligms/m3), the other at chronic worker exposure thresholds (microgms/m3). The high M device irradiates the aerosol directly with the output of an interchangeable anode x-ray tube and detects returning XRF photons. The more complex low M version pumps the aerosol through a section of filter paper tape which, in turn, undergoes on-site XRF analysis using Cd-109 x-rays. Both devices are totally self-contained using small gas proportional counters and multichannel analyzers for detection and counting. Both also employ digital automation of instrument control, data reduction and recordkeeping.

GD 8 Evaporated and Implanted Reference Layers for Calibration in Ion Beam Analysis.*
U. WATJEN, *CEC-JRC, Central Bureau for Nuclear Measurements, Belgium.* (5 min.) (Invited Poster Paper. See Poster Display PB 57)

The potential of thin reference layers prepared by the Central Bureau for Nuclear Measurements especially for calibration purposes in ion beam analysis is presented.

Our special preparation procedure is outlined, making use of an ultrahigh vacuum microbalance with the substitution principle of weighing applied.[1] Besides thin metal layers evaporated onto vitreous carbon substrates, which can serve for external yield calibration as well as for energy calibration[2], we are making use of thin layers as internal standards on implanted samples in order to perform high-accuracy determinations of the retained dose. In turn those implants are made available as reference samples. Further we prepare special compound layers in order to support the further improvement of PIXE (and EDXRF) spectrum evaluation codes with respect to unresolved peaks. Varying mass ratios of the interfering elements allow the systematic investigation of the code behaviour in such conditions.

* This work was performed with continuous support by H. Bax and P. Rietveld.
[1] H.L.Eschbach, I.V.Mitchell, and E.Louwerix, Thermochimica Acta 51, 33 (1981).
[2] U.Wätjen, D.Schroyen, E.Bombelka, and P.Rietveld, Nucl. Instr. and Meth. in Phys. Res. B50, 172 (1990).

GD 9 X-Ray Microfocusing Studies at ELETTRA.
F. ZANINI,* *Sincrotrone Trieste and Istituto Nazionale Fisica Nucleare, Italy.* (20 min.)

The development of Synchrotron Radiation (SR) beamlines dedicated to trace-element microanalysis has given a new impetus to the design of X-ray microprobe systems. The use of SR Induced X-Ray Emission (SRIXE) for analytical purposes allows the measurement of elemental concentrations at levels not detectable with other excitation sources. The main advantages of using X-rays rather than protons or electrons are the smaller amount of energy deposited by X-rays, a higher penetration and the possibility of analyzing wet samples in air. A number of techniques is presently available for X-ray focusing (metal coated curved mirrors, bent crystal monochromators, multilayer coated optics, Bragg-Fresnel lenses). At ELETTRA, the 2 GeV high-brilliance photon source under construction by Sincrotrone Trieste, different hard X-ray microprobes are being studied for analyzing and imaging biological and geological materials, complementing the information obtained with optical, electron and soft X-ray microscopes. The high-brilliance SR facilities of the last generation are particularly suitable for this kind of microprobes. At SR sources with relatively low energies, like ELETTRA, microprobes for mapping light elements should be developed, even if our evaluations show that a reasonable minimum detection limit can be achieved for a wide range of chemical elements. ELETTRA is the optimum source for soft X-ray microscopy of biological samples in the water window, but the possibility to combine this technique with elemental mapping at the same SR facility is particularly attractive for the life science community.

* In collaboration with R. Devoti, C. Tuniz, F. Zontone.

SESSION GE: ATOMIC PHYSICS AND RELATED PHENOMENA

Wednesday morning, 7 November 1990; Union Building, Room 418 at 9:00; S. L. Varghese, University of South Alabama, presiding

GE 1 Recent Experiments on the KSU CRYEBIS.* M. SCHULZ, *J. R. Macdonald Laboratory, Kansas State University.* (20 min.)

The CRYEBIS at KSU has been in operation since April 1989. We report here on experimental results obtained since then. In one experiment Dielectronic Recombination (DR) was studied for He-like Ar. The ratio of the Ar^{15+} and the Ar^{16+} yields as well as the Ar K x-ray yield were measured as a function of the electron beam energy. Absolute cross sections were obtained for a number of doubly excited states populated by DR and are in very good agreement with theoretical calculations. In a second experiment we measured K x-ray yields from slow H-like Ar interacting with a single crystal Ge surface as a function of the projectile velocity component perpendicular to the surface v_p. v_p was varied by rotating the target with respect to the beam axis. An angular range of 1° (near grazing incidence) to 60° was covered corresponding to initial vertical projectile energies of 15 eV to 38.2 keV. An increase of the x-ray yield as well as a shift of the K x-ray lines to higher energies with decreasing v_p was observed. A characteristic time for an electron captured above the surface to cascade down all the way to the K shell of approximately 10^{-12} sec was extracted from the data.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Science, Office of Energy Research, U.S. Department of Energy.

+ Inst. F. Kernphysik, Univ. Frankfurt, Frankfurt, FRG.

GE 2 Electron Emission in Heavy-Ion Collisions.*
H. SCHMIDT-BÖCKING, *Universität Frankfurt, Federal Republic of Germany.* (20 min.)

Recent data on the δ-electron emission in heavy ion-atom collisions are presented. From the comparison of the experimental energy- and angular distributions for Uranium rare gas collisions with nCTMC calculations information on the ionisation process can be deduced. It demonstrates the importance of the polarisation of the electronic states in the strong two-center potential of the nuclei. Using electron-particle coincidence techniques, multiple differential electron emission

probabilities have been measured, which illustrate the strong deviations compared to light ion impact.

* supported by GSI, Darmstadt and Bundesministerium für Forschung und Technologie (BMFT), FRG

GE 3 Atomic Physics Experiments at ORNL-ECR Multicharged Ion Source Facility.
R. A. PHANEUF, *Oak Ridge National Laboratory.* (20 min.)

Atomic physics experiments in electron-ion, ion-atom and ion-surface interactions are being carried out at the ORNL-ECR Multicharged Ion Research Facility.[1] The experimental techniques include merged and crossed beams, which require relatively high ion beam intensities, as well as gas-target and particle-surface interaction studies. To maximize the utilization of this facility for research, the beamlines and apparatus have been designed and organized such that high-intensity, low-energy beams of multiply charged ions may be switched to any one of five different experiments, four of which require ultrahigh vacuum conditions. Results from some of these experiments will be highlighted, as well as plans for a recently-initiated upgrade of the ECR ion source from 10.6 GHz to 14.5 Ghz. This upgrade will increase high charge-state performance, opening up additional collision systems to experimental study.

*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400.
[1]F. W. Meyer and J. W. Hale, Rev. Sci. Instrum. 61, 324 (1989).

GE 4 Physics of, and Recent Results from Lawrence Livermore EBIT Source.*
P. BEIERSDORFER, *Lawrence Livermore National Laboratory.* (20 min.)

The electron beam ion trap (EBIT) at Lawrence Livermore is a powerful tool for studying the physics of highly charged ions. EBIT uses an electron beam to produce, trap, and excite ions, and charge states as high as neonlike U^{82+} have been investigated. Since EBIT was conceived as an x-ray source, precision x-ray techniques have been developed to study electron-ion interactions. As examples, we present novel schemes to infer outershell and innershell ionization cross sections from high-resolution x-ray observations, and discuss recent measurements of dielectronic recombination of Fe XXV which are state-specific. High-resolution x-ray techniques have also allowed us to investigate the atomic structure of highly charged heliumlike and neonlike ions. The measurements probe the effects of relativity and QED in multi-electron ions and show systematic discrepancies with theory.

*This work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

GE 5 Angular Distributions of Single- and Double-Electron Capture in Very Slow Ar^{4+}-Ar and Ar^{6+}-He,Ar,Xe Collisions.†
C. BIEDERMANN, *University of Tennessee.* (20 min.)

Capture-state resolved angular distributions of one- and two-electron processes in 19 to 800 eV Ar^{4+}-Ar collisions have been measured. Structure in the experimentally observed angular distribution of single-electron capture to six close-lying 4*p* LS-levels of Ar^{3+} is reproduced by using a seven-channel classical trajectory Landau-Zener calculation to demonstrate that the main features are caused by multiple rainbow scattering. From the angular distributions for the true double-capture process it is seen that a two-step mechanism involving the 4*p* single-capture channels, which then couple to the double-capture potential curves, dominates the two-electron transfer. Angular differential one- and two-electron capture in 60 to 1200 eV Ar^{6+}-He collisions have been measured. Model calculations indicate contributions of two-electron transfer to explain the structure of the single capture distribution[1]. In the case of the 32 to 800 eV Ar^{6+}-Ar collisions, several active *nl*-channels of the single-electron capture process give rise to structures in the angular distribution. The energy-gain spectra of double-electron capture has two main peaks, of which only one also decays via autoionization. The corresponding angular distribution for transfer ionization shows a subset of structures seen in the true double-capture angular distribution. The difference between angular distributions of autoionizing double capture and true double capture is even larger for Ar^{6+} on Xe collisions.
In collaboration with H. Cederquist*, L.R. Andersson*, J.C. Levin, R.T. Short, S.B. Elston, J. P. Gibbons, H. Andersson*, L. Liljeby*, N. Keller and I.A. Sellin. *Manne Siegbahn Institute of Physics, Stockholm, Sweden.
†Work supported in part by the National Science Foundation and by the U.S. Department of Energy under contract No.DE-AC05-840R21400 with Martin Marietta Energy Systems Inc. [1] L.R.Andersson, this conference.

GE 6 Angular Distributions for Electron Capture from He by Low-Velocity Ar^{6+} Ions.
W. T. WAGGONER, *Hastings College.* (5 min.) (Invited Poster Paper: See Poster Display PA 28)

Angular distributions, $d\sigma/d\theta$ vs. θ, for electron capture from He were measured for Ar6+ projectiles produced in a recoil ion source at the J. R. Macdonald Laboratory at Kansas State University.[1] Projectile energies between 1287 and 296 eV were used. At 1287 eV the distribution contains a main peak lying just inside the half Coulomb angle, $\theta c = Q/2E$, for capture to a 4p final state. As the projectile energy decreases the width of the distribution increases with the contributions inside θc increasing in magnitude, and with the location of the primary peak shifting to angles substantially inside θc. At the lowest energies additional structure begins to appear at large angles, where at 296 eV the primary and secondary peaks heights are the same magnitude. Using a simple two state diabatic curve crossing model employing Coulomb potential curves, angular distributions

have been calculated at the highest and lowest projectile energies.

*Work supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U. S. Department of Energy.
†Collaborators included C. L. Cocke, Kansas State University., E. Y. Kamber, Western Michigan University., S. L. Varghese, South Alabama University.

GE 7 Electron Capture by O^{8+} from Aligned Molecular Deuterium.*
S. CHENG, *Kansas State University.* (5 min.) (Invited Poster Paper: See Poster Display PA 29)

Cross sections for ionization and electron capture for 10 MeV oxygen ions in collision with molecular deuterium targets were measured. The experiment was performed by applying an extraction electric field perpendicular to the beam axis to project the whole velocity distribution of the recoil ions into a two-dimensional position sensitive detector. By additional measurement of the time-of-flight of these recoil ions, we are able to reconstruct the three dimensional velocity distribution. From the reconstructed results, the dependence of the cross sections on the alignment of the molecular axis with respect to the beam axis was determined. Detailed experimental techniques and results will be discussed.

* This work was supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy. Work performed in collaboration with C.L. Cocke, E.Y. Kamber, and S.L Varghese.

GE 8 Detection of Long-Lived Highly Excited Ions by Means of Charge-Stripping Processes.
E. Y. KAMBER,* *Western Michigan University.* (5 min.) (Invited Poster Paper: See Poster Display PA 7)

Translational energy spectroscopy is being used for detection of metastable and long-lived highly excited Ar^{q+} and Kr^{q+} ions, produced in an electron impact ion source, by means of state-selective single-electron stripping processes in collisions of 2-8 keV Ar^{q+} and Kr^{q+} ions with rare-gas atoms. Translational energy-loss spectra indicate that stripping of a single electron from Ar^{q+} occurs predominantly by a reaction channel due to ionization of long-lived highly excited states with excitation energies very close to the ionization potential of Ar^{q+}. This reaction channel is found to be overwhelmingly dominant at electron impact energies $E_e \geq 87$ eV and is consistent with the energy for the production of Ar^{3+}. Weaker processes are also observed due to ionization of highly excited metastable states of Ar^{q+} such as 3d, 4s, 4p and 4d with excitation energies from 18 to 35 eV, low-lying metastable, and the ground state of Ar^{q+} ions. These highly excited ions are found to be more sensitive to charge-stripping processes than electron capture processes.

*Work done in collaboration with A. G. Brenton, Mass Spectrometery Research Unit, University College of Swansea, Swansea, SA2 8PP, U.K.

GE 9 Electron Energy Distribution in Multiply Ionizing Collisions, Differential in Recoil Charge States.
H SCHOENE, *Oak Ridge National Laboratory.* (5 min.) (Invited Poster Paper: See Poster Display PA 24)

SESSION HA: SUPERCONDUCTING SUPER COLLIDER DETECTORS

Wednesday afternoon, 7 November 1990; Union Building, Lyceum at 14:15;
F. T. Avignone, University of South Carolina and M. Month, Brookhaven National Laboratory, presiding.

HA 1 Solenoidal Detector Collaboration. G. H. TRILLING, *University of California at Berkeley.* (25 min.)

HA 2 The L* Detector at the SSC. D. DIBITONTO, *University of Alabama.* (25 min).

HA 3 The Empact Detector for the SSC. J. E. BRAU, *University of Oregon.* (25 min.)

HA 4 "TEXAS": A Calorimeter-Based High-Rate Detector for the SSC. L. SULAK, *Boston University.* (25 min.)

HA 5 A Super Fixed Target B-Physics Facility. B. COX, *University of Virginia.* (25 min.)

HA 6 Proposed Detectors for the SSC. N. LOCKYER, *University of Pennsylvania.* (25 min.)

SESSION HB: ACCELERATOR TECHNOLOGY

Wednesday afternoon, 7 November 1990; Union Building, Room 410 at 14:00; K. Bethge, University of ...akfurt, presiding

HB 1 The Texas A&M K500 Cyclotron Facility.* D. H. YOUNGBLOOD, *Texas A&M University.* (20 min.)

The Texas A&M K500 cyclotron, using a PIG source, produced first beam in June, 1988, with beam delivered for experiments in July, 1988. Performance and reliability improved considerably with the completion of an ECR source in November, 1989. The design limits of the cyclotron allow

delivering Q/A ≈ 1/2 beams to 80 MeV/nucleon and uranium beams to 8 MeV/nucleon with current ECR source technology. Instrumentation is in operation or under construction for a variety of studies. A 4 pi neutron calorimeter for heavy ion reaction studies is now in operation, a proton spectrometer for (d,^{2}He) and (n,p) studies of Gamow-Teller states is nearing completion, a 57 element BaF_2 array is on order, a beta spectrometer for studying anomalous positron-electron emission from very heavy ion reactions will be ready this year, and a recoil mass spectrometer of new design capable of beam rejection for most reactions of interest is under construction.

*Supported in part by The Robert A. Welch Foundation and the U.S. Department of Energy under Grant DE-FG05-86ER40256.

HB 2 Status of the K1200 Cyclotron at the NSCL.* P. MILLER, *Michigan State University.* (20 min.)

During the past 16 months the K1200 cyclotron has delivered heavy ion beams to an interim target area while beamlines and target station equipment were converted to their planned final (Phase 2) configuration. This construction and subsequent testing will be completed by the end of 1990. The target stations and detectors are S320 (magnetic spectrometer), 4 pi Array, Miniball, 92 inch chamber, U of M superconducting solenoid, RPMS (reaction product mass spectrometer), and the activation and recoil implantation station. A beam analysis system called the A1200 connects the K1200 cyclotron to the rest of the beam transport system. It is designed as a large acceptance fragment separator to produce and deliver radioactive secondary beams to other experimental apparatus. The K1200 cyclotron and its predecessor, the K500, receive ions from any of 3 ECR ion sources via a beam switchyard. Either cyclotron may be used independently. The highest beam energies delivered so far are 100 MeV/u for ^{14}N and ^{40}Ar, 85 MeV/u for ^{20}Ne, 60 MeV/u for ^{86}Kr and 50 MeV/u for ^{129}Xe. Fully stripped ions at energies above 150 MeV/u will be available in 1991.

*Supported by the National Science Foundation #PHY89-13815.

HB 3 Calculation of "Ghost" Beam Parameters in Linear Accelerators.* J. D. FOX, *Florida State University.* (20 min.)

Different ion species with equal charge/mass ratios will be accelerated and deflected equally by an accelerator system. We have explored the acceleration of ions with unequal charge/mass through the F. S. U. superconducting linear accelerator. An example of a ghost beam which was accelerated through the tandem Van de Graaff injector and linear accelerator will be discussed along with examples of other ghost beam phenomena of importance to nuclear reaction experiments.

*Supported by the National Science Foundation and the State of Florida. The work reported here was done in collaboration with A. D. Frawley and N. R. Fletcher.

HB 4 The Neutral Beam Test Facility and Radiation Effects Facility at Brookhaven National Laboratory.*
R. B. McKENZIE-WILSON, *Brookhaven National Laboratory.* (20 min.)

As part of the Strategic Defense Initiative Brookhaven National Laboratory (BNL) has constructed a Neutral Beam Test Facility (NBTF) and a Radiation Effects Facility (REF). These two facilities use the surplus capacity of the 200-MeV Linac injector for the Alternating Gradient Syncrotron (AGS). The REF can be used to study radiation damage effects in space from both natural and man made radiation sources. The H^- beam energy, current and dimensions can be varied over a wide range leading to a broad field of application. The NBTF has been designed to carry out high precision experiments and contains an absolute reference target system for the on-line calibration of measurements carried out in the experimental hall. The H^- beam energy, current and dimensions can also be varied over a wide range but with restrictions depending on the required accuracy. Both facilities are fully operational and will be described together with details of the associated experimental programs.

*Work performed under the auspices of the U.S. Army Strategic Defense Command, Huntsville, AL.

HB 5 A High Stability Accelerator for Ion Beam Diagnostics in a Tokamak.
J. B. SCHROEDER, *National Electrostatics Corporation.* (5 min.) (Invited Poster Paper. See Poster Display PB' 14)

A 2 MV single ended accelerator has been developed for probing a Tokamak plasma with a heavy ion beam. This high current Pelletron is designed to deliver up to 200 μA of 2 MeV Tl^+ for plasma diagnostics. Stringent energy stability requirements have led to the development of an improved accelerator voltage control system incorporating a capacitive tank liner. The special design features and performance of this system will be discussed.

HB 6 Ion Beam Acceleration by RFQ with LC Resonance Circuit.* Y. HAKAMATA, *Hitachi Research Laboratory, Japan.* (20 min.)

To develop a high current MeV implanter, ion beam acceleration feasibility using a variable energy RFQ system has been studied. The RFQ system consists of an LC resonance circuit and conventional RFQ electrodes 1.3 m in length. The energy can be continuously varied by changing the resonance frequency of the circuit. The electrodes are designed to accelerate an N^+ beam of 10 keV to 270 keV in order to investigate fundamental acceleration characteristics

of this system. An intervane voltage of 26 kV is needed to accelerate N^+. By improving the LC resonance circuit to generate a high voltage of radio frequency, the intervane voltage of 40 kV at 21kW RF power was obtained, a value sufficient for MeV-range acceleration. Experimental results showed that N^+ beams were accelerated to 265 keV and Ar^{4+} to 750 keV. Energy was varied by changing the frequency, in agreement with the calculated value. It was concluded that the RFQ system driven by the LC-circuit should be very useful for MeV ion implantation in semiconductor fabrication.

*This work was carried out under the R&D Program "Advanced Material Processing and Machining System", conducted by the New Energy and Industrial Technology Development Organization.
[1]Work performed in collaboration with K. AMEMIYA, K. TOKIGUCHI and N. SAKUDO, Hitachi Res. Lab., S. YAMADA and Y. HIRAO, National Institute of Radiological Science, Anagawa Chiba 260 Japan.

HB 7 Status of the ATLAS Accelerator. G. P. ZINKANN, *Argonne National Laboratory.* (20 min.)

SESSION HC: RADIATION PROCESSING

Wednesday afternoon, 7 November 1990; Union Building, Room 412 at 14:00; M. Cleland, Radiation Dynamics, Inc., presiding

HC 1 Dual Linear Accelerator System for Use in Sterilization of Medical Disposable Supplies.
T. SADAT, *MeV Industrie SA, France.* (25 min.)

Accelerators are used for sterilization or decontamination (medical disposables, food, plastics, hospital waste...). Most of these accelerators are inserted in an industrial environment and have to have a high availability. Industrial and economic constraints have to be taken into account by the manufacturers of linear accelerators:

- the system must be flexible and reliable,
- maintenance has to be easy,
- components must be strong and available on the market (which reduces maintenance cost),
- the system must fit with handling system.

Some 10 MeV 20 kW accelerators have been operating for about 10 years and are well-tested machines. Economic and industrial data are also available. In some cases, higher power seems to be requested (because of a higher throughput). However, instead of proposing a prototype machine with higher power, it seems to be more reasonable to propose a dual system. A dual accelerator system (composed of two accelerators) offers an optimal flexibility and reliability. The main advantage of this system is "all-in all-out" because it does not need a turnover of products. Such a dual system, composed of two 10 MeV 20 kW linear accelerators (instead of a 40 kW one), has been chosen by a Swedish company (Molnlycke). Technical, industrial and economic advantages of such a system will be described in this lecture.

HC 2 Materials Modification with Accelerator. S. V. NABLO, *Energy Sciences, Inc.* (25 min.)

HC 3 The Impela 10 MeV, 50 kW Electron Linacs: Launching an Industrial Accelerator Project.
A. J. STIRLING, *Atomic Energy of Canada Limited, Canada.* (25 min.)

HC 4 Advances in X-Ray Processing Technology II. M. R. CLELAND, *Radiation Dynamics, Inc.* (25 min.)

* In collaboration with C.C. Thompson, Radiation Dynamics, Inc., Edgewood, NY; C.M. Herring and M.C. Saylor, Johnson & Johnson, New Brunswick, NJ; D.P. Sloan, CH2M Hill, Albuquerque, NM; M.T. O'Neill, Becton Dickinson & Company, Franklin Lakes, NJ and J.M. Hansen, Isomedix, Inc., Whippany, NJ.

HC 5 A New Linear Accelerator Facility for the Treatment of Agricultural Commodities.
B. J. SMITTLE, *Department of Agriculture and Consumer Services.* (25 min.)

* In collaboration with M.E. Rhodes

HC 6 Production of Uniform and Well-Confined Beams by Nonlinear Optics.
BARBARA BLIND, *Los Alamos National Laboratory.* (25 min.)

Particle beams with uniform and well-confined intensity distributions are desirable for medical treatment, food irradiation and ion implantation. Moreover, such beams are essential in the development of high-intensity accelerators whose beams are to be directed onto targets for use or disposal. One accepted method for beam shaping employs nonlinear beamline elements, in particular octupoles and to a lesser degree magnets of even higher odd multipolarity. This method is not limited to the production of uniform beam distributions. The history of this field is reviewed. Beam redistribution is explained and the degree of uniformity and confinement achievable under various conditions is discussed. The effect of beam jitter on the distribution is considered. A possible alternative to the use of combined-function multipoles is presented. Applications of the method are given as examples throughout.

*Work supported by Los Alamos National Laboratory Program Development, under the auspices of the United States Department of Energy.

SESSION HD: ACCELERATOR PRODUCTION OF MEDICAL RADIOISOTOPES
Wednesday afternoon, 7 November 1990; Union Building, Room 411 at 14:00;
H. B. Hupf, Hybritech, Inc. and J. E. Beaver, Oak Ridge National Laboratory, presiding

HD 1 Alternate Methods of Stable Isotope Enrichment for Medical Accelerator Targets.
G. E. MICHAELS, *Oak Ridge National Laboratory.* (20 min.)

HD 2 Design, Construction, and Automation of a New Positron Emission Tomography Facility.
R. D. HICHWA, *University of Iowa Medical Center.* (20 min.)

PET technology is becoming more widely accepted as a diagnostic imaging modality for the determination of brain, heart, tumor and other organ system function. The number of PET centers in the U.S. is expected to double from approximately 30 to 60 in the next 2-3 years. Few architects have experience with the design of these special laboratories. There is an extreme shortage of qualified radiochemists, physicists and technicians to staff these facilities. In order to facilitate this expansion, criteria have been established to tailor the design of the laboratory to meet the needs of the clinical and research community. Systems that were once handled manually can now be automated to reduce personnel requirements. New radiation protection standards are forcing PET Centers to develop methodologies to cut releases by 100 to 1000 fold. Alternatives to concrete vaults for cyclotron shielding; unattended operation of the cyclotron; robotic radiochemistry; radioactive exhaust gas monitoring and control; and integration of computing facilities for image processing, data storage, and laboratory automation will be discussed.

HD 3 Regulation of Cyclotron Radiopharmaceutical Production and Distributions: An Agreement State Perspective.
JON R. SHARP, *Texas Department of Health.* (20 min.)

While research accelerators producing radioactive material have been regulated for some time, the use of such devices in the preparation and distribution of radiopharmaceuticals has been confined to a few commercial firms and pioneering medical institutions. Such use requires multi-agency approval. The agencies involved, particularly state agencies, may not always be equally informed in the state of the art, may not have adopted positions or developed guidance with regard to their own rules for such activities and may not have staff trained and/or available to respond expeditiously to authorization requests. Accelerator operators may also not be conversant with applicable requirements. This presentation will describe the recent experience of the Texas Bureau of Radiation Control with two cyclotron facilities within its jurisdiction.

HD 4 Radionuclide Production with 70-MeV Proton Accelerators: Current and Future Prospects.
M. C. LAGUNAS-SOLAR, *University of California, Davis.* (20 min.)

The production of radionuclides via proton/deuteron beam accelerators is rapidly being expanded as a result of new medical research and clinical needs. New diagnostic modalities such as Positron Emission Tomography (PET) requires that short-lived (< 2 h) positron emitters be produced and incorporated onto radiopharmaceuticals rapidly and efficiently, and within the proximity of imaging facilities. Therefore, the planning and installation of most PET facilities around the world includes a proton accelerator (i.e., cyclotron) and ancillary radiochemistry/radiopharmaceutical facilities. These facilities would then operate a low-energy proton/ deuteron accelerator, capable of large production throughput, but severely limited in their capabilities to produce other medical/ research radionuclides or to support regional needs. While the current justification for low-energy accelerators is strong, long- term needs and the expectation for PET techniques to be expanded to other types of PET radiopharmaceuticals labeled with longer-lived positron emitters, are not being considered. The production of F-18 via high-energy reactions, and of longer-lived positron emitters, such as 18-h Co-55, and 6-d Te-118 -> Sb-118 [3.5 min] and 25-d Sr-82 -> Rb-82 [1.27 min] generators, with 70-MeV accelerators is being developed (*) and would justify considering the installation of regional-type facilities to support present (i.e., O-15, C-11, N-13, F-18) as well as future radionuclide production needs. Modern high-intensity H- accelerators are available, with simultaneous dual-beam capabilities, and high reliability of operation. These accelerators should then be strong candidates to support the planning and operation of regional facilities. The integration of modern 70-MeV accelerators as a resource to supply future needs and the expectations for an expanded role for PET, will be discussed based upon newly-developed radionuclide production methods (1-3).

(*) Supported by UC Davis/Crocker Nuclear Laboratory Research Grants.
(1) M. Lagunas-Solar et al., Int. J. Appl. Rad. Isotopes, 39, 41-47 (1988);
(2) M. Lagunas-Solar et al., Int. J. Appl. Rad. Isotopes, 41, 349-357 (1990);
(3) M. Lagunas-Solar et al., Int. J. Appl. Rad. Isotopes, 41, 521-529 (1990).

HD 5 Utilization of a Hospital-Based Medical Cyclotron for Commercial Radionuclide Production.
T. E. BOOTHE, *Mount Sinai Medical Center, Miami Beach.* (20 min.)

Mount Sinai operates a TCC (Cyclotron Corporation) CS-30 cyclotron capable of accelerating protons to 26.5 MeV. The machine was installed in 1972 and since that time has been used for radiopharmaceutical research and development for nuclear medicine, for routine radiopharmaceutical deliveries, and for commercial sales of radiochemicals. The emphasis in each of these areas has changed over the years with the financial situation of the hospital being the major determinant. Various aspects of the production of gallium-67 will be used to illustrate how a commercial operation fits into the daily schedule and controls to a large extent the

goals of the facility. Recently, in order to maximize the output, we have investigated the production of several radionuclides that are produced simultaneously with gallium-67 from the same target. Some of these are copper-64, copper-67, and zinc-62 (copper-62), all of which are useful in radiopharmaceutical R&D and have commercial potential.

HD 6 Scattering of Particle Beams Through Thick Foils and the Application to Cyclotron Targetry.*
D. J. SCHLYER, *Brookhaven National Laboratory.* (20 min.)

The growing application of PET requires the production of short-lived positron emitting isotopes using an accelerator with the associated targetry. One of the important parameters of the design of these targets is the front foil window and the angle of scatter through this window. The case of thin windows has been extensively explored but the thicker windows (.0025 cm to .0075 cm) has been less well studied. A systematic study of the scattering through these windows and a comparison to the theoretical calculations has been carried out. A comparison of the experimental results to calculated results form several different theoretical models demonstrates that the simple model predicts the results within experimental uncertainty and the more sophisticated models are not necessary. The calculated values agree quite well for the thinner windows if the scattering angle at the average energy of the beam is used.

* Research carried out at King Faisal Specialist Hospital Research Center, Riyadh, Saudi Arabia 11211.

SESSION HE: ATOMIC PHYSICS AND RELATED PHENOMENA

Wednesday afternoon, 7 November 1990; Union Building, Golden Eagle Suite A at 14:00;
A. L. Ford, Texas A&M University, presiding

HE 1 Multiple Ionization of He, Ne, and Ar by High Velocity N^{7+} Ions.* O. HEBER,+ *Texas A&M University.* (20 min.)

The velocity dependence of multiple ionization by fully stripped nitrogen ions is being investigated from 10 to 40 MeV/amu. The He, Ne, and Ar target ion charge state distributions, produced in single collisions, are measured by time-of-flight spectroscopy. The ratios of the double to single ionization cross sections for He are much larger and decrease more slowly with velocity than the ratios predicted by current theories.[1] The multiple ionization cross section ratios for Ne and Ar targets display similar behaviors and their velocity dependencies are not replicated by independent particle model calculations. These results suggest that electron correlation effects are more important in the high velocity regime than previously believed. New results with 40 MeV/amu N^{7+} and comparisons with the semiempirical analysis of Andersen et al.[2] will be presented.

*Work supported by the Division of Chemical Sciences of the U.S. Department of Energy and the Robert A. Welch Foundation.
+Present address: Department of Nuclear Physics, Weizmann Institute, Rehovot, Israel
[1]O. Heber, B. B. Bandong, G. Sampoll, and R. L. Watson, Phys. Rev. Lett. 64, 851 (1990).
[2]L. H. Andersen, P. Hvelplund, H. Knudsen, S. P. Moller, A. H. Sorensen, K. Elsener, K.-G. Rensfelt, and E. Uggerhoj, Phys. Rev. A36, 3612 (1987).

HE 2 Two-Electron Excitation in Slow Ion-Atom Collisions. Excitation Mechanism and Interferences Between Autoionizing States.*
M. KIMURA, *Argonne National Laboratory.* (20 min.)

By measuring the ejected electron in coincidence with the projectile, Morgenstern and co-workers[1] were able to extract information about scattering amplitudes for the $He(2p^2)\ ^1D$, $He(2s2p)\ ^1P$, and $He(2s^2)\ ^1S$ excited states in Li^+ + He collisions in the energy range from 1 keV to 3 keV. On the basis of this information, they proposed excitation mechanisms. Furthermore, Morgenstern's group[2] and Furune et al.[3] had previously reported the ejected electron energy distribution (EED) resulting from collisions of Li^+ ions with He atoms in the energy range of 0.8 keV to 3 keV and the observation of several interference structures. We have recently investigated the two-electron excitation process and the EED in H^+ + He and Li^+ + He collisions in the energy range 0.5 keV to 10 keV. We focused on a systematic study to identify the origins of interferences that cause structures in the EED. Candidates we examined for dominance were interference between (i) different H_L states of one doubly excited state, (ii) doubly excited states from both the autoionizing atomic state and the Penning state, (iii) different ionization mechanisms (direct ionization or autoionization), (iv) different paths of heavy particles, (v) incoming and outgoing parts of the collisions, and (vi) electrons with identical energy ejected at different internuclear distances. We found that causes (ii), (iv), (v), and (vi) dominate. Our results provide a reasonable interpretation of the structures in the observed[3] EED and also predict new structures (i) in the tail on the lower side of the molecular autoionization (MA) peak and (ii) between the MA peak and the atomic autoionization peak.

*Work supported in part by the U.S. Department of Energy, Assistant Secretary for Energy Research, Office of Health and Environmental Research, under Contract W-31-109-ENG-38.
[1]P. van der Straten, R. Morgenstern, and A. Niehaus, J. Phys. B 21, 1573 (1988).
[2]C. J. Zwakhals, R. Morgenstern, and A. Niehaus, Z. Phys. A 307, 41 (1982).
[3]H. Furune, F. Koike, and A. Yagishita, J. Phys. B 16, 2539 (1983).

HE 3 Far uv Spectroscopy of Highly Ionized Argon Using Complementary Technique.
EMILE KNYSTAUTAS, *Universite Laval, Canada.* (5 min.) (Invited Poster Paper: See Poster Display PA 86)

The far uv spectroscopy of highly ionised argon has been studied with particular attention paid to core-excited metastable states. Excitation by foil-excited MeV beams is compared with single- and double-electron capture into excited states during low-energy charge exchange of highly ionised argon ions in helium and hydrogen targets. The use of complementary techniques aids in line identification through the high charge-state selectivity of the charge-exchange process, the use of lifetime measurements, and consideration of the different excitation and cascade processes involved. Finally, comparisons are made using isoelectronic sequences and model-potential calculations. A number of new lines are reported as well as lifetime determinations. A concurrent experiment using MeV hydrogen beams on gaseous argon targets is also presented.

HE 4 Convoy Electrons Produced by 50 MeV $^3He^{2+}$ Ions. M. MANNAMI, *Kyoto University, Japan.* (20 min.)

Yields of beam-foil convoy electrons are measured at transmission of 50 MeV $^3He^{2+}$ ions through thin solid foils. The foils were *C*, *Al*, *Ti*, *Ni*, *Mo*, *Ag*, *Ta* and *Au* of thicknesses about 1 μm, *C* of thicknesses ranging from 1μ g/cm^2 to 100μ g/cm^2 and *Au* coated by *C* layers of thicknesses less than 15 μm. From the calculated charge state fractions of the foil transmitted ions, it is shown that the yield of convoy electrons is proportional to the fraction of $^3He^+$ in the transmitted beam. They are related by $Y = K \cdot F_1$, where Y is the yield of convoy electrons per ion, K is $(2.4 \pm 1.5) \times 10^{-3}$ and F_1 is $^3He^+$-fraction in the transmitted beam. This result is shown to be explained in terms of last layer ELC process. The process of convoy electron production is discussed in relation to the Rydberg states formation.

HE 5 A Study of LMM Auger Spectra, Transition Energies, and Peak Intensity Variation in Si (SiH_4) and P (PH_3) Produced by 0.4 to 2.1 MeV He^+ Ion Bombardment. D. POWERS, *Baylor University.* (20 min.)

S and P LMM Auger spectra with resolution 0.45 eV produced under 0.4 to 2.1 MeV He^+ ion bombardment of silane and phosphine gas, respectively, reveal more lines (12 or more in Si and 10 or more in P) at an ion velocity near that of the electrons in the $L_{2,3}$ shell of the target atoms than at other ion velocities. Auger peak energies, widths, and relative intensities in Si and P produced with resolution 0.30 eV under 0.8 and 1.05 MeV He^+ ion bombardment, respectively, are given. The Auger peak energies in Si are compared to those produced under 500 eV electron-bombardment elsewhere and to existing theory, while those in P are discussed.

*In collaboration with W. M. Ariyasinghe

HE 6 Spectroscopy of Sub-keV, Ion-Induced X-Rays Using Si (Li) Detectors.*
R. G. MUSKET, *Lawrence Livermore Naticnal Laboratory.* (20 min.)

Windowless and ultra-thin windowed Si(Li) detectors are useful for energy-dispersive spectroscopy of x-rays with energies above 200 eV. With a few precautions, such detectors are well-suited for analysis of particle-induced x-ray emissions (PIXE). PIXE has proven useful both as a stand-alone analysis technique and as a complement to other ion-beam analysis techniques. Properties of the detectors are reviewed with regard to the limits they impose on detection efficiency, output linearity, energy resolution, and peak shapes. In addition, considerations related to vacuum requirements, x-ray absorption due to ice and to various windows, removal of scattered ions from the x-ray detector axis, and long-term detector stability are discussed. Finally, the question of efficiency calibration for sub-keV x-rays is addressed.

*Work was performed under the auspices of the U.S. DOE by Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

HE 7 Resonant Dielectric Excitation. C. R. VANE, *Oak Ridge National Laboratory.* (20 min.)

SESSION HF: ATOMIC PHYSICS AND RELATED PHENOMENA (STORAGE RINGS)

Wednesday afternoon, 7 November 1990; Union Building, Golden Eagle Suites B and C at 14:00;
J. R. Mowat, North Carolina State University, presiding

HF 1 Results and Perspectives after Two Years of Atomic Physics Experiments at the TSR.
ANDREAS WOLF, *Physikalisches Institut der Universitat, Federal Republic of Germany.* (40 min.)

Results of the atomic physics experiments at the heavy ion Test Storage Ring (TSR) in Heidelberg are presented and plans for the next future are discussed. The main fields

of study are inelastic interactions of highly charged ions with free electrons, laser cooling and spectroscopy of fast ion beams, and the properties of very cold stored ion beams. State-selective dielectronic recombination rates and radiative recombination rates of few-electron heavy ions were measured using the electron cooling device of the TSR. In particular, dielectronic recombination of hydrogen-like ions was measured for the first time at a high energy resolution. Further studies of inelastic processes with free electrons and their use for spectroscopic investigations are planned. Using singly charged Li and Be ions, laser cooling of relativistic ions in a storage ring was demonstrated for the first time, yielding beam temperatures below 1 K. Work is in progress on reaching even lower temperatures. A precision experiment aiming at tests of special relativity and making use of the low beam temperature is in preparation. Diagnostic methods for cold ion beams were tested and are being further developed.

HF 2 Laser Physics with Fast Stored Ions at ASTRID. M. KRISTENSEN,[1] *University of Aarhus, Denmark.* (40 min.)

At the ASTRID storage ring in Aarhus, cold beams of different singly charged ions were successfully stored at low energies in the spring of 1990. Using beam-position monitors and Schottky noise pick-ups a wide spectrum of collective beam-dynamics was observed. Laser spectroscopy was used to probe the velocity distribution and beam dynamics in a 100keV $^7Li^+$ beam. The method offer new possibilities to investigate intra-beam scattering, debunching and other relaxation phenomena for an ion beam. After an initial phase of intra-beam relaxation lasting a few hundred milliseconds, it was possible to laser cool the part of the beam present in the metastable $^2S_{\frac{1}{2}}$ state. Two lasers co- and counterpropagating with the ion beam were used. The beam energy and velocity spread of the laser cooled distribution was completely determined by the lasers, and an ion temperature close to the diffusion limit for laser cooling $^7Li^+$ was obtained.

[1]In collaboration with: J.S. Nielsen, P. Shi and O. Poulsen, to be published.

HF 3 Atomic Physics at the IUCF Cooler Storage Ring.* J. A. TANIS, *Western Michigan University.* (40 min.)

An atomic physics program has been initiated at the Indiana University Cyclotron Facility utilizing the Ion Storage Ring and Electron Cooler. Fundamental atomic processes are investigated by merging a high velocity (> 0.1c) ion beam with the electron cooling beam. The intense electron beam (up to ~ 1 A) coupled with the high energy resolution (> 2×10^{-3}) possible for the ion beam permit the study of processes which were previously difficult or impossible using conventional crossed- or merged-beam techniques. In our initial effort at IUCF we investigated dielectronic recombination (DR) for $1s\rightarrow n\ell n'\ell'$ transitions in $He^+ + e^-$ collisions.[1] This work was done using the storage ring and cooler in a "single-pass" mode, i.e., the He^+ ions circled the ring, passed through the electron cooling region, were deflected by a ring magnet, and then collected in a Faraday cup. Events resulting in DR in the 2.8-m long electron cooler region were detected by observing neutral He atoms which exited through a 0° port. By ramping the relative electron energy, DR maxima were observed for electron velocities less and greater than the ion beam velocity, respectively. At zero relative energy, a peak due to radiative recombination was observed between the DR maxima. Because the measurements were conducted in a single pass mode, the ion beam current was accurately measured, thereby giving reliable cross section values. Additional DR studies are planned for Li^+ ions and higher Z ions if these latter ions can be made available at IUCF, and it is also planned to study radiative recombination for these various ions. Once the DR and radiative recombination results are understood and calibrated, these results may provide valuable beam diagnostics for the storage ring and cooler facility.

*Supported in part by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Chemical Sciences.
[1]See J. A. Tanis et al., Nucl. Instrum. Meth. Phys. Res. B43, 290 (1989).

HF 4 The Experimental Program at the ESR Heavy-Ion Cooler Ring.
T. KÜHL, *GSI Darmstadt, Federal Republic of Germany.* (40 min.)

In april of this year, operation started of the heavy-ion storage ring ESR[1]. First electron-cooling of a beam of naked argon ions was performed by the end of may. The design allows to store ions from the SIS heavy-ion synchrotron or secondary beams produced and prepared in an in-flight fragment separator[2] at energies up to 1 GeV/u. At these energies, uranium ions can be fully stripped. Specific experimental equipment of the system includes, besides the electron-cooler section, pick-ups and kickers for stochastic cooling, an internal gas target, detectors for charge-changed ions, x-ray and optical detectors.[3] Experiments are under way to measure the size and energy dependence of the electron-cooling force and of charge changing processes in the cooler, i.e. radiative electron capture and dielectronic recombination, for heavy, highly charged ions. In addition, a laser system is set up to study light-induced electron capture and to perform precision optical spectroscopy

1. B. Franzke, Nucl. Instr. & Meth. B24/25,18 (1987)
2. G.Münzenberg et al., Proceedings of the First Int. Conf. on Radioactive Beams, W.D. Myers, J.M. Nitschke and E.B. Norman ed., World Scientific, Singapore 1989, p. 91
3. W. Henning, The Research Program at SIS/ESR, GSI preprint 89-34(1989)

HF 5 CRYRING, A Small Synchrotron Storage Ring for Cold Highly Charged Beams.
R. SCHUCH, *Manne Siegbahn Institute, Sweden.* (40 min.)

SOCIAL HOUR
Wednesday evening, 7 November 1990
Union Building, Second Floor at 17:00

BANQUET
Wednesday evening, 7 November 1990
University of North Texas Coliseum at 18:30

SOCIAL HOUR
Wednesday evening, 7 November 1990
Union Building, Second Floor

TRAVELING PHYSICS CIRCUS
Wednesday evening, 7 November 1990
Physics Building, Room 102 at 21:00

SESSION IA: SYNCHROTRON RADIATION II
Thursday morning, 8 November 1990; Union Building, Room 410 at 9:00; K. W. Jones, Brookhaven National Laboratory, presiding

IA 1 Recent Developments at the Synchrotron Radiation Center.*
D. L. HUBER, *Synchrotron Radiation Center, University of Wisconsin—Madison, Stoughton.* (20 min.)

We present an overview of the current status of the Synchrotron Radiation Center. New beamlines and improvements to the Aladdin storage ring are discussed, and plans for future insertion devices and accompanying beamlines are highlighted.

* Supported by the National Science Foundation.

IA 2 Research Opportunities at the Advanced Light Source.[1] A. S. SCHLACHTER, *Lawrence Berkeley Laboratory.*[2] (20 min.)

Now under construction at the Lawrence Berkeley Laboratory, the Advanced Light Source (ALS) is a third-generation synchrotron radiation facility based on a low-emittance, 1.5-GeV electron storage ring with 10 long straight sections available for insertion devices and, initially, 24 bend-magnet ports. Undulators will provide high-brightness radiation to photon energies above 2 keV; wiggler and bend-magnet radiation will extend the spectral coverage with high fluxes to above 10 keV. Research opportunities when the ALS begins operations as a U.S. Department of Energy national user facility, now scheduled for the spring of 1993, will be described.

[1]This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Division of Materials Sciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.
[2]In collaboration with A. L. Robinson, Lawrence Berkeley Laboratory

IA 3 Technological Applications of Synchrotron Radiation at the Synchrotron Radiation Center of the University of Wisconsin.*
E. M. ROWE, *Synchrotron Radiation Center, University of Wisconsin—Madison, Stoughton.* (20 min.)

The use of synchrotron radiation for fundamental research in a wide range of disciplines is now well established, world wide. Not so well known are the technologically oriented programs that are now in progress on Aladdin (1), the 1 GeV electron storage ring at the Synchrotron Radiation Center of the University of Wisconsin-Madison. We describe three such programs : X ray lithography, X ray microscopy, and high T_c superconductor to normal conductor junction technology.

*Supported by the National Science Foundation.

1. E.M. Rowe, Proceedings of the Ninth International Conference on the Application of Accelerators in Research and Industry, Denton, TX, November 10-12, 1986, 414.

IA 4 Utilization of a Commercially Supplied Synchrotron Radiation Source.
BEN CRAFT, *Louisiana State University Center for Advanced Microstructures and Devices, Baton Rouge.* (20 min.)

Louisiana State University (LSU) is developing the Center for Advanced Microstructures and Devices[1] (CAMD) in Baton Rouge, Louisiana. The centerpiece of CAMD will be a 1.2 GeV electron storage ring purchased from Maxwell Laboratories, Inc.[2] The hi-tech building for CAMD has been designed by TECH-IV of Baton Rouge with engineering support from Lester B. Knight and Associates of Chicago. The storage ring has been optimized for X-ray lithography. The procedures developed at CAMD for printing integrated circuits may well be of significant importance to U.S. competativeness in semiconductor and related industries. The spectral range of the ring also supports scientific and engineering activities in other areas of research and analysis that may be of industrial intrest.

[1]B.C. Craft, A.M. Findley, G.L. Findley, J.D. Scott, and F.H. Watson, NIM B40/41, 379 (1989).
[2]R. Sah, "The LSU Electron Storage Ring," this conference.

IA 5 Survey and Alignment of the Advanced Light Source in Berkeley.* R. KELLER, *Lawrence Berkeley Laboratory.* (20 min.)

The Advanced Light Source (ALS), now under construction at Lawrence Berkeley Laboratory, is a synchrotron radiation source of the third generation designed to produce extremely bright photon beams in the UV and soft X-ray regions.[1] Its main accelerator components are a 1 - 1.9

GeV electron storage ring, a 1.5 GeV booster synchrotron, and a 50 MeV linac. The storage ring has particularly tight positioning tolerances for lattice magnets and other components to assure the required operational characteristics. The general survey and alignment concept for the ALS is based on a network of fixed monuments to which all component positions are referred.. Measurements include electronic distance measurements and direction sightings with electronic data capture. Data are processed by a customized version of the computer code GEONET[2] which provides raw data reduction, calculation of adjusted coordinates, and error analysis. Additionally, for local survey tasks the commercial software package ECDS[3] is used. In this paper, the ALS survey and alignment strategy and techniques are presented and critically discussed; first experiences with alignment of the linac and booster components are described.

* Work supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Material Sciences Division, U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.
[1]1-2 GeV Synchrotron Radiation Source, Conceptual Design Report, LBL Pub. 5172 Rev.), 1986.
[2]H. Friedsam, R. Pushor, and R. Ruland, SLAC-PUB-4142, Nov, 1986
[3]Kern Instruments Inc., Electronic Coordiante Determination System, Instruction Manual, 1986

IA 6 The Louisiana State University Electron Storage Ring.
RICHARD SAH, *Brobeck Division, Maxwell Laboratories, Inc., Richmond.* (20 min.)

The Brobeck Division of Maxwell Laboratories, Inc., is building an electron storage ring for Louisiana State University (LSU). This turnkey project, the first storage ring to be built commercially in the United States, will be located at the Center for Advanced Microstructures and Devices[1] (CAMD) in Baton Rouge. The storage ring system consists of a 1.2 GeV, 400 mA storage ring and a 200 MeV linac injector, and it will provide intense beams of x-rays for research in x-ray lithography and in other areas. The magnet lattice has a Chasman-Green design; and four 3-meter, zero-dispersion straight sections are incorporated in the storage ring, which has a 55.2-meter circumference. The design phase of the construction project has been completed, and major components are being fabricated.

[1]B.C. Craft, A.M. Findley, G.L. Findley, J.D. Scott, and F.H. Watson, Nucl. Instr. and Meth. in Phys. Research, B40/41, 379 (1989)

IA 7 Investigations of Catalysts Using Synchrotron X-Ray Microscopy.* K. W. JONES, *Brookhaven National Laboratory.* (20 min.)

Synchrotron x-ray microscopy (XRM) is an effective approach to the characterization of different types of catalysts. XRM can be used to measure the spatial distribution of elements in thin sections of catalytic pellets with spatial resolution of less than 10 micrometers and with minimum detection limits around 1 part per million. In this mode it is complementary to the use of the electron microprobe. XRM can also be used for computed microtomography (CMT) based on x-ray absorption measurements and in some cases on the detection of fluorescent x rays. These techniques are being used at the Brookhaven National Synchrotron Light Source X-26 XRM facility to investigate several different types of catalysts. The distribution of Cr-silica catalyst in polyethylene pellets was investigated using CMT. CMT was also applied to study of fluid catalysis cracking and hydrotreating catalysts. In the latter cases maps were also made using x-ray fluorescence to relate the distribution of specific elements to the tomographic linear attenuation coefficient images.

*Supported by US Department of Energy, Office of Basic Energy Sciences, Chemical Sciences Division, Contract No. DE-AC02-76CH00016.

SESSION IB: ATOMIC PHYSICS
Thursday morning, 8 November, 1990; Union Building, Golden Eagle Suite A at 9:00;
G. Basbas, Physical Review Letters, presiding

IB 1 Atomic Physics with the Texas A&M ECR Source.* R. L. WATSON, *Cyclotron Institute, Texas A&M University.* (20 min.)

An electron-cyclotron-resonance (ECR) ion source has been constructed to provide highly charged ions for injection into the K500 superconducting cyclotron. The ECR source is medium-sized with a Sm-Co hexapole surrounding a 13.7 cm diameter second stage. Microwave power for the source is provided by a 2.0 KW, 14.5 GHz transmitter for the first stage and a 3.25 KW, 6.4 GHz transmitter for the second stage. The ions are extracted at 10 to 20 KeV/charge. An atomic physics beamline is now connected to the source and is being used extensively for a variety of experiments ranging from the investigation of charge exchange with gas targets to the study of x-ray emission following electron capture from solid surfaces.

*Work supported by the Division of Chemical Sciences of the U.S. Department of Energy and the Robert A. Welch Foundation.

IB 2 Double Excitation of Helium by Fast Protons and Antiprotons.* JACK C. STRATON, *Kansas State University.* (20 min.)

The charge sensitivity of this two-electron process is investigated as a tool for understanding correlation. The helium wave function is approximated by a sum of pair-products of one-electron wave functions, with the coefficients chosen by minimizing the fully correlated two-electron Hamiltonian. Thus, spatial correlation is included in both the asymptotic and scattering regions by using these Configuration Interaction (CI) wave functions for initial, intermediate, and final states. Use of CI wave functions also allows the first-order contributions to be expressed in closed, analytical form. Both the energy-conserving and energy-nonconserving parts of the second-order amplitude are found. The former (a correlated generalization of the Independent Electron Approximation) is analytical and the latter is a one-dimensional integral. It is found that the double excitation cross sections are sensitive to the sign of the projectile charge. Comparison is given with the experimental results of Pedersen and Hvelplund[1] and Giese *et al.*[2]

*Supported by the Division of Chemical Sciences, U.S. Department of Energy.
[1]J.O.P. Pedersen and P. Hvelplund, Phys. Rev. Let. 62, 2373 (1989).
[2]J. Giese *et al.*, Phys. Rev. (August 1, 1990)

IB 3 Space and Time Correlation in High-Velocity Multiple Electron Transitions.*
J. H. McGUIRE, *J. R. Macdonald Laboratory, Kansas State University.* (20 min.)

In collisions of high velocity projectiles of charge Z and velocity v, perturbations expansions in Z/v usually converge when $Z/v < 1$. Under these conditions Z^3 contributions to cross sections for two electron transitions (e.g. double excitation) may arise if there is interference between first order and second order contributions to the probability amplitude. Non-zero Z^3 terms in two electron excitation or ionization cross sections occur if spatial electron correlation is present. For double excitation non-zero Z^3 contributions require a correlation in time as well. This time correlation corresponds to quantum time ordering arising from virtual off-energy-shell intermediate states. As with second order amplitudes for Thomas singularities in single electron capture, the energy non-conserving amplitude is connected to the energy-conserving amplitude in second order in Z by a dispersion relation. Generalization to higher order transitions (e.g. triple excitation) is discussed.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Science, Office of Energy Research, U.S. Department of Energy.

IB 4 Secondary Electrons from Charged Particle Collisions with Atoms and Molecules.*
M. E. RUDD, *University of Nebraska, Lincoln.* (20 min.)

Since a large fraction of the energy transfer in energetic atomic collisions is in the production of secondary electrons, most of the radiation effects are a result of this process. Therefore, a knowledge of the energy spectrum (and for some purposes the angular distribution) of secondaries is crucial in understanding the interaction of charged particles with matter. Semi empirical models for the differential cross sections for secondary electron production by proton[1] and electron impact on atoms and molecules have been developed which summarize a large amount of information in the form of analytical equations with a few parameters for each target species.

*Supported by the National Science Foundation.
[1]M.E. Rudd, Phys. Rev. A. 38, 6129-6137 (1988).

IB 5 Kansas State Zero Degree RTEA Experiments.* P. RICHARD, *J. R. Macdonald Laboratory, Kansas State University.* (20 min.)

The $(2\ell\ 2\ell')^{2S+1}L$ resonances formed by resonance excitation in e^- + Ion (1s) collisions are studied by the Resonant Transfer and Excitation Auger (RTEA) decay method.[1] Loosely bound H_2 Target Electrons observed at zero degrees in the laboratory frame correspond to 180° elastic scattering in the projectile frame. The *ab initio* theoretical calculations of the coherent resonance plus Rutherford elastic scattering cross sections[2] are compared with the experimental results. The resonances are observed with a resolution of approximately 1.5 eV. The experimental Auger decay rates are obtained from the resonance analysis. The $(2p^2)^1D$ resonance is the dominate resonance in the Auger decay channel for the cases studied (C^{5+}, N^{6+}, O^{7+}, and F^{8+}). The results of this experiment are compared with the e^- + O^{7+} DR measurements recently performed with the heavy-ion Test Storage Ring in Heidelberg.[3]

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.
+ In collaboration with: H.I. Hidmi, D.H. Lee, J.M. Sanders, J.L. Shinpaugh, T.J.M. Zouros,++ C.P. Bhalla, and B.D. DePaola.
++ Dept. of Physics, Univ. of Crete, Iraklion, Crete, Greece.

[1] T.J.M. Zouros, D.H. Lee, P. Richard, J.M. Sanders, J.L. Shinpaugh, S.L. Varghese, K.R. Karim, and C.P. Bhalla, Phys. Rev. A 40, 6246 (1989); and Phys. Rev. A 42, 678 (1990).
[2] C.P. Bhalla, Phys. Rev. Letts. 64, 1103 (1990).
[3] G. Kilgus, J. Berger, P. Blatt, M. Grieser, D. Habs, B. Hochadel, E. Jaeschke, D. Krämer, R. Neumann, G. Neureither, W. Ott, D. Schwalm. M. Steck, R. Stokstad, E. Szmola, and A. Wolf, Phys. Rev. Letts. 64, 737 (1990).

IB 6 Coupled Subshell Description of the L-Shell Ionization in Asymmetric Ion-Atom Collisions.
V. ZORAN,* *Institute of Atomic Physics, Romania.* (20 min.)

L-Subshell ionization cross section for collisions of Be, C, F, Mg, Si and S ions with Au and Th in the energy range of 0.5-2.5 MeV/U are calculated within a one (relativistic) electron coupled subshell approximation, and compared with the experimental data of ref. (1). A fair agreement is obtained once the matrix elements of the projectile perturbing potential are renormalized to account for the screening due to the target spectator electrons. The present calculations provide the first consistent, almost quantitative description of the direct coulomb ionization and vacancy sharing among the L-Subshells during an asymmetric ion-atom collision.

[1] A. Berinde *et al.*, In Lecture Notes in Physics Vol. 294, Eds D. Berenyi and G. Hock (Springer, Berlin 1988) P. 107

*In Collaboration with: The Authors of (1), in Particular I.C. LeGrand

IB 7 Resonant Transfer and Excitation (RTE) in a Crystal Channel. K. H. WANSER,* *California State University–Fullerton.* (20 min.)

We have derived a transition amplitude for resonant transfer and excitation (RTE) in a crystal channel. Here we present results of a comparison with the recent observations of Belkacem et al. of titanium ions channeled in a thin gold crystal.[1] We introduce a 1D *tight-binding* model of the gold lattice to represent the crystal's periodicity and connect with an electron's momentum profile in *atomic* gold. We find, with approximation, that the RTE cross section is proportional to the Compton profile of atomic gold times a crystal-structure factor. Our results are analogous to multi-slit interference of light with diffraction. Because of the narrowness of the 6s and 5d Compton profiles in gold, Belkacem et al. observed the principle maximum with a very narrow width determined by the crystal's Fermi energy. Unlike the observations, however, we predict no shift in the RTE peak other about 6eV from the crystal's work function.

* *Research supported by the U.S. Department of Energy, Division of Chemical Science, Office of Basic Energy Science and Energy Research.*
[1] A. Belkacem et al., Phys. Rev. Lett. 64, 382 (1990).

SESSION IC: ATOMIC PHYSICS AND RELATED PHENOMENA

Thursday morning, 8 November 1990; Union Building, Golden Eagle Suites B and C at 9:00;
S. M. Shafroth, University of North Carolina at Chapel Hill, presiding

IC 1 Resonant Transfer and Excitation with Very Heavy Ions.* W. G. GRAHAM, *Queen's University, Northern Ireland.* (20 min.)

Resonant transfer and excitation (RTE) occurs in the single collision of an ion with an atom through the electron - electron interaction and involves the capture of a target electron simultaneously with the excitation of the projectile ion. This leads to the formation of an intermediate doubly excited state of the projectile. Since RTE is the inverse

of the Auger transition, resonant formation of the intermediate states will occur at incident ion velocities which equal the Auger electron velocities. RTE has been studied in some detail for ions with atomic number less than 32. It has been established[1] that RTE is analogous to dielectronic recombination (DR), where a free electron is captured and there is generally good agreement between theory, based on DR calculations, and experiment. RTE competes with direct capture and the observation[2] of RTE in single-electron capture cross section measurements suggested that the relatively simple measurement of electron capture cross sections could provide a determination of RTE cross sections for very heavy ions. Recent measurements[3] of RTE for U^{90+} in H_2 which provide the first test of relativistic RTE, and hence DR, calculations will be presented.

* Supported in part by the Science and Engineering Research Council, U.K.

1. See, for example, J.A. Tanis, Nucl. Instrum. and Methods A262, 52 (1987) and references therein.
2. W.G. Graham et al, Phys. Rev. A33, 3591 (1986).
3. W.G. Graham, K.H. Berkner, E.M. Bernstein, M.W. Clark, B. Feinberg, M.A. McMahan T.J. Morgan, W. Rathbun, A.S. Schlachter and J.A. Tanis (submitted to Phys. Rev. Lett.).

IC 2 Effects of Relativity on RTE in Collisions of U^{89+} with Light Targets.* M. H. CHEN, *Lawrence Livermore Laboratory.* (20 min.)

We have calculated the resonant transfer and excitation cross sections in collisions of U^{89+} ion with light targets in impulse approximation using the multiconfiguration Dirac-Fock method. The calculations were carried out in intermediate coupling with configuration interaction for intermediate states from the $1s2s2\ell n\ell'$ ($2\le n\le 12$ and $0\le\ell'\le 3$) and $1s2s3\ell 3\ell'$ configurations. The QED and finite nuclear size corrections were included in the calculations of transition energies. The Auger rates were calculated including the contributions from Coulomb as well as the transverse Breit interactions. Effects of relativity not only shift the peak positions but also change the peak structure. The total dielectronic recombination strength has been found to increase by 50% due to the effects of relativity. The MCDF results for U^{90+} and U^{82+} will also be discussed.

*Supported under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

IC 3 High-Resolution Studies of Dielectronic Capture by Channelled Heavy Ions. E. KANTER, *Argonne National Laboratory.* (20 min.)

IC 4 Angular Distribution of Projectile Auger Electrons Emitted Following O^{5+}+He Collisions.
M. BENHENNI, *University of North Carolina, Chapel Hill.* (20 min.)

IC 5 Angular Distribution of Auger Electrons and Photons in Resonant Transfer and Excitation in Collisions of Ions with Light Targets.
C. P. BHALLA, *J. R. Macdonald Laboratory, Kansas State University.* (20 min.)

It is shown that angular distributions of Auger electrons and x-rays from deexcitation of doubly excited states produced in the resonant transfer and excitation of projectiles in collisions with an atom is, in general, not isotropic in the projectile frame. The x-ray emission is nonisotropic with respect to the projectile beam direction because the doubly excited states produced are collisionally aligned.[1] The x-rays are linearly polarized in RTEX. The Auger electron emission to the ground state shows nonisotropic behavior due to the alignment, and the interference with the elastic scattering channel. Theoretical results are presented for several cases. The angular distribution of the Auger electron is strongly peaked in the forward direction in the laboratory, and the Auger electrons exhibit significant deviations from the Lorentzian profile, in particular for large angles in the laboratory frame.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

[1]C.P. Bhalla, Phys. Rev. Lett. 64, 1103 (1990).

IC 6 Angular Distribution of Decay Products in Resonant Processes.*
YUKAP HAHN, *University of Connecticut, Storrs.* (5 min.) (Invited Poster Paper: See Poster Display PA 10)

The resonant processes[1] in electron-ion collisions (resonant excitation and dielectronic recombination) and in ion-atom collisions (resonant transfer excitation followed by radiative or Auger electron emission) are often studied experimentally[2,3] by detecting the target ion in its final charge state, in coincidence with the decay products (photons or electrons) at some fixed angles.

However, detailed study of the angular distribution and polarization of the decay products can provide additional information on the formation mechanism and the character of the resonant intermediate states. We examine this problem theoretically[4,5], with special emphasis on the influence of external fields which may be present in the interaction region, which can drastically modify the resulting cross sections[1]. Sensitivity of the angular distribution on the collision environment and its potential applications are explored.

*Supported in part by a DOE grant.
1. Y. Hahn and K. LaGattuta, Phys. Reports 166, 195 (1988)
2. G. H. Dunn, XIV ICPEAC, D. C. Lorents et al eds. (North-Holland 1986) p23
3. J. A. Tanis, Nucl. Inst. Methods Phys. Res. A262, 52 (1987)
4. J. Eichler and W. Fritsch, J. Phys. B9, 1477 (1976)
5. A. Pochat et al, J. Phys. B15, 2269 (1982)

IC 7 Satellite and Hypersatellite Structure in the K-Auger Spectrum of Carbon Following Collisions of C^{4+} with He.*
J. M. ANTHONY, *United States Naval Academy.* (5 min.) (Invited Poster Paper: See Poster Display PA 35)

C^{4+} ion beams, ranging in energy from 3 MeV to 7 MeV, were obtained from the ORNL EN tandem Van de Graaff facility. After passing through a differentially pumped helium target cell, Auger electrons ejected in the decays of excited ions were energy analyzed using the HRPES electrostatic spectrometer.[1] Yields of 260 eV to 310 eV (in the projectile rest frame) electrons were measured and normalized into Auger production cross sections. Since a significant fraction (up to ~ 30%) of the incident ions are in the metastable 1s2s ^{3}S configuration, single electron capture into a $n \geq 3$ projectile orbital results in a satellite Auger transition ($1s2sn\ell\ ^{2S+1}L - 1s^2\ ^1S$). Measured Auger production cross sections and known values of the ^{3}S metastable fraction at the various collision energies[2] were used to obtain ^{2}D production cross sections which are in reasonable agreement with calculations by McLaughlin and Hahn[3] for $1s2s\ ^3S - 2s2p^2\ ^2D$ production through resonant transfer and excitation (RTE).

* Work supported in part by the Naval Academy Research Council and Oak Ridge Associated Universities.
+ Oak Ridge National Laboratory, Oak Ridge, TN 37831
++ Dept. of Physics and Astronomy, Univ. of North Carolina, Chapel Hill, NC 27514

[1] J.K. Swenson, Nucl. Instr. & Meth. B10/11 899 (1985).
[2] T.R. Dillingham *et al.*, Phys. Rev. A 29, 3029 (1984).
[3] D.J. McLaughlin and Y. Hahn, private communication.

IC 8 Coulomb "Two-Path" Interference in Low-Energy Ion-Atom Collisions.*
J. K. SWENSON,† *Lawrence Livermore National Laboratory.* (5 min.) (Invited Poster Paper: See Poster Display PA 25)

A new interference mechanism, analogous to the "classic" double-slit electron scattering phenomenon, has been identified in low energy ion-atom collisions. This two-path or Coulomb interference mechanism results from the existence of two indistinguishable trajectories along which autoionizing electrons, ejected following the collision, may scatter from the attractive potential of the slowly receding spectator ion and arrive at the detector with identical kinetic energies. A simple semi-classical description of this effect, which is essentially an extension of Morgenstern's overlapping resonances model[1], is presented. The result is a Coulomb-focused[2] PCI-broadened lineshape with a pronounced oscillatory structure which changes in its character rapidly with observation angle. Calculated interference lineshapes, which include contributions from nearby overlapping states, are in excellent agreement with the anomalous shape and strong angular dependence of the He target $2s^2\ ^1S$ autoionizing state lineshape measured near 0°, following 10 keV He^+ + He collisions.

*Work supported in part by the Office of Fusion Energy, U.S.D.O.E. under contract No. AC05-84OR21400 with Martin Marietta Energy Systems, the National Science Foundation, and under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.
†In collaboration with J. Burgdörfer, C. C. Havener, D. C. Gregory, N. Stolterfoht, and F. W. Meyer, *Oak Ridge National Laboratory, Oak Ridge, TN 37831-6372.*
[1]R. Morgenstern, A. Niehaus, and U. Thielmann, J. Phys. B: Atom. Mol. Phys. 10, 1039 (1977).
[2]J. K. Swenson, C. C. Havener, K. Sommer, N. Stolterfoht, and F. W. Meyer, Phys Rev. Lett. 63, 35 (1989).

IC 9 RTE Interference Calculations. T. REEVES, *Carolina College, Conway.* (5 min.)
(Invited Poster Paper: See Poster Display PA 32)

IC 10 Double Differential Cross Sections for Electron Capture to the Continuum of Bare H and He Projectiles in Noble Gases and Hydrocarbons.
G. BISSINGER, *East Carolina University.* (5 min.) (Invited Poster Paper: See Poster Display PA 27)

To further examine observed cusp shape changes between atomic and molecular gas targets[1], zero-degree electron spectra differential in angle (0°-4.5°) and energy ($d^2\sigma/d\theta dE$) have been collected for 0.8 MeV/u H^+ and He^{++} on Ar, CH_4, and C_4H_8 with a spherical-sector electron analyzer coupled to a drift region to

derive angular information. The cusp spectra, taken in sixteen angular steps of ~0.3° each, are examined for systematic changes in the cusp shape with increasing effective detector half-angle, as well as for differences among cusp angular distributions from atomic, small and large hydrocarbon molecule gases.

[a]Present address: U. Central Arkansas, Conway, AR 72032
[1]G. Bissinger, J. Gaiser, J.M. Joyce and M. Numan, Phys. Rev. Lett. 55, 197(1985); G. Bissinger, J.M. Joyce and R. Mehta, Nucl. Instr. and Meth.B40/41, 33(1989).

IC 11 Collisional Dissociation of HD_2^+ Molecular Ions in H_2 in the Energy Range 1.5–5.0.*
C. CISNEROS,* *Instituto de Fisica, UNAM, Mexico.* (5 min.) (Invited Poster Paper. See Poster Display PA 45)

The Collisional dissociation of HD_2^+ on H_2 has been studied for collision energies in the range 1.5 to 5.0 keV. The angular distributions of the dissociation fragments H^+, D^+, HD^+ and D_2^+ were measured at six energies in this range. In addition, the velocity distribution for each dissociation product has been determined for collision energy 3.75 keV. The dissociation energies corresponding to the structures in the velocity distributions were determined. Substantial differences were observed between the angular distributions of the D^+ and H^+ fragments, suggesting an isotopic effect.

*Research partially supported by CONACyT and DGAPA.

**In collaboration with: I. Alvarez, H. Martinez, J. de Urquijo and A. Morales.

SESSION ID: SURFACE ANALYSIS WITH ION BEAMS
Thursday morning, 8 November 1990; Union Building, Room 418 at 9:00;
T. J. Shaffner, Texas Instruments Incorporated, presiding

ID 1 Grazing-Incidence Scattering and Beam-Tilted-Foil Transmission of Protons. N. H. TOLK,* *Vanderbilt University.* (30 min.)

The proton-surface complex constitutes an important model system for studies of dynamical processes at surfaces. This paper will review the electron-transfer processes associated with grazing-incidence scattering and beam-tilted-foil transmission of protons. When a proton is scattered from a nickel surface at a grazing angle, the loosely bound metal conduction electrons are captured into excited states of the hydrogen atom. In a similar manner, electrons are captured into excited hydrogenic states upon the emergence of a beam of protons through a thin carbon foil. As a result of the anisotropic distribution of electrons available to the protons at the moment of the electron capture, these excited states will have an anisotropic distribution of electrons in their magnetic sublevels. This anisotropy will be manifest in the polarization and angular distribution of the radiation emitted as the excited states decay to lower energy levels. We study the influence of surface adsorbates on the final states of the proton-surface interaction in order to better understand the mechanisms involved in the electron exchange that leads to the neutralization of the beam. In the grazing-incidence experiment we have found that even a slight contamination of the surface drastically reduces the degree of polarization and alters the pattern of *quantum beats* induced by an applied electric field.[1] Recently, we have begun to measure the spin-polarized electron pickup by protons scattering from an Fe crystal. Marked differences in the quantum beats have been observed depending on the magnetic alignment of the electrons in the crystal. In the beam-foil experiment, initial data exhibit anomalous circular polarization which is dependent on the dose. Further experimental and theoretical studies are necessary in order to quantify the effects of overlayers on the proton-surface interaction and to develop models which describe the mechanisms that lead to the observed final states.

[1] D.P. Russell, R.G. Albridge, A.V. Barnes, D.L. Harper, P.Nordlander, P.M. Savundararaj, J.C. Tully, and N.H. Tolk, Surface Science, 211/212, 198-206 (1989).

* This work was carried out in full collaboration with D.L. Harper, P.M. Savundararaj, R.G. Albridge, A.V. Barnes, P. Nordlander, D.P. Russell and J.C. Tully and is supported in part by a grant from University Research Initiative of the Air Force Office of Scientific Research Contract No. DASG60-86-C-0014 and by Contract No. F49620-86-ABC-0125.

ID 2 Interaction of Slow Ions with Surfaces. W. HEILAND, *Universität Osnabruck, Federal Republic of Germany.* (20 min.)

The interaction of ions with solids causes a number of phenomena like sputtering, radiation damage and secondary emission of electrons which are due to the nuclear interaction and to the mutual interaction of the electrons of target and of the projectile. At low primary energies the penetration of the projectiles into the target can become negligible, such that the interaction with the surface atoms prevails. The backscattered projectiles carry information about the composition and the structure of the surface. The electronic interaction, i. e. charge exchange processes, are probably a key for the understanding of some processes like beam assisted film growth[1]) and maybe some catalytic reactions[2,3]). The secondary electron or photon emission is also a useful tool to study different surface properties, including surface magnetism[4]).

1) S. R. Kasi, H. Kang, C. S. Sass and J. W. Rabalais, Surf. Sci. Rep. 10 (1981) 1
2) S. Schubert, U. Imke and W. Heiland, Surf. Sci. 219 (1989) 2576
3) P. H. F. Reijnen, Thesis, Amsterdam 1990, P. H. F. Reijnen and A. W. Kleyn, J. Chem. Physics
4) H. Winter, H. Hagedorn, R. Zimny, H. Niehaus and J. Kirschner, Phys. Rev. Lett. 62 (1989) 296

ID 3 Angle-Resolved Imaging of Single Crystal Materials with MeV Helium Ions.
MICHAEL D. STRATHMAN, *Charles Evans & Associates.* (20 min.)

A simple form of angle resolved mapping of single crystal materials is the technique of channeling angular scans. Several laboratories have expanded this simple procedure to include mapping as a function of two independent tilts. One particularly notable image of this type was distributed in the form of a poster by Zigler (etal). These images are particularly suited to the measurement of many crystal parameters including disorder, lattice location of impurities, and lattice stress. This paper will describe the use of the Charles Evans & Assocates RBS-400 RBS End station for acquisition, display, and analysis of angle resolved images obtained from both backscattered helium ions (RBS) and particle induced X-Rays (PIXE). Typical data acquisition times are 20 minutes for a +/- 2 Degree X-Y tilt scan with 2,500 pixels (8/100 degree resolution), and 10 nanocoulombs per pixel.

ID 4 Case for Linking Partilce Backscattering and Particle-Induced X-Ray Emission in an Integrated System.*
A. LI-SCHOLZ,† *State University of New York–Albany.* (20 min.)

The many benefits of having a fixed system which allows for simultaneous data acquisition for elastically-backscattered ions and particle-induced x-rays are discussed. We show that linking the two types of measurements provides a particularly simple means of measuring non-Rutherford scattering cross sections and x-ray production cross sections. In the materials analysis context, it generates the non-Rutherford cross sections which are precisely appropriate to the researcher's system in terms of scattering angle, detector resolution and accelerator energy calibration and beam spread. In PIXE application, it allows comparable accuracies to be attained using L x rays as using K x rays. The method is self-calibrating in that it does not require knowledge of the total projectile number, the target atom density or the solid angles of the individual detectors, or to use any additional reference element.

* Supported in part by National Science Foundation Grant No. PHY-8808570.
† In collaboration with W. Scholz and K. A. Stevenson.

ID 5 Ion Scattering Studies of Modified Metal Surfaces.* R. J. SMITH, *Montana State University.* (20 min.)

The technique of ion backscattering and channeling provides valuable information about the structure of solid surfaces, both clean and as modified by adsorbed atoms. Analysis of the backscattering data is based on the concepts of shadowing and blocking. Because the theory of Rutherford scattering is well understood, it is possible, using comparisons between experiment and computer simulations for model structures, to extract information about the geometry and dynamics of atoms on solid surfaces. Studies of the structur of clean W(110) and Nb(110) surfaces, and the modification of these surfaces with H adsorption/absorption will be presented. Ion scattering also provides structural information about solid-solid interfaces. Results for Pd deposited on Al(111), and for Ni on W(110) will be discussed.

* Supported by the National Science Foundation and the MONTS program.

ID 6 Interface Adhesion Enhanced by MeV Ions. YUANXUN QIU, *Fudan University, People's Republic of China.* (20 min.)

Electronic excitation provided by penetrating MeV ions can be used to improve significantly the adhesion strength between a deposited film and a substrate without severe disturbance in the proximity of the interface. Since the discovery of this phenomenon extensive research efforts have been made for both scientific and technological interests, but an unified picture of the processes, by which the increased bondings are actually produced, is still lacking. The difficulty in search for the origin of the adhesion enhancement is mainly due to several distinct effects may occur simultaneously in the interface region under MeV ion bombardment. In this paper we shall present some experiments on Ag/Ta, Au/Ta and Ag/Ta_2O_5,Au/Ta_2O_5 interfaces with 1.5–18 MeV Si ions. The threshold doses for these systems to pass Scotch tape test as a function of ion stopping power have been measured. Significantly increased threshold doses were observed with samples irradiated at low temperature showing that radiation–enhanced interdiffusion may be involved in the processes. The different behaviour between Ag and Au films indicate that possible bonds between film and oxygen atoms may play an important role in interface chemistry induced by MeV ions.

SESSION IE: TOMOGRAPHY—RADIOGRAPHY AND INTENSE SOURCES
Thursday morning, 8 November 1990; Union Building, Room 411 at 9:00;
I. L. Morgan, IDM Incorporated and W. E. Dance, LTV Missiles and Electronics, presiding

IE 1 Ten Years After: Industrial Computed Tomography as a Maturing Technology.
F. HOPKINS, *Scientific Measurement Systems, Inc.* (20 min.)

IE 2 New Environmer s at the Aurora Flash γ-Ray Generator.† F. J. AGEE, *Harry Diamond Laboratories.* (20 min.)

Aurora is a 14-TW generator built in 1970 to produce a dose of up to 400 Gy(Si) (40 krad(Si)) in a single ~100 ns pulse of 10-MeV bremsstrahlung. In recent years the machine has been upgraded, both by gradual improvements to the original design and by retrofitting with new front ends. The machine can now produce a very intense bremsstrahlung pulse of 3 kGy(Si) (300 krad(Si)) over a small volume, and both diffuse and intense electron beams. In the electron-beam mode, gas erosion cells have shortened the pulse to 30 ns FWHM with a 15-ns risetime. the corresponding bremsstrahlung pulse has a risetime of 10 ns and a width of 20 ns. Combining these capabilities produces the environment desired for various tests that need a combination of bremsstrahlung and electron beams. In another retrofit, the primary γ-rays with energies around 1 MeV are converted by backscattering to x-rays with peak energy around 0.2 MeV and a source strength of 25 Gy(Si)-m^2 (2.5×10^7 rad(Si)-cm^2).

All other generators of this type produce only a single pulse, but Aurora can now generate two equal pulses with arbitrary time delay. The two pulses can be the same amplitude or can be adjusted to different levels, and they can each be bremsstrahlung, electron beam, or a combination of both. The paper describes the different modifications and their products in some detail, and discusses other upgrades under consideration.

† Supported by the Defense Nuclear Agency and the US Army.

IE 3 Improving Data Acquisition Efficiency for Ion Microtomography.*
A. J. ANTOLAK, *Sandia National Laboratories, Livermore.* (20 min.)

The rate of data acquisition can limit the feasibility of implementing ion microtomography (IMT) imaging in some applications. For fine spatial resolution of extended objects, the number of required resolution elements (resels) is extremely large. Additionally, the time to acquire these data and the computer memory required to store the data can be prohibitive. In existing IMT systems, immediate improvement can be achieved both by minimizing the number of ions per resel necessary for a given density confidence level and by excluding extraneous resels from the data base. A tomography simulation computer program is developed and used to study these techniques on carbon phantoms. The simulated data are reconstructed using a filtered back - projection algorithm and presented for comparison.

D. L. WIERUP, *Lawrence Livermore National Laboratory, Livermore, CA 94550*
A. E. PONTAU, *Sandia National Laboratories, Livermore, CA 94551*
*Work supported by U.S. Department of Energy under contract No. DE-AC04-76P00789.

IE 4 Integration of an Advanced Sealed-Tube Neutron Generator into a Mobile Neutron Radiology System and Resulting Performance.
W. E. DANCE, *LTV Missiles and Electronics Group, Missiles Division.** (20 min.)

The first DIANE+,1 neutron radiology system is being prepared for operation in the IABG laboratories in Ottobrunn (FRG). It utilizes a new D-T generator, designated GENIE 46, developed by SODERN (France) for this application. The generator is being integrated into an upgraded LTV-produced mobile neutron radiology system suitable for practical non-reactor inspection of components and structures. Maximum output of the present version of the GENIE 46 is 5×10^{11} n sec^{-1} (14 MeV) with less than 10 mA ion beam current at 225 KV. Tube lifetime at maximum output is approximately 500 hours, while at 10^{11} n sec^{-1} the tube is designed for a minimum lifetime of 1000 hours. Geometry of the neutron tube, VHV connectors, ion source power supply, and cooling tubes comprises a cannister designed to be compatible with the 10-inch diameter opening in the LTV moderator/collimator assembly. 3-D Monte Carlo neutron/ photon transport simulations of the new integrated radiology system operation have been performed by IABG. The calculations predict a thermal neutron flux at the collimator exit (L/D = 13) of ϕ_{th} ($0 \le E_n \le 0.3$ ev) = 1.2×10^5 n cm^{-2} sec^{-1}. Comparisons of this value and other Monte Carlo results with actual performance will be made in the near future with the accrual of operational data.

*In collaboration with Serge Cluzeau, SODERN (France) and Hans-Ulrich Mast, IABG (FRG).
+Project in the framework of the European Eureka initiative.
1W. E. Dance, J. R. Huriet, S. Cluzeau, H.-U. Mast, and F. Albisu, Nuclear Instruments and Methods in Physics Research B40/41 (1989) 1316-1321.

IE 5 Flash X-Ray Sources Powered by Blumlein Pulse Generators.*
F. DAVANLOO,+ *Center for Quantum Electronics, University of Texas at Dallas.* (5 min.)
(Invited Poster Paper: See Poster Display PB 56)

Design and construction of pulse power generators capable of discharging at high repetition rate was reported recently by our group.[1-2] They consisted of eight triaxial Blumleins stacked in series at one end. These lines were charged in parallel and synchronously commuted with a single thyratron at the other end. In this way relatively low charging voltages were multiplied to give the desired

discharge voltage without the need for complex Marx bank circuitry. X-ray diodes matched to these pulse power systems emitted high average bremsstrahling exposure rates from a sequence of 20-40 ns pulses. Progress in scaling of these stacked Blumlein generators to obtain open circuit voltages in excess of 0.5 MV is reported. Peak powers generated by discharging in an x-ray diode load exceed 10^7 R/s and high repetition rate allows for an average emitted x-ray dose of 25 R/s.

*Supported by SDIO/IST through NRL.
+Co-workers: J.J. Coogan, R.K. Krause, J.D. Bhawalkar and C.B. Collins
[1]F. Davanloo, J.J. Coogan, T.S. Bowen, R.K. Krause, and C.B. Collins, Rev.Sci. Instrum. 59,2260 (1988).
[2]J.J. Coogan, F. Davanloo, and C.B. Collins, Rev. Sci. Instrum. 61,1448 (1990).

IE 6 Computerized Tomography with Monochromatic X-Rays from the National Synchrotron Light Source.*
F. A. DILMANIAN,[1] *Brookhaven National Laboratory.* (20 min.)

A multiple-energy computed tomography (MECT) system which employs monochromatic and tunable 33-100 keV X-rays from a superconducting wiggler at the National Synchrotron Light Source is being developed at Brookhaven National Laboratory. The CT configuration is that of a fixed horizontal fan beam and a subject seated in a rotating chair. Two quantitative CT methods will be used: a) K-edge subtraction of intravenously-administered iodine or a heavier contrast element, to image brain tumors, large blood vessels of the lower head and neck, and arteriovenous malformations; and b) dual- or multi-photon absorptiometry, to obtain two brain CT images that map the low-Z elements and the intermediate-Z elements (i.e. P, S, Cl, K, and Ca) separately. The system is expected to provide 0.5 mm in-plane spatial resolution, with unprecedented image contrast and accuracy of quantification. The system, which is currently being developed, will employ a two-crystal monochromator and a high purity Ge linear array detector. Phantom and small-animal studies are planned for the autumn of 1990.

*Supported by the U.S. Department of Energy under Contract DE-AC02-76CH00016.
[1]Collaborating scientists include: L. E. Berman, L. D. Chapman, R. F. Garrett, J. B. Hastings, T. Oversluizen, D. P. Siddons, D. N. Slatkin, V. Stojanoff, W. C. Thomlinson, A. Thompson, N. D. Volkow, and H. D. Zeman.

IE 7 Associated Particle Imaging. PAUL HURLEY, *Special Technologies Laboratory.* (20 min.)

The design and fabrication of a fast-neutron-based associated particle imaging system are discussed. The neutrons, at a nominal 14 MeV, are produced in a sealed-tube neutron generator (STNG) via the t(d,n)He4 reaction. The associated alpha-particle is imaged to define the neut n direction, while the timing of detection and energy of a neutron-produced inelastic-scatter gamma ray define source-to-target distance and target isotope respectively. The design and manufacture of the (STNG), including beam optics calculations, alpha detector characterization measurements, and prototype beam studies, are described. These are characteristic of this system and will define many of its final performance limitations. Additional items to be discussed include gamma-ray timing and energy resolution measurements, computer image enhancement algorithms, data handling component selection, and suggested applications.

*Collaborated with: Albert Beyerle, Laura Tunnell

IE 8 An X-Ray Monochromator for Dual-Energy Computerized Tomography Using Synchrotron Radiation.*
H. D. ZEMAN,[1] *University of Tennessee, Memphis.* (20 min.)

Dual-energy CT examinations of the brain will be performed using synchrotron radiation X-ray beams at 40 and 80 keV to visualize the altered concentrations of the intermediate-Z elements that occur in tumors and blood clots. The monochromator designs being considered allow rapid switching between these two energies without any change in the position or direction of the X-ray beam. One design uses the fundamental and second harmonic radiations from an existing dual-Bragg-crystal Si<2,2,0> monochromator. The 40 and 80 keV beams would be isolated by detuning or gold filtration, respectively. The other designs utilize fundamental radiations for both energies and would require some modification of the existing monochromator mechanism to achieve adequate tuning speed. These designs use two Si<2,2,0> crystals, one with a Bragg and the other with either a Bragg or a Laue geometry. Various arrangements are being considered to achieve the best compromise between speed and accuracy of tuning.

*Supported by the U.S. Department of Energy under Contract DE-AC002-76CH00016.
[1]Collaborators include: L.E. Berman, L.D. Chapman, F.A. Dilmanian, R.F. Garrett, J.B. Hastings, T. Oversluizen, D.P. Siddons, V. Stojanoff, and W.C. Thomlinson.

SESSION IF: NUCLEAR PHYSICS
Thursday morning, 8 November 1990; Union Building, Room 412 at 9:00;
George Vourvopoulos, Western Kentucky University and F. E. Dunnam, University of Florida, Gainesville, presiding

IF 1 Spectroscopy of Proton-Rich Nuclei in the Rare-Earth Region.* K. S. TOTH, *Oak Ridge National Laboratory.* (20 min.)

We have used heavy-ion-induced fusion reactions to produce rare earth nuclei close to the proton drip line. Their decay properties were then investigated with the use of γ-ray, x-ray, and particle detectors. Shell-model states near the 82-neutron shell were examined and their excitation energies determined. Numerous new isotopes, isomers, and β-delayed proton emitters were discovered. In addition, the α-decay properties of nuclides with N > 84 were re-examined; this led to the discovery of several previously unobserved α transitions. In this talk the overall experimental program will be summarized and illustrated with some recently obtained results.

*Research supported by the U.S. Department of Energy under contract No. DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

IF 2 Compound Nucleus X-Ray Production Across a Nuclear Resonance in the $p + {}^{134}Ba$ Reaction.*
D. W. SPOONER, *Stanford University.* (20 min.)

The intensity of compound nucleus (CN) and separated atom (SA) x rays emitted in p+ ^{134}Ba collisions has been measured as a function of proton energy near the isobaric analog nuclear resonance at 9.295 MeV. X-ray spectra were recorded in coincidence with protons scattered to a mean laboratory angle of 176° and detected by a cooled surface barrier detector which resolved elastically scattered protons from those scattered protons which ionized one of the target's inner-shell electrons. Our on-line results at 5 different bombarding energies show excellent agreement for the predicted K-shell ionization probability in the neighborhood of the nuclear resonance.[1] The measured ratio of CN to SA x rays is less than 3% throughout the region of interest. No significant enhancement of the CN x-ray yield is seen in our data, yielding an upper limit for the CN cross section $\sigma_o < 5$ mb.

*In collaboration with W.E. Meyerhof, J.N. Scheurer, N. Guardala, A. Belkacem and H.P. Hulskotter.
[1]P.A. Amundsen and K. Aashamar, J. Phys. B19, 1257 (1986).

IF 3 He^3+Be Neutrino Experiment. T. S. BHATIA, *Los Alamos National Laboratory.* (20 min.)

IF 4 High-Resolution Inelastic Gamma-Ray Measurements with a White Neutron Source from 1 to 200 MeV.
R. O. NELSON, *Los Alamos National Laboratory.* (20 min.)

Measurement of prompt gamma rays following neutron induced reactions using HPGe detectors at the spallation neutron source LAMPF provides extensive excitation function data for inelastic neutron scattering as well as other reactions such as (n,α), (n,nα), (n,d), (n,nd), (n,p), and (n,xn) for 1<x<11. The continuous energy coverage available from below 1 MeV to over 200 MeV is ideal for excitation function measurements and greatly extends the energy range for such data. The results of these measurements will provide a database for interpretation of gamma-ray spectra from the planned Mars Observer Mission, aid in radiation heating and shielding design calculations, allow verification of nuclear reaction models, and improve the evaluated neutron reaction database.

IF 5 Reaction Rate of $^{22}Na(p,\gamma)^{23}Mg$.* H. P. TRAUTVETTER, *West-Wilhelms-Universitat, Federal Republic of Germany.* (20 min.)

The reaction $^{22}Na(p,\gamma)^{23}Mg$ has been investigated at E_p = 0.17-1.29 MeV using a ^{22}Na implanted target, a D_2O threshold detector as well as NaI(Tl) and Ge-detectors. Six resonances in this reaction have been observed for the first time. Their strengths as well as upper limits on the strength for expected resonances in the energy range covered are given. They are significantly lower compared to previous estimates. The stellar reaction rates are known to sufficient accuracy at the important temperature range T_9 = 0.1-3.0 covered by the experiment. At lower temperatures, additional work is needed to reduce the present uncertainties in the rates. The data show that the hot NeNa cycle comes into play above T_9 = 0.08 for a wide range of stellar densities. Astrophysical consequences, such as for the Ne-E problem and future γ-ray astronomy, are discussed.

*Supported by DFG, BMFT, EEC and NSF.

IF 6 Studies on Fission Phenomena Induced by Charged Particles Using the JAERI Tandem Accelerator.
Y. NAGAME,* *Japan Atomic Energy Research Institute, Japan.* (20 min.)

Using the JAERI tandem accelerator, we are studying fission in light mass region of $A \sim 100$ to actinide region. In the light mass system, to investigate a feature of the symmetric mass division at high angular momentum, we have measured mass, angular and total kinetic energy distributions in the reactions $^{37}Cl + {}^{68}Zn$ and $^{16}O + {}^{89}Y$. Observed characteristics of the fully damped symmetric mass division products are consistent with those of the fission products in heavier mass

systems The broad widths of the mass and total kinetic energy distributions cannot be accounted for within the liquid drop model This result suggests contribution of a dynamical effect including a large amount of angular momentum. In the heavier mass system, to study a dynamical motion of nucleus from a nearly spherical to a deformed scission shape, pre-scission ^{4}He particles in coincidence with fission products have been measured in the ^{19}F + ^{197}Au system. From the energy spectra of pre-scission ^{4}He, the effective emission barrier is reduced by the amount of 2 MeV compared to the respective absorption barrier. The pre-scission multiplicity of ^{4}He is explained by statistical model calculations which take into account the reduced emission barrier. This suggests that the pre-scission ^{4}He is predominantly emitted at a strongly deformed compound nucleus.

*In collaboration with H. Ikezoe, T. Ohtsuki and N. Shikazono.

IF 7 Angular Dependence of the Doppler Broadening in the Resonance of the ^{1}H(^{15}N,$\alpha\gamma$)^{12}C Reaction.*
Y. IWATA, *Electrotechnical Laboratory, Japan.* (20 min.)

The Doppler broadening in the resonance of the ^{1}H(^{15}N,$\alpha\gamma$)^{12}C(E_{res}=6.385 MeV) reaction was demonstrated changing the incident angle of ^{15}N ion beam to the target system of hydrogen atoms adsorbed at saturation in coverage on a well defined W(001) surface. Excitation functions of the reaction which suffered the Doppler broadening due to the atomic vibration of hydrogen on the surface[1] were measured by detecting the γ-ray yield as a function of the incident energy of ^{15}N ions. Although the integral of the obtained yield curve increases in proportion to hydrogen density allowed by the ion beam as the incident angle changed from 0° to 45°, the resonance width (the FWHM of the curve) took a maximum value at about 15°. Present result surports the aproved EELS and IRAS data which indicated that saturated hydrogen on W(001) shows three vibration modes, a stretch mode normal to the surface and two lateral vibrations.

*In collaboration with the University of Tokyo and Osaka University.

[1]Y Iwata, F Fujimoto, E Vilalta, A.Ootuka, K.Kobayashi, H.Yamashita and Y.Murata, Jpn. J. Appl. Phys. 26 L1026 (1987), and Nucl. Instr. and Methods B33 574 (1988).

IF 8 Accelerator Tests of the Pauli Exclusion Principle in Nuclei. ĐURO MILJANIĆ,* *Ruđer Bošković Institute, Yugoslavia.* (20 min.)

Recently there have been several theoretical and experimental studies considering the possibility of small violations of the Pauli exclusion principle. We focus attention on accelerator experiments which can search for small violations in nuclei. Two types of experiments are considered: (1) a search for nuclear processes prohibited by the exclusion principle, (2) a search for nuclei which violate the same principle. Several proposals for very sensitive tests will be discussed. The results from the searches will be presented.

*In collaboration with A. Ljubičić, Ruđer Bošković Institute, E. Nolte, Th. Faestermann, H. Gail, A. Gillitzer, G. Korschinek, D. Müller, R. Scheuer, Technical University of Munich, G. Calvi, M. Lattuada, F. Riggi, C. Spitaleri, M. Zadro, Laboratorio Nazionale del Sud and Università di Catania, B.A. Logan, University of Ottawa.

SESSION JA: ATOMIC PHYSICS AND RELATED PHENOMENA

Thursday afternoon, 8 November 1990; Union Building, Room 412 at 14:00; S. Matteson, University of North Texas, presiding

JA 1 Ionization Plus Excitation and Excitation of He in Fast H^++He, e^-+He Collisions.
S. FUELLING, *University of Nevada, Reno.* (20 min.)

We have studied single collisions of H^+ on He (impact velocities v. 1.4 to 8 a.u.) and e^- on He (v. 3.5 to 8 a.u.) and have observed the extreme ultraviolet (EUV) emission from He^+(np) and He(1snp)^{1}P°. The aims of the present contributions are twofold (i) experimentally, to extract absolute cross sections for ionization plus excitation of helium at medium and large velocities and (ii) theoretically, to assess the effects of first and second order scattering contributions of the production of state selective target states. A comparison of the e^- and H^+ data for ionization-excitation provides clear evidence that the e^- + He cross sections above v=4 a.u. are consistently larger for all He^+(np) states than the corresponding H^+ + He ones. This in turn may provide a direct measure of the importance of coherence effects in the scattering process.

JA 2 Effective Charge of Helium Ions in Solids. P. M. ECHENIQUE, *Universidad del Pais Vasco, Spain.* 20 min.)

A summary of density functional calculations of life times, stopping power and straggling of low velocity ions interacting with condensed matter is presented. For protons and antiprotons the density functional stopping power results are compared with recent Z_1^3 corrections to the linear stopping power obtained from a second order Born approximation.

JA 3 Electron Emission in H^{0-} Atom Collisions: A Coincidence Study of the Angular Dependence.*
O. HEIL,# *Universität Frankfurt/M, Federal Republic of Germany.* (20 min.)

Differential electron emission occurring as the result of fast hydrogen atom impact on helium and argon targets has been studied using standard non-coincidence and emitted electron-ionized projectile coincidence techniques. Impact energies were 0.5 and 1 MeV; electron emission was measured between approximately 20 and 2000 eV for selected laboratory emission angles ranging from 0° to 180°. These data demonstrate the importance of simultaneous target-projectile ionization as was previously observed for energetic He^+ impact.[1] The experimental data for the helium target, when compared to PWBA calculations using hydrogenic wave functions, indicate good agreement with theory for projectile ionization and, indirectly, reasonably good agreement for target ionization. Simultaneous target-projectile ionization events were not included in the model. The argon data are compared with more sophisticated calculations for electron loss. These comparisons indicate the importance of second order effects for large emission angles.

in collaboration with R.D.DuBois, R.Maier, M.Kuzel, K.O.Groeneveld

*Supported by BMFT, contract No. 06 OF 110/ II Ti 476
1. R.D. DuBois and S.T. Manson, Phys. Rev. Lett. 57, 1130 (1986)

JA 4 Dynamic Screening, Charge States, and Energy Loss at Ions in Solids.
F. FLORES, *Universite Autonoma de Madrid, Spain.* (20 min.)

The stopping power for light ions in solids is discussed by considering the dynamic screening of the moving ion and its charge states[1] as a function of the ion velocity. Charge states are analysed by considering three different mechanisms for the electron capture and loss: (i) In the Auger processes, electrons are transferred between the ion and the solid due to the screening Coulomb interaction between electrons. (ii) In the Dynamical Resonant processes, the crystal pseudopotential creates excitations whereby electrons are transfered between the ion and the solid. (iii) Finally, in the Shell process, electrons bound to the deep levels of the solid are captured by the moving ion.
The different charge states for H and He moving in Al have been obtained as a function of the ion velocity.
Finally, the stopping power for the same systems have been obtained by calculating the dynamical screening of the ion charge states and the contribution of the capture and loss processes.

1. P.M.Echenique, F.Flores and R.H.Ritchie, Solid State Physics Series. Ed. Ehrenreich and Turnbull 43, 229 (1990).

JA 5 The Implementation of an Orbital Local Plasma Approximation (OLPA) for Calculation of Bethe Stopping in Ultrathin Films: Hydrogen. JOHN SABIN, *University of Florida, Gainesville.* (20 min.)

The calculation of Bethe stopping powers of materials for swift protons in the orbitally decomposed version of the kinetic theory of stopping has been quite successful for atomic and molecular targets[1]. We now extend the treatment to ultra-thin film targets in order to understand better static quantum size effects and the transition from gas to solid target behavior. As the target electronic structure calculations are done in the local approximation to density functional theory which produces neither the orbitals nor excitation energies necessary to calculate orbital/band mean excitation energies, we have chosen to formulate an orbital version of the local plasma approximation of Lindhand and Scharff for this purpose. In this contribution we will discuss the proper choice of the decomposition of the total electron density for use in an OLPA, and will present results of its use in calculating Bethe stopping in 1, 2 and 3 atomic layer hydrogen films.

*In collaboration with S. B. Trickey, J. Z. Wu, and D. E. Meltzer. Supported in part by the Army Research Office (Contract #DAA-LO3-87-K-0046).
[1]cf. eg. J. Oddershede and J. R. Sabin, Atomic Data Nuclear Data Tables 31, 275(1984).

JA 6 Electron-Atom Collisions in a Laser Field.* PHILIP H. G. SMITH, *Georgia Institute of Technology.* (5 min.)
(Invited Poster Paper: See Poster Display PA 87)

The time-independent laser-assisted electron-atom collision:

$$e^-(50, 100, 200eV) + H(1S \longrightarrow 2S, 2P_0) + N\hbar\omega(.117eV)$$

is considered in the soft photon, weak-field limit.[1] Dressing of the projectile electron is achieved using the well known Volkov states, and results in the usual high order multiphoton effects, which are shown not to greatly effect the total state to state cross sections. More interestingly, an exact description of the atomic dressing is found using Floquet theory[2]

This results in a very concise description of the laser assisted event, where photon absorption-emission is shown to occur at three distinct phases of the laser-atom interaction - before, during and after the collision event. Perturbative dressing of the atom provides an incomplete description of the laser assisted collision, and is therefore unable to predict the distinct features exhibited up by Floquet theory.

* Research supported by AFOSR-89-0426.
[1] Philip.H.G.Smith and M.R.Flannery (In preparation)
[2] Jon.H.Shirley Phys Rev 138 B979 (1965).
‡ In collaboration with M.R.Flannery.

JA 7 Isotopic Fractionation in Sputtering.* D. L. WEATHERS,† *University of North Texas.* (20 min.)

Collector-type experiments have been conducted to investigate isotopic fractionation in sputtering induced by keV ions. Isotopically enriched $^{92}Mo/^{100}Mo$ targets were bombarded with 5 and 10 keV beams of Ar^+ and Xe^+, and the sputtered Mo was collected on carbon foils surrounding each target These foils were analyzed using Secondary Ion Mass Spectroscopy (SIMS) for variations in the isotopic composition of the sputtered material as a function of emission angle in the sputtering geometry and as a function of projectile fluence. Definite preferential effects were found, with the general trend being an enrichment of the lighter isotope that was maximum in the near-normal emission direction; this enrichment dropped continuously by as much as several percent towards more oblique sputtering angles The overall enrichment in the light isotope was observed to drop with increasing projectile fluence, although a pronounced angular variation remained even at the highest fluences, after the sputtered flux had reached a steady-state distribution. The most extreme fractionation was observed for the lowest-fluence (3.0×10^{14} ions/cm^2) bombardment by 5 keV Xe^+, for which the light isotope was found to be enriched by 53 ± 5‰(note: 1.0‰≡ 0.1%) in the near-normal direction with respect to the isotopic composition of the material sputtered in the same direction under steady-state conditions. Similar results were found for secondary Mo ions sputtered by 14.5 keV O^- The observed effects are consistent with other low-fluence measurements of sputtered neutrals and secondary ions, with the exception of Ga isotopes sputtered from a liquid In:Ga eutectic target. The preferential effects described are also consistent with the results of multiple-interaction computer simulations, and are considerably larger than the predictions of the dominant analytic theory.

* Work supported in part by NSF [DMR86-15461] and IBM, Inc.
† In collaboration with S. J. Spicklemire, *Physics Dept., Univ. Indianapolis, Indianapolis, IN 46277*; T. A. Tombrello, *Div. Phys., Math., & Ast., Caltech, Pasadena, CA 91125*; I. D. Hutcheon, and G. J. Wasserburg, *Div. Geol. & Planet. Sci., Caltech*; and H. Gnaser, *FB Phys., Univ. Kaiserslautern, D-6750 Kaiserslautern, FRG.*

SESSION JB: SELECTED TOPICS
Thursday afternoon, 8 November 1990; Union Building, Golden Eagle Suite A at 14:00;
R. L. Schulte, Grumman Corporation, presiding

JB 1 Industrial On-Line Bulk Analysis Using Nuclear Techniques. G. VOURVOPOULOS, *Western Kentucky University.* (20 min.)

Various nuclear techniques such as gamma-ray backscattering, neutron inelastic scattering, etc. have been shown to be quite effective for the on-line determination of several physical and chemical parameters. In the coal industry, parameters such as density, ash content, sulfur and chlorine content can be monitored on-line using one or a combination of nuclear techniques. In the cement industry, component determination and control of the raw materials is afforded with nuclear methods. For on-line analysis, nuclear methods have been shown to be superior to chemical methods because of the speed of the analysis, and the quantitative determination of the parameters in bulk without the need of sampling. Various nuclear techniques will be described and specific examples of the elemental analysis of coal and the chemical composition of cement will be presented. The utilization of a pulsed neutron source for some of the measurements will be discussed.

JB 2 Electron Screening in Low-Energy Nuclear Reactions.
K. LANGANKE, *Westfälische Wilhelms-Universität Munster, West Germany.* (20 min.)

JB 3 Space Radiation Characterization of Materials and Devices for the NRL High-Temperature Superconducting Space Experiments (HTSSE). G. P. SUMMERS, *Naval Research Laboratory.* (20 min.)

JB 4 Radiation Aspects of High-Power Deuterium Beam Injectors for the Next Generati n of Tokamaks.
J. KIM, *General Atomics.* (20 min.)

JB 5 High-Resolution Ion Beam Experiments.
S. WUSTENBECKER, *Westfälische Wilhelms Universität-Munster, Federal Republic of Germany.* (20 min.)

JB 6 Resonance Effects in Thin Film Proton Backscattering Spectrometry.* H. J. FISCHBECK,** *University of Oklahoma.* (20 min.)

The use of protons in Rutherford backscattering analysis rather than He ions can be of advantage when detecting low Z elements in a matrix of high Z material, due to enhancement of the cross section by nuclear potential scattering. For light elements resonances in the nuclear scattering cross section become important in thin film analysis. The spectrum of backscattered protons then shows a peak whose width may not only depend on the film thickness but also on the

resonance. We have studied this in detail in the case of carbon where the cross section for the elastic nuclear potential scattering at the 1.73 MeV resonance is about 50 times larger than the cross section for Coulomb scattering. The work we describe is a study of the effects of thickness on the analysis of thin films in the region of the 1.73 MeV resonance in the elastic backscattering spectrum of protons from carbon. Films of carbon and carbon compounds such as Mylar, Kapton, and Formvar varying in thickness from 20 $\mu g/cm^2$ to 2000 $\mu g/cm^2$ were used.

*Supported in part by the Shell Oil Company Foundation
**In Collaboration With. Jingai Liu, Engineering Physics, The University of Oklahoma, Norman, OK 73069 and Tianbao Xie, Physics Department, University of North Texas, Denton, TX 76203.

SESSION JC: ATOMIC PHYSICS AND RELATED PHENOMENA

Thursday afternoon, 8 November 1990; Union Building Golden Eagle Suites B and C at 14:00;
F. D. McDaniel, The University of North Texas, presiding

JC 1 Electron Emission During Multicharged Ion-Surface Interactions.*
P. A. ZEIJLMANS VAN EMMICHOVEN, *Oak Ridge National Laboratory, and Joint Institute for Heavy Ion Research, Oak Ridge.*
(20 min.)

Recent electron spectra and total electron emission yields for slow multicharged N ion-surface collisions will be presented. The emphasis will be on potential emission, i.e., the electron emission related to the neutralization of the ions. When using N ions that carry a K-shell vacancy into the collision, characteristic K-Auger electron emission from the projectiles is observed, as well as, for specific surfaces, target atom Auger transitions (resulting from vacancy transfer). Measurements of the intensity of these Auger transitions as a function of the time the ions spend above the surface can serve as a useful probe of the timescales characterizing the relevant neutralization processes. This technique will be elucidated with the help of some model calculations. It will be shown that neutralization timescales required in the atomic ladder picture, in which neutralization takes place by resonant capture followed by purely atomic Auger transitions, are too long to explain our experimental results.

*Research in collaboration with C. C. Havener, F. W. Meyer, and D. M. Zehner, Oak Ridge National Laboratory. Research supported by the Office of Basic Energy Sciences, Division of Chemical Sciences, U.S. DOE, under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc., and the Joint Institute for Heavy Ion Research through Contract No. DE-FG05-87ER40361 with the University of Tennessee.

JC 2 Time Resolved Spectroscopy on Ion Beams as a Tool for the Study of Long-Lived Levels in Multiply Charged Ions.*
E. TRÄBERT, *Ruhr-Universität Bochum, Federal Republic of Germany.* (20 min.)

The decays of long-lived levels in highly charged ions often indicate higher-order effects in atomic structure. Recently measurements have been done on spin-changing E1 transitions, spin-changing M1 transitions, M1/E2 fine structure transitions within the ground-complex of highly-charged heavy ions, and E1 transitions which are induced by weak configuration mixing. They involve spectroscopy in the EUV, XUV and x-ray spectral regions and ion beams in a wide range of energies, from less than 1 keV/amu to more than 10 MeV/amu. The relative merits of fast and slow ion beams for such measurements are discussed, and future experimental developments are outlined.

*Supported in part by the Deutsche Forschungsgemeinschaft, the German Minister for Research and Technology, and by NATO

JC 3 Angular Distribution of K- and L-Auger Electrons Ejected in 60-keV O^{6+}+He Collisions.
N. STOLTERFOHT, *Laboratoire de Spectroscopie Atomique, France.* (20 min.)

We measured angular distribution of K-and L-Auger electron emission in 60-keV O^{6+}+He collisions using the method of high-resolution electron spectroscopy. The experiments were carried out at the Electron Cyclotron (ECR) source of the GANIL facility at Caen. They were made to verify cross sections[1] for double electron capture previously measured at an observation angle of 0° only. The Auger transitions follow the capture of two electrons into the ground state projectile forming the configurations $1s^23lnl'$ where $n\geq3$. The K-Auger transitions follow the formation of the configuration 1s2snl where $n\geq2$ by single capture into the projectile incident in the metastable state $1s2s\ ^3S$. The observation angle ranged from 0° to 180°. Whereas the K-Auger data were found to be almost isotropic, the L-Auger data showed an anisotropic angular distribution enhanced by a factor of ≤2 at 0°. At 0° the kinematic Doppler broadening effects are avoided. Hence, the K- and L-Auger electrons were measured with relatively high resolution allowing for an improved spectral analysis.

[1] N. STOLTERFOHT, C.C. HAVENER, R.A. PHANEUF, J.K. SWENSON, S.M. SHAFROTH and F.W. MEYER, Phys. Rev. Lett. 57, 74 (1986).

JC 4 RTE in Heavy-Ion–Atom Collisions.
TH. STÖHLKER, *Justus-Liebig-Universität Giessen and Gesellschaft für Schwerionenforschung Darmstadt m.b.H., Federal Republic of Germany.* (20 min.)

In collisions between highly charged ions and light target atoms at adiabaticity parameters of $0.5 \leq u^2/v^2 \leq 0.75$ resonant transfer and excitation (RTE) is the dominant projectile charge exchange process. In this process the energy gained by the captured excites a projectile electron producing a doubly excited projectile state which stabilizes radiatively. The experiments for medium heavy ions are reviewed and a outlook for the study of this electron correlation process using

heavies projectiles is given. In particular we elucidate results yielded by the x-ray/x-ray coincidence technique for hydrogenic projectiles up to $_{36}Kr^{35+}$ ions. With this technique we could isolate a single RTE resonance, the one to the $2s2p^1P_1$ state, which stabilizes radiatively to the $1s2s^1S_0$ state. This state can only decay via two photon emission (2E1). The properties of this rare process are studied.

JC 5 One- and Two-Electron Transitions in Ion-Atom Collisions.*
RAJIV SHINGAL, *J. R. Macdonald Laboratory, Kansas State University.* (20 min.)

One and two electron transitions in collisions between light bare ions and helium atoms have been studied for intermediate impact energies. The helium atom was treated as an effective one electron atom. The multi-channel semi-classical impact parameter model with travelling atomic orbital expansion and rectilinear trajectories was used to calculate the transition probabilities. Cross sections for all one electron processes calculated in the independent electron approximation, employing a large basis set, are in good agreement with the experimental data. A two step mechanism is proposed to describe the two electron collision processes. Predicted cross sections for double capture to individual doubly excited states and the total cross sections for various electron processes are found to be in good agreement with the available experimental data.

* Supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

JC 6 RTE and Other Processes in C^{3+}+He Collisions. S. M. SHAFROTH, *University of North Carolina, Chapel Hill.* (20 min.)

JC 7 Two-Photon Emission Processes in Electron-Atom Interactions.* C. A. QUARLES, *Texas Christian University.* (20 min.)

We will describe the experimental techniques and discuss the results of an on-going three-parameter coincidence experiment in which two-photon spectra are obtained by electron bombardment of target foils of selected thicknesses. The atomic number of the foils ranges from Z = 26 to 82. Incident electrons have been provided both by the beta spectrum of a Pm147 source and by a 50-150 keV electron beam from an accelerator. Processes considered to date include: double bremsstrahlung, double inner-shell ionization, and coherent emission of both a characteristic and a continuum x-ray. The cross sections for these two-photon processes are much smaller than the processes that produce single photons in the target. This can lead typically to a large accidental rate in the accelerator experiment, or to the need to do a target thickness study of the real rate in the source experiment where thicker targets have been used to increase the statistics.

*Supported by the Welch Foundation.
Work in collaboration with H.E. Lehtihet, D.J. Lawrence, and D.L. Kahler.

SESSION JD: ATOMIC PHYSICS AND RELATED PHENOMENA

Thursday afternoon, 8 November 1990; Union Building, Room 410 at 14:00; L. A. Rayburn, Oliver Springs, Tennessee, presiding

JD 1 Transitions in Highly Charged Ions of Heavy Atoms.* D. D. DIETRICH,† *Lawrence Livermore National Laboratory.* (5 min.)
(Invited Poster Paper: See Poster Display PA 91)

The study of the behavior of electrons bound by the extremely high fields found in the vicinity of highly stripped heavy atoms is an extremely chalenging field for both experimentilists and theorists. The production of highly charged ions in an environment suitable for precision spectroscopic measurements presents the largest experimental difficulty. Large quantities of any charge state of any element in the periodic table will soon be available with the current generation of accelerators and storage rings. Precision spectroscopic experiments on the beam foil light source have tradionally been hampered by the possibility of large systematic errors caused by the Doppler effect. We present a new measurement designed to minimize the Doppler effect. In particular, we have performed an exploratory measurement of the n=3 to n=3 transitions in highly ionized lead at GSI where we use measurements taken on the LLNL EBIT[1] to develop internal fast ion calibration lines. Here we attempt to exploit the ability to make precision measurements, free from systematic effects, on the relatively weak resonance transitions from ions available in the EBIT device. This new approach to beam foil spectroscopy will allow one to design spectrometers to maximize resolution and sensitivity without regard to the Doppler effect, thus, taking full advantage of the multitude of population mechanisms available in the beam foil light source.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48
†Work performed in collaboration with A. Simionovici, P. Beiersdorfer, T. Cowan and F Mokler.
1. T.E. Cowan, C.L. Bennett, D.D. Dietrich, J. Bixler, C.J. Hailey, J.R. Henderson, D.A. Knapp, M.A. Levine, R.E. Marrs and M.B. Schneider, Phys. Rev. Lett. (submitted).

JD 2 Intra- and Intermolecular Electron Transfer Reactions in Covalently Linked Donor-Acceptor Molecules.*
A. M. BRUN, *University of Texas at Austin.* (20 min.)

Electron transfer reactions at interfacial sites are crucial processes in cell metabolism and represent the first reactions steps after exposure of biological cells to ionizing radiation. Studies using aggregated assemblies, e.g. micelles, are important for a better understanding of such reactions in systems that are reminiscent of biological milieu. We synthesized a homologous series of molecules (MVnn'Q) where a methylviologen (MV) and a chloronaphthoquinone (Q) moiety are linked to each other via an amino alkane chain. Using the electron pulse radiolysis technique, we have measured time-resolved spectra and rate constants for intra- and intermolecular electron transfer between donor and acceptor site of these molecules in water and in SDS micellar solution. The intramolecular rate constants measured for all molecules MVnn'Q in water were surprisingly low, and we obtained even lower values in SDS. Possible explanations for this slow electron transfer rates will be discussed.

*supported jointly by the Biotechnology Program of the Division of Research Resources of NIH (Grant RR00886) and by The University of Texas at Austin. Partial support from NIH Grant GM 31603 and the R.A. Welch Foundation.
+Coworkers: W.H. Wade; S.M. Hubig, Center For Fast Kinetics Research, The University of Texas at Austin; M.A.J. Rodgers, Center for Photochemical Sciences, Bowling Green State University.

JD 3 Electron Capture by Multicharged Ions from Hydrogen Atoms at eV Energies.*
C. C. HAVENER, *Oak Ridge National Laboratory.* (20 min.)

To quantitatively study electron capture collisions of multiply charged ions with neutral atoms near thermal energies (1-1000 eV/amu), keV-energy beams from the ORNL-ECR multicharged ion source are merged with ground-state beams of H or D atoms. Improvements in our apparatus have increased our signal-to-background ratio by a factor of five and increased angular collection by 30%. Recent data for O^{3+} and O^{4+} will be presented and compared with theoretical predictions. Because of discrepancies with theory at the lowest energies, the O^{5+} + H(D) system will be re-examined with the improved apparatus.

*Research in collaboration with M. Nesnidal and R. A. Phaneuf. Research supported by the Office of Basic Energy Sciences, Division of Chemical Sciences, U.S. DOE, under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

JD 4 Fano Profiles Resulting from the Interferences Between Nuclear Internal Conversion K-Shell Electrons and K-Shell Delta Electrons. NOEL A. GUARDALA,* *Stanford University.* (20 min.)

The probability for electromagnetic excitation of low-lying nuclear rotational states by charged-particle collisions with deformed nuclides can be comparable in magnitude to K-shell ionization probabilties. These nuclear states decay preferentially via the non-radiative internal conversion (IC) process. The IC electrons have well-defined energies, angular momentum, intrinsic widths and angular distrubitions[1]. In contrast, the K-shell delta electrons constitute a continuum of energies and a mixture of at least three angular momenta. This combination of electron decay modes is similar to one of the familar examples illustrated by Fano[2]. Namely, the case of a single discrete state embedded in a smoothly varying continuum. We identify the K-shell IC electron as the discrete autoionizing state, i. e. resonant state. The smoothly varying continuum is represented by the K-shell delta electrons. Information regarding the relative phases and amplitudes of both decay processes could be obtained from coincindence-type experiments involving the ejected electron's angular correlations.

1. Internal Conversion Processes, J. H. Hamilton ed. , Academic Press , New York, 1966.

2. U. Fano, Phys. Rev. 124, 1866, (1961).

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JD 5 Ion Trap Measurement of U^{64+} X-Ray Transition Spectra.*
N. K. DEL GRANDE, *Lawrence Livermore National Laboratory.* (5 min.) (Invited Poster Paper. See Poster Display PA 8)

Highly charged uranium ions with a dominant nickel like component (U^{64+}) were produced using the Electron Beam Ion Trap (EBIT) with an electron bombardment energy of 7.3 keV. A comparison of the measured n=4 to n=3 x-ray transition spectra with calculations for U^{64+} gave excellent qualitative agreement. The low-energy region of the 4-3 spectrum for the Ni like ions was characterized by a strong electric quadrupole 4s-3d transition, about as large as the leading dipole of 4f-3d transition. This was associated with cascading for Ni-like ions which have 28 electrons in a closed $3d^{10}$ configuration. It tagged the

abundance of U^{64+} ions. High resolution spectroscopy measurements indicated charge states were about 53% Ni-like, 32% Cu-like and 15% Zn-like. The ionization balance associated with 9.0 keV electron bombardment was dominated by five charge states: U^{65+} to U^{69+}.

*Worked performed under the auspices of the U. S. Department of Energy at the Lawrence Livermore National Laboratory under Contract W-7405-ENG-48 in collaboration with J. R. Henderson, A. L. Osterheld and J. H. Scofield.

JD 6 "Molecular Effect" in Ion-Atom Collision: A Summary Review. CHENG-MING FOU, *University of Delaware.* (20 min.)

A survey of the experimental studies of ion-atom collision in MeV/amu range using molecular-ion beams (such as H_2^+, or H_3^+) will be presented. Particular attentions will be given to those where comparisons with experimental results using isotachic (same velocity or same energy/amu) atomic-ion beams (H^+) were made. Semi-classical discussion and/or explanation of the observed differences - so called "Molecular Effect" - based on the spatial and temporal correlations of the atoms belonging to the same molecular-ion will be made. The role played by the binding electron(s) which accompanys the atoms of the same molecular-ion in the process of collision with the target atom will be assessed. I shall point out some of the un-answered questions, and doubts of some of the published experimental studies and shall also attempt to make some suggestions for further studies.

SESSION JE: ION MICROBEAMS

Thursday afternoon, 8 November 1990; Union Building, Room 418 at 14:00;
C. J. Maggiore, Los Alamos National Laboratory, presiding

JE 1 Practial Problems with a Proton Probe.* J. L. CAMPBELL, *University of Guelph, Canada.* (20 min.)

Two years of experience in running the Guelph Proton Microprobe as an analytical facility are reviewed. Using micro-PIXE we have conducted several thousand spot analyses of mineralogical, geochemical and metal specimens, mainly through contractual arrangements. User-friendly target chamber design with TV-viewing of the incident beam spot at magnification ×300 throughout analysis is crucial to our efforts. Accurate, reliable analysis has demanded careful attention to beam integration; a new system incorporating on-demand beam deflection is described together with a new PC-based data accumulation facility. Immediate data processing, equally crucial, is accomplished with our GUPIX software; current enhancements to this are reported. Finally we make some observations on the challenge of running a contract-based analysis facility in the University environment.

†Supported by NSERC and various industrial and government contracts.
*I acknowledge the valued contributions of J.A. Maxwell and W.J. Teesdale.

JE 2 Proton Microprobe Analysis of the Trace Element Distribution in Fly Ash Particles.
M. JAKŠIĆ, *R. Bošković Institute, Yugoslavia.* (20 min.)

The spatial distribution of trace elements in individual coal fly ash particles is an important factor in assessing their environmental impact. The Oxford Scanning Proton Microprobe (SPM) has been used to determine the distribution of elements in fly ash particles with sub-micrometre spatial resolution. PIXE was used to detect the minor and trace elements and simultaneous proton backscattering analysis was used to determine the matrix composition and thickness. Both areal maps and radial line scans of elemental concentrations were obtained. Preliminary analyses of particles ranging in size from 5 to 20 μm show that many elements have a highly inhomogeous distribution, with elements such as Ti, V, Mn, Ni, Cu and As deposited preferentially on the surface. This finding has important implications for determining the chemical properties and environmental effects of fly ash particles.

JE 3 Microprobe Analysis of Gold Mine Samples. FUJIA YANG,[1] *Fudan University, People's Republic of China.* (20 min.)

A MeV microbeam probe with PIXE, RBS and Secondary Electron Image detection facilities has been set up on a 3 MV tandem electrostatic accelerator (9SDH-2) at Fudan University. The beam-spot size is 2 μm and the proton beam on target is 30 pA/μm2. The sample is mounted on a motorized x-y stage with a step of 1.6 μm, so that any point within a 2.5 x 2.5 cm2 area can be accessed. The beam can also be scanned over areas ranging from 1 x 1 μm2 to 500 x 500 μm2. The system was used to analyze gold mine samples from different sources. The gold and iron phases were experimentally observed to extend over an area of several hundred microns in agreement with the traditional idea that gold is often macroscopically intergrowing with compounds containing iron. On the other hand, the distribution of gold and silver remains closely associated even on the micron scale.

1 In collaboration with S. Zhou, C. Ren, F. Huang, W. Wu and J. Tang.

JE 4 Channeling Studies on Fe-doped High-T_c Superconductors Using a High-Resolution Proton Microbeam.
G. W. GRIME, *University of Melbourne, Australia.* (20 min.)

The Oxford Scanning Nuclear Microprobe has been used to investigate microcrystals of $Y_1Ba_2Cu_{3-x}Fe_xO_{7-y}$ with the aim of determining the lattice location of the Fe. Channeling measurements were made on the (001) and (011) directions of the YBCO lattice observing both proton-induced X-rays and backscattered protons. Anomalies in the PIXE channeling yield for Fe show that the Fe is displaced out of the (001) plane. Maps were also made of the channeled yield as a function of position on the crystal. These show that the channeling angle varies across the crystal in the Fe-doped crystals probably as a result of lattice strain.

JE 5 Nuclear Microscopic Imaging of Single Event Upset Integrated Circuits.
B. DOYLE, *Sandia National Laboratory, Albuquerque.* (20 min.)

JE 6 5 MeV RBS Microprobe for Materials Analysis in the Semiconductor Industry.
G. M. KLODY, *National Electrostatics Corporation.* (20 min.)

In the development and manufacturing environment, there is a growing need for easy analysis of materials within sample regions smaller than 100 micrometers with automation for unattended multiple sample analysis. A recently developed system with a new microprobe lens has been tested for industrial applications of microbeam RBS and channeling analysis. A 1.7 MV tandem accelerator, NEC Model 5SDH Pelletron, provides helium ions at energies up to 5.1 MeV. The new electrostatic quadrupole lens is fitted in a Charles Evans & Associates, Inc Model RBS-400 end station The accelerator, microprobe beamline, and end station are computer controlled for unattended, multiple sample analysis We compare the performance of the microprobe lens to ion optic calculations and describe examples of applications.

JE 7 Achromatic Focussing for Probeforming of High-Resolution Microbeams.*
U. A. STAFFAN TAPPER, *Lund Institute of Technology, Sweden.* (20 min.)

If Nuclear Microprobes (NMP) with a spatial resolution of the order of 100 nanometers is to be reached, the aberrations in the focussing must be suppressed. With a highly limited beam divergence the dominating aberration is chromatic. Using a combination of electrostatic and magnetic quadrupole lenses achromatic focussing properties can be obtained. The complex design of such focussing systems yields, however, a potential hazard of introducing new aberrations more severe than the suppressed chromatic. The main problem is the harmonic contamination to the quadrupole field.

The potential of the grid-shadow method, when applied to achromatic focussing systems is shown. The method has been used at the new focussing system at the Lund NMP. Measurements at each singlet lens have been performed. The possibility to use the grid-shadow measurements for evaluating lens corrections on-line is discussed. In addition the shadow pattern can guide during the alignment procedure which is crucial for such complex focussing systems. Finally the current spatial resolution attainable at the Lund NMP is presented; both for a 100 pA analytical probe as well as for transmission imaging (STIM), requiring only beam currents in the fA range.

* This project is supported by Carl Trygger's Foundation.

POSTER SESSION PB: Particle Induced X-Ray Emission (PIXE), Rutherford Backscattering and Channeling (RBS), Nuclear Reaction Analysis, Neutron Activation Analysis, Ion Implantation, Medical Applications, Accelerator Technology, Targets, Accelerator Mass Spectrometry, Detectors, and Spectrometers
(The Poster Session is split as PB and PB' for indexing purposes only. This is all one session.)
Thursday afternoon, 8 November 1990
University Union Building,
Silver Eagle Suites A, B, and C at 14:00

PB 1 Alpha-Induced Ionization Cross Secti Studies for some Selected Elements by PIXE a RBS Yield Measurements.* A.B. HALLAK, M.M A KOFAHI, and H.A. AL-JUWAIR, Energy Resear Laboratory, Research Institute, King Fe University of Petroleum and Minerals, Dhahr 31261, Saudi Arabia.--The yield for x-r production from PIXE by 2 MeV ^{4}He ions along wi the Backscattering yield from some select elements in thin and thick forms are used determine the ionization cross sections. T method of analysis make use of the joint PIXE/R setup and avoids absolute method errors by usi the ratio of the PIXE and BRS yields. The resul are compared with theory and reasonable agreeme is found.
*submitted by A.B. Hallak

PB 2 PIXE Analysis of Welding Fume. T. A. WITHERS [1], K. GARDINER [2], L. G. EARWAKER [1]. [1]School of Physics and Space Research, University of Birmingham, UK. [2]Institute of Occupational Health, University of Birmingham, UK. — This paper discusses the use of proton induced X-ray emission (PIXE) for the multi-elemental analysis of welding fume, paying particular regard to the quantitative analysis of any toxic metals which may be present. The welding fume was sampled on Nuclepore polycarbonate filters located in specially modified cranially mounted sampling heads. The samples were taken at a major industrial location in Birmingham, UK, from two different welding processes, Metal Inert Gas (Gas Metal Arc Welding) and Spot welding, and were analysed using a 2.5 MeV proton beam from a 3MV Dynamitron accelerator. The results are presented together with a discussion on their degree of precision, accuracy and sensitivity. This study has shown PIXE to be a useful analytical technique for the quantitative analysis of welding fume from various sources.

PB 3 PIXE Analysis of Stainless Steel Samples in the X-Ray Region Between 0.5 and 18 keV Using a Windowless Si(Li) Detector. D.K.Wilson, J.L.Duggan, D.Weathers, F.D.McDaniel and S.Matteson, Physics Dept. University of North Texas*, Denton, TX 76203, T.Thompson, Texas Utilities Electric, Dallas, TX 75201 and I.L.Morgan, IDM Inc., Austin, TX 78758.--Absolute concentrations of contaminant elements in stainless steel samples obtained from a local power utility have been measured using the thin target PIXE technique. Of particular interest were those elements with x-ray energies less than 1.5 keV. The PIXE spectra were obtained using 1 MeV protons from the 3 MV NEC 9SDH-2 Tandem Accelerator in conjunction with a Link Analytical windowless Si(Li) detector at UNT. The low energy detector efficiencies were measured by carefully analyzing the field bremsstrahlung from a 66.5 keV electron beam bombarding various thin targets. The PIXE spectra were analyzed using both the PIXE Analysis Program developed at the University of Guelph(Canada) and software developed in-house. In addition, sample preparation techniques are detailed along with a brief comparison of thin and thick target results.

* Work Supported in part by the State of Texas Coordinating Board, Texas Utilities Electric, IDM Inc., TI, NSF, DNA, ONR and the Robert A. Welch Foundation.

PB 4 Trace Elements in Hoxie Gorge Creek Sediments R M Wheeler, R P Chaturvedi. SUNY College at Cortland --Sediment samples from Hoxie Gorge Creek in Upstate New York have been studied by x-ray fluorescence using synchrotron radiation from the Cornell High Energy Synchrotron Source. These samples were previously examined for major elemental concentrations in creek sediments and their ability to regulate soluble reactive phosphorous. The samples were obtained from a single site over a year's time. We have used two monochromatic x-ray energies, 12 and 20 keV, to study trace element concentrations for elements in the range $20 \leq z \leq 40$. Variations in trace elements as a function of time of year will be discussed.

PB 5 **Detection of Elements and Trace Elements in Endoscopy Biopsies of Colonic Mucosa in Normal and High Risks Colon Cancer Patients.**

M.C.BUOSO*, S.FAZINIC*^, S.GALASSINI*#, P.E.LECIS*, M.MAKAREWITCZ°, G. MOSCHINI*+, R. NACCARATO*, R. OGRIS°, H.R.SHAO*°, G.C. STURNIOLO* AND V. VALKOVIC°^.

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^Rudjer Boskovic Institute Zagreb, Yugoslavia.

°IAEA Laboratories-Seibersdorf,Austria.

°Institute of High Energy Physics, Beijing, China.

In the present study efforts are made to obtain a correlation between the trace elements levels in patients and the incidence of digestive cancer. The aim of the study is to detect the Se, Zn, Cu and Ca concentrations in different segments of colonic mucosa and to find out if there is any difference between the normal and pathological colonic mucosa. The concentrations data (averages, standard deviations and ranges) obtained by the Neutron Activation Analysis and Proton Induced X-ray Emission are presented and the data distribution analyzed.

PB 6 A PIXE Study of Chlorine Loss from Proto Irradiated PVC, J. Rickards and E.P. Zironi Instituto de Fisica, Universidad Nacional Autonon de Mexico. Poly-vinyl chloride samples wer irradiated with protons of different energies fro 250 to 750 keV from a Van de Graaff accelerator The chlorine lost during irradiation was measure using the PIXE technique by monitoring the Cl K line. The chlorine loss curves were obtained i steps of 2 μC, using a low beam current (5-10 nA) In order to avoid charg buildup and to allo measuring the beam current, a thin copper film wa deposited on the target, or alternately a ve fine copper mesh was placed over i Simultaneously, the residual gas in the targ chamber was monitored with a quadrupole ma analyzer, indicating that the chlorine loss is the form of HCl. The Cl decay curves can fitted with three exponential function suggesting different and independent mechanis for emitting chlorine. This seems to indica that the effect is strongly dependent on t chemical environment of the chlorine.

PB 7 PIXE-PIGE Analysis of Nigerian Coals

S.O.OLABANJI*, R.CHERUBI. I, S.GALASSINI, A.M.I.HAQUE+, G.MOSCHINI, R.POLICRONIADES** AND V.VALKOVIC++, I.N.F.N. Laboratori Nazionali Di Legnaro, Padova, Italy.-- The measurement of the concentration of major, minor and trace elements in Nigerian bituminous and sub-bituminous coals from different deposits were carried out using Particle Induced Gamma-ray Emission (PIGE) and Particle Induced X-ray Emission (PIXE) techniques. Particle beams furnished by a 2.5 MV AN 2000 and a 7 MV CN Van de Graaff accelerators at I.N.F.N. Laboratori Nazionali Di Legnaro, Padova, Italy, were used. Ge(Li) and Si(Li) detectors were employed for measurement purposes respectively. The comprehensive results using these two complementary techniques are presented and compared with earlier measurements performed using ASTM, INAA and FNAA techniques.

* ICTP Fellow, on Sabbatical leave from C.E.R.D., O.A.U., Ile-Ife, Nigeria.
+ ICTP Fellow
** ICTP Fellow, on leave from ININ, Mexico
++ The Rudjer Boskovic Institute, Zagreb, Yugoslavia

PB 8 PIGE Analysis of Esie Museum Soapstone Sculptures. S.O. OLABANJI*, R. CHERUBINI, S. FAZINIC+, G.MOSCHINI, D.ZAFIROPOULOS, I.N.F.N. Laboratori Nazionali Di Legnaro, Padova, Italy.-- Recent studies[1] have shown that Esie stone sculptures, the largest collection in Africa, were carved using talc-tremolite, talc-chlorite, talc-tremolite-anthophylite, and talc-amphibolite schists. However, the light elements were not covered because PIXE technique was not adequate for elements lighter than Silicon. For the first time, PIGE analysis of the sculptures and the outcrops were carried out using protons and alpha particles produced by a 7 MV CN Van de Graaff accelerator at I.N.F.N. Laboratori Nazionali di Legnaro, Padova, Italy, and a Ge(Li) detector. Talc-schists, the material from which the sculptures were carved are quite important economically, finding use in the manufacture of paint, ceramics, abrasives, tiles, asbestos, cement and a few other metallurgical applications. Results of this novel measurements are presented.

* ICTP Fellow, on Sabbatical leave from C.E.R.D., O.A.U., Ile-Ife, Nigeria.
On leave from the Rudjer Boskovic Institute, Zagreb, Yugoslavia

[1] S.O.Olabanji, V.O.Olarewaju and O.Onabajo, Nucl.Instr.Meth. in Phys. Res. B47, No.4 (1990).

PB 9 A simple external-beam ion milliprobe system for in-air PIXE*. STEVE A. MACLAREN, F.D. CORRELL, JAMES R. HUDDLE, and JEFF VANHOY, U.S. Naval Academy, Annapolis, MD.--A simple external-beam ion milliprobe system was designed and constructed as part of an undergraduate student honors research project. The system includes an adjustable object slit, a compact electrostatic quadrupole triplet lens, a lens positioner, and a shielded tip with a thin Kapton window through which the beam exits the accelerator vacuum and enters a target enclosure with interlocked doors. Auxiliary equipment includes a four segment lens-entrance collimator with a beam-current monitor that facilitates steering the beam and an interlock system that intercepts the beam when any of the doors to the target

enclosure is opened. Details of the design and construction of the system will be presented and its performance will be described.

*Supported by the Office of Naval Research through the Naval Academy Research Council and the Trident Scholar Program.

PB 10 PIXE-Microanalysis of Rootlet Samples from (*Fagus Sylvatica*). MIKAEL HULT, Department of Nuclear Physics, Lund Institute of Technology, Solvegatan 14, S-223 62 Lund, Sweden, and BENGT BENGTSSON, Department of Plant Physiology, Lund University, Box 7007, S-220 07 Lund, Sweden.--- Cryosectioned and freeze-dried cross sections of rootlet samples from beech trees (*Fagus Sylvatica*) were analysed using the micro PIXE technique (Particle Induced X-ray Emission). A beam of 2.55 MeV protons focussed down to 5x5 μm^2 was scanned along the diameter of the rootlets. The purpose was to study the effects of $AlCl_3$, on the uptake and distribution of calcium and phosphorous in roots of intact beech plants. It was found that the presence of aluminium in soils or nutrient solutions led to reduced concentrations of calcium, magnesium and phosphorous in the plants and increased concentrations of potassium. The proton microprobe has proven to be an excellent tool for trace element analysis of biological samples. Since Aluminium only was present in trace element concentrations it was necessary to analyse each sample for a couple of hours to reach the lowest detection limits. Thus full use of a new microprobe and data collection system were necessary conditions for this analysis. Analysis of back- and forwardscattered protons was performed simultaneously as the PIXE analysis. This information made it possible to quantitatively determine the matrix elements so that the trace element concentrations could be accurately calculated.

PB 11 Distrubution of Trace Elements in Rats Following Lead Acetate Supplementation. R. GOEL, R.R. GARG, S. KUMAR, S. SINGH, J. GOSWAMY, B. CHAND, D. MEHTA, M.L. GARG, N. SINGH, P.C. MANGAL, Department of Physics, Panjab University, Chandigarh-160014, India, PELLE LARSSON, K.G. MALMQVIST, Department of Nuclear Physics, Lund University, Solvegatan-14, S-22362 Lund, Sweden, and P.N. TREHAN, Department of Physics, Panjab University, Chandigarh-160014, India.--- The effect of orally administered lead on the distribution of other trace elements has been studied using PIXE and EDXRF techniques. Male and female rats were administered 15 and 50 mg/kg body weight of lead acetate daily for 2 and 4 weeks. Five organs/tissues namely kidney, liver, brain, femur and blood were taken. Fifteen elements namely P, S, Cl, K, Ca, Cr, Mn, Fe, Cu, Zn, Se, Br, Sr, Rb and Pb were detected with PIXE. With EDXRF only K, Ca, Fe, Cu, Zn, Br, Rb and Pb could be detected. Reasonable agreement between the results of PIXE and EDXRF is found for K, Ca, Fe, Zn, Rb and Pb. From this study it is seen that lead supplementation alters the distribution of many trace elements.

PB 12 Trace Element Composition Characteristics and Acidity of Central Alabama Rain. S.K. GHORAI*, O. TEKYI-MENSAH, and J.F. SIMS, Alabama State U.-- and J.R. Williams and W.L. ALFORD, Auburn U. --Elemental concentrations and acidity of central Alabama rain have been studied over a period of five years. PIXE methods were used to determine elemental concentrations. Seventeen elements were found in the rain samples. Samples collected during the initial five-month period showed characteristics that are described here. The elemental composition of southerly air flow rains differed from that of northerly air flow rains with the latter containing relatively higher concentrations of S, Ca, Cu and Zn, indicating a more polluted area to the north. For northern rains, four relatively strong pair-correlations were observed: S with Ca and Cl with Na, K and Cu, the latter three suggesting many sources of Cl. In southern rains, eight strong pair-correlations were found: Ca with S,K and P, K with S, Ca, and Zn, and S with K and Ca, indicating a strong marine influence on Ca,K and S. Average pH values were 4.95 (northern) and 5.40 (southern). A strong correlation found between pH and logarithmic sulfur concentration in the northern rain but not in the southern rain suggests that the sulfur found in the northern rain comes largely from sulfuric acid which originates in polluted areas to the north. Sulfur in the southern rain appears to come mostly from neutralized sea water sulfate.

*Supported by NIH Grant No. GM08219

PB 13 Five-Year Data Base Resulting From PIXE Analysis of Central Alabama Rain. S.K. GHORAI*, O. TEKYI-MENSAH and J.F. SIMS, Alabama State U., and J.R. WILLIAMS and W.L. ALFORD, Auburn U.-- Rain samples were collected during every rainfall in Montgomery, Alabama between January, 1985 and November, 1989. A total of 297 samples were collected. The pH value of each sample was measured immediately after its collection, and the elemental concentrations of the sample were then determined by using proton induced x-ray emission (PIXE) methods. The seasonal weighted average pH values were lower for north air flow rains than for south air flow rains, indicating that the northern rains were more acidic than the southern rains. A plot of the seasonal weighted average pH values for the five-year period revealed that there has been a slight decrease in the average pH since the summer of 1986, suggesting that the acidity of the rain has increased in Montgomery since that time. Graphs of average seasonal elemental concentrations of frequently occurring elements Na, Si, P, S, Cl, K and Ca have been plotted for different wind directions. The main purpose of these graphs was to establish a data base for these elements over the five-year period. Besides providing a five-year data trend, these graphs reveal certain features about the elemental distributions. For example, the sulfur concentration in the northerly rain tends to be higher than in the southerly rains. A high correlation can be found between the seasonal concentrations of Ca and K for south air flow rains but not for north air flow rains. Other similar correlations and distributions can also be observed.

*Supported by NIH Grant No. GM08219

PB 14 PIXE Analysis of Thick Metallic Samples at KSU

S.A. ELBAKR, Physics Department, King Saud University, Riyadh, Saudi Arabia --- A PIXE system for analysis of thick samples has been established at KSU Van de Graaff accelerator. Energies and intensities of X-rays emitted from metallic alloys have been measured using a high resolution energy-dispersive X-ray spectrometer. Concentration of elements present in alloys has been determined by comparing the X-ray yield from the samples to that from spectroscopically pure thick targets of Fe, Ni Cu, Zn, Ag, Sn, Au and Pb. Corrections for matrix effects have been included in the results. Photon induced X-ray fluorscence technique has also been used to analyze the same alloys. A good agreement between PIXE and XRF results has been obtained.

PB 15 An Investigation of the IR Spectra Feature for Doped Sapphires by High-Energy Proton Radiation. CHEN CHUAN, Analytical and Testing Center, Chengdu Branch, Academia Sinica, Chengdu, Sichuan, P.R. China, LIN LIBIN, ZHAO HUICHUAN, and WU DENGXUE, Department of Physics, Sichuan University, Chengdu, Sichuan, P.R. China.--- With high-energy (2MeV) proton radiation for doped sapphires, the new IR spectra peaks were first time found at 2851cm^{-1}, 2919cm^{-1} and 2955cm^{-1}, which bear a relationship to proton radiation and have nothing to do with kinds of the transition and rare earth metal ions in doped sapphires. By comparing the results of IR spectra studies of a large number of doped Verneuil sapphires with-

high-temperature annealing in H^+ atmosphere, the three IR spectra peaks were recognized H^+ ion symmetry stretch vibration of the O-H-O^{2-} system. And the H^+ ion is nearby crystal lattice Al^{3+} ion (or is not nearby impurity ions and other point defects) in consideration of distribution difference of H^+ ion after proton radiation and thermal diffusion in crystal. According to calculating results of the formula $\Delta Vs=4430x(2.84-R)$, which is a relationship of the distance R between oxygen and oxygen with frequency shift ΔVs of the O-H-O^{2-} system, the H^+ ion exist between the layers of oxygen ions of the corundum structure. Some experimental phenomena were explained better.

PB 16

Mexico City aerosol samples analysed by PIXE. F. J. Flores, R. Díaz and G. Anguiano. Instituto Na de Investigaciones Nucleares, Mexico. Aerosol sa from local atmosphere in Mexico City have been a by measuring the X-Rays induced by proton bombar (PIXE). We present some first results obtained u 3 MeV proton beam from the Tandem Van de Graff A rator of ININ, Mexico, and some others in collab with CNL University of California, Davis. Some a have been collected with an integral sampler onc since January 1988 and others daily, every six h during a whole week. The elements that are prese the aerosols, the monthly average concentrations the temporal variation in lead concentration dur weekly samplings in summer and winter time are p

PB 17 Influence of Film Thickness on Oxygen Determination of High T_c Materials by RBS S.C. TIDROW, H.J. FISCHBECK. Engineering Physics Program, University of Oklahoma.---RBS determination of oxygen content in high T_c materials deposited on substrates used for oriented film growth, such as SiO_2, MgO, Al_2O_3 and $SrTiO_3$, can be difficult due to substrate interference. This is especially the case if the relatively small oxygen signal from the film appears on a large substrate signal and is overlapping the oxygen signal from the substrate. We will show oxygen determination in films can be significantly improved by properly choosing film thickness and incident beam energy such that the front edge of the oxygen signal from the film is separated from the substrate signal. RBS analysis of varying film thickness $La_{1.8}Sr_xCu_yO_z$ films, deposited on SiO_2 and MgO substrates by a RF planar magnetron, is shown. RBS simulation is used to demonstrate the importance of film thickness and beam energy for determination of oxygen in high T_c material films deposited on other substrates.

PB 18 Simulation Problems in Proton RBS.* S. R. RYAN, and H. FISCHBECK, University of Oklahoma, and T. XIE, University of North Texas —The enhanced non-Rutherford cross section for proton backscattering from light elements above 1 MeV can be utilized to profile the concentration of low-Z nuclei in a high-Z matrix. Simulation programs used to determine elemental profiles which work well for helium RBS do not accurately simulate proton spectra from a variety of high-Z materials. Simulations of proton spectra of high-Z samples consistently underestimate the yield of protons backscattered deep in the sample. The discrepancy increases as the incident proton energy increases. Evidence will be presented which suggests that multiple scattering rather than inaccurate stopping power data or a low energy component in the beam is responsible for the discrepancy.

*Supported in part by the Shell Oil Company Foundation.

PB 19 Ion channeling determination of interfacial atomic registry for GaAs/ErAs/GaAs (001) heteroepitaxy, N. G. STOFFEL, C. J. PALMSTROM, AND B. J. WILKENS, Bellcore.---We used the angular dependence of MeV He ion backscattering from Er to determine the specific atomic registry of thin ErAs films with respect to the substrate and overlayers in MBE-grown GaAs/ErAs/GaAs (001) heterostructures. A knowledge of the interface registry is required to calculate the electronic structure of the ErAs layers and to understand the mechanisms of hetero-epitaxial growth. Blocking and focusing of the ion flux by the atomic rows in the GaAs overlayer resulted in a sensitive dependence of the Er backscattering signal upon incident angle near specific channeling directions. From detailed measurements of the ion-blocking and flux-focusing patterns, combined with Monte Carlo simulations of the expected ion flux at various possible Er sites, the registry of the ErAs layer could be determined with respect to the GaAs overlayer to an accuracy of about 0.01 nm. The crystal structures of ErAs (rock-salt) and GaAs (zinc blende) both contain face-centered-cubic As sublattices. Our results demonstrate that the atomic registry at the GaAs/ErAs interface is such that the As sublattices form an essentially continuous fcc lattice across the interface.

PB 20 An RBS Analysis of the Low Temperature Diffusio of Au in GaAs. C. S. Patuwathavithane, J. R. Williams, C. C. Tin, P. A. Barnes and M. J. Bozack, Auburn U. -- A temperatures above approximately 500°C, the interaction o Au and GaAs at the Au/GaAs is not uniform over the surfac of the sample, and the interaction leads to the formation of various Au-Ga phases. As a result, broad beam spot (≈ 400 μm) RBS techniques are normally applied for only qualitative analysis of such samples. The non-uniform interaction is much less apparent for short anneal times (≤ 16 mins.) at temperatures below 450°C. For these conditions, a fast Au diffusion component has been identifie using RBS techniques and analyzed using the dilute alloy approximation. The resulting effective diffusion coefficients are the order of $10^{-13}cm^2/s$ and are in agreement with those assigned using other techniques (radioactive tracer and SIMS). These coefficients are believed to be accurate within a factor or two.

*Work supported by the SDIO Office of Innovative Science and Technology through Contract # DNA001-85-C-0183.

PB 21 Ion Channeling Analysis of $SrTiO_3$ (100) and (110) Surfaces., K.Oura,M.Watamori,F.Shoji, Faculty of Engineering, Osaka University.---- Crystalline quality of $SrTiO_3$ (100) and (110) single crystalline surfaces has been studied by ion channeling method utilizing 2-4 MeV He^+ ion beams. $SrTiO_3$ crystals obtained from different manufacturers revealed quite different crystalline quality. The minimum yield χ_{min} varied between 5 % and 52 %. Such a wide distribution of crystalline quality cannot be observed for other materials such as MgO and Si. Polar angle scans of backscattered yields along the <001>,<011> axes have also been measured. For some specimens, angles between two channeling dips measured at <001>,<011> ,and <101> have been found to be larger up to about 0.5° than 45°,suggesting possible deviations of lattice constants of $SrTiO_3$ at the surface regions examined by ion channeling. In addition ,the effect of substrate crystalline quality on the growth of $YBa_2Cu_3O_z$ thin films has been also discussed.

PB 22 A New Ion Beam Handbook for Materials Scientists. C.J. MAGGIORE, M. NASTASI and J.R. TESMER, Los Alamos National Laboratory. C.J. Barbour, Sandia National Laboratories, and J. W. Mayer, Cornell University. -- Starting with the foundation laid at the Workshop on High Energy and Heavy Ion Beams in Materials Analysis in held in Albuquerque in June, 1989, a new handbook for ion-beam materials analysis is being written. The new handbook will expand upon the material in the existing handbook.

Ion Beam Handbook for Materials Analysis, ed. by Mayer and Rimini, 1977, Academic Press. Particular emphasis in the new handbook is given to higher energies and heavier ions, as well as, new subjects such as elastic recoil detection, activation analysis and pitfalls in ion-beam analysis. A consistent, expanded data section will also be included. The chapter editors and contributors, outline and layout of the handbook will be presented.

PB 23 (p,^{6}Li) and (p,^{7}Li) Elastic Scattering Cross Section. J.M. KNOX, S. BANERJEE, Idaho State University --- The elastic scattering cross section for proton energies under 2MeV. In this energy region, the cross section is definitely not Rutherford with some energy ranges of enhanced scattering and resonance as well as energy ranges where the cross section is less than Rutherford. Fits of the data suitable for use in modeling programs will also be given.

PB 24 Rutherford Backscattering/channeling Studies on Thin-film $YBa_2Cu_3O_7/Y_2O_3$ Layers on (001) MgO substrates. H. JHANS and L. G. EARWAKER, Department of Physics and Space Research, University of Birmingham, Birmingham B15 2TT, UK. N. G. CHEW, J. A. EDWARDS and A. G. CULLIS, RSRE, Malvern, Worcs. WR14 3PS, UK.---Rutherford backscattering(RBS)/channeling measurements have been carried out on $YBa_2Cu_3O_7$(YBCO), YBCO/Y_2O_3 and YBCO/Y_2O_3/YBCO thin-film structures grown onto single crystal (001) MgO substrates by e-beam coevaporation in the presence of atomic oxygen. The YBCO layers typically have T_c~90 K, J_c>10^6 A/cm^2 and are epitaxially c-axis oriented. Aligned <001> spectra display low backscattering minima, χ_{min}, which further confirms the good epitaxy of these films. The YBCO/Y_2O_3 and YBCO/Y_2O_3/YBCO layers are found to grow (001) oriented; low χ_{min} in the <001> aligned spectra again indicates good epitaxial crystallinity. At the optimized YBCO composition, RBS spectra indicate all interfaces to be sharp, however, increased dechanneling at the interfaces indicates the presence of crystallographic defects. Initial results from a high-quality YBCO layer (J_c~10^6 A/cm^2) grown on an MgO buffered sapphire substrate indicate good epitaxy of the superconducting layer. Further details of this technologically important system will be given.

PB 25 Measured Deviations from Rutherford Backscattering Cross Sections Using Li-Ion Beams K.M Hubbard, M Bozoian, J R Tesmer, and M Nastasi, Los Alamos National Laboratory -- Bozoian et al.[1] have developed an analytical theory which predicts the incident ion energy at which elastic backscattering cross sections begin to deviate from their Rutherford values. The results are in good agreement with experimental data for proton and helium-ion beams, and should be applicable to heavier projectiles. The theory has also been extended to account for isotopic variation of the incident beam [2]. As a further test of the theory, we have performed a series of backscattering measurements using both ^{6}Li and ^{7}Li ion beams. Lithium-ion backscattering is of importance to thin-film analysis because it offers improved depth resolution as compared to helium. Elastic backscattering cross sections for F, Al, and Ti were measured relative to those of high-Z reference elements over an energy range of 2-12 MeV, and the energies at which they began to deviate from their Rutherford values were determined. The experimental results are compared with predictions from the analytical theory, and from optical model calculations.

[1] M. Bozoian, K.M. Hubbard, and M. Nastasi, accepted for publication in *Nucl. Instr. Meth.* B.

[2] M. Bozoian et al., these proceedings.

PB 26 Application of Ion Beam Techniques to Catalyst Loading in Fuel Cell Electrodes. J.G. BEERY, J.R. TESMER, S. GOTTESFELD, Los Alamos National Laboratory, D.R. WASHINGTON, University of Houston, M.E. PIZA, Massachusetts Institute of Technology.--- We have studied platinum/carbon fuel cell electrodes with ion beam backscattering. These electrodes consist of a platinum/carbon/PTFE powder mixture which has been hot-pressed onto a carbon cloth backing. We determined the Pt/C ratio using a 2.2 MeV α-particle beam. The catalyst layer was too thick to be completely penetrated at 2.2 MeV so we determined the total platinum loading with an 8.8 MeV α-particle beam. This also gave us the depth profile for the Pt/C ratio. We also studied the spatial variation of the platinum loading over a 15 cm x 15 cm electrode. We found a significant spatial variation in platinum catalyst loading. In addition to the RBS studies we utilized the F^{19} (p, γ) reaction to determine the flourine depth profile. This gave us information about the penetration of a solid polymer electrolyte which was applied to the electrode, since the solid polymer has a higher concentration of flourine than the rest of the elecurode.

PB 27 Thickness Measurements of Conducting Polymers Using Ion Beam Backscattering Techniques. J.G. BEERY, S. GOTTESFELD, Los Alamos National Laboratory, E. SABATANI, Weizmann Institute of Science, Rehovot, Israel.--- Conducting polymers are a class of new materials at an important stage of development. The combination of mechanical flexibility, light weight, high corrosion resistance, and high electronic conductivity makes these materials interesting for a number of applications. They have the potential for replacing metallic conductors in cases in which low weight or high corrosion resistance is critical. We have electrochemically grown polyanaline films on gold and platinum and determined their thicknesses with RBS techniques. By observing the energy shift of the underlying gold or platinum edge, we obtained the film thickness. This technique was successful for thicknesses down to about 100 Å. The same films were characterized *in situ* in the electrochemical cell by optical and microgravimetric techniques. The thickness evaluated for the "soaked" film *in situ* could be compared with the thickness derived by RBS for a dry film. The additional microgravimetric results allow us to derive film density.

PB 28 Analysis of Textured Thin-Film Superconductors Utilizing MeV Ion Beams. J. G. BEERY, M. G. HOLLANDER, C. R. EVANS, I. D. RAISTRICK, and F. H. GARZON, Los Alamos National Laboratory.--- We have fabricated thin-film high-temperature superconductors of $YBa_2Cu_3O_7$ for electronic device applications. The films are made either by coevaporation from three sources or by off-axis sputtering from a stoichiometric target. The properties of the films depend strongly on microstructure and texture. We have found that, for the coevaporation process, we obtain the strongest c-axis texture for film thicknesses of 2500 Å or less. Ion beam channeling is an important tool for measurements of crystal quality. We also use ion beam analysis to determine the physical thickness of the films, using an experimental relation between the areal density as measured by RBS, and the thickness of the as-deposited films measured by a surface profilemeter. Ion beam analysis is also very useful for observing the sharpness of the substrate film interface. Various techniques for improving data quality on different types of substrate are also discussed.

PB 29 Characterization of Electrochemically Polymerized Metal Phthalocyanines using Rutherford Backscattering Spectrometry. E.M. BAUM, H. Li, T.F. GUARR, J.D. ROBERTSON, Chemistry Dept., Univ. of Kentucky.---- A new electrochemical polymerization method for producing electronically conductive thin films (0.1-0.5 μm) of metal phthalocyanines has been developed. Potential applications of these films include nonlinear optics, fuel cells, and gas sensing. The film thickness is a crucial factor in controlling the speed at which these films undergo reversible electrochemical reduction. The rapid instrumental determination of the thickness, elemental composition, and solvent and electrolyte incorporation of the polymeric films by RBS will be discussed.

PB 30 Influence of accidental channeling on the analysis of oxygen in crystals, using the $^{16}O(^{3}He,p)^{18}F$ reaction. E. HANNA BAKRAJI, G. DUCOURET, G. BLONDIAUX, J.L. DEBRUN, CNRS-CERI, 45071 Orléans (France)--Channeling has been widely used in combination with methods like RBS, PIXE or prompt nuclear reactions, and accidental channeling has been recognized as a possible source of errors. This is not the case for charged particle activation (CPA), which has very seldom been used in combination with channeling, and for which the influence of accidental channeling has never been studied. This work presents results concerning the analysis of oxygen by CPA in $Ga_{1-x}Al_xAs$ epitaxial layers using the $^{16}O(^{3}He,p)^{18}F$ reaction at 3 MeV, and discusses the errors introduced by accidental channeling. In these layers, for the higher aluminium concentrations and the higher arsine flows, oxygen is mostly interstitial; it is mostly substitutional for the lower oxygen concentrations and the lower arsine flows. Accidental channeling then leads to oxygen concentrations higher than the real concentration in the first case, and to lower concentrations in the second case (up to a factor of 3).

PB 31 RBS Experiments on a Rough Surface with Variation of Ion, Energy and Geometry. A. BARRAGÁN-VIDAL, E.ANDRADE, J.C. PINEDA, E. PEREZ, Instituto de Física UNA de México, and F. GARCÍA-SANTIBAÑEZ, ININ, MÉXICO.--- When using Rutherford Backscattering (R3S) for analysing solids, it is well known that the shape of the spectrum is affected by the sample's topography. For the general purpose, of studying metals with some degree of damage by this technique, we have prepared a series of samples, with different rough surfaces in order to simulate the process. One of these samples consider is the surface made of the edges of a package of razor blades, with small quantities of P_t on the surface edge. To determine those conditions under which it impossible to obtain the most reliable information of surface composition and surface morphology, the following parameters were considered ion type (p,d,), energy, and geometry. The RBS experiments were complemented with PIXE. These measurements were done with two Van de Graaff accelerators, one of 700 KeV and the other of 5.5 MeV.

PB 32 The Lattice Site of Helium in Ceramic Oxides W.R. ALLEN, M.B. LEWIS and L.K. MANSUR, Oak Ridge National Laboratory.*--The lattice location of ^{3}He in sapphire (α-Al_2O_3) and magnesium oxide (MgO) has been established by techniques of ion channeling and nuclear reaction analysis. For 200 keV implantations in α-Al_2O_3 near room temperature, helium atoms prefer to locate near the octahedral interstitial site, referenced with respect to the oxygen sublattice. The occupation of this site dominates over substitutional placement in irradiation-produced vacancies or tetrahedral interstices. In contrast, a definite lattice site could not be assigned for similar ^{3}He implantations in MgO. This disparity is attributed to differences in the lattice structure of α-Al_2O_3 and MgO. In both materials, the tendency for helium to accumulate in bubbles appears to be minimal.

* Research sponsored in part by the Division of Materials Sciences, U.S. Department of Energy under Contract DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc., in part by an appointment to the Postgraduate Research Training Program under Contract DE-AC05-760R00033 between the U.S. Department of Energy and Oak Ridge Associated Universities, and in part under Contract 41B07685C between the U.S. Department of Energy and The University of Tennessee, Knoxville.

PB 33 Materials Impurity Analysis by Means of Nuclear Resonance Reactions.* R. S. HORNADY, UC/LLNL.---A beamline for automated impurity measurements is installed on the FN tandem in the Center for Accelerator Mass Spectrometry at the Lawrence Livermore National Laboratory. The major purpose of the beamline system is to determine the diffusion of water into glasses by use of the $^{19}F(p,\alpha\gamma)^{16}O$ reaction. This study is stimulated by the radiation-waste-isolation program; however, the system is applicable to studies of other impurities in many material matrices. The target wheels, each of which holds 24 samples, can be changed in less than an hour. The beamline control system both indexes the target wheel and controls the tandem energy as it steps through the requested measurement protocol. The tandem control system, in response to a request, adjusts the terminal potential and other transport elements so as to maintain constant spot size and location. Details of the installation and analysis capabilities will be presented.

*This work was performed under the auspices of the U. S. Department of Energy at the Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

PB 34 A Tritium Profiling Experiment. J.F. HARMON, S SRINIVASAN, J.M KNOX, Idaho State University.--- A technique for detecting and depth profiling T in solid materials is discussed. Based on the T(p,n) threshold reaction one is able to detect and profile T at levels ~ 10^{12}T/cm^2 in carbon at depths up to ~ 10μm. Results from several different samples are presented.

PB 35 Materials Science Application with Positrons P.L. JONES, Duke University, Durham, NC, USA.

See Session Number: EA9

PB 36 Free-Volume Properties of Polymers Probed by Positrons
Y.C. JEAN, University of Missouri-Kansas City, Kansas City, MO.

See Session Number: EA8

PB 37 WITHDRAWN

PB 38 Assessment of Nuclear Reaction Analysis For the Measurement of ^{18}O Concentration in Organic Samples, Sylvanus N. Nwosu, Department of Physics/Engineering, Xavier University, New Orleans---- Nuclear reaction analysis (NRA) was assessed as a fast and simple method of determining the natural abundance of ^{18}O in Beet sugar, L. Aspartic acid, L.glutamic acid, Cellulose and Sorbic acid. Attempts were made to determine the ^{18}O abundance of these samples relative to that of Beet sugar by determining the ratios of the reaction α-particles emitted when the samples were bombarded with a 20-30 nA current of 0.73 MeV protons. A thick target correction factor was applied to the measured ratios of reaction α-particles to account for proton energy losses through the target. Most of the samples investigated seemed to be unstable under the beam bombardment. This and other difficulties encountered during the investigation are also discussed.

PB 39 Preparation of Tantalum Oxide film Targets For Nuclear Reaction Analysis of Oxygen Isotopes in Biological Solutions

Sylvanus N. Nwosu, Department of Physics/Engineering, Xavier University, New Orleans LA A simple method of preparing Ta_2O_5 films in blood plasma, serum, and urine is devised, based on electrochemical oxidation of tantalum using a current limiting constant voltage method. Anodization was carried out at an initial current density of 10 mA/cm^2 up to a well defined anodization voltage, and a residual current density of 0.04 mA/cm^2. Although the mechanism of oxide growth in these electrolytes was similar to anodization in 3 % ammonium citrate solution of water, there seemed to be a higher oxide growth rate for anodization in biological solution (pH ~ 6.5-8.0) than water (pH ~6.4)

PB 40

HIGH RESOLUTION DEPTH PROFILING USING D(^{3}He,^{4}He)H NUCLEAR REACTION :: DETECTION OF ^{4}He AT A FORWARD ANGLE: U.K.Chaturvedi[a], *E.P.* Div.,CERN,Geneva,Switzerland; *U.Steiner, O.Zak, G.Krausch*[b], G.Schatz[b] and J.Klein, *Dept. Polymer Research, Weizmann Institute of Science, Rehovot, Israel.* High spatial resolution obtained in deuterated polymers using $D(^3He,^4He)H$ nuclear reaction analysis[1,2] is explained analytically on the basis of the kinematics of the nuclear reaction.An amplification in the energy of emitted ^4He is obtained while detecting them at a forward angle < 45°.This enhances the spatial resolution substantially *FWHM* spatial resolution of 14 and 18 *nm* (1.5 and 2.1 $\mu g/cm^{-2}$) is thus obtained experimentally at the surface using 700 and 900 *keV* ^3He beams.

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[a]This work was done during author's affiliation with Weizmann Institute. [b]Visiting from Phys.Department,Konstanz University, Konstanz,W.Germany

[1]Chaturvedi *etal., Phys. Rev. Lett.*,63(1989)616,[2] Chaturvedi *etal.*;*Appl. Phys. Lett.* 56(1990)1228

PB 41 A Nuclear Reaction Study of Nitro Diffusion into Titanium and its Relation Microhardness, L.M. Apátiga, E. Andrade, Rickards, and F. Alba, Instituto de Fisi Universidad Nacional Autonoma de Mexico. reactions $^{14}N(d,\alpha)^{12}C$ and $^{14}N(d,p)^{15}N$ were used measure the diffusion of nitrogen into titani with the beam from a 5.5 MV Van de Gra accelerator. By bombarding with 2.6 MeV deuter and observing the spectra at a laboratory angle 170°, a fairly flat region in the excitation cu of the ground state α particles is found. shape of the energy spectrum is theref indicative of the nitrogen profile, allowing study of about 10 μm from the metal surfa Titanium samples were heated in a nitro atmosphere for up to four hours at temperatu between 800°C and 1200°C. The amount of nitro diffused was then correlated to microhardn measurements.

PB 42 Ion Beam Analysis at the University Mexico, E. Andrade, Instituto de Fisi Universidad Nacional Autonoma de Mexico. Ion b analysis (IBA) facilities at the Instituto Física was restricted before 1988 to the use o 0.7 MV positive ion Van de Graaff accelerator. installation of a vertical single ended 5.5 MV de Graaff accelerator (HVEC model CN) at U.N.A has been completed and it has been operatio since 1989. This accelerator and associa equipment was obtained as a donation from R University. The different types of ion beam (p, ^{3}He, ^{4}He, ^{14}N, ^{15}N, etc.) with energies above 1 obtained with this accelerator have turned it i a very versatile tool for analyzing solids. M of the IBA techniques are availab backscattering, (p,α) and (p,γ) nuclear react resonances, (d,α) and (d,p) reactions, PIXE, e A brief summary of some of the measurements presented.

PB 43 A Neutron Generator for Thermal Neutron Activation G. A. Norton, R. D. Rathmell, P. D. Cleven and J. B. Schroeder, National Electrostatics Corp., Middleton, WI. A 1MV single ended Pelletron has been developed to be a simple, reliable source of neutrons for thermal neutron activation (TNA). The 1MV accelerator is designed to provide up to 50 μA of deuterium at the fixed energy of 1MeV to produce neutrons by the ^{9}Be(d,n) reaction with a flux up to 5 X 10^9 neutron/second. An RF ion source in the terminal has been designed for long life, trouble free operation. This system has been demonstrated to run 4000 hours without servicing. The features and operational experience will be reviewed.

PB 44 Thin Layer Activation Technique Applied to the On-Line Iron Wear Measurement of Engine Cam Nose. TOSHISO KOSAKO, HOSHIO EGUCHI, KOJI SHIDA, Research Center for Nuclear Science and Technology, The University of Tokyo, Yayoi-2-11-16, Bunkyo-ku, Tokyo, Japan, and KAZUO NISHIMURA, Central Research Laboratory, General Sekiyu K.K., Ukishima 6-1, Kawasaki-ku, Kawasaki, Japan.--- Thin layer activation technique, in which 7MeV proton beam was irradiated on the iron surface to produce a very thin (several ten μm) activated region, was applied to the on-line iron wear measurement of engine cam nose. The wearing amount of this activated part was measured using Ge-semiconductor detector by on-line and nondestructive method. The calibration curve of iron wear was obtained through the comparison of this radiometric method and the usual

electromicrometers using an iron block wear test by a polishing machine. For the application of this method to the real car engine part (engine cam nose), the data acquisition system using microcomputers was built. The wear characteristics were successfully measured and an effectiveness of this method was verified.

PB 45 Multielement analysis of Turkish Marble (ES) sampl means of FNAA and TNAA. S.DOKMEN, H.ATASOY, Y.OZBIR, G.TA Dept. of Physics Çekmece Nuclear Research and Training Ce ISTANBUL, TURKEY

Natural Eskişehir Sübrem (ES, a kind of Turkish Marble) s. were irradiated with 14.5 MeV neutrons provided by $_9$SAMES$_2$ low energy ion accelerator at a flux of about $2x10^7$ n/cm^2 by the rabbit$_{13}$system$_2$of 5 MW TR-2 reactor at a thermal fl about $2.4x10^{13}$ n/cm^{2}sec at the Çekmece Nuclear Research . Training Center.

A variety of activation, decay and count times were used determine the concentration of elements in ES and nearly elements such as, La, Ca, Si, Mn, Al, K, Na, Mg have been found by gamma-ray spectroscopic method. It is shown that is a useful material for shielding against gamma-rays and possible applications examined.

PB 46 New Neutron Generators for Industry: The GENIE Family. SERGE CLUZEAU and JEAN R. HURIET, Société SODERN, France.--Since 1962 SODERN has developed neutron generators making use of sealed tubes containing deuterium and tritium for production of "on-off" 14-MeV neutron sources. The technology gained over more than 25 years is now being applied to new high-reliability neutron generators for industry. The GENIE family is transportable equipment which is suitable for various applications depending upon the level of emission achieved. The GENIE 26 covers the 10^6 to $5x10^8$ n/s range. It has been in-plant tested over 2000 hours of continuous and pulsed emission. Some tubes, in operation for more than 5000 hours, are used for civil engineering and nuclear waste container survey. The GENIE 46 delivers up to 10^{11} n/s (nominal value). It is designed to be used up to $5x10^{11}$ with a special target cooling device under development. Until now the GENIE 46 has operated in the continuous emission mode. A pulsed mode is under development. Expected lifetime is in the range of 1000 hours at nominal emission. In between will be a GENIE 36 covering the range of 10^8 to 10^{10} n/s. All of the GENIE series use the same kind of very high voltage power supplies similar to those of X-ray machines.

PB 47 Resonance ionization mass spectrometry applied to insulating samples : problems for sputtering and for calibration.

M.F. BARTHE[1], T. GIBERT[2], B. DUBREUIL[1], R.L. INGLEBERT[1], J.L. DEBRUN[2]. 1) CNRS-CERI, 45071 Orléans (France), 2) GREMI, Université d'Orléans (France)--Ion sputtering of samples followed by laser resonance ionization and mass spectrometry is a very powerful method for trace and surface analysis. In the case of insulating samples there are charging problems during KeV ions bombardment (sputtering). To overcome this problem we have used a pulsed Ar^+ beam (15 µs pulse duration at 10 Hz). A stable photoion signal can be obtained, provided that the insulating samples are "prepared" beforehand by sputtering with a continuous argon beam and for a minimum dose of $\sim 7.10^{18}$ ions/cm^2. Calibration is not as easy as in the case of conductors, because the experimental conditions (especially the optimization of the mass spectrometer) have to be adjusted for each type of sample. For that reason, we have developped an internal calibration method : the photoion signal for the impurity of interest is compared to the signal from a major element of the matrix. Examples will be given in the case of SiO_2 and fluoride glasses.

PB 48

Boron ion implantation in YBaCuO superconducting thin films. J. Wu, Jiarui Liu, Zuhua Zhang, Y. J Zhao, N.Yu, P.Y.Hsieh and Wei-Kan Chu Texas Center for Superconductivity and Department of Physics, University of Houston, TX-77204-5506 Denes Marton, Department of Chemistry, University of Houston, Houston, TX 77204 --We have studied microstructure, annealing effect and superconductivity of YBaCuO film implanted with B ion . The degree of radiation damage was monitored by the room temperature resistance of YBCO during ion implantation. The annealing was done in oxygen atmosphere at the temperature from 400 C to 800 C. The effect of ion implantation before and after annealing has been measured with XPS, SEM and X-ray diffraction for different dosages. The T_c and J_c have been measured by a four-point probe method. The effect of boron ion implantation on YBCO will be compared with ion implantation by nitrogen, fluorine and neon ions.

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Effects of Nitrogen and Neon ion implantation to the YBCO superconductor thin films Zuhua Zhang, Jiarui Liu, Ning Yu, Ki Ma, Judy Wu, Y. J. Zhao, W. A. Lam, P.Y. Hsieh and Wei-Kan Chu. Texas Center for Superconductivity, Department of Physics, University of Houston, Houston, TX-77204. Denes Marton, Department of Chemistry, University of Houston, Houston, TX 77204 --The effects of nitrogen and neon ion implantation on thin films of YBCO superconductor have been investigated by means of SEM, XPS and in situ room temperature resistance measurement. Ion implantation was carried out at energies ranging from 50 keV to 200 keV to achieve uniform distribution of implants within the implanted layer. The ion beam current were set under 100 nA during the implantation to limit the heating effect. The XPS measurement indicate that Cu^{++} has been converted into Cu^+ and the oxygen peak became broader after the nitrogen ion implantation. Apparently chemical reaction has been induced by nitrogen ion implantation. SEM shows that, before ion implantation, the YBCO grains have sharp rectangular shape; but after ion implantation, these grains lost their sharp edges and their surfaces appears as if they have been melted. This reaction suppresses the superconductivity of the YBCO thin film. The room temperature resistance of the sample changed from 9.8Ω to several MΩ after being bombarded with $5x10^{15}$ N^+/cm^2 . Annealing in flowing O_2 can not recover the superconductivity of the nitrogen implanted sample. As a comparison, the neon ion implantation has also been studied.

PB 50

Flux pinning studies on proton irradiated YBCO thin film Yuan Jun Zhao, Jiarui Liu, Zuhua Zhang, K. Ma, Shashank Deshmakh, and Wei Kan Chu. Texas Center for Superconductivity and Dept. of Physics, Univ. of Houston, Texas 77204 5506 Radiation damage study of 200 keV proton in YBCO thin films, prepared by an Inverted Cylindrical Magnetron Sputtering system, were made as a function of fluences. The range of 200 keV proton in YBCO is about one micro-meter, much larger than thin film thickness, which is about 3000 Angstrom. So proton can transmit through film easily and leave behind only randomly localized defects. Critical current measurement by AC transport technique on ion beam etched YBCO thin films reveal the flux pinning strength.

Scanning electron microscopy (SEM) verify the clustering of localized defects and nucleation of extended defects after proton irradiation. Correlated with SEM, AC transport measurement is able to identify the flux pinning center. Broadening of resistive transition , together with X-ray diffraction tell us the crystal structure change after irradiation. Flux pinning mechanism and its correlation with radiation defect will be reported. Potential application of this study in microelectronics interconnect will be discussed.

PB 51

Fluorine ion implantation in YBaCuO Superconductor Jiarui Liu, Zuhua Zhang, J. Wu, K. Ma, Y.J.Zhao, N.Yu, P.Y. Hsieh and Wei-Kan Chu, Texas Center for Superconductivity and Department of Physics, University of Houston, Texas-77204-5506. Denes Marton, Department of Chemistry, University of Houston, Houston, TX 77204 --We investigated the annealing behavior of fluorine implants in YBCO superconductors. Resonance nuclear reaction analysis, XPS and SEM were used for characterization. YBCO superconductor thin films, prepared by inverted magnetron sputtering on various substrates, are implanted with fluorine ions at 50 keV to get the projected range of about 600 Angstroms. The degree of amorphization during the implantation has been monitored by room temperature resistance of the sample during the implantation. The fluorine distribution before and after thermal annealing have been measured by the resonance nuclear reaction, $^{19}F(p, \gamma\alpha)^{16}O$, at the proton energy of 872 keV. The possible replacement of oxygen by fluorine in YBCO have been investigated by XPS measurements. The influence of this oxygen replacement on the superconductivity will be discussed.

PB 52 Effect of Implantation Current Density on the Microstructure of SIMOX SOI. H.Yang and R.F.Pinizzotto, Center for Materials Charac., University of North Texas, and F.Namavar and E.Cortesi, Spire Corporation.--- Implantation current density is the primary experimental parameter that affects the implantation temperature. Oxygen ions were implanted into Si substrates to a total dose of $4 \times 10^{17}/cm^2$ with the current density varying from 10 to 60 $\mu A/cm^2$. Samples were examined using cross-sectional transmission electron microscopy. With an implantation current of 60 $\mu A/cm^2$, the sample surface is heavily damaged. The top silicon layer is discontinuous and contains large pits. This damage can be eliminated by covering the Si substrate with 70 nm of thermal SiO_2 before implantation. In the 10 to 50 $\mu A/cm^2$ range, the current density affects only the microstructure of the top Si layers of as-implanted samples. After high temperature annealing, the top layers are defect-free, regardless of the implantation current used. Therefore, in this current density range, the current density does not affect the microstructure of annealed samples.

PB 53 EFFECTS OF BEAM CURRENT DENSITY ON THE ELECTRICAL CONDUCTIVITY OF ION IMPLANTED POLYMERS. Y.Q. Wang, L.B. Bridwell, R.E. Giedd and M.J. Murphy, Southwest Missouri State University, Springfield, MO 65804--Several kinds of polymers were implanted by 50 keV nitrogen (N and N_2) with different incident beam densities (0.16-2.04 $\mu A/cm^2$). The resistivity was measured using a improved two-contact alumiunum evaporation method. The beam density was found to significantly influence the resistivities of implanted polymers. The temperature of the targets at the end of the implant depended more sensitively on the total fluence than beam density. While some variation of resistances of the conducting layer was observed for different implant cur
rents, no blistering of bubble formation occurred under these conditions.

PB 54 Sputtering Yield of Cobalt by Argon and Xenon Ions with Energies from 50 to 500eV*. A. K. Handoo, P. K. Ray, Tuskegee University.-- Sputtering yields of cobalt by argon and xenon ions with energies from 50 to 500 eV are reported. The ion beams, having a current density ranging from 0.015 to 0.1 mA/cm^2 at an operating pressure of 2×10^{-5} Torr, are produced by a low-energy ion gun. A radioactive tracer technique has been used for the quantitative measurement of the sputtering yield of the target material electroplated on a copper substrate.
* Supported by NASA Grant NAG8-020

PB 55 The Advanced Light Source at LBL.
A. L. ROBINSON, *Lawrence Berkeley Laboratory, Berkeley, CA.*

See Session Number: FA9

PB 56 Flash X-ray Sources Powered by Blumlein Pulse Generators
F. DAVANLOO, Center for Quantum Electronics, University of Texas at Dallas, Richardson, TX.

See Session Number: IE5

PB 57 Evaporated and Implanted Reference Layers for Calibration in Ion Beam Analysis.
U. WATJEN, CEC-JRC, Central Bureau for Nuclear Measurements, B-2440 Geel, Belgium.

See Session Number: GD8

PB 58 3 MV Pelletron Accelerator at IPAS.
E.K. LIN, Academia Sinica, Nankang, Taipei, Taiwan.

See Session Number: FD4

POSTER SESSION PB': Particle Induced X-Ray Emission (PIXE), Rutherford Backscattering and Channeling (RBS), Nuclear Reaction Analysis, Neutron Activation Analysis, Ion Implantation, Medical Applications, Accelerator Technology, Targets, Accelerator Mass Spectrometry, Detectors, and Spectrometers
(The Poster Session is split as PB and PB' for indexing purposes only. This is all one session.)
Thursday afternoon, 8 November 1990
University Union Building,
Silver Eagle Suites A, B, and C at 14:00

PB 1 The Alabama A&M University, Center for Irradiatio of Materials Laboratories. D Ila, L R Holland, H Karimi, and G. H. Jenkins, Center for Irradiation o Materials (CIM), Alabama A&M University.* I Dalins NASA-Marshal Space Flight Center, Alabama -- The CIM a AAMU has bought a NEC 2 MV 5SDH-2 Pelletron Accelerator This system produces 4 MeV (H^+) and 6 Mev (He^{++}) particles. H^+, H^-, H^0, He^{++}, and He^0 in various energie are available for irradiation damage studies, RBS Channeling analysis, and NRA. The CIM also has a 25K Curi Gamma-Cell, LEED unit, and a TPD unit. The Pelletron is i a self contained, 2500 square foot laboratory. The LEED TPD, and Gamma-Cell occupy 650 square foot in a nearb laboratory. This accelerator will be upgraded by the en of 1990 with a SNICS-II sputter ion source, large analyzing magnet, and a MeV ion implantation station. A

present we have a fully automated RC43-RBS end station with Channeling capability which will be upgraded for PIXE analysis. Results of the test runs on the current configuration will be presented, as well as the plans for the upgrades. If available, results of the upgraded capabilities will be presented.
• Supported by NASA-NAG8-115, NSF-RIMI, and AAMU

PB'2
THE DETERMINATION OF OXYGEN DISTRIBUTION IN BURIED SILICON OXIDE LAYERS BY $O^{16}(\alpha,\alpha)O^{16}$ RESONANT NUCLEAR SCATTERING. H.-S.JIN, D.Yan. Department of Physics, Brooklyn College of CUNY, Brooklyn, NY 11210. T.-M.LU. Center for Integrated Electronics, Rensselaer Polytechnic Institute, Troy, NY 12181.

The oxgen distribution in silicon on insulator (SOI) materials formed by oxygen ion implantation has been measured using $O^{16}(\alpha,\alpha)O^{16}$ resonant nuclear scattering at E_α=3.045 MeV. The sample was prepared using an oxygen ion energy of 200 KeV and a dose of $2x10^{17}$ ions/cm^2. The substrate temperature during the implantation was 200°C and the sample was post annealed at 700°C for 0.5 hour and 1100°C for 1 hour. The measured distribution was found to have three distinct regions: two connecting regions where the ratios between the atomic densities of oxygen and silicon were quantitatively measured and found to be considerably lower than that of silicon dioxide; and a separate thin layer in front of them, which is not observable in the measurements using Rutherford Backscattering Spectrometry. The results indicate that both the sensitivity to oxygen and the depth resolution have been improved.The resonant scattering has also been used to study the energy straggling of helium ions. An expression for the energy straggling as a function of the incident energy is proposed and is found to fit the measured results well.
Partially supported by PSC-CUNY Research Award #6-69375.

PB'3
The Application of Channeling to Masked Ion Beam Lithography. D.K. Allison and R.R. Texas A&M University– Various orientations of undoped single-crystal silicon examined from the standpoint of their suitability for Masked Ion Beam Lithography (M The resolution of MIBL using channeling membranes depends directly on the amou scattering in the oriented membrane. The angular distributions of protons transm through thin (< 1.0 microns) silicon crystals along primary axes and planes will be discus Half-angles were measured in the energy range of 80 to 160 keV. In particular azimuthal variation in half-angle which leads to a significant azimuthal variation in resol will be discussed. Measurements show that major planes have transmitted half ar significantly less than major axes but may suffer from a larger variation azimuthally. Fu the effect on the transmitted half-angle of a slight misalignment of the crystal with incident beam will be discussed.

PB'4 Residual Lattice Disorder in GaAs from Neutron Transmutation Doping. K. D. SEAGER and R. R. HART, Texas A&M University -- The production of lattice disorder in high-purity undoped, semi-insulating Crochralski-grown GaAs due to neutron transmutation doping has been investigated by single- and double-alignment Rutherford backscattering and channeling measurements of 120-keV protons incident on <100> GaAs. GaAs samples were irradiated for 100 and 300 hours with a thermal neutron flux density of approximately 1.8×10^{12} n/cm^2 sec and a fast neutron flux density of about 4.6×10^{12} n/cm^2-sec. The measured residual lattice disorder agreed reasonably well with the predicted displacement concentrations and was observed to be approximately uniform to a depth of 2000 Å. *In situ* isochronal annealing of the GaAs samples without an encapsulant was performed for 30 minutes at temperatures up to 550°C. The single- and double-alignment spectra for the neutron-irradiated GaAs samples which were annealed for 30 minutes at 550°C matched the spectra obtained from a nonirradiated sample within the 8% error attributable to reproducibility. The activation energy for lattice recovery of GaAs samples irradiated for 300 hours was estimated to be 0.06 eV for annealing temperatures below 350°C. For annealing temperatures above 350°C, the observed results were consistent with a published activation energy of 0.3 eV. Finally, the average number of displacements produced by 120-keV protons incident along the <100> aligned direction and random-equivalent direction in GaAs were determined.

PB'5 The Study of Magnetic Hyperfine Interaction of Rare-Earth Implanted in Iron by Low Temperature Nuclear Orientation. P.M. WALKER, A. BHAGWAT, B.D.D. SINGLETON, Department of Physics, University of Surrey, Guildford GU2 5XH, J. RIKOVSKA, N.J. STONE, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, and I.S. GRANT, Schuster Laboratory, University of Manchester, Manchester M13 9PL.--- A versatile 100kV isotope separator is operational at UK SERC's Daresbury laboratory. Ion sources suitable for implantations of various radioactive or stable isotopes are available. Extensive nuclear spectroscopic studies are being carried out at this facility, primarily by low-temperature nuclear orientation (LTNO) technique. Here, radioactive nuclei may be implanted into a polycrystalline Fe target held below 10mK by a ^{3}He/^{4}He dilution refrigerator. Because of the presence of hyperfine interaction (hfi) between the implanted nucleus (with magnetic moment μ) and the local field B_{hf} (polarised in an external field $B_{ext} \sim 0.8T$), LTNO experiments also give atomic information such as the substitutional fraction of the implanted impurity. Nuclear orientation is measured by the angular distribution (anisotropy) of the γ-rays emitted by the unstable nuclei with respect to the direction of B_{ext}. The temperature dependence of the anisotropy is related to the hyperfine interaction strength (μB_{hf}) and the fraction in "good sites". More detailed information about the distribution of implanted atoms can be obtained by nuclear magnetic resonance of oriented nuclei (NMR/ON).

PB'6 Effects of Rapid, High-dose, Elevated Temperature Ion Implantation on the Microstructure and Tribology of Ferrous Surfaces. D.L. WILLIAMSON, Dept. of Physics, Colorado School of Mines, Golden, CO, USA.

See Session Number: CC4

PB'7 High Energy Oxygen Ion Irradiation Effects on High-T_c Superconducting Films. K Oura ,H.Ohnishi,F.Shoji. Faculty of Engineering, Osaka University.——— The effect of oxygen ion implantation into thin films of the superconductor $YBa_2Cu_3O_x$ have been studied. Specimens were $YBa_2Cu_3O_x$ films of 320 nm thickness,which were grown epitaxially on MgO(100) substrates by sputtering method. Using 0.5 and 1.0 MeV oxygen ions,the superconducting transition temperature,the change in room temperature electrical properties from conducting to insulating,and the crystalline to amorphous structural transition in the films were studied as a function of ion dose in the range of $1x10^{14}$ - $4x10^{15}$ ions/cm . Monte Calro simulation of implantation and damage formation has been also performed.

PB'8 Fluorine displacements in NdF_3 films und argon ion irradiation. A. Oliver, J. Miranda and Andrade. Instituto de Física, UNAM, México.--T fluorine displacements in NdF_3 films under arg

ion irradiation at 300 keV is studied. T. fluorine and neodymium deph profiles of NdF_3 fil evaporated on carbon thick substrates determined with RBS spectra of 2 MeV $^4He^+$ ion The displacement determination of the fluorine complemented with the $^{19}F(p,\alpha\gamma)^{16}O$ nucle resonance at 340 kev. The excitation curve f this resonance suggests an accumulation fluorine atoms at greater depths. The relati displacements between the neodymium and fluori atoms lue to the argon bombardment is al calculated with the TRIM code.

PB'9

Efficiency and Radiation Hardness of Phosphors in a Proton Beam. L.R. Holland, G. M. Jenkins, Alabama A&M U., J.H. Fisher, W.A. Hollerman, Nichols Research Corp.*--A new system has beer used to measure the relative peak efficiency and radiation damage endurance of several phosphor - binder combinations on aluminum substrates. The phosphors tested are Gd_2O_2S doped with Pr, Tb, and Eu; Y_2O_2S doped with Tb and Eu; "YAG" doped with Ce; and ZnS doped with Ag. The binders used are a polysiloxane resin and sodium silicate. Binder with suspended phosphor was sprayed on the heated substrates. Tests were done in a 3MeV proton beam at the Lowell University Van de Graaff accelerator. The aluminum substrates are formed as rotatable turrets to facilitate sample changes. Light measurement was by means of a silicon photodiode with no optical filter except a glass window. Ce doped "YAG" shows the best radiation hardness, while Y_2O_2S:Eu shows the highest fluorescence efficiency.

*Supported by USA/SDC contract #DASG60-89-0127

PB'10 A Comparative Study of Damage Accumulation in GaAs, Ge, and Si During Ion Implantation.* T. E. HAYNES and O. W. HOLLAND, Oak Ridge National Laboratory, Oak Ridge, TN — The damage produced in GaAs, Ge, and Si by implantation of 100 keV Si^+ has been measured as a function of fluence, implantation rate, and temperature using ion channeling. One universal feature is the characteristic sigmoidal shape of the curve of damage vs. fluence, which may be indicative of common stages in damage development. Important differences have also been observed. At room temperature, damage production in Si was characterized by a low damage efficiency ($\epsilon \approx 0.1$ defects per atomic displacement) which was somewhat dependent on implantation rate ($\epsilon \propto J^{0.2}$). This contrasts with Ge, where ϵ was more than an order of magnitude greater ($\epsilon \approx 2.5$) and was not sensitive to implantation rate. Moreover, in GaAs, where the collision kinematics are essentially identical to Ge, ϵ was much smaller ($0.1 < \epsilon < 0.7$) and was also strongly rate-dependent ($\epsilon \propto J^{0.3}$). In addition, the temperature for the transition from large to small ϵ was found to be well-defined in both Ge (+140°C) and GaAs (-10°C) as compared with the much broader transition in Si. Implications of these similarities and differences for a comprehensive description of implantation damage in semiconductors will be discussed.

* Research sponsored by the Division of Materials Sciences, U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

PB'11 The Influence of the Process Mode of Ion Beam Assisted Deposition on Oxygen Impurities in Titaniumnitride Films W. ENSINGER, Phys.Chem.Inst., Univ. Heidelberg Evaporation of a film combined with bombardment with highly energetic ions from an ion source (ion beam assisted deposition) is performed in two ways: one is the dynamic mode where the condensing film is irradiated simultaneously, the other one is the sequential mode where a thin film is alternatingly deposited and bombarded with ions. Up to now these two process modes have not been differentiated and no differences in the coating properties have been reported. In this work the oxygen incorporation of titaniumnitride films obtained by evaporation of titanium and bombardment with nitrogen ions of an energy of 18 keV was investigated with Auger electron spectroscopy in dependence of the two process modes. Titanium is very reactive towards water and oxygen in the residual gas and easily incorporates it. Ion bombardment strongly reduces this contamination. The results show that the dynamic process generally leads to lower oxidation than the sequential mode.

PB'12 Non-contacting Position Measurement of Continuous (dc) Ion Beam. W. J. SZAJNOWSKI, Univ Surrey, U. K. - The electromagnetic induction phenomenon and stochastic characteristics of a continuous (dc) ion beam have been exploited to develop a non-contacting beam position monitor. The desired information about the beam position is extracted from random signals induced by an ion beam on suitably shaped metal electrodes. The statistical properties of induced signals are discussed in terms of their power spectral densities, probability density functions, and effective signal-to-noise ratios. Results of experiments performed with various ion beams generated by a Freeman ion source are presented. The tests carried out on an ion implanter have shown that the monitor is capable of tracking the position of an ion beam scanned linearly at frequencies up to 1000 Hz, over a 7 cm x 7 cm aperture. The position monitor does not interfere with an ion beam and can be used in an active closed-loop system to stabilize the beam position or to obtain an optimum beam scan pattern.

PB'13 Orbit Analysis of the Superconducting Storage Ring "Super-ALIS". M. NAKAJIMA, K. YAMADA, J. NAKATA, T. HOSOKAWA, NTT LSI Labs. --- A compact storage ring dedicated to X-ray lithography has been developed[1]. Superconducting bending magnets and a low-energy (15 MeV) injection scheme were adopted to reduce the size and the cost of the total system. We selected iron-yoke-type superconducting magnets (max. 3T) in order to secure a wide good field region at the injection energy and to reduce the maximum field strength at the superconducting coil. To examine the effects of the fringing field and non-linear field of the superconducting magnets (especially above 1.5 T where the iron yokes become saturated), we have developed an orbit analysis code which integrates the equation of motion numerically to derive an electron trajectory. The field distribution of the bending magnets was estimated by the three-dimensional finite-element method. As a result of the analysis, we derived stable system conditions. We have succeeded in accelerating and storing more than 100 mA at the final operating energy (600 MeV).

1) T. HOSOKAWA, et al., Rev. Sci. Instr., Vol. 60, 1779 (1989).

PB'14 A High Stability Accelerator for Ion Beam Diagnostics in a Tokamak. J.B. SCHROEDER, National Electrostatics Corporation, Middleton, WI, USA.

See Session Number: HB 5

PB'15 The LSU Electron Storage Ring Control System. B. W. Robinson, R. Legg, K. Lochtel, D. Meaney, B. Ng, J. Zhou, Babcock Division, Maxwell Laboratories, Inc., 4905 Central Ave., Richmond, CA 94804.

The control system being built to operate the LSU Light Source is based on a modular design and is almost entirely built with standard commercial hardware and software. It is designed to provide for quick and cost effective development, ease of adaptation during

commissioning, quick commissioning through the use of model support and verification software, ease of expansion to interface with optical beam lines, the layering of automated sequences and fault recovery, and ease of adaptation to new technology.

The system is built around a standard, commercially supplied, distributed, online database from Vista Control Systems. A Vaxstation is the operator interface. The Vaxstation, a microVAX, and a VME crate are the processors and are linked through Ethernet. Standard system communications software links portions of the database on different processors automatically. CAMAC, VME, and Allen-Bradley input-output standards and PLC's are used. Almost all input-output modules are also commercially supplied. All processors use standard, commercial operating systems.

The basic control system has been operating since May, 1990. Subsystem controls are to be complete by early 1991. System design philosophy, system architecture, status, and future plans are discussed.

PB'16 An RF Plasma Source for D^+ and D^- Ions. R McAdams, A J T Holmes, L M Lea, M Thornton M Irman, and J Smith. AEA Industrial Technology, Culham Laboratory, Abingdon, Oxon, OX14 3DB, England, (Euratom/UKAEA Fusion Association) — The development of an RF induction source for D^+ and D^- ions is described. The source is a large 55 x 33 x 20 cm^3 source with magnetic multipole confinement. Some of the magnets are arranged to give the magnetic field distribution to create a temperature gradient in the source necessary for preferential production of negative ions. The RF system consists of a 50 kW, 2MHz oscillator, and a matching unit to couple the power efficiently to an internal antenna. The source and its derivatives have applications in fusion, particle accelerators and plasma processing.

PB'17

Synchrotron Radiation Topography Studies of the Phase Transition in $LaGaO_3$ Crystals. *†G.-D. YAO and M. DUDLEY, Dept. of Materials Science & Engineering, State University of New York at Stony Brook, NY 11794. An investigation of the orthorhombic to rhombohedral phase transformation occurring at 145°C in lanthanum gallate has been conducted using white beam synchrotron x-ray topography (WBSXRT). The existence of this first order transition was confirmed by differential thermal analysis (DTA) and x-ray diffractometer analysis. During observation, synchrotron white beam Laue patterns were recorded in situ as a function of temperature. Before the crystal was taken through the transition, $(112)_{orth}$ type reflection twinning was found to be dominant although a small amount of $(110)_{orth}$ type twinning was also observed in the same crystal. However, beyond the transition point, not only did the structural change become evident but also twinning on $(110)_{rhom}$ planes was observed. This kind of twinning is on a scale which becomes finer as the temperature is increased beyond the transition temperature. Also this twinning gives rise to deformation of $(011)_{rhom}$ surface plane which creates problems for the potental use of this material as a substrate for superconducting epilayers.

*Topography conducted at the Stony Brook Synchrotron Topography Station on Beamline X-19C at the NSLS which is supported by DOE under contract # DE-FGO284ER45098.

†Research Supported in part by the Donors of the Petroleum Research Fund which is administered by the American Chemical Society (MD).

PB'18

Application of White Beam Synchrotron Radiation Topography to the Analysis of Twins.*†G.-D. YAO, S.Y. YOU and M. DUDLEY, State University of New York at Stony Brook. White beam synchrotron X-ray topography (WBSXRT) has been used to characterize room temperature twinning structures in lanthanum gallate and p-terphenyl single crystals. Both Laue and Bragg geometries are utilized to reveal the nature of twinning in $LaGaO_3$. WBSXRT conducted on a $(110)_{orth}$ surface lanthanum gallate crystal indicated the presence of reflection twins on $(1\bar{1}2)_{orth}$, $(1\bar{1}\bar{2})_{orth}$, $(1\bar{1}\,.)_{orth}$ and $(112)_{orth}$ planes. The geometric relationships between the twin domains and the directions of corresponding diffracted beams are clearly established. The calculated and measured values of domain image shifts on topographs due to the twins are given. Also described is the application of WBSXRT to reveal the twin law in the solution grown organic crystal p-terphenyl. The active twin plane was unambiguously determined to be $(201)_{mono}$ plane by determination of the orientation relationship between parent and twinned structures through Laue pattern analysis. For both materials, no radiation damage was observed throughout the experiments. These results demonstrate the usefulness of WBSXRT for the study of twins.

*Topography conducted at the Stony Brook Synchrotron Topography Station on Beamline X-19C at the NSLS which is supported by DOE under contract # DE-FGO284ER45098.

†Research Supported in part by the Donors of the Petroleum Research Fund which is administered by the American Chemical Society (MD).

PB'19 Computer Automated Goniometer for Ion Beam Channeling. P. Y. VanStaagen, J. R. Williams and P. A. Barnes, Auburn U. -- A Custom Goniometer Systems Model TPV goniometer has been automated for ion channeling experiments using an IBM-AT personal computer, a Galil motion control system and a Nucleus PCA-8000 multichannel analyzer board. The system software has been written specifically for channeling experiments conducted in our laboratory; however, the software is generally applicable for other RBS experiments. Features of the system include coarse and fine scan capabilities for the location of planar minima, an automatic channel location routine and good graphics output support. The results of calibration measurements with this system will be presented and compared with the predictions of channeling theory.

*Work supported by the SDIO Office of Innovative Science and Technology through Contract # DNA001-85-C-0183.

PB'20 Description of the Argonne National Laboratory Target Making Facility* GEORGE E. THOMAS and JOHN P. GREENE, Argonne National Laboratory, Physics Division, 9700 S. Cass Avenue, Argonne, IL 60439 USA. A description is given of some recent developments in the target facility at Argonne National Laboratory. Highlights include equipment upgrades which enable us to provide enhanced capabilities for support of the Argonne Heavy-Ion ATLAS Accelerator Program. Work currently in progress is described and future prospects discussed.

*This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract No. W-31-109-ENG-38.

PB'21 Design of 10 T Superconducting Wiggler for Angiography. S. SUGIYAMA, T. TOMIMASU, T. YAMAZAKI, H. OHGAKI, H. ONUKI, M. MIKADO, K. YAMADA, M. CHIWAKI, R. SUZUKI, M. KOIKE, Electrotechnical Laboratory, and T. KEISHI, Y. HOSODA, Sumitomo Electric Industries. --- The development of a 10 T superconducting wiggler for angiography is in progress at 800 MeV electron storage ring "TERAS" in Electrotecnical Laboratory. Preliminary design of the wiggler has been carried out. The magnet structure consists of a main magnet with nominal field strength of 10 T, and two auxiliary magnets operated at 5.6 T. The coils are racetrack shaped with a cross sections of 260 mm high and 190 mm wide. The distance between the main and auxiliary magnets and the size of the magnetic gap are 230 mm and 30 mm, respectively. The maximum horizontal displacement peaks at 5.0 mm at the point where the magnetic field reachs 10 T. The three-pole superconducting horizontal wiggler operated on the 800 MeV storage ring provides synchrotron radiation with a critical energy of 4.3keV. For a current of 300 mA, the central brilliance at 36.6 keV is computed to be 1.46×10^{10} photons / sec $mrad^2$ 0.1% bandwidth.

PB'22 Computer automation of a small Tandem controls, G.SPADACCINI, F.TERRASI, M.VIGILANTE, L.CAMPAJOLA, B CORTESE, Dip.Scienze F'siche-Univ. Napoli (Italy) ---- A distributed system based on intelligent substations and a central MacIntosh II console has been designed to perform automatic monitoring and control of the HVEC Model TTT-3 Tandem of our University. Each substation is a crate containing a G-64 bus, a 6809 CPU and several specific interfaces connected to various accelerator devices (e.g. vacuum meters, valve -, quartz- and faraday cup actuators, magnet supplies and related field meters and so on). Communications between peripheric stations and centrale console are supported by a low cost optical link. All interfaces are commercial ones, except a few designed for the purpose, particularly an ADC board which performs in hardware a conversion of the digitized data in absolute value according to a previously stored table. Modular software has been developped to obtain user-friendly system interaction, taking advantage of the graphic interface of the MacIntosh.

PB'23

Beam Structure Studies of Low Energy Ion Beams * K Saadatmand, J D Schneider C Geisik & R R Stevens, Jr., Los Alamos National Laboratory The ion beam structure at various axial positions along the beam transport line has been monitored and studied utilizing a fluor screen and a video camera Fluor material is aluminum oxide that is plasma-jet-sprayed onto the surface of an aluminum or a water-cooled copper substrate. The visual representation of the beam structure is digitized and enhanced through use of false-color coding and displayed on the TV monitor for the on-line viewing of the experimentalist. Digitized information is also stored for farther off-line processing and extracting more information about the beam such as beam profiles. This inexpensive and effective diagnostic enables the experimentalist to observe in real time the beam response (such as evolution of the beam structure, shifts in the beam intensity at various spatial location within the beam perimeter, and shifts in the beam center and position) to parameter changes. Initial operational results will be presented.

*Work supported and funded by the Department of Defense, US Army Strategic Defense Command, under the auspices of the Department of Energy.

PB'24 Success with an Automated Computer Control System.* M. L. ROBERTS, T. L. MOORE, UC/LLNL.--- LLNL has successfully implemented a distributed computer control system for automated operation of an FN tandem accelerator. The control system software utilized is the Thaumaturgic Automated Control Logic (TACL) written by the Continuous Electron Beam Accelerator Facility and co-developed with LLNL. Using TACL, accelerator components are controlled through CAMAC using a two-tiered structure. Analog control and measurement are at 10 or 16 bit precision as appropriate. Automated operation has been implemented for several nuclear analytical techniques including hydrogen depth profiling and accelerator mass spectrometry. An additional advantage of TACL lies in its expansion capabilities. Without disturbing existing control definitions and algorithms, additional control algorithms and display functions can be implemented quickly. Details of the control system and its capabilities will be presented.

*This work was performed under the auspices of the U S. Department of Energy at the Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

PB'25 Performance study of superconducting bending magnets with iron in a compact synchrotron light source, B. KREVET, H.O. MOSER, Kernforschungszentrum Karlsruhe, Germany --- Superconducting bending magnets with iron have found widespread use in existing and planned storage rings. Besides the contribution to the field amplitude and the reduction of stray field the iron can also influence the focusing and the nonlinear behaviour of a magnet. The contribution of the iron shield will depend on its geometry and on the total field level. A study of these influences is not only necessary to avoid performance constraints, but may in addition be used to get a better performance. The results presented refer to a conceptual design of a compact light source at Karlsruhe and show that properties like the dynamic aperture can be improved through the choice of the iron geometry, in particular at lower fields.

PB'26 A warning sign and safety interlock system for an NEC 5SDH accelerator, JAMES R. HUDDLE, JEFF VANHOY, AND F.D. CORRELL, U.S. Naval Academy, Annapolis, MD.---Safety is of utmost concern in an undergraduate teaching laboratory. In this paper, we describe a system we have designed and assembled which is intended to protect users of a small tandem accelerator from serious exposure to ionizing radiation. This goal is complicated by the fact that our accelerator, control console, and data-acquisition area are all contained in a single room. In our system, commercially-available gamma and neutron monitors, illuminated warning signs, and magnetic door switches are combined with a custom-built interlock chassis and a simple modification to the accelerator's chain motor power contactor. A key switch prevents unauthorized personnel from energizing the chain. Warning signs above the entrances to the accelerator room indicate one of three operating conditions: accelerator off, chain power on, and radiation warning (radiation levels above 0.1 mR/hr). If radiation levels in the room exceed 2 mR/hr, power to the chain motor is cut off. Further, chain power is also cut off when an accelerator room door is opened, unless the operator deliberately and temporarily overrides the system to permit authorized entrance or exit.

PB'27

5MV 30mA Industrial Electron Beam Processing System. Y.Hoshi NHV America, Westford, Mass. K.Mizusawa Nissin-High Voltage, Kyoto, Japan.----Industrial electron beam processing systems have been in use among various application fields such as to improve heat resistivity of wire insulation, to control quality of automobile rubber tires and melt index characteristics of PE foams, and to cure paintings or printing inks. Recently,there comes up a need for electron beam with energy higher than 3MV in order to disinfect salmonella in chicken meat, to kill bugs in fruits or to sterilize medical disposables. To meet this need we developed a 5MV 30mA electron processing system with a X-ray conversion target. The machine was tested in NHV's plant in kyoto at continuous operation of full voltage and full current. It proved very steady operation with high efficiency as much as 72%. Also, the X-ray target was tested at continuous run of 5MV 30mA(150kW) and proved to be viable in industrial utilization. This paper introduces the process and the results of the development.

PB'28 Evaporation Techniques for Preparing Rare-Earth Targets* JOHN P. GREENE and GEORGE E. THOMAS Argonne National Laboratory, Physics Division, 9700 S. Cass Avenue, Argonne, IL 60439 USA. The preparation techniques for producing nuclear targets of the rare-earth isotopes depends greatly upon the physical properties of the particular rare-earth element. In most cases the isotope is supplied in the oxide form which then requires reduction to obtain the metal. Collection efficiencies will be discussed as this is of vital importance when considering the price and availability of the isotopic material.

*This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract No. W-31-109-ENG-38.

PB'29 Interference Effects in X-ray Transition Radiation with a 500 MeV Electron Beam, P. GOEDTKINDT, CEC, JRC, CBNM Geel 2440, Belgium, X. ARTRU, IPN-Lyon, Villeurbanne, France, P. DHEZ, LURE and LSAI, Orsay, France, M. JABLONKA, DPhN/STAS - CEN Saclay, France, N. MAENE, F. POORTMANS, SCK/CEN, Mol 2400, Belgium, J.-M.

SALOME, CEC, JRC, CBNM Geel 2440, Belgium, and L. WARTSKI, IEF Lab, CNRS, Orsay F-91405. Measurements of multifoil interference effects in Transition Radiation were performed at the Accelerateur Lineaire de Saclay (ALS) with electron energies between 400 and 575 MeV. Angular distributions of radiation produced by stacks of foils of various thicknesses, spacings and materials were registered by means of a PCD linear image sensor. This detector is sensitive in the 1-10 keV photon range. Stacks of up to 10 foils of kapton (7.6 μm thick), mylar (2.5 μm to 5 μm), aluminium (1.5 μm) and copper (2.5 μm) were investigated. Spacings from 115 μm to 345 μm were chosen for the study of many foil interference. For comparison, the incoherent superposition was measured with much larger foil spacing (1.5 mm). Despite the large bandwidth of the detector, clear peaks in the angular distribution were observed, whose positions varied with foil spacing and electron energy in accordance with theory. This demonstrated that multifoil interference can be important in applications such as microlithography.

PB'30 Improvements on the Performance and Capabilities of a 2 MV Van de Graaff Accelerator, S. FUELLING, M. BAILEY, M. ROTTMANN and R. BRUCH, University of Nevada, Reno. -- The existing 2 MV Van de Graaff accelerator has been improved for high resolution absolute photon and electron emission cross section measurements following ion-atom and ion-molecule collisions. Such accurate studies require high beam currents, typically 1 - 20 μA, small beam diameters (d ≤ 1.5 mm) and long term stability of the machine over a wide range of atomic and molecular projectiles, charge states and impact energies. We present here some of our inexpensive yet very effective designs for a SF_6 recycling system with a nearly complete recovery, terminal voltage and slit controller, magnetic quadrupole doublet lens plus electronic focussing and steering unit, various high voltage power supplies and column resistor replacements as well as a gas stripper for the production of multiply charged ions.
*Work supported in part by Hewlett Packard, Xerox, Lockheed, Edwards High Vacuum, MKS, Granville-Phillips and Bentley Nevada Corp.

PB'31 Application of RF Superconductivity to Linear Accelerators for High-Brightness Ion Beams. J.R. DELAYEN, C.L. BOHN and C.T. ROCHE, Argonne National Laboratory, Engineering Physics Division, 9700 South Cass Avenue, Argonne, IL 60439, USA.--- A development program is underway to apply rf superconductivity to the design of continuous-wave linear accelerators for high-brightness ion beams. The key issues associated with this endeavor have been delineated in an earlier paper.[1] Considerable progress has been made both experimentally and theoretically to resolve a number of these issues. Recent experiments indicate that superconducting accelerating structures can provide higher cw gradients and accelerate higher cw currents than is possible with normal conducting structures. In this paper we summarize this progress. We also identify current and future work in the areas of accelerator technology and superconducting materials which will confront the remaining issues and/or provide added capability to the technology.

[1]J.R. Delayen, "Application of rf Superconductors to Linacs for High-Brightness Proton Beams", Proceedings of the Tenth International Conference on the Application of Accelerators in Research and Industry.

PB'32 Initial Operation of a New Plasma Source Ion Implanter, J. R. Conrad, University of Wisconsin-Madison.-- We report the initial results of a new Plasma Source Ion Implantation[1] (PSII) device for surface modification of industrial scale components. PSII is a non-line-of-sight technique for surface modification of materials which is optimized for ion implantation of non-planar targets. In PSII, targets to be implanted are placed directly in a plasma source chamber and are then pulse-biased to high negative voltage (10-100 kilovolts in our experiments). A thick, ion matrix sheath forms around the target, and ions accelerate through the sheath drop and bombard the target from all sides simultaneously without the necessity of target manipulation. The system has a cubical vacuum chamber with an inside dimension of 30 inches, substantially larger than the original PSII chamber, which is a cylinder 18 inches high and 14 inches in diameter. Access for diagnostics and co-deposition sources for ion beam enhanced deposition and ion beam mixing is provided by four 8" Conflat flanges and 38 Kwik-Flange ports. Plasma is generated with a LaB_6 cathode. The system, which operates under microprocessor control, has both turbomolecular and cryogenic pumping to provide shorter pumpdown times compared to the original chamber. The design accommodates toxic, corrosive and flammable gases for implantation of a wider variety of ion species.
[1]J. R. Conrad, J. L. Radtke, R. A. Dodd, F. J. Worzala, N. C. Tran, J. Appl. Phys. 62, 4591 (1987).

PB'33 Data Acquisition and Control for the triple Ion-Irradiation Facility.* R. A. Buhl, Oak Ridge National Laboratory. A data acquisition and control system was developed to assist in the routine operation of the Oak Ridge National Laboratory's Triple Ion Irradiation Facility. The sophisticated multi-purpose ultra high vacuum chamber system is used to study the interaction of accelerated ions from up to three Van De Graaf accelerators with the near-surface region of solid targets. The basic hardware for this system is a Hewlett Packard AT compatible PC connected via a IEEE-488 interface to a Hewlett Packard HP3852A controller with a HP3853A extension. A menu driven touch screen is used to enter commands. A voice synthesizer is employed to audible alert the operator of impending problems. Signal from beam profile monitors are used for live time beam integration. Data is stored to floppy disk and the screen is updated on a one minute interval during a run. *Research sponsored by the Division of Material Sciences, U.S. Department of Energy, under contract DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

PB'34

MAFIA Study of the RFQ1 Accelerator. P.P. ADAMS, M.S de JONG, AND R.M. HUTCHEON, Chalk River Nuclear Laboratories. ---

We modelled the RFQ1 accelerator using the rf code MAFIA. The effects that vane coupling rings and other elements of the model have on the resonant frequency agree reasonably well with measurements. The MAFIA model predicts elevated power dissipation on the vane coupling rings and on the racetrack seal at the base of the vane end. These predictions are consistent with observations of the effects of local heating.

PB'35

MAFIA Analysis of the Effects of Coupling Slots in Linacs. P.P. ADAMS, J. UNGRIN, AND M.S. de JONG, Chalk River Nuclear Laboratories. ---

We have used the 3D rf code MAFIA to analyze on-axis-slot-coupled π/2-mode standing-wave linac structures. The model predicts electric and magnetic quadrupole fields in accelerating and coupling cavities. The net effect is to produce an elliptical accelerated beam, as has been observed. Aligning the coupling slots in the opposite walls of the accelerating cavity is predicted to greatly reduce the effect of the quadrupole fields. Experimental confirmation of this design concept is planned.

PB 36 Electrostatic Accelerators with High Energy Resolution. T. UCHIYAMA, Y. AGAWA, T. NISHIHASHI, N. UEDA, R. FUKUI, S. SEKI, H. YAMAKAWA, ULVAC Japan Ltd., 2500 Hagisono, Chigasaki, Kanagawa, 253 Japan, and A. ISOYA, Research and Development Institute and Department of Physics, Tokai University, 1117 Kitakaname, Hiratsuka, Kanagawa, 259-12 Japan.--- Several models of electrostatic accelerators based on rotating disks (Disktron) have been manufactured for various ion beam applications in surface analyses and implantations. The high voltage terminal of the disktron with terminal voltage up to 500 kV is open in air, while the generator part is enclosed in ceramic or FRP vessel filled with SF_6 gas. The 1 MV model is completely enclosed in a steel vessel. Compact tandem accelerators of pellet chain type with terminal voltage of 1.5 MV have also been manufactured. Good energy stability of these accelerators, typically in the range of 10^{-4}, has proved to be quite favorable for applications in precise studies of material surfaces including the use of microbeam techniques.

PB'37 Triply-Ionized Molecules from a Tandem Accelerator.* D L. WEATHERS, F D. MCDANIEL, S. MATTESON, and J. L. DUGGAN, *Dept. of Physics, University of North Texas, Denton, TX 76203*, J. M. ANTHONY, *Central Research Lab., Texas Instruments Inc., Dallas, TX 75265*— Beams of $^{10}B^{11}B^{+++}$ ions have been observed to emerge from the 9SDH-2 NEC Pelletron Tandem Accelerator at UNT. $^{10}B^{11}B^{-}$ molecules were injected into the accelerator with its terminal at a potential of 1.5 MV, and positive ions emerging from the machine were analyzed for momentum per charge and energy per charge before being stopped in a solid state particle detector for total energy analysis. Intensities of singly-, doubly-, and triply- charged molecules were measured as a function of N_2 gas pressure in the accelerator terminal stripper canal. These intensities were found to exhibit the same qualitative behavior for all charge states, with the number of triply-charged molecules consistently a factor of $\sim 10^4$ less than for the other charge states. No quadruply-ionized molecules were seen. The observation of particles corresponding to the breakup products of the multiply-ionized molecules indicates that these species were decaying in flight, and are apparently metastable with lifetimes of $\sim \mu s$. Implications of the existence of such triply-charged molecules for accelerator mass spectrometry are discussed

* Work supported in part by the State of Texas Coordinating Board, Texas Instruments Inc., NSF, ONR, and the Robert A. Welch Foundation.

PB'38 **The heavy ion injector at the Zürich AMS facility.** H.A.Synal, G.Bonani, W.Wölfli; Institute of Intermediate Energy Physics, ETH-Zürich; R.C.Finkel, M.Suter; Paul Scherrer Institute, c/o ETH-Zürich -- A heavy ion mass spectrometer has been set up at the low energy side of the ETH/PSI-AMS facility. The new system provides better resolution for all measurements and expands the accessible mass range to the upper end of the periodic system. To achieve high mass resolution, a combination of energy and momentum filters has been used. A 90° spheric electrostatic analyzer (r=75cm) acts as an energy filter and is followed by a double focusing 90° dipole magnet (r=60cm, m×E=12.5 MeV amu). The magnet is supplied with a fast beam pulsing system for quasi simultaneous injection of all isotopes of an element. The system is now used for measurements of the heavy radioisotopes ^{36}Cl and ^{129}I. It opens the possibility for studies with heavy stable isotopes. The details of the experimental set up and first results of measurements are discussed.

PB'39 AMS at the CSIRO HIAF Laboratory. S.H. SIE, G.F. SUTER, C.G. RYAN, CSIRO Exploration Geoscience, N. Ryde, NSW 2113, Australia.--- The CSIRO Heavy Ion Analytical Facility is a 3 MV Tandetron based laboratory dedicated to applications in minerals exploration research. Facilities include a nuclear microprobe, and recently the Accelerator Mass Spectrometry system became operational. The first stage of the AMS system enables dating and tracer studies based on cosmogenic radioisotopes C14 and Be10 from bulk samples. Further development will be directed towards in-situ microanalysis of ultra-traces (parts-per-billion level) of heavy elements (e.g. Au, PGE) in mineral samples. Initial results in C14 application will be presented.

PB'40 A Dedicated AMS Facility for ^{3}H and ^{14}C.* M. L. ROBERTS, J. R. SOUTHON, J. C. DAVIS, I. D. PROCTOR, UC/LLNL.---Accelerator mass spectrometry is a high sensitivity technique for the detection of numerous long-lived radionuclides at extremely low concentrations. The present use of this measurement tool is primarily in archaeology and the geosciences. However, novel applications and technological advancements that can have a significant impact on both biomedical research and clinical procedures and environmental investigations have been identified. We are studying a small spectrometer for the simultaneous injection and detection of both hydrogen and carbon radioisotopes. Details of the concept and experimental tests of it to date will be presented.

*This work was performed under the auspices of the U. S. Department of Energy at the Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

PB'41 Electrostatic Octupole Elements for MeV-Ion Applications S. MATTESON, D.K WILSON, D L WEATHERS, F.D. MCDANIEL, J.L. DUGGAN, Center for Materials Characterization, University of North Texas, Denton, Texas, J.M ANTHONY, Texas Instruments Incorporated, Dallas, Texas. --- In the application of a tandem electrostatic accelerator (NEC Pelletron) to accelerator mass spectrometry, the need for various optical elements such as dipoles, quadrupoles and low aberration ion optical lens systems has arisen Cylindrical configurations of eight electrodes have been shown in the past[1] to provide many desirable features. These optical elements are loosely referred to as "octupoles." In this work we present new designs using cylinders in a cylindrical arrangement which provide, with various voltage excitations superimposed dipole deflection, quadrupole focusing and octupole correction for spherical aberration. A novel but simple and precisely reproducible mechanical design is presented along with experimental verification of the predictions of numerical solutions for the optimum geometries.

[1] J Kelly, in Advances in Electronics and Electron Physics (L. Marton, ed.) vol. 43 (1977) pp. 43-138.

PB 42 An Electrostatic Lens and Wien Velocity Filter System as an Ion Beam Monochromator, J. S. ALLEN and T. J. KVALE, University of Toledo.*--The ion beam monochromator system on the University of Toledo Negative Ion Accelerator is described. The ion beam monochromator consists of a multi-cylinder, electrostatic lens and a Wien velocity filter. The ions extracted from the accelerator's duoplasmatron ion source are decelerated by the electrostatic lens before passing through the Wien filter. By decelerating the ions to a sufficiently low energy it is possible to obtain an ion energy resolution of about 1 eV FWHM at the exit of the Wien filter. The electrostatic lens has been designed and modelled with the aid of an ion trajectory tracing program (SIMION[1]). The lens has been designed to allow a deceleration voltage ratio of 1/100.

*Supported by US DOE Grant DE-FG05-88ER13971

[1] D. A. Dahl and J. E. Delmore, Idaho National Engineering Laboratory, EGG-CS-7233, Rev. 2 (1988).

PB'43 A TOF Mass Spectrometer for Studies of Positron-Molecule Interactions
L.D. HULETT, Oak Ridge National Laboratories, Oak Ridge, TN, USA.

See Session Number: DD 8

PB'44 Application of Channeling STIM (Scanning Transmission Ion Microscopy)
M. CHOLEWA, Micro Analytical Research Centre, School of Physics, The University of Melbourne, Parkville, Vic.3052, Australia.

See Session Number: FC 7

PB'45 **LEHIFI: a Low Energy Heavy Ion Fragment Identifier.** M. L. MUGA, Z. MILOSEVICH, R. L. COLDWELL, and F. E. DUNNAM, *U. of Florida*.--LEHIFI is a compact multi-stage particle detector utilizing a series of thin-film scintillators (tfd's) [1] followed by a surface-barrier detector in an "E-ΔE" configuration, with which we have been able to distinguish the atomic number Z of fission fragments with an uncertainty of ± 0.3 to ±2 units, depending upon the mass and energy range. The specific luminescence of ionizing particles of energy E passing through the tfd is directly proportional to the transiting particles' specific energy loss ΔE/Δx. The "ΔE" pulse from each tfd is used as a timing signal to measure the particle's velocity as it passes between LEHIFI elements. Specific luminescence measurements indicate that above about 2.5 MeV/nucleon the spread in ΔL/Δx corresponds to an uncertainty of ± 0.3 Z for intermediate-mass ions. Near 50 amu, resolution degrades to about ±2 Z . Multiple tfd's will improve this response with independent data on each transiting particle. Continuing investigations [2] include measurement of response to Cf-252 fission fragments in coincidence with the prompt gamma-rays emitted from the fragments, to selectively identify the transiting particles.

Supported in part by USDOE Grant # DE-FG05-84ER40149 and the University of Florida Division of Sponsored Research

[1] M. L. Muga and H. E. Taylor, U. S. Patent # 3,567,925 [March 1971]
[2] Z. Milosevich, M. S. Thesis, University of Florida , 1988 (unpublished)

PB'46 **Charge Collection Measurements and Theoretical Calculations for Partially Depleted Silicon Dev'ces*;** W.G. Abdel-Kader, S.S. El-Teleaty†, and P.J. McNulty, Physics Dept., Clemson University, Clemson, SC29634-1911 Charge collection measurements were carried out using partially depleted silicon devices. The amount of charge collected at a given junction can be used to estimate the thickness of the sensitive volume to be associated with that junction. The assumption that the charge generated within this sensitive volume equals the charge collected at the junction forms the basis of current methods of predicting SEU rates for components exposed to the natural radiation environments of space. A simple analytic expression [1] provides reasonable agreement with the experimental results of charge collection with alphas. The dimensions estimated from this expression for some partially depleted junctions are used in Monte-Carlo simulations of charge generation in the sensitive volumes through protons-induced spallations reactions. The results were found be in good agreement with measured charge collection spectra obtained by exposing the junctions to energetic protons incident at various energies. * Work supported by the Air Force Geophysics Laboratory and the Defense Nuclear Agency.
† Presently at King Saud University, Riyadh, Saudi Arabia.
[1] P. J. McNulty, W.G. Abdel-Kader and J.E. Lynch, accepted for publication in Nuclear Instruments and Methods.

PB'47 Pulse Height Defect of Low Energy Ions in Surface Barrier Detectors. H. FUNAKI, M. MASHIMO, M. SHIMIZU and E. ARAI, Tokyo Institute of Technology, Japan -- The pulse height defects (PHD) of silicon surface barrier detectors (SBD) were measured for protons (control) and heavy ions (^{16}O, ^{19}F, ^{28}Si, ^{35}Cl and ^{81}Br) in the incident energy range from 1 to 8 MeV. The results for ions heavier than 28 were generally consistent with data of Kaufman et al.[1] For light heavy ions such as ^{16}O or ^{19}F, however, the PHD values were smaller than ref. 1 by a factor of 10 at energies of a few hundreds in LSS dimensionless units. To explain this discrepancy, we have calculated the distributions of energy loss and the number of ion pairs in the SBD by the TRIM85 code. The result shows that the contributions from nuclear stopping power and the window were small in this energy region. We will discuss at the conference the contribution from residual (recombination) defect as a function of the ionization density.
[1] S.B. Kaufman, et al., Nucl. Inst. and Meth. 115, 47 (1974)

PB'48 Target Station for Production of PET Radionuclides. RICHARD M. LAMBRECHT, MUNAWWAR SAJJAD, LAVON BENNETT, King Faisal Specialist Hospital and Research Centre, Saudi Arabia.— Positron emission tomography (PET) in combination with a regional or hospital-based compact cyclotron is now accepted both as a clinical tool for patient management, and for biomedical research. A flexible PET program requires: (1) on-line availability of the short-lived gases ^{15}O, ^{13}N and ^{11}C for direct patient use or as precursors required to synthesize radiopharmaceuticals; and (2) either more than 1 beam port or the ability to rapidly switch targets to assure continuous on-line availability and delivery of the needed radionuclide. We designed and fabricated a remotely controlled target changer that operates horizontally on a single line beam to sequentially position up to 4 gas targets. The target station provides common target water cooling for each target. Individual targets are controlled by pneumatic pins driven by gas pressure. The assembly will be described with special reference to requirements of a hospital-based cyclotron/PET program.

PB'49 Proton Radiotherapy: Fixed vs. Variable Energy Accelerators. K. P. GALL, B. GOTTSCHALK, A. M. KOEHLER, J. M. SISTERSON, M. WAGNER Massachusetts General Hospital, and the Harvard Cyclotron Laboratory Several centers around the world are now considering construction of hospital based proton radiation therapy facilities. The accelerator for such a facility should have a maximum energy of about 250 MeV, and beam current of at least 20 nA. These specifications are readily met by several types of accelerator including isochronous and frequency modulated cyclotrons, synchrotrons, and linear accelerators. The treatment prescribed for each patient requires a maximum depth of penetration a well as an extent in depth determined by the thickness of the tumor. This can be done either passively by means of absorbers or actively by adjusting the energy of the extracted beam We consider advantages and compromises associated with fixed energy, step wise choice of energy, and continuously variable energy in order to help select the appropriate accelerator design.

PB'50 An Automated Beam Shutter Control System. C.J. MCKINNEY, J.L. NEED, Department of Radiology, Duke University Medical Center. —In order to assist with quality control record keeping and to alleviate operator intervention during radiopharmaceutical production, a computer controlled system for controlling the beam shutter on a manually operated CS-30 cyclotron has been designed and implemented. The system allows the operator to preselect the total charge or total bombardment time desired. The system prints a permanent record of the run index number,

date, start time, stop time, elapsed time, and total charge. In addition, the unit also monitors and provides a printed record of the radiation level, as read by an ion chamber in the radiopharmaceutical production unit, to verify the amount of activity transferred from the target to the hot lab.

PB'51 Focusing of a Megavoltage Electron Beam in a Medical Accelerator. - - P. FRIEDRICHS, G. KONRAD, Siemens Medical Laboratories. - Due to packaging constraints in the radiotherapy machine gantry of Siemens Mevatrons, the electron linac used in the lower energy models has a long drift tube between the end of the linac and the 270° achromatic bend assembly. Space charge spreading causes the electron beam to grow so that it frequently impinges upon the entrance hole to the bend assembly. Space and weight constraints prevent the use of a solenoid and associated power supplies. A permanent magnet structure has been designed that is effective in reducing the intercepted beam by at least 40%. Trajectory calculations obtained through use of the electron linac design code PARMELA are in good agreement with the experimentally observed results. Supporting data for several electron energies over the normal operating range of 4 to 6 MV photons from these Mevatrons is presented.

PB'52 Consequences of Electroplated Targets on Radiopharmaceutical Preparation. R. FINN, S. TIRELLI, H. SHEH, A. KNOTT, A. GELBARD, S. LARSON. Memorial Sloan-Kettering Cancer Center, New York, N.Y.--- The staff of the cyclotron facility of Memorial Sloan-Kettering Cancer Center is involved in a comprehensive radionuclide preparation program which culminates with the formulation of numerous requested short-lived, positron emitting radiopharmaceutical agents for clinical investigation. Both the produced radionuclide as well as the final radiolabeled compound are subjected to stringent quality assurance standards including both radiochemical and chemical purity. The subtle chemical consequences resulting from the irradiation of a nickel-plated target for nitrogen-13 production serves to emphasize some of these potential technical difficulties.

PB'53 Rededication of the Memorial Sloan-Kettering Cancer Center Cyclotron. R. FINN, A. KNOTT, H. SHEH, S. TIRELLI, S. LARSON, J. FISSEKIS, J. LAUGHLIN. Memorial Sloan-Kettering Cancer Center, New York, N.Y.--- The Memorial Sloan-Kettering Cancer Center cyclotron, (Model CS-15 manufactured by The Cyclotron Corporation) is one of the earliest research accelerators dedicated to serve a medical complex. It has recently undergone an extensive reconditioning and refurbishment effort to insure the continued application of the cyclotron as a key resource for the center's clinical research effort into tumor growth, metabolism and pharmacological responses. With improvements to several subsystems of the cyclotron including the high vacuum system, ion source gas supply system, and the harmonic control system completed, and several other subsystems being rebuilt such as the targetry system, the result has been enhanced operational performance and reliability as well as improvements to the radiochemical production. Technical difficulties both anticipated and/or uncovered during the refurbishment shall be detailed.

PB'54 Proton Radiation Therapy: Fixed vs. Variable Energy Accelerators. K.P. GALL, B. GOTTSCHALK, A.M. KOEHLER, J.M. SISTERSON, and M. WAGNER, Massachusetts General Hospital Department of Radiation Medicine, and the Harvard Cyclotron Laboratory.--- Several centers around the world are considering construction of hospital based proton radiation therapy facilities. The accelerator for such a facility should have a maximum energy of about 250 MeV, and beam current of at least 20 nA. These specifications are readily met by several types of accelerator including isochronous and frequency modulated cyclotrons, synchrotrons, and linear accelerators. The treatment prescribed for each patient requires a maximum depth of penetration as well as an extent in depth determined by the thickness of the tumor. This can be done either passively by means of absorbers or actively by adjusting the energy of the extracted beam. We consider advantages and compromises associated with fixed energy, step wise choice of energy, and continuously variable energy in order to help select the appropriate accelerator design.

PB'55 Cyclotron Production of Medical Radionuclides.
R.M. LAMBRECHT, King Faisal Specialist Hospital and Research Centre, Saudi Arabia.

See Session Number: GC 5

PB'56 Study of Deuterium Diffusion Behavior in SiO_2 by means of $D(^3He,p)^4He$ Reaction.
Q. QIU, Fraunhofer-Arbeitsgruppe fur Integrierte Schaltungen, Erlangen, FRG.

See Session Number: BE 5

PB'57 Self-Consistent Multi-Species Fluid-Poisson Modeling of LBL Negative Ion Source Data. JOHN L. ORTHEL, G. H. Gillespie Associates* --- The modeling of various aspects of recent LBL volume negative ion source data using a self-consistent multi-species fluid-Poisson code is described. First, a brief description of the code and the physics equations and numerical technique is presented. Then the interdependence of plasma density, current density, nonuniformities, extraction voltage, cross-field transport, electron suppression, space charge, aperture size (and number of apertures in the case of multiaperture extraction), perveance, neutral flow and stripping, and emittance are explored using the code. Various submodels for surface and volume production, transport, and destruction of the negative ions and electrons are examined and the results are compared with the data.

*Supported by the U. S. Army Strategic Defense Command, Huntsville, AL and Teledyne Brown Engineering, Huntsville, AL under contract numbers DASG60-87-C-0042/SC-7638.

PB'58

A Multipurpose Experimental Irradiation Plant. A. STRASSER, F. KUNTZ, E. MARCHIONI, AERIAL Strasbourg and R. SELTZ, Centre de Recherches Nucléaires IN2P3 and Université Louis Pasteur STRASBOURG (France) -- A 2.5 MeV Van de Graaff accelerator is used as an electron source of a multipurpose beam processing facility. Specialized equipment has been developed : 20 Hz scanning device, multiwire beam shape analyzer, optical coder controlled conveying system, scattering foils for dose uniformity improvement, Cu-W 2 MeV optimized X-ray conversion target.

The facility is used for R & D in dosimetry, food processing, irradiation detection, material science, defect simulation in semiconductors.

AUTHOR INDEX

Minutes of the Forty-Second Annual Gaseous Electronics Conference

Palo Alto, California; 17–20 October 1989

PREAMBLE

The Forty-Second Annual Gaseous Electronics Conference was held on 17–20 October 1989, hosted by SRI International, Menlo Park, California. This meeting was a topical conference of the American Physical Society and was sponsored by the Division of Atomic, Molecular, and Optical Physics. All technical sessions were held at the Rickeys Hyatt, Palo Alto, California. Financial support was provided by the Air Force Office of Scientific Research, the Army Research Office, the National Science Foundation, the General Electric Company, and GTE Incorporated. The Forty-Second Gaseous Electronics Conference featured arranged sessions with invited papers and two workshops on the following topics:

1. Plasma Chemistry and Processing
2. The Atomic Xe:Ar (He, Ne) Laser
3. Fundamental Data from Discharge Plasmas
4. Electron Impact Ionization
5. Heavy-Particle and Excited State Collisions
6. Workshop on Cross Sections I Wish I Knew
7. Workshop on the Reference System for RF Plasma Processing Research

EPITOME

16 OCTOBER 1989
MONDAY EVENING

6:30–9:30		Registration and Reception.

17 OCTOBER 1989
TUESDAY MORNING

8:00–8:23		Introductory Remarks. D. L. Heustis.
8:23–9:41	A	Diagnostics of Processing Discharges. H. H. Sawin.
10:00–11:55	BA	Hydrocarbon Plasmas. L. W. Anderson.
10:00–11:04	BB	Kinetic Models. B. M. Penetrante.
11:04–12:08	BC	Electron Diffusion. W. N. G. Hitchon.

TUESDAY AFTERNOON

1:30–3:18	CA	Plasma Processing. H. M. Anderson.
1:30–3:28	CB	Heavy Particle and Excited State Collisions. M. R. Flannery.
3:45–5:30	D	Workshop on the Reference System for RF Plasma Processing Research. K. E. Greenberg.

TUESDAY EVENING

7:30–10:00	E	Posters. H. Helm.

18 OCTOBER 1989
WEDNESDAY MORNING

8:00–9:25	FA	Ionization. S. K. Srivastava.
8:00–9:31	FB	Laser Phenomena. L. A. Schlie.
10:00–11:31	GA	Arcs and Glows. V. A. Godyak.
10:00–11:07	GB	Electron and Heavy Particle Collisions. D. C. Lorents.
11:30–12:00	H	Business Meeting. J. B. Gerardo.

WEDNESDAY AFTERNOON

1:30–3:30	J	Posters. Y. K. Bae.
4:15–6:00		Laboratory Tour. Molecular Physics Laboratory and Chemical Kinetics Department, SRI International.

WEDNESDAY EVENING

6:00–7:00		Social Hour.
7:00–10:00		Banquet.

19 OCTOBER 1989
THURSDAY MORNING

8:00–9:39	KA	Ar/Xe Lasers I. A. Garscadden.
8:00–9:43	KB	Breakdown and Switching. L. E. Kline.
10:10–11:50	LA	Ar/Xe Lasers II. A. Garscadden.
10:10–12:04	LB	Cross Section Data I. R. A. Phaneuf.

THURSDAY AFTERNOON

1:30–3:18	MA	Fundamental Data from Plasmas. J. E. Lawler.
1:30–3:25	MB	Cross Section Data II. B. Bederson.
3:30–5:30	NA	Posters. J. B. Jeffries.
3:45–5:16	NB	Novel Plasmas. C. B. Fledderman.

THURSDAY EVENING

7:30–10:00	P	Cross Sections I Wish I Knew. C. C. Lin.

20 OCTOBER 1989
FRIDAY MORNING

8:00–9:39 QA Single Wafer Plasma Processing. J. H. Keller.

8:00–9:30 QB Collisions Between Atoms, Molecules, and Ions. J. R. Peterson.

10:00–11:31 RA RF Discharges: Models and Experiments. M. A. Lieberman.

10:00–11:43 RB Optical Diagnostics. J. T. Dakin.

MAIN TEXT

SESSION A: DIAGNOSTICS OF PROCESSING DISCHARGES

Tuesday morning, 17 October 1989
Rickeys Hyatt, Camino Ballrooms C and D at 8:23 A.M.
H. H. Sawin, presiding

A-1 Detection of Atomic Chlorine in rf Plasmas by Laser-Excited Amplified Spontaneous Emission, ANDREW D SAPPEY and JAY B JEFFRIES, SRI International--Laser-excited stimulated emission is used to detect atomic chlorine in an rf etching plasma. Two laser photons near 233.3 nm excite the spin- forbidden $3p^4 4p\ ^4S^0 \leftarrow 3p^5\ ^2P^0$ transition. Amplified spontaneous emission (ASE) is observed from $3p^4 4p\ ^4S_0 \rightarrow 3p^4 4s\ ^4P_J$. The stimulated emission signals are compared to simultaneously acquired laser induced fluorescence (LIF) from the same transition. For J=1/2 the ASE intensity is nearly 1000 times larger than the LIF. This strong, collimated stimulated emission provides a means to detect atomic chlorine which only requires a single optical access window.

*Supported by internal research and development funds of SRI International

A-2 Two-Photon Detection of F and F_2,* G. W FARIS, M. J DYER, W. K. BISCHEL, and D. L. HUESTIS, SRI International--Optical detection of F and F_2 is of interest for diagnostics of plasma processing and for laser kinetics studies. F_2 is detected by excitation of the $F^1\Pi_g$ and $f^3\Pi_g$ states from the ground state with two photons near 207 nm and measurement of either VUV fluorescence or ionization by a third photon. Recent measurements with a VUV spectrometer have shown that the fluorescence occurs at 158 nm, corresponding to the F_2 laser transition. Detection of F atom emission at 776 nm resulting from two-photon excitation of the ^2D_J level was demonstrated previously[1], using the 170 nm 6th anti-Stokes wave of a doubled dye laser Raman shifted in H_2. We describe attempts to increase the sensitivity of the F atom detection by producing the 170 nm photons by Raman shifting an ArF laser in HD and using the 2nd anti-Stokes wave.

* Supported by AFOSR under Contract No. F49620 88 K 0003
[1] G. C. Herring, M. J. Dyer, L. E. Jusinski, and W. K. Bischel, Opt Lett. 13, 360 (1988).

A-3 Laser-Induced Fluorescence Diagnostics of Silicon Etching, ANDREW D. SAPPEY and JAY B. JEFFRIES, SRI International--Laser-induced fluorescence is used to detect CF and SiF_2 radicals in an 13.56 MHz rf discharge of CF_4 and O_2 during the etching of a silicon wafer. Under conditions which minimize the reactive ion etching, the spatial gradients of concentration show that CF is lost from the gas phase to the silicon surface. Similar measurements on the SiF_2 radical show that it is produced on the surface and diffuses into the gas phase. Rotational and vibrational temperatures of CF are in equilibrium with one another and have a value similar to that estimated for the silicon wafer temperature.

*Supported by internal research and development funds of SRI International

A-4 Laser Induced Fluorescence Detection of SO and SO_2 in 13.56-MHz SF_6/O_2 Discharges, K. E. GREENBERG and P J HARGIS, JR., Sandia National Laboratories -- Laser-induced fluorescence (LIF) excited by a tunable KrF laser was used to detect SO and SO_2 in the active volume of SF_6/O_2 plasma etching discharges. Typical conditions for the 13.56-MHz, parallel-plate discharge were: 0.7 - 2.7 W/cm^2, 40 sccm SF_6, 0 - 6 sccm O_2, and 300 - 340 mTorr total pressure. SO was identified by using unfocussed KrF laser light to excite the SO v"=2 to v'=2 and v"=1 to v'=0 X-B transitions. When the laser was tuned near 248.0 nm, the v"=2 to v'=2 X-B transition was excited and the resulting fluorescence spectrum could be assigned to transitions from v'=2 of the B state to v"=3-19 of the X (ground) state. When the laser was tuned near 248.5 nm, the v"=1 to v'=0 X-B transition was predominantly excited and the fluorescence spectrum was dominated by transitions from v'=0 of the B state to v"=2-18 of the X state. SO_2 B $^1B_1$ emission was observed over the entire tuning range of the laser. Measurements of the SO_2 fluorescence lifetime indicate very fast quenching of the laser excited SO_2 states in our discharge system. Fast quenching is also supported by SO_2 LIF spectra recorded 1 μs after the laser pulse which show a red shifted peak fluorescence emission. Estimates of the SO number density and comparisons with sulfur dimer measurements will be presented.

A-5 S_2, SO, and SO_2 Spatial Distributions in SF_6/O_2 Radio-frequency Glow Discharges,* K.E. GREENBERG and P.J. HARGIS, JR., Sandia National Laboratories -- A gated multichannel detector was used to measure spatially resolved laser-induced fluorescence from S_2, SO, and SO_2, in 13.56-MHz SF_6/O_2 discharges. Spatial profiles were measured across the gap between the parallel-plate electrodes, in the center of the discharge. Typical operating conditions were: 0.3 to 2.7 W/cm^2, 40 sccm SF_6, 0 to 80 sccm O_2, and 300 to 500 mTorr total pressure. Spatial profile measurements showed an enhancement of S_2 at both electrodes; a depletion of SO at both electrodes; and a minimum in the SO_2 density a few millimeters from the powered electrode. Etching a refractory metal (Ta) in the SF_6 discharge produced an order of magnitude increase in the S_2 density but no change in the S_2 spatial profile. A tunable dye laser was used to measure the distribution of the $S_2(X)$ v"=0 and v"=1 states across the discharge gap. The effect of the interelectrode gap spacing (12, 18, or 25 mm) on profile measurements will also be reported.

*This work performed at Sandia National Laboratories supported by the U.S. Department of Energy under contract no DE-AC04-76DP00789.

A-6 Ion Cyclotron Resonance Mass Spectrometry in ECR Plasmas* J.B. Friedmann, J.L. Shohet and A.E. Wendt, Engineering Research Center for Plasma-Aided Manufacturing, University of Wisconsin-Madison and J.T. Brenna, IBM Corporation, Endicott, New York. -- In-situ mass spectrometry measurements may be an effective means for process control of ECR plasmas. Mass measurements of active species in an ECR plasma reactor have been made using ion cyclotron resonance mass spectrometry. An ECR plasma, generated by a magnetron supply operating at 2.45 GHz, has been produced in a magnetic mirror geometry. The plasma is physically separated from a low pressure analysis cell. Plasma is coupled to the cell through a small orifice (0.0369 cm in diameter). The system has been operated in an Omegatron[1] configuration and mass spectra for Nitrogen, Helium, Argon and CF_4 have been obtained during ECR plasma production. Typical operating pressures are 5×10^{-5} torr in the analysis cell region and 3×10^{-2} in the plasma production region.

* Work supported in part by the National Science Foundation under Grant No. CDR-8721545 and in part by IBM Corporation.
[1] D E. Post and R Behrisch, eds Physics of Plasma-Wall Interactions in Controlled Fusion (Plenum Press New York). 165 (1988).

SESSION BA: HYDROCARBON PLASMAS

Tuesday morning, 17 October 1989
Rickeys Hyatt, Camino Ballrooms C and D at 10:00 A.M.
L. W. Anderson, presiding

BA-1 Role of Gas Discharge in Chemical Vapor Deposition of Diamond Films, Y. TZENG, Department of Electrical Engineering, Auburn University--We have investigated various plasma as well as non-plasma chemical vapor deposition (CVD) processes for deposition of diamond thin films. Gas discharges not only provide energetic electrons for dissociating large hydrocarbon molecules in mixtures with hydrogen and/or oxygen but also cause high fluxes of

ions bombarding the substrates on which diamond is to be deposited. The role of these ions is unique for plasma CVD as compared with other non-plasma CVD processes such as the thermal CVD and combustion CVD of diamond. Depending on the ion energy distribution, ions can either promote or retard diamond deposition. In this paper, various diamond deposition processes will be reviewed with emphasis being put on the comparison among CVD's enhanced by different plasmas and between plasma and non-plasma CVD processes. From this comparison, the role of gas discharge in the chemical vapor deposition of diamond films will be discussed.

BA-2 Diamond Synthesis in a 50 kW Inductively Coupled Atmospheric Pressure Plasma,* M. GORDON, T. OWANO, C. H. KRUGER and M. A. CAPPELLI, Stanford University -- Polycrystalline diamond coatings have been deposited on a variety of metal substrates using a 50 kW thermal plasma reactor. The growth morphology is found to vary significantly with reactor processing conditions. In this work, we explore the effects of varying the parameters controlling both the surface kinetics (substrate temperature) and gas phase chemistry (initial gas feed composition and plasma temperature). Scanning electron microscopy indicates that well faceted crystals are obtained with growth along the 100 and 111 planes. Raman scattering data is used to compare the bonding structure to that obtained by low pressure microwave plasma deposition.

* Work Supported in part by the Department of Energy (BES) and Office of Naval Research.

BA-3 Hydrocarbons from Discharges in Methane and Discharges over a-C:H Films,* R.N. RUDOLPH** and J.H. MOORE, Department of Chemistry and Biochemistry, University of Maryland -- Neutral hydrocarbons are observed from a microwave discharge in a fast flow of (a) 0.5 - 6% methane in argon, (b) 0.5 - 6% methane in hydrogen, and (c) hydrogen over a previously deposited a-C:H film. System (a) produces polyacetylenic and other hydrocarbons through C8 by predominantly gas-phase reactions and deposits an a-C:H film. (b) and (c) produce hydrocarbon radicals and molecules with masses through 300 which in case (b) arise from both gas-phase reactions and film ablation, and in case (c) from film ablation alone. Proposals are made for the mechanisms of gas-phase polymerization, film deposition, and ablation. Hydrocarbon ions observed downstream from these discharges appear to arise from ionization of neutrals with a distribution determined by subsequent ion-molecule reactions and selective diffusion losses.

*Supported by NSF grant CHE-87-21744.

**on sabbatical from Adams State College, Alamosa, CO.

BA-4 Absolute Density and Spatial Distribution of the Free Radical CH_3 and CH_2 in a Methane rf Plasma,* H.SUGAI, H.TOYODA and H.KOJIMA, Nagoya University, Japan Neutral radical CH_3 and CH_2 in a capacitively coupled rf discharge in methane have been detected using threshold-ionization mass spectrometry.[1,2] The absolute density of CH_2 radical in the 13.5 MHz-10 W discharge in 10 mTorr CH_4 is two orders of magnitude less than the CH_3 density(10^{11} cm^{-3}). Space-resolved density measurement of radical species shows the uniform distribution of the CH_3 density whereas the CH_2 density is higher near the powered electrode. Time-resolved density measurement of the afterglow of rf discharges provides the decay time of ~100 ms for CH_3 radical and ~10 ms for CH_2 radical. The CH_3 decay is well explained in terms of the recombination reaction $CH_3 + CH_3 \rightarrow C_2H_6$. The CH_2 decay is attributed to surface loss (sticking coefficient ~0.025), in addition to gas phase loss due to the CH_2 reactions with CH_3 and CH_4.

*Work supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science & Culture, Japan.
[1] H. Toyoda, H. Kojima and H. Sugai, Appl. Phys. Lett. 54, 1507(1989).
[2] H. Kojima, H. Toyoda and H. Sugai, to be published in Appl. Phys. Lett.

BA-5 Measurement Method of the SiH_2 Radical Density Using Infrared Laser Absorption Spectroscopy*, T. GOTO N. NISHIWAKI, N. ITABASHI and K. KATO, Nagoya Univ., C. YAMADA and E. HIROTA, Inst. for Molecular Science. -- The SiH_2 radical density has never been measured for want of a measurement method. In this work, using the infrared diode laser absorption method, the measurement of the density of the SiH_2 radical formed from phenyl-silane by an ArF excimer laser has been carried out and first it has been shown to be able to determine the absolute value of the SiH_2 radical density. The glass tube of 12 cm diameter and 200 cm length has been used as an absorption cell. The phenyl-silane diluted with hydrogen in the cell has been decomposited by the ArF excimer laser traveling along the tube axis to form the SiH_2 radical. The transient absorption intensity of the P branch line of the SiH_2 ν_2 band has been observed at a phenyl-silane pressure of 10 mTorr, a hydrogen pressure of 830 mTorr and a hydrogen flowing rate of 500 sccm, and the $SiH_2(X^1A_1)$ radical density has been determined to be 5×10^{11} cm^{-3} assuming a rotational temperature of 360 K.
*Supported by Grant-in-Aid for Scientific Research on Priority Areas of the Ministry of Education, Science and Culture.

BA-6 Infrared Laser Absorption Studies of CF_4 and CH_4 RF Plasmas,* J. WORMHOUDT, Aerodyne Research, Inc. --Infrared tunable diode laser absorption studies of process plasmas are being carried out in a laboratory reactor which allows a long absorption path. Here we report studies of CF_4 and CH_4 radio frequency plasmas. The molecular species whose concentrations have been measured include CF_2 and C_2F_6 as well as CF_4 in CF_4 plasmas, and CH_3 and C_2H_2 as well as CH_4 in methane plasmas. Observations are made for ranges of reactor parameters, including RF power, dilution by Ar or H_2, total pressure, and O_2 addition. Spectroscopic determination of translational, rotational and vibrational temperatures will also be discussed.

*Work supported by the Air Force Office of Scientific Research under Contract F49620-87-C-0052.

BA-7 Particulate Generation in Silane/Ammonia RF Discharges, H.M. Anderson R. Jairath, Dept. Chem. Engr., University of New Mexico, Albuquerque, NM The rate of particle generation in a SiH_4/NH_3 rf discharge has been studied as a function of the discharge operating parameter space, electrode geometry, and power supply coupling mode. Measurements of the bulk quantity of particles produced in the discharge indicate the mode of coupling (capacitative or dc) and the electrode temperature significantly affect particle generation rates. Laser light scattering measurements made as function of the plasma power density also indicate that particle generation abruptly ceases at a threshold value sufficient to induce spark breakdown at the dc coupled electrode. Particle characterization of samples collected from the discharge chamber reveals that the primary particles are sub-micron, N-rich or Si-rich dependent on the feed gas ratio, and that substantial clustering of primary particles occurs in the gas phase simultaneous with particle growth. Based on the above observation implicating electrode interactions with particle generation rates, a new mechanism for the growth of particles in low pressure rf discharges for plasma processing is proposed.

SESSION BB: KINETIC MODELS

Tuesday morning, 17 October 1989
Rickeys Hyatt, Camino Ballroom B at 10:00 A.M.
B. M. Penetrante, presiding

BB-1 Kinetic Models of Glow Discharges* W N G Hitchon, T J Sommerer and J E Lawler, University of Wisconsin, Madison, Wisconsin 53706 U.S.A. -- Very efficient numerical solutions of kinetic equations[1,2] have been applied to DC and RF discharges. The electron and ion distribution functions (in one spatial and two velocity variables (x,v,μ) $\mu \equiv v_x/v$) and the electric field are

calculated self-consistently. Strong effects of varying frequency, voltage and secondary emission coefficient in RF discharges in He have been observed for f = 10 - 13.56 MHz, V_a = 500-1000 V (peak-to-peak), γ = 0 and .1, p = 100 mtorr. Conditions in the cathode fall and negative glow of a DC discharge in He, obtained using a detailed set of atomic processes, will be discussed. In particular, the peak negative glow electron density is related to the electron 'temperature' (measured as ~ 10^{11} cm^{-3} and 0.1 to 0.2 eV) which are determined by elastic cooling and energy deposition by beam electrons.

1 W.N.G. Hitchon, D.J. Koch and J.B. Adams, J. Comp. Phys., (to be published).
2 T.J. Sommerer, W.N.G. Hitchon and J.E. Lawler, Phys. Rev. A, 39, (1989) 6356.

* Work supported by the UW/NSF ERC in Plasma-Aided Manufacturing, Grant CDR-8721545.

BB-2 A Multigroup Approach to Electron Kinetics,* S. Clark and E. E. Kunhardt, Weber Research Institute, Polytechnic University. Given initial and/or boundary conditions, the behavior of an assembly of electrons in a gas can be obtained from solution of the kinetic equation for the distribution function, f(v,r,t). By expanding the distribution in terms of localized functions in v-space, an equivalent formulation can be obtained in terms of the expansion coefficients. For a set of modulated gaussian functions, the expansion coefficients are proportional to the density of "electron groups" associated with the localized functions. Equations of evolution for these coefficients are explicity derived. With this formulation, the dynamical behavior of the electrons in various regions of velocity space and the influence of the scattering process on these dynamics can be elucidated. This approach is illustrated by numerically solving the initial value problem for the amplitude equations.

* Work supported by the Office of Naval Research.

BB-3 Time and Spatially Dependent Monte Carlo Simulations of Partially Ionized Plasmas Including Electron-Electron Collisions.* Yilin Weng and Mark J. Kushner. University of Illinois, Urbana, IL. Electron-Electron (e-e) collisions are important in describing the electron energy distribution at fractional ionizations > 10^{-5}. These collisions are typically not included in Monte Carlo Simulations (MCS) of partially ionized gases. We have developed a new method whereby e-e collisions may be included in time and spatially dependent MCS of partially ionized plasmas. The method is based on the use of a velocity resolved background electron fluid (BEF) as a species equivalent to heavy atoms. In doing so, we can use the same algorithms as used in treating e-neutral collisions to account for e-e collisions. Since momentum exchange occurs with the BEF, we periodically update the velocity distribution of the fluid using the intermediate results during the simulation. This method is made tractable by using a modified null cross section technique. As an example of the new method, we will present electron energy distributions for swarms in Ar and N_2.

*Work supported by NSF (ECS-88-15781).

BB-4 The Effects of Particulate Contamination on Electron Transport in Glow Discharges.* Michael J. McCaughey and Mark J. Kushner. University of Illinois, Urbana, IL. Glow discharge devices such as gas lasers or plasma deposition reactors are typically contaminated by particulate matter, or dust, which results from gas phase chemical reactions or sputtering. Sufficient large gas phase particulates (> a few μm) will develop negatively charged sheaths which act as scattering centers and which perturb electron trajectories. We report on a hybrid molecular dynamics-Monte Carlo computer simulation of electron transport in dusty plasmas to study these conditions. The sheath potential at the dust surface is self consistently solved for from the electron energy distribution (EED) by requiring a balance between electron and ion fluxes to the surface of the particles. The perturbation of the EED by the particulates, and the effect on electron impact rate coefficients and self sustaining E/N of glow discharges are presented.

*Work supported by the National Science Foundation (CBT88-03170).

SESSION BC: ELECTRON DIFFUSION

Tuesday morning, 17 October 1989
Rickeys Hyatt, Camino Ballroom B at 11:04 A.M.
W. N. G. Hitchon, presiding

BC-1 Diffusion Theory of Electrons in a Constant Field: TOF Analysis, JOHN INGOLD, GE Lighting, Cleveland, OH 44112--Electron diffusion theory is based on energy moments of the scalar equation for the isotropic part of the energy distribution, which is found by the spherical harmonic expansion method of solving the Boltzmann equation. The zeroth energy moment gives the particle balance equation, or diffusion equation, and the first energy moment gives the energy balance equation. These two equations are solved numerically in time and one space dimension along the electric field, including non-equilibrium regions near the electrodes, with a pulsed source of electrons at the incoming plane and a perfect sink at the outgoing plane. Calculated pulse widths for constant cross section are significantly less than those obtained from solution of the diffusion equation alone, using equilibrium values of diffusion coefficient and drift velocity. These results suggest that the concept of anisotropic diffusion is superfluous when energy balance is satisfied, i. e., when both density and average energy are allowed to vary in time and space.

BC-2 DGE Analysis of Asymmetric TOF Current Pulses at Different Drift Distances: Determination of V_d, D_L, D_3 and D_4† C. A. DENMAN and L. A. SCHLIE Advanced Laser Technology Division (WL\ARDI) Kirtland AFB, NM 87117-6008 – Previously reported high-temporal-resolution electron time-of-flight (TOF) experiments in the noble gases have enabled the first observation of the higher-order asymmetric current pulse shape characteristics predicted by the density gradient expansion (DGE) theory. Preliminary analysis of these skewed current pulses utilizing the second-order diffusion approximation of the DGE yielded values for the drift velocity (V_d), longitudinal diffusion (D_L) and the first reported values for the skewness diffusion (D_3). Because of the observed divergence of the second-order diffusion approximation for the largely skewed pulses, the analysis is extended to the third-order diffusion approximation yielding the higher-order diffusion coefficient D_4. To further assess the temporal behavior of the electron current pulse as well as provide a consistency check of the analysis, the original drift distance of 15.7 cm is reduced by half. The unique feature of this sensitive high-resolution TOF apparatus is its virtual-ground current-to-voltage amplifier (4.4×10^7 V/A at 3 MHz BW) which detects the arrival-time-spectra of the electron current pulse.

†Supported by the Air Force Office of Scientific Research

BC-3 Boltzmann and Monte Carlo Calculations of Higher-Order Transport Coefficients.* B. M. PENETRANTE and J. N. BARDSLEY, Lawrence Livermore National Laboratory -- The density gradient expansion theory is only asymptotically correct, and therefore can never adequately describe non-equilibrium boundary regions with strong density gradients. Nevertheless, the asymptotic values of the transport coefficients provide a practical means by which collisional cross sections can be

inferred. The higher-order coefficients, such as the skewness, if measurable, may provide for a more unique inference of cross section data. We have performed Boltzmann and Monte Carlo calculations of electron transport in various gases in order to study the sensitivity of the higher-order transport coefficients to the energy dependence of the collision cross sections. We have also computed the arrival time spectra of the electron swarm under various drift tube conditions.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG 48.

BC-4 Non-linear Diffusion,* E. E. Kunhardt, Weber Research Institute, Polytechnic University. A continuity equation for the transport of electron density is derived using the concept of a macro-kinetic distribution (MKD) for electrons in a background gas.[1] In lowest order this distribution is shown to obey an equation that is equivalent to the steady-state Boltzmann equation with an equivalent field that is velocity dependent. An explicit form for the MKD is presented for the case of a quasi-Lorentz gas model. The MKD has been used to evaluate the electron current density and to obtain expressions for the mobility and diffusion coefficient. These coefficients are dependent on the electron density gradient, so that the resulting continuity equation is non-linear. The consequences of these results are illustrated for the case of constant collision frequency.

* Work supported by the Office of Naval Research.

[1] E. E. Kunhardt, J. Wu, and B. Penetrante, Phys. Rev. A37, 1654 (1988).

SESSION CA: PLASMA PROCESSING

Tuesday afternoon, 17 October 1989
Rickeys Hyatt, Camino Ballroom C at 1:30 P.M.
H. M. Anderson, presiding

CA-1 Power Deposition, Damage Monitoring, and End-Point Detection Using Photoluminescence Spectroscopy in rf Glow Discharges, R.A. GOTTSCHO, A. MITCHELL, S.J. PEARTON, and G.R. SCHELLER, AT&T Bell Laboratories - Photoluminescence (PL) spectroscopy is used to measure wafer temperatures, damage, and process end-points during rf plasma etching of III-V compound semiconductors such as GaAs and AlGaAs. To discriminate against the plasma glow and minimize PL photo degradation, we use pulsed excitation and gated electronic detection of the PL intensity. Exploiting the PL peak position dependence on temperature, we measure *in situ* wafer temperatures to better than 1°C from 25°C to 150°C. Thus, power deposition to the surface is determined as a function of discharge frequency, gas composition, applied power, and pressure. Because PL intensity is inversely proportional to surface state density, it is a useful and quantitative measure of surface damage and the effectiveness of damage passivation processes. We report results from BCl_3 plasma etching of AlGaAs and GaAs under a variety of conditions and show how plasma-induced damage is removed using H_2 plasma treatments. We also show how PL can be used in process end-point detection.

CA-2 Effects of Feed Gas Impurities on the Plasma Etching of Polysilicon, G ZAU and H H SAWIN, M.I.T. - - The effects of different feed gas impurities on the polysilicon etching rate in several plasmas were measured. Changes in the polysilicon etching rate typically correlated well the ion flux and/or plasma induced emission. Impurities containing oxygen, water and molecular oxygen, can however cause abrupt etch stoppage. This is attributed to the formation of a surface oxide layer. Most impurities had little effect below 1000 ppm concentration. The most sensitive impurity was a stoichiometric mixture of hydrogen and oxygen used as a water substitute. This mixture reduce the etching rate of CF_4 and Cl_2 plasma at about 100 ppm. Water measurements were carried out using plasma induced emission and mass spectrometry. Both OH^+ and H_2O^+ ions were detected with the addition of the mixture. This indicates that water is formed in the plasma with the addition of the mixture.

CA-3 Computer Simulation of the Dynamics of Physical and Chemical Processes on Surfaces, W.L. MORGAN, JILA, Univ. of Colorado & NIST and Kinema Research, Monument, CO 80132--I will discuss the methodology behind simulating the dynamics of surface processes and will present results drawn from simulations of atomic collisions with silicon surfaces. The most exciting of these involve collisions of F atoms and F_2 molecules with Si. In such collisions reactive chemistry occurs which can locally heat the surface and which can cause etching of the surface with SiF_x molecules as reaction products. The development of two and three body potential functions[1] for the interactions of combinations of silicon and fluorine atoms now allows us to directly simulate the dynamics of such chemsitry on surfaces.

[1] F.H Stillinger and T.A. Weber, Phys. Rev. B 31, 5262 (1985), J. Chem. Phys. 88, 5123 (1988); Phys. Rev Letts. 62, 2144 (1989).

CA-4 Surface Reactions of Atomic Chlorine on Polycrystalline Ni and Si(110) WOLFGANG MUELLER-MARKGRAF and MICHEL J. ROSSI, Department of Chemical Kinetics, Chemistry Laboratory, SRI International, Menlo Park CA 94025--Gas-wall interaction studies of neutral transients are thought to be of prime importance in etching and deposition processes. We have studied in a controlled experiment the sticking coefficient and surface chemistry of $Cl(^2P_{3/2})$ and $Cl(^2P_{1/2})$ on polycrystalline Ni and Si(110) in the 10^{-3} Torr regime in a Knudsen cell. The Cl atoms were injected using a pulsed solenoid valve downstream from a microwave discharge in Cl_2 or CF_3Cl. The detection of both Cl species was performed by [3+2] Resonance Enhanced Multiphoton Ionization (REMPI) around 405 nm, whereas stable product species were monitored by on-line phase sensitive electron-impact mass spectrometry. In addition, a necessary ancillary experiment of Cl interaction with Teflon (PTFE) had to be performed in order to search for an "inactive" wall material. The results reveal a surprisingly large variation of the Cl sticking coefficient on the examined surfaces, ranging from 10^{-6} to essentially 1.0. Kinetic model calculations support the results in cases, where the Cl atom decays are complex. They thus reveal details of their interaction at substantial coverages, for example in the Cl/Ni case, where some thermodynamic data are known.

CA-5 Radiation Damage to Silicon by Combined Microwave and RF Plasma Reactive Ion Etching Y. TZENG, T.H. LIN and C.C. TIN, Department of Electrical Engineering, Auburn University--We have investigated the radiation damage caused by ion bombardment during reactive ion etching of silicon in a combined microwave and RF reactive ion etching reactor. Microwave plasma is used to generate high density reactive species. RF power is applied to a substrate for adjusting the RF self-bias as well as exciting plasma species in the down-stream of the microwave plasma. By controlling the substrate temperature, the rate of chemical reaction is adjusted. The ion bombardment enhanced the vertical etching rate and thus provide high etching anisotropy. The silicon wafer etched by this plasma is used to fabricate electronic devices for characterization. Current-voltage measurement as well as DLTS analysis are applied to

correlate the plasma etching conditions with radiation damage. From this study, the etching of silicon using the combined microwave and RF plasma can be optimized.

CA-6 Plasma Etching of Y-Ba-Cu-Oxide Thin Films, M. R. POOR and C. B. FLEDDERMANN, Center for High Technology Materials, U. of New Mexico -- The commercial viability of electronic applications of high temperature superconducting ceramics will require the development of technologies for patterning thin films into devices. Studies of plasma etching of Y-Ba-Cu-Oxide thin films have been initiated using a dilute chlorine/helium mixture in a d.c. hollow cathode discharge configuration. Unannealed thin films deposited on alumina substrates are etched over a wide range of pressure, input power, substrate temperature and substrate bias. Energy dispersive spectroscopy (EDS) is used to detect the changes in stoichiometry undergone by the films during etching. The etch rate of these films is highly dependent upon substrate temperature, and our measurements show that the rates of etching of the metallic components of the film by chlorine are not the same: copper is most readily removed, followed by barium and yttrium. The dependence on discharge parameters of the etch rates of the individual metals as well as the overall film etch rates will be discussed.

CA-7 Positive ion formation in positive polarity SF_6 corona discharges,* I. Sauers and G Harman, Oak Ridge National Laboratory.--Positive ions were sampled into a mass spectrometer from a positive point-to-plane corona discharge in SF_6 in the pressure range 10-200 torr. Under moderately dry conditions (typically less than 100 ppm, H_2O) the ion fragments SF_5^+, SF_3^+, and SF_2^+ were the major ions observed. The intensity ratios of SF_3^+ and SF_2^+ to SF_5^+ are similar to those observed for electron-impact ionization of SF_6 at ~30 eV electron energy. A weak SF^+ ion was also observed. Since the threshold for SF^+ formation by electron impact is 31 eV, considerable electron energy is apparently available in the discharge. The absence of SF_4^+ and possible reactions will also be discussed.

*Work supported by the Office of Energy Storage and Distribution, Electric Energy Systems Program, US Department of Energy under contract DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

SESSION CB: HEAVY PARTICLE AND EXCITED STATE COLLISIONS

Tuesday afternoon, 17 October 1989
Rickeys Hyatt, Camino Ballroom D at 1:30 P.M.
M. R. Flannery, presiding

CB-1 Association Reactions of Metastable Helium Atoms, J. STEVEFELT, GREMI/CNRS, U. of Orléans, France - Theoretical description of termolecular association of helium triplet atom with normal helium in a gas will be presented. The initial capture involves barrier tunneling in the He_2 $a^3\Sigma_u^+$ state, and the subsequent relaxation of highly excited vibrational and rotational states will be discussed. Results for the overall rate at which the product He_2 v=0 appears will be compared with measured reaction rates for the metastable atom-molecule conversion.

CB-2 Half Collision Studies of the H + H_2 Transition State P. C. COSBY AND H HELM, SRI International - Charge transfer of H_3^+ in Cs produces an intense beam of H_3 molecules in the long-lived $2p^2A_2''$ state. We have recently demonstrated[1] that these molecules can be photoexcited into other H_3 excited states which predissociate along the repulsive ground electronic state surface. The optical excitation completely defines the angular momentum, vibrational, and nuclear spin state of the dissociating molecule, as well as its total energy. The discrete energy releases that accompany the production of particular rovibrational levels in the H_2 photofragment are observed by explicit measurement of the velocity vectors of the correlated H + H_2 dissociation fragments. The rovibrational distribution in the H_2 fragment is found to be highly dependent on the transition state selected. Initial experiments have thus far probed only a few transition state configurations at energies 7.6 - 8.1 eV above the H + H_2(v=0) asymptote, however much lower energy regions of the ground state potential will be accessible using stimulated emission pumping with this technique.

[1]P. C. Cosby and H. Helm, Phys. Rev. Lett. 61, 298 (1988).

CB-3 Study of Low-Energy Electron-Molecule Interactions Using Rydberg Atoms,* F. B. DUNNING, Rice University -- Many collision processes involving atoms in high Rydberg states ($n \geq 40$) can be described by invoking the "essentially-free" electron model and considering only the interaction between the Rydberg electron and target particle. Thus, because the mean kinetic energy of a Rydberg electron is only a few meV, Rydberg atom collision studies provide a novel means to explore electron-molecule interactions at subthermal electron energies. Rate constants and cross sections for free electron capture by a variety of molecules have been derived from Rydberg atom studies. Translational energy release in dissociative electron capture has also been investigated in kinematic studies using a position sensitive detector. This work reveals that for some molecules (e.g. CH_3I) essentially all the excess energy of reaction appears in translation, whereas for others (e.g. CCl_4) much of this energy is stored as internal energy in the fragments. Kinematic studies also show that for intermediate n post-attachment interactions between the Rydberg core ion and product negative ion are important.

*Research supported by the NSF under Grant #PHY87-09637 and the Robert A. Welch Foundation.

CB-4 Recombination of Xe^+ Ions and F^- Ions in Ambient Helium*. H.S Lee and R. Johnsen, University of Pittsburgh — We have determined rate coefficients for ion-ion recombination of Xe^+ with F^- ions by observing the decay of the ionic conductivity in a photoionized helium afterglow plasma (helium pressures < 1 at.) containing admixtures of Xe and F_2. In addition, we observed the fluorescence resulting from ion-ion recombination into the XeF^* excimer state, and we monitored the ion composition of the plasma by mass-spectrometric sampling of afterglow ions The recombination coefficients were found to increase approximately linearly with helium pressure, reaching a value of about 1×10^{-6} cm^3/s at a helium presssure of 1 at.. The results will be compared to theoretical calculations by Flannery and Yang [1] and to Monte Carlo simulations by Morgan et al..

1. M.R. Flannery and T.P. Young, Appl. Phys.Lett. 33, 574, (1978)
2. W.L. Morgan et al. Phys. Rev. A 26, 1696 (1982)
*Work supported by US Army Research Office

SESSION E: POSTERS

Tuesday evening, 17 October 1989
Rickeys Hyatt, Camino Ballrooms A and B at 7:30 P.M.
H. Helm, presiding

E-1 Cylindrical Simulations of RF Plasma Discharges and Plasma Immersion Ion Implantation*, M.V. ALVES**, V VAHEDI, and C.K. BIRDSALL, ERL, UC Berkeley — A cylindrical many particle simulation code, PDC1, has been used to model 1) RF discharges in which the electrodes have different areas, and 2) plasma immersion io.

implantation, where the target has a transient negative bias. PDC1 is a 1D radial, electrostatic code. It has an external circuit with an RF source and RLC components and has an electron-neutral and ion-neutral collision model the same as in PDW1[1]. The differences between having parallel planar and concentric cylindrical electrodes are examined. In particular, with RF discharges, the self-bias voltage at the powered electrode is measured and compared with theory[2].

*This work supported in part by DOE contract DE-FG03-86ER53220 and ONR contract N00014-85-K-0809

**On leave from INPE - S. J. Campos - SP - Brazil

[1] I. J. Morey, V. Vahedi, J. P. Verboncoeur, to be presented at this conference.

[2] M A Lieberman, J Appl. Phys. 65, 4186 (1989).

E-2 Particle Simulation Code for Modeling Processing Plasmas*, I.J. MOREY, V. VAHEDI, J. VERBONCOEUR and M. A. LIEBERMAN, ERL, UC Berkeley — The bounded plasma particle code PDW1[1] now has elastic, excitation, ionization and charge exchange collisions, so that a number of different processing plasmas can be simulated. RF discharge simulations have shown rectification of the plasma potential, ions responding to the average potential, sheath heating and joule heating. Both voltage and current driven RF discharges have been examined, and differences have been observed between the harmonic contents of the potential Ion velocity distributions at the boundaries exhibit features due to charge exchange and ionization within the sheath regions. Plasma immersion ion implantation simulations will be compared with theory[2]. The PC version of PDW1 has many quanitative diagnostics displayed in a window format, readily accessed using a menu system.

*This work supported in part by DOE contract DE-FG03-86ER53220 and ONR contract N00014-85-K-0809.

[1] W. S. Lawson, J. Comp. Phys. 80, 253 (1989).

[2] M. A. Lieberman, to appear in J. Appl. Phys. (Oct 1989).

E-3 DC Self-Bias Voltages in Low Pressure Discharges in Finite Cylindrical Chambers, M.A. LIEBERMAN, University of California, Berkeley, and S.E. SAVAS, Applied Materials, Santa Clara — We have developed a theory of dc bias formation in low pressure capacitive rf discharges in finite cylindrical chambers where the powered electrode area is less than the area of the grounded and insulating walls. Results of analytical and numerical calculations are shown Both of these assume that ionization is simply proportional to the electron density. The analytical model makes further assumptions that the ion mobility is constant and that the sheaths are purely capacitive in order to calculate the ratio R = plasma-to-powered / plasma-to-grounded electrode dc voltage. It is found that R is not proportional to any power of the electrode area ratio, as is so often assumed The numerical results use a variable ion mobility and rf sheath model incorporating phase dependent admittance and capacitance to compute self-consistent values of R. Non-zero sheath admittance is found to have a small effect on R. Comparisons of the model with measurements[1,2] will be presented.

1. J.W. Coburn and E. Kay, *J. Appl. Phys.* 43, 4965 (1972).
2. C.M. Horwitz, *J. Vac. Sci. Technol. A* 1, 60 (1983).

E-4 Parallelizing the Monte Carlo Simulation in Weakly Ionized Plasmas, C. J. Wang, Department of Electrical and Computer Engineering, U. of Colorado at Colorado Springs, and C. Wu, Electrical Engineering Department, Auburn University.--The Monte Carlo method is a useful technique to study the evolution of charged particle assembly. The simulation takes a considerable amount of time, even when few particles are used. However, this problem has inherent parallelism in nature. Parallel Monte Carlo techniques for simulating the evolution of an assembly of charged particles interacting with the background gas medium under the influence of the electrical field are presented. We have overcome three major difficulties. 1) the number of particles to be simulated is increasing over time due to the ionization process, 2) the conditional branching statements do not inhibit multiprocessing, 3) concurrency and vectorization are fully utilized through the new parallelized Monte Carlo method. The shared-memory vector multiprocessor Alliant FX/80 has been used for performance measurements. Significant speedup has been achieved on the simulation of an electron avalanche.

E-5 The Plasma Sheath Transition in an Asymmetric Collisionless Plasma, H. van den BERG, K.-U. RIEMANN, Ruhr-Universität Bochum, FRG. The plasma-sheath problem ($\lambda_D/L \to 0$) for an asymmetric warm collisionless plasma is solved in plane parallel geometry. To this end Emmert's model source term [1] is generalized to account for a superimposed plasma drift. The quasineutral plasma approximation results in a system of coupled integral equations which can be solved analytically. In contrast to Ememrt's symmetric model one sheath edge shows the usual field singularity. At the other sheath edge we find a finite field strength and an oversatisfied Bohm criterion. These results are in full agreement with general relations on the Bohm criterion and on the sheath edge field singularity [2].

[1] G. A. Emmert et al., Phys. Fluids 23, 803 (1980).

[2] K.-U. Riemann, Phys. Fluids B1, 961 (1989).

E-6 Parametric Studies of Ar and SF_6 rf Discharges Using the Continuum Model, and Comparison with Experimental Data, E. GOGOLIDES, J. LIU, and H.H. SAWIN, MIT. -- A self-consistent continuum model[1] is used to simulate Ar and SF_6 discharges. Parameters that are varied in the model are pressure, rf current, and rf frequency. The effects of these parameters on the spatial and temporal profiles of particle densities, electron energies, ionization rates, electric fields, and other variables are examined. Model predictions of current-voltage waveforms, power deposition, ion fluxes and ion bombardment energies are in good agreement with experimental data. The characteristics of typical electropositive and electronegative discharges, Ar and SF_6, are contrasted. For example, as power is raised, the electron densities in both the Ar and SF_6 plasma increase, resulting in an increase of the current. In Ar, the voltage also increases while in SF_6 it remains approximately constant.

[1]Gogolides *et al*, J. Vac. Sci. Technol. A7, 1001 (1989).

E-7 PIC Simulation at High Plasma Densities,* R. K. PORTEOUS and D. B. GRAVES, Chemical Engineering, U. of California, Berkeley -- As the plasma density rises in a PIC simulation the number of Debye lengths increases and usually the grid spacing must be reduced to compensate. When the system contains more than 10^3 Debye lengths, or in multidimensional geometries, this represents a large overhead. Further, if the number of superparticles per cell is held constant, the total number of particles increases with the number of cells and inversely with the Debye length, i.e. as $n_e^{0.5}$.

The time for simulated plasmas to come to equilibrium is of the order of the ion residence time which is approximately independent of n_e. However the timestep must be kept at some fraction of the plasma period which decreases as $n_e^{0.5}$. For $n_e > 10^{17}m^{-3}$ simulations may involve 10^6 - 10^7 timesteps.

These combined increases in size and duration determine the limitations of practical simulations. Techniques for extending simulations of time-invariant plasmas to high densities, such as particle smearing and multi-timescaling, will be discussed and some results from such plasmas presented.

*Work supported in part by IBM.

E-8 Ion Bombardment Energy Distributions from RF Discharges, M. F. TOUPS, D. W. ERNIE, and H. J. OSKAM, U. of Minnesota--Experimental measurements of the energy distribution and the flux of ions bombarding an electrode of a parallel plate rf reactor were performed in various noble gases and noble gas mixtures using a

hemispherical retarding grid energy analyzer. Quadrupole mass analysis was performed to identify the ions which were bombarding the electrode. Frequencies from 1 to 40 MHz and pressures from 0.025 to 1 Torr were studied. For a given amplitude of the applied rf potential, the frequency of the applied rf potential and the reactor gas pressure were found to be significant in determining the shape of the measured ion bombardment energy distributions The total ion flux to the electrode surface was found to be determined by the frequency and amplitude of the applied rf potential and to be insensitive to the reactor gas pressure. These results will be discussed with reference to the physics of rf gas discharges.

E-9 A Tuned Langmuir Probe for Measurements in RF Glow Discharges, A.P. PARANJPE*, J.P. MCVITTIE** and S.A. SELF*, *Dept. of Mechanical Engineering and **Dept. of Electrical Engineering, Stanford University, Stanford, CA 94305 - Measurements of charged particle concentrations and the electron energy distribution function (EEDF) have been made in argon and SF_6 glow discharges using a tuned Langmuir probe technique. A simple passive circuit connected to the probe when properly tuned, increases the impedance between the probe and ground, thereby forcing the probe to follow the instantaneous plasma potential. In this manner RF induced distortion of the probe characteristic is mitigated. At 13.56 MHz the electron collection characteristic of a detuned probe is distorted by RF interference, the ion collection characteristic is unaffected. The EEDF is highly non-Maxwellian in argon discharges, but quite Maxwellian in SF_6 discharges. The mean electron energy increases with decreasing pressure and increasing power in argon discharges, but is independent of pressure and power in SF_6 discharges. The measured distribution functions and charged particle concentrations are in agreement with calculations.

E-10 Collisional Effects on Plasma Flow Along the Divergent Magnetic Field of an ECR Plasma Stream Source, M. HUSSEIN and G. A. EMMERT, University of Wisconsin-Madison--Plasma flow along decreasing magnetic field lines from the resonance cavity to the specimen plate in an ECR plasma stream source is numerically simulated. The approach is kinetic in which a Monte Carlo description for the ion dynamics, coupled with Boltzmann electrons is used to develop an iterative scheme for solution of the Vlasov equation and quasi-neutrality. Collisions between ions and neutrals are included in the context of Monte Carlo techniques. The effect of the divergent magnetic field on the plasma potential profile, the floating potential, and the energy distribution of the ions incident on the specimen are presented. Collisional effects are shown to produce a wider ion energy distribution than that obtained with a collisionless simulation(1).

(1) M. A. Hussein and G. A. Emmert, 16th IEEE Int. Con on Plasma Science, Buffalo, N.Y, 22-24 May 1989.

E-11 A Comparison of Three Power Measurement Techniques in a Low Pressure RF Discharge, R. B. PIEJAK, V. A. GODYAK, GTE Laboratories Inc., Waltham, MA -- The power dissipated in a low pressure argon RF discharge driven symmetrically at 13.56 MHz has been measured in three different ways and compared. One measurement technique is just the product of the RMS voltage and current and the cosine of the phase shift between them. The second method of power measurement consists of taking the integral over one period of the voltage-current product. The third discharge power measurement is based on power meter measurements in the transmitting line (incident minus reflected power) with and without a discharge while having the matcher in both cases tuned to resonance. This enables the power dissipated in the discharge and that dissipated in the matcher to be calculated separately. All three measurements are compared versus the discharge voltage. The power dissipated in the matching system was found to be larger than the discharge power in some cases.

E-12 TIME - DEPENDENT EXCITATION IN A 13-MHz ARGON DISCHARGE, M.J. Colgan and D.E. Murnick, Physics Department, Rutgers University,Newark NJ 07102--The spatial and temporal dependence of ArI spectral lines are being measured in an argon discharge at 13-MHz using the time-to-amplitude conversion method on spatially resolved plasma-induced emission (PIE). Using single photon counting and fast phototubes, sub-nanosecond time resolution is achieved and radiative lifetime effects are observed. The discharge is maintained between parallel electrodes of equal area with applied r.f. power between 1 and 5 Watts at 1 Torr gas pressure. Previous measurements of this type have been reported for argon in a 50kHz discharge with asymmetric electrodes[1]. Time-dependent electron collision excitation rates can be determined by deconvolution of PIE originating in 2p (Paschen notation) and higher-lying levels. These data may be used in combination with absolute 1s densities which we obtain by laser absorption spectroscopy to evaluate and improve fluid-type discharge models[2].

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[1]R.J. Seebock and W.E. Kohler, *J. Appl. Phys.* 64, 3855 (1988)
[2]D.B. Graves, *J. Appl. Phys.* 62, 88 (1987)

E-13 Transient Electron Kinetics in Crossed Electric and Magnetic Fields and Circularly Polarized Microwave Field,* P. Hui and G. Schaefer, Weber Research Institute, Polytechnic University --The Monte Carlo Flux method[1] is used to calculate electron velocity distribution functions in cases where the distribution functions are fully 3-dimensional in velocity space. Examples are crossed electric and magnetic fields and circularly polarized microwave fields with and without crossed magnetic field. Steady state distributions and time dependent distributions after step-wise changes of the electric and the magnetic fields will be presented. The similarity relations between crossed electric and magnetic fields and microwave fields will be discussed.

*Work supported by the NSF

[1]G. Schaefer and P. Hui, Submitted to J. Comp. Phys., to be published.

E-14 Experimental and Theoretical Longitudinal Electron Diffusion Coefficients in Molecular Gases, J. L. PACK,* R E VOSHALL, A. V. PHELPS+ and L. E. KLINE, Westinghouse STC, Pittsburgh, PA 15235 -- Values of the ratio of the longitudinal diffusion coefficient to mobility (D_L/μ) for electrons in D_2, N_2, H_2O, N_2O, NO_2, CO, CO_2 and NH_3 were obtained during earlier measurements of electron mobility. The measured D_L/μ values agree well with predictions based on the theory of Parker and Lowke. The experimental values of D_L/D_T, where D_T is the transverse diffusion coefficient, are about 0.5 for D_2, N_2 and CO in agreement the theory. The experimental D_L/D_T values for H_2O, N_2O and CO_2 are > 1, also in agreement with theory. The occurrence of D_L/D_T values > 1 near and below the peak of the D_L/μ vs E/N curve is caused by the decrease in the momentum transfer cross section with increasing electron energy below the Ramsauer minimum. Calculated transport coefficients are given for E/N values from thermal E/N to 10 Td.

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E-15 Photodetachment Technique for Measuring H⁻ Velocities in a Hydrogen Plasma, P. DEVYNCK, M. BACAL, P. BERLEMONT, J. BRUNETEAU, R. LEROY, and R. A. STERN* Ecole Polytechnique, Palaiseau, France--We report work in progress on laser diagnostics of negative ion transport velocity in H^- ion volume sources. The plasma dynamics after the laser shot is discussed in detail, and the effect of the plasma potential perturbation on the H^- is evaluated. A method of evaluation of the H^- transport velocity from single laser beam photodetachment experiments is proposed. To substantiate this method, two laser beam photodetachment experiments have been developed. The velocities thus determined are pressure dependent, they correspond to H^- energies in the range 0.23 to 0.08 eV.

(Work supported in part by Direction des Recherches, Etudes et Techniques, and the Oak Ridge National Laboratory)

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E-16 Fokker-Planck Swarm Energy Spectrum, N.J. CARRON, Mission Research Corp - A Fokker-Planck expansion in energy space of the Boltzmann collision integral for electron swarms, valid for small fractional energy loss, is presented and studied. Treating angle variables in a two term Legendre series, there results a useful, physically meaningful, differential equation for the spectrum evolution in a time varying electric field. Elastic, inelastic and super-elastic collisions are included. The time independent solution in a constant field gives an approximate expression for the steady state swarm energy spectrum. The physical meaning of its functional form is made clear via ordinary convection-diffusion theory. Previous spectra by Wannier; Chapman and Cowling; Morse, Allis, and Lamar; Davydov; and Druyvesteyn are special cases. The new spectrum is exact in the limit of small quantum transition energies. The reasons for the inadequacy of the Continuous Slowing Down A oximation (CSDA) become apparent, and it is shown that the CSDA violates detailed balance. The spectrum is used with experimental cross sections to compute transport coefficients in O_2 and N_2, in which fractional energy loss is small at most energies. Agreement with swarm data is excellent from .01 to 100 Td for most coeffici ts.

E-17 Particle Focusing Using Two-Stage Laser Ablation,* K. D. BONIN and M. A. KADAR-KALLEN, Princeton U. — We have used two-stage laser ablation to produce a focused beam of neutrals, ions, and clusters.[1] The technique has enabled us to generate a collimated beam and beams which are focused in one and two dimensions. For a barium beam focused in two dimensions over a distance of 10.7 cm the on-axis density was measured to be 5×10^{15} atoms/cm^3. An on-axis density of 10^{15} atoms/cm^3 was measured for a collimated beam at the same distance. The particle beam is produced by a two stage process. In the first stage a pulse from the ablating laser ($\lambda = 532$ nm) strikes a barium slab in a vacuum chamber (10^{-6} torr) in front of a transparent substrate. The distance between the solid barium slab and the substrate is 0.5 cm. Material is removed from the barium slab and is deposited as a thin film on the substrate. A rotating stage then moves the barium and replaces it with a hole in front of the now coated substrate. The laser is pulsed again, ablating the barium deposited on the substrate and forming a beam which propagates freely. The particle beam's focusing properties are determined by the shape of the substrate's surface. Material deposited on a cylindrically or spherically curved glass substrate is focused to its center of curvature. A quartz crystal microbalance (QCM) was used to measure the total mass deposited by the focused barium beam. This technique should be especially useful to those interested in producing atomic beams of refractory elements.

*Supported by DOE LLNL/DOE S/C 1133303 and ARO DAAL-87-K-0068.

[1]M. A. Kadar-Kallen and K. D. Bonin, Appl. Phys. Lett. 54, 2296(1989).

E-18 Two Approximate Sheath Solutions for a Planar Plasma Anode, O. BIBLARZ, GTE Products Corporation, Danvers, MA 01923. -- Solutions to the anode sheath have been obtained when the electron and plasma temperature are equal and when the electron is substantially above the plasma temperature. A single, highly nonlinear equation for the electric field at the sheath is derived. A description for this electric field is used which does not satisfy all the conditions of the problem. The approximation can be improved by identifying the coefficients for the net production of charges a posteriori. This approach allows for largely non-numerical solutions of some validity. When the electron and plasma are at equal temperature, reasonable results are obtained for nitrogen which at sufficiently low currents are realistic. The second case, however, yields only unreasonable answers which are thought to be related more to the inadequacy of the planar geometry model than to the approximation of the electric field distribution. Conceivably, the reactivity of the sheath can also drive the problem to a multi-dimensional mode for equal electron and plasma temperatures.

E-19 The Universal Resputtering Curve, W.L. MORGAN, Kinema Research, Monument, CO 80132--Recent measurements[1] of the fraction of material resputtered during rare gas sputter deposition of metals have shown what appears to be a universal curve for fraction resputtered versus a dimensionless mass parameter for a wide range of metals and rare gases. I will present the results of Monte Carlo trajectory simulations and theoretical analyses that provide some insight into the reason for this universal behavior. The analysis provides a simple analytical model that can be used to estimate the contributions to resputtering from the target atoms being deposited and from the reflected rare gas atoms in the sputtering system.

[1]D.W. Hoffman and J.S. Badgley, J. Vac. Sci. Technol. A 5, 1791 (1987); ibid. 6, 1691 (1988).

E-20 Optical Diagnostics of Sputtered Metal Atoms in DC and RF Discharges, G.M. JELLUM and D.B. GRAVES, Department of Chemical Engineering, University of California, Berkeley -- A study of the gas phase metal species sputtered from electrodes of DC and RF discharges has been carried out using various discharge diagnostics. In particular, time- and space-resolved laser induced fluorescence (LIF) and optical emission spectroscopy (OES); and space-resolved laser absorption and Langmuir probes. The discharge conditions, gases, and electrode materials have been varied to examine, systematically, the effects of electrode sputtering: the pressures have been varied from 0.03 to 3 torr and powers up to 1.5 W/cm^2. A dramatic difference is found between the spatially-resolved optical emission and laser induced fluorescence signals; this difference cannot be accounted for by considering only the electron density/energy dependence of the OES signal. A laser pump/probe experiment shows the gas phase metal species is not a neutral atom, we speculate that this species is a negatively charged metal cluster. The creation and loss mechanisms of this species are examined by combining the diagnostics with a pulsed discharge.

E-21 ELECTRICAL CONDUCTIVITY OF HIGH PRESSURE IONIZED XENON,* J. Kocejć and S. Popović, Institute of Physics, Zagreb, Yugoslavia,— Radial temperature distributions and voltampere characteristics were used to evaluate electrical conductivity of high pressure ionized xenon. This experiment confirms the influence of dense plasma conditions on transport properties of xenon plasmas. Possible contribution of excited states and ion-acoustic turbulences to the electron transport were also discussed.

*Submitted by L. Vušković

E-22 Electric Field in Super Narrow Tube Low Pressure Hg-Ar Electric Discharge Lamps,* G.Zissis, A. Bénétruy, J.J.Damelincourt, C.P.A.Toulouse France -- We report here the first measured and calculated values of electric field strength in super narrow tube (diameter<6 mm) low pressure Hg-Ar lamps. In our experimental apparatus, the cold spot temperature could be fixed to within ±2°C by using an oil circulation around the lamp. Measurements of electrical field have been carried out for three different diameters and for two different currents (20 and 40mA) using a high frequency power supply (28 kHz), the rare gas pressure was 15 Torr (24°C) in all cases. The experimental accuracy has been estimated to be ±6% in all

cold spot temperature range (-15 to 85 °C). We observe that, electric field remains almost constant (within ±8%) as a function of cold spot temperature and its absolute value has been found to be several Volts/cm depending on the tube radius and discharge current. The electric field has also been calculated by using a self consistent collisional radiative model. Diffusion controlled positive column has been taken into account, and a non Maxwellian electron energy distribution function as proposed by Lagushenko[1], has been used. Our calculated values are in very good agreement (within ±1%) with the experiment for T_{cs}>30°C, but important discrepancies have been found for the lower cold spot temperatures. This later may be explained by taking into account the possibility of rare gas ionization which may occur in these cases because the elevated electron temperature (>20000K).

*Work supported in part by CIE Philips Eclairage, Pont-à-Mousson, France

[1]R. Lagushenko and J. Maya, Journal of IES, 14, 306 (1984)

E-23 Low Electric Field Measurements in Plasmas, J. R. SHOEMAKER, Wright Research and Development Center, WPAFB OH -- Low electric fields in plasmas have previously been measured using Inglis-Teller series termination and line broadening of high n (Rydberg) states of atoms. A misinterpretation in the definition of series termination, which has been propagated in the literature for the past 50 years is shown to change measured field values by a factor of two. The incorporation of instrumental resolution in the derivation of the series termination relation is shown to alter field values significantly. Problems with applying hydrogen line broadening theory to triplet and singlet helium are discussed, as well as a correction for hydrogen.

E-24 Modelling of a surface wave sustained helium discharge at low pressure, * S.DAVIAUD, G.GOUSSET, J.MAREC, LPGP, Univ. Paris-Sud, Orsay, FRANCE

A collisional radiative model has been realized to model helium surface wave discharges at low pressure (0.5-10 Torr) with an electron density of 10^{12} to 10^{13} cm^{-3} .The calculated values of the 2^3S and 2^3P densities are in good agreement with the densities measured by a selfabsorption technique. Furthermore, the model describes well the characteristics ν (effective collision frequency for momentum transfer) and θ (power needed to maintain an electron), which had been previously obtained experimentally [1]. Using the model, the main mechanisms occuring in the discharge are studied: the plasma is stepwise excitated by electron collisions.

*Work supported in part by Microcontrole, Evry, FRANCE

[1]S.DAVIAUD, C.BOISSE-LAPORTE, P.LEPRINCE, J.MAREC, J. Phys. D (Appl. Phys.) 22(6) (1989) 770

E-25 VUV Spectroscopy of an Argon Surface Wave Plasma with Supersonic Flow*, M. E. BANNISTER, J.L. CECCHI, G. SCOLES, Princeton University -- The VUV emissions from the supersonic expansion of an argon plasma sustained by electromagnetic surface waves are studied. A 2.45 GHz surfatron[1] excites the plasma in a 4 mm I.D. quartz tube which is terminated by a converging nozzle, which produces supersonic flow into a vacuum chamber. Variations in the spectra in the 60-150 nm range, including features associated with Ar_2^* excimer emission, are investigated as functions of discharge pressure, nozzle diameter, and absorbed power. Emission spectra with and without a luminous expansion jet are compared. In addition, a scheme for the breakdown of the supersonic expansion is proposed based on experimental results.

*Work supported in part by U.S. Department of Energy Contract #DE-AC02-76CH03073

[1]M. Moisan, C. Beaudry, P. Leprince, Phys. Lett. 50A, 125 (1974).

E-26 Simulation of Electron Avalanches near a Gas-Solid Interface, S. M. Mahajan and K. W Lam, Tennessee Technological University - - - Electron avalanches near a solid dielectric surface in nitrogen gas (at 0.1 MPa) have been simulated. The electrons are assumed to propagate primarily in the gas. Nearby solid dielectric surface has been included in the simulation via (i) non-uniform electric field and (ii) photoemissive contribution to the ongoing avalanche in the gas. Photoemission from the solid dielectric surface has been assumed to be most effective near the tip of the ongoing avalanche. Field enhancement near cathode triple junction and field reduction near anode triple junction describes the non-uniform electric field along the length of the solid dielectric. Electron avalanches have been simulated with several different electric field profiles (linear, exponential, and step function), and at various values of electric fields.

Results indicate that if a nearby solid dielectric has reasonably high value of photoemission coefficient, then the surface flashover could occur at relatively low values of electric field. Experimental data on photoemission coefficient from various solid dielectrics is needed.[1] Electron avalanches in various non-uniform electric field profiles could provide information about the growth of electrons near a charged dielectric surface.

1. M. Tanaka, Y. Murooka, and K. Hidaka, *J. App. Phys., 61(9), 4471 (1987).*

E-27 Creation of an Electrostatic Image on a Dielectric Surface in a Small Gap, V. Meytlis, T. Kegelman, B. Fagen, KCR Technology, Inc. - The discharge in an extremely small gap width (approx 10μm) is investigated experimentally and theoretically. The positive electrode has a metallic surface and the negative electrode is covered by a dielectric. The dielectric surface moves with respect to the fixed metal surface at a constant velocity. This allows creation of a sustained discharge between the surfaces. The positive charge which forms on the dielectric surface after a discharge creates a field concentration. The relationship between the applied and residual voltage (the positive charge on the dielectric) was obtained for different configurations of the metal annode and for different dielectric film thickness on the cathode. A converging surfaces model was used to describe the discharge under these conditions. Within this model it is possible to apply the Townsend Theory of Discharge to explain the experimental results.

E-28 Conductivity Probe for High Pressure Plasmas* S.M.Jaffe, S.A.Self, M.Mitchner Stanford University.--In our efforts to study three body recombination in afterglows at atmospheric pressure, we have developed a conductivity probe based on the capacitive coupling appoach of Johnsen[1]. The probe is a coaxial resonator operating at 250 Mhz with one end open to the plasma. The presence of plasma in this end reduces the signal transmission and this effect can be simply related to the plasma conductivity. Only a signal generator and diode detector are required. The measurable range of conductivity extends from $5x10^{-4}$ to 10^{-1} S/m. Afterglows of photoionized, high pressure plasmas have been measured with this probe and compared with kinetic models.

*Work supported by AFOSR

[1]R.Johnsen, Rev. Sci. Inst 57, March 1986 P 428

E-29 Optical Emission and Langmuir Probe Diagnostics of a Hydrocarbon Arc Jet Plasma, K. R. STALDER AND R. L. SHARPLESS, SRI International--We have made spectroscopic measurements of an arc jet plasma used to synthesize polycrystalline diamond films on a silicon substrate. A subsonic plasma jet is ejected from the orifice of the arc chamber and impacts the substrate. Using 200 Torr hydrogen with 1% added CH_4, 900 watts discharge power and a substrate-orifice distance of 10 mm, we observed polycrystalline diamond films to grow at a rate of 1 micron per minute. Spectroscopic

measurements show strong emission from C_2 and CH. Synthetic spectra fits to the C_2 emission show that the excited state C_2 temperature near the orifice is 5000 K, and drops to 4000 K 8mm downstream. The decrease in optical emission intensity is consistent with local thermodynamic equilibrium (LTE) conditions which are likely to prevail in this high pressure plasma. Langmuir probe measurements indicate the electron temperature is about 10,000 K, so this supports the LTE nature of this plasma.

E-30 In-Situ Density and Temperature Measurements of Vibrationally-Excited Hydrogen Molecules in H^- Ion Source Plasmas* G. C. STUTZIN, A. T. YOUNG, A. S. SCHLACHTER, K. N. LEUNG and W. B. KUNKEL, Lawrence Berkeley Laboratory, University of California -- Production of vibrationally-excited hydrogen molecules has been postulated to be an intermediate step in H^- formation in ion source discharges, but until recently, measurements have been scarce We have measured the rotational- vibrational distribution up to $v'' = 8$ and $J'' = 13$ (not simultaneously) using VUV laser absorption spectroscopy in a pure H_2 discharge. The vibrational populations appear to be well-described by a plateau in the vibrational distribution from $v'' \sim 5$ to $v'' \sim 11$ Further study of an ion source optimized for H^- production is in progress, in which the atomic and molecular populations as well as extracted H^- current and thermal electron characteristics will be measured at various discharge parameters. By correlating these data, one can attempt to determine the validity of the theoretical models for these sources.

* Supported by AFOSR and US DOE under Contract No. DE-AC03-76SF00098.

E-31 Atomic Hydrogen Measurements in Hydrogen Bearing Plasmas B. L. Preppernau, A. Tserepi, T. Czerny, and T. A. Miller, Ohio State University - - Hydrogen bearing plasmas are finding wide applications to the production of novel materials and properties. A recently developed laser probe diagnostic of atomic hydrogen concentrations has been applied to the study of the role of atomic hydrogen in various hydrogen bearing plasmas. The technique offers both excellent spatial and temporal resolution of atomic hydrogen profiles in these plasmas. The diagnostic has been shown to have a dynamic response capable of being utilized over a broad range of plasma conditions, particularly near plasma/surface interfaces.

E-32 Detection of atomic hydrogen near a surface by resonant four-photon ionization technique.* G. SULTAN, G. BARAVIAN, J. JOLLY, and P. PERSUY, L.P.G.P., (Associé CNRS), U. of PARIS-SUD 91405 ORSAY FRANCE - Hydrogen atoms are created in a flowing dc discharge in H2. The gas pressure is in the range 0.1-10 Torr and the discharge current may be fixed between 1 and 100 mA. The H atoms produced in the discharge are driven out by the gas flow to the detection chamber, where a laser beam is focussed at few mm from a biased electrode. The laser wavelength is scanned in the range 364-366 nm, the value 364.7 nm corresponds to a resonance with 3 photons for atomic hydrogen. In this case the H atom is excited with 3 photons and ionized by a fourth one. The produced ions are collected in an applied field equal to about 30 V/cm and the intensity of the signal can be related to the H atom density. In this experiment the direct non resonance four-photon ionization of H and H2 is negligible as compared with the resonance enhanced process. The resonance line is asymmetric and presents a FWHM between 0.05 and 0.2 nm.

* Work supported in part by DRET

E-33 Stochastic Properties of Trichel Pulse Corona Discharges in O_2 and Ne/O_2 Mixtures,* R.J. VAN BRUNT and S.V. KULKARNI, NIST, V K LAKDAWALA, Old Dominion Univ.—The stochastic behavior of ultra-violet sustained negative point-plane corona discharge pulses in O_2 and Ne/O_2 at atmospheric pressure have been investigated using a newly developed method[1] to directly measure various conditional discharge pulse-height and time-separation distributions. As in the case of negative corona pulses in air or N_2/O_2 mixtures, the strong correlation between pulse amplitude and time separation from the previous pulse can be explained by the influence of residual negative-ion space charge in reducing the electric field strength at the cathode. For Ne/O_2, the correlations between amplitudes of successive discharge pulses and between amplitude and time-to-initiation of the subsequent discharge pulse are the opposite of those found for O_2 and N_2/O_2 mixtures. It is argued that this difference between the stochastic behavior of corona pulses in Ne/O_2 and O_2 or N_2/O_2 can be attributed to the different relative roles played in these mixtures by residual metastables in enhancing both the ionization rate and secondary electron emission at the cathode. The influence of metastables appears to be more important O_2 and N_2/O_2.

*Work supported in part by U.S. Department of Energy.

[1]R.J. Van Brunt and S.V. Kulkarni, Rev. Sci. Instrum. (in press, 1989).

E-34 Absolute Total Inelastic Electron Impact Excitation of He and Ne,* DAVID SPENCE and MICHAEL A. DILLON, Argonne National Laboratory--We have identified a previously unrecognized systematic error in the use of the "trapped electron method" which may have affected some previous measurements of inelastic electron scattering cross-sections. We have employed this technique to measure the total inelastic cross section in helium and neon from the first inelastic threshold to the ionization threshold. In our experiments, all experimental parameters are measured absolutely for the first time. Though our cross-section values are somewhat larger than some previous measurements, they are in excellent agreement (~5%) with recent R-matrix calculations[1,2] over the whole energy range.

*Work supported in part by the U.S. Department of Energy, Office of Health and Environmental Research, under Contract W-31-109-Eng-38.

[1]K. A. Berrington and A. E. Kingston, J. Phys. B 20, 6631 (1982).
[2]K. T. Taylor, C. W. Clark, and W. C. Fon, J. Phys. B 18, 2962 (1985).

E-35 Low Energy Shape Resonance in the Ground Electronic State Vibrational Excitation of Silane and Disilane,* H. TANAKA,† L. BOESTEN,† H. SATO,§ M. KIMURA, M. A. DILLON, and D. SPENCE, Argonne National Laboratory--Vibrational excitation functions and angular distributions obtained with electrons of ~ 1-7 eV incidence have been used to investigate resonance electron scattering from silane (SiH_4) and disilane (Si_2H_6). Calculations that use the discrete variable X_α multiple scattering model[1] show that a shape resonance with a maximum in the range of ~ 1.5-3.5 eV observed in the vibrational excitation functions of SiH_4 and Si_2H_6 arises from the decay of compound states with respective symmetries of t_2 and e_u.

*Work supported in part by the U.S. Dept. of Energy, OHER, under Contract W-31-109-Eng-38.

†General Sciences & Physics Dept., Sophia University, Tokyo 102, Japan.

§Physics Dept., Ochanomizu University, Tokyo 112, Japan.

[1]H. Sato, M. Kimura, and K. Fujima, Chem. Phys. Lett. 145, 21 (1988).

E-36 Elastic Scattering Cross Section Measurements for Collisions of 1.5-100 eV Electrons with Silane and Disilane,* H. TANAKA,† L. BOESTEN,† H. SATO,§ M. KIMURA, M. A. DILLON, and D. SPENCE, Argonne National Laboratory--Energy and angular distributions for elastic collisions of electrons with silane (SiH_4) and disilane (Si_2H_6) have been measured for incident energies of 1.5-100 eV over a scattering angular range of 20-130°. Relative scattered electron intensities were normalized to helium cross sections by using the relative flow method. Experimentally determined cross sections are

compared with theoretical results obtained from the discrete-variable X_α multiple scattering formulation.[1]

*Work supported in part by the U.S. Dept. of Energy, OHER, under Contract W-31-109-Eng-38.

†Sophia University, Tokyo 102, Japan.

§Physics Dept., Ochanomizu University, Tokyo 112, Japan.

[1]H. Sato, M. Kimura, and K. Fujima, Chem. Phys. Lett. 145, 21 (1988).

E-37 Positron-CO Collisions Using Parameter-Free Positron Correlation Polarization Potential. Ashok Jain, Florida A & M Univ., Tallahassee -- Recently, we[1] have proposed a parameter-free polarization potential for low-energy positrons collisions with atoms and molecules. This new potential is based on the correct asymptotic form ($-\alpha_0/2r^4$) which is smoothly joined with the positron-electron correlation energy $\epsilon_{corr}(r)$ at near-the-target distances. The $\epsilon_{corr}(r)$ is determined in an analytic form from *ab initio* calculations of the positron-electron correlated system. We employ this Positron Correlation Polarization (PCOP) potential for the positron-CO collisions below the Ps formation threshold energy under a close-coupling scheme. The converged cross sections are obtained in the multipole-extracted- Adiabatic-Approximation (MEAN). Our final total cross sections compare very well with measurements and improve upon all previously available calculations.

1. Ashok Jain, Phys. Rev. A39 (Aug. 1989 issue)

E-38 Cross Sections for Some Core-Excited NaI Quartet States*, Alfred Z. Msezane, Atlanta University -- Electron-impact excitation cross sections from ground $3s\ ^2S$ and excited $2p^53s3p\ ^4S$ states to the lowest core-excited quartet states of NaI arising from the configurations $2p^53s3p$, $2p^53s3d$ and $2p^53s4s$ are calculated and contrasted using a twelve-state R-matrix[1] method for energies from near threshold to 6 Ry. Extensive configuration interaction target wave functions are employed. Reach resonance structure characterizes the cross sections in the threshold region and the maxima of those from the $2p^53s3p\ ^4S$ state dominate the corresponding ones from the ground state by atleast two-orders of magnitude. The results may be important to the understanding of xuv lasers[2].

*Work supported in part by US DOE, Basic Energy Sciences, Division of Chemical Sciences.

[1]K. A. Berrington et. al. Comput. Phys. Commun. 14, 367 (1978).

[2]D. E. Holmgren et. al. Phys. Rev. A31, 677.

E-39 Energetics of Negative Ion Formation via Dissociative Attachment of e + LiH*, H. H Michels, UTRC, and J M Wadehra, Wayne State U.--- The formation of $H^-(Li^-)$ by dissociative attachment (DA) of $e + H_2(Li_2)$ is thought to be the dominant volume process in discharge type negative ion sources. The role of $Li_xH_y(Cs_xH_y)$ molecules, which could be formed from seeding an alkali into a hydrogen plasma, is presently not well understood, but the addition of an alkali such as Cs appears to enhance the H^- production rate. This observation is interesting in light of the study by Gauyacq, et al[1], which indicates that charge transfer and collisional detachment processes should reduce H^- production in Na seeded plasmas. We have analyzed the electron attachment to LiH and $(LiH)_2$ in terms of calculated potential energy curves. In agreement with previous studies, we find that the ground state of LiH^- is thermodynamically bound relative to LiH + e, with a calculated electron affinity of ~ 0.3 eV. The first excited state of LiH^-, which asymptotically correlates to $Li^- + H$, exhibits repulsive behavior in the region $3.0 \leq R \leq 6.0$ Å. Based on these preliminary studies, DA of e + LiH to form Li^- should occur mainly for $E_{coll} > 3.0$ eV. The formation of $Li + H^-$ products may occur by non-adiabatic coupling of $^1\Sigma^+$ $X^2\Sigma^+$ state of LiH^- to the continuum for $E_{coll} > 2.1$ eV. The role of LiH dimers is presently under study.

*Supported in part by AFOSR under Contract F49620[illegible]-C-0019 and Grant AFOSR-87-0342.

[1]J. P. Gauyacq, et al, Phys. Rev. A, 38, 2284 (1988).

E-40 Low-Energy Electron Impact Dissociation of H_2 Using Fully Correlated target Wavefunctions W. M. HUO, NASA Ames Research Center, -- The dissociation of H_2 by low-energy electron impact excitation to the $b^3\Sigma_u^+$ state has been studied using a two-state approximation with the target described by a full configuration-interacation (CI) wavefunction. The full CI treatment ensures that the molecule and dissociated products are described on an equal footing, an important consideration in calculating the dependence of the dissociation cross section on the initial vibrational state of the target. The different roles of target correlation and electron-target correlation will also be discussed.

E-41 Three-Body Association of Atomic Ions in Atomic Gases*. B.K. Chatterjee and R. Johnsen, University of Pittsburgh. -- We have derived a relatively simple formula to estimate three-body rate coefficients for association of atomic ions in atomic gases. While the derivation of this formula is rather crude, it reproduces available experimental data quite well and it may be useful for a quick estimation of rate coefficients, as is often needed for model calculations of discharges. We will outline the derivation and will present a comparison to available experimental data. We have also obtained new experimental data on the three-body association of protons (and the corresponding process for deuterons) in helium

$$H^+ + 2\,He \longrightarrow HeH^+ + He$$

at temperatures of 77 K and 300 K using a drift-tube apparatus. The results will be presented and will be compared to the theoretical formula.

* Work supported by ARO and NASA

E-42 Ion-Molecule Reactions of Atmospheric Ions with Dimethyl-Methylphosphonate *. R. Tosh, B.K. Chatterjee, and R. Johnsen, University of Pittsburgh. -- We will present the results of a series of measurements on reactions of O^+, O_2^+, N^+, N_2^+, NO^+, $NO^+(^3\Sigma_u)$, H_2O^+, and H_3O^+ ions with Dimethyl-methylphosphonate. (DMMP). Measured data include total rate coefficients into all product channels and product-ion branching ratios for ion energies (center-of-mass of the ion/reactant system) from 0.04 to about 1 eV. All measurements were carried out using a selected-ion drift-tube mass-spectrometer apparatus. Most reactions proceed by fast dissociative charge transfer (rate coefficients near 1×10^{-9} cm ^{3}/s) and lead to product ions similar to those observed in electron impact studies of DMMP. Ground-state NO^+ ions react by three-body association only while proton transfer is the only observed reaction of H_3O^+ ions.

* Work supported by the US Air Force (WPAFB)

E-43

Association Reactions in $C_2H_2^+/C_2H_2$ and HC_3N^+/HC_3N Systems, A. D. Sen, V. G. Anicich and M. J. McEwan, JPL — Rate coefficients of the association reactions, $C_4H_2^+ + C_2H_2$, $C_4H_3^+ + C_2H_2$ and HC_5N HC_3N have been measured at pressure between 1×10^{-7} and 1×10^{-5} Torr by the ion cyclotron resonance technique. At low pressures the bimolecular association rates were $k_2 = 2.8 \times 10^{-10}$ $cm^3.s^{-1}$, $..4 \times 10^{-10}$ $cm^3.s^{-1}$ and 5.1×10^{-10} $cm^3.s^{-1}$ for $C_4H_2^+$, $C_4H_3^+$ and HC_5N^+ respectively. Above ~ 5×10^{-6} Torr termolecular association was observed with rate coefficients $k_3 = 5.7 \times 10^{-23}$ $cm^6.s^{-1}$, 1.3×10^{-23} $cm^6.s^{-1}$ and 1.1×10^{-22} $cm^6.s^{-1}$ for $C_4H_2^+$, $C_4H_3^+$ and HC_5N^+ respectively when the parent neutrals were the third bodies. The lifetimes for unimolecular dissociation were ≥ 73 µs for $(C_6H_4^+)^*$, ≥ 18 µs for $(C_6H_5^+)^*$ and ≥ 20 µs for $(H_2C_8N_2^+)^*$. The radiative stabilization rates were 3.7×10^3 s^{-1} for $(C_6H_4^+)^*$, 9.0×10^3 s^{-1} for $(C_6H_5^+)^*$ and 1.1×10^4 s^{-1} for $(H_2C_8N_2^+)^*$. It was also observed that the secondary ions $C_4H_2^+$, $C_4H_3^+$ and HC_3N^+ were produced with excess energy from $C_2H_2^+ + C_2H_2$ and $HC_3N + HC_3N$ reactions required collisional de-excitation before association with the parent neutrals.

E-44 Decay Product and Energy Distributions from H_3 n=2 Rydberg States,* P. DEVYNCK, W. G. GRAHAM,† and J. R. PETERSON, SRI International--The lowest bound states of H_3, 2s A_1' and 2p A_2'' are produced in keV beams from H_3 by near-resonant electron capture in Cs, and undergo rapid predissociative decay to the repulsive ground state. Translational spectroscopy is used on H^- atoms exiting the Cs oven along the beam axis to deduce the c.m. translational energies of the dissociation products. Both two-body and three-body energy distributions are observed, and the branching ratio is obtained from H_3, D_3, and HD_2. The 3-body/2-body ratios depend on the rovibrational energy in the parent H_3^+ (beams were obtained from two different ion sources) and are smaller than those observed from dissociative recombination. The H_2 products are highly vibrationally excited, into the continuum. A distinct isotope effect is observed in the two-body decay of HD_2.

*Research supported by AFOSR and NSF.

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E-45 Near Zero Projectile-frame Kinetic Energy H^+ in H_2^+-He Collisions at 4.0 keV.* O. YENEN, L. WIESE, D. CALABRESE, and D. H. JAECKS, University of Nebraska-Lincoln--In some ion sources, one can quench upper vibrational states of H_2^+ by mixing Ne with H_2 in 5:1 ratio. We have inserted varying mixtures of Ne and H_2 in a duoplasmatron that we monitored by a quadrupole mass spectrometer just outside of the source, to alter the vibrational content of the H_2^+ beam. Using translational spectroscopy techniques in H_2^+-He collisions at 4.0 keV, we found that the central peak of the H^+ lab energy distribution is shifted differently from $E_o/2$, depending upon the H_2/Ne ratio. Our results suggest that when high vibrational states are present, the dominant process for producing near zero projectile frame energy H^+ is electronic excitation from $1s\sigma_g$ to $2p\pi_u$ or $3d\delta_g$ states. We also conclude that insertion of Ne in the duoplasmatron does depopulate the upper vibrational levels at least to a degree that other processes dominate the production of near zero energy H^+ in the c.m. of H_2^+.
* Supported by NSF Grant PHY-8701905.

E-46 $SO_2^-.(SO_2)_n$, $(SO_2-O_2)^-.(SO_2)_n$ and $(SO_2-O_3)^-.(SO_2)_n$ clusters ($0 \leq n \leq 7$), M.JORDA, E.LEDUC, M.FITAIRE, LPGP, Univ. Paris-Sud, Orsay, FRANCE —Negative ion clusters have been identified in SO_2 and SO_2/O_2 mixtures (p ~ 100Torr) with a previously described [1] experimental set-up (ionization by α-particules and detection with a mass spectrometer). Equilibrium constants of the reactions are measured as a function of gas temperature (253 K-390 K). This allows the determination of the enthalpy (ΔH) and entropy (ΔS) variations of the studied reactions. Mass discrimination between the observed ions has been done using O^{18} (for ex. ions of mass $112+n64$ could have been $(SO_3-O_2)^-.(SO_2)_n$). In pure SO_2, ΔH and ΔS which depend on the size of the clusters have values respectively between -3 and -7 kcal/mol (~ 0.2eV) and -21.5 and -26 cal/mol/K (~ 10^{-3} eV/K).

[1] C.V.SPELLER, M.FITAIRE, A.M.POINTU, J.Chem.Phys. 79 (1983) 2190

E-47 Spectroscopic Study of a Bound Triplet State of H_2 Perturbed by a Doubly Excited State L. J. LEMBO, N. BJERRE*, D. L. HUESTIS, AND H HELM Molecular Physics Laboratory, SRI International, Menlo Park, CA -- A double-resonance technique is employed to measure the positions of energy levels of the $2^3\Pi_g$ state of H_2. This state arises from the homogeneous interaction of the singly excited $1s\sigma_g 3d\pi_g$ diabatic Rydberg state with the core-excited $2p\sigma_u 2p\pi_u$ state. This state was relied upon in a previous study to explain an unexpectedly intense photoionization behavior in triplet H_2 involving large changes in the vibrational quantum number. Some of these ionization lines correspond to $2^3\Pi_g$ levels reported herein, which are observed to dissociate as well. The energy-level spacings are in good agreement with theoretical predictions. We also summarize all new information regarding the ionization transitions and levels.

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E-48 Two Color Photo-ionization Spectra of He_2 $a^3\Sigma_u^+$, N. BJERRE,* L. LEMBO, D. C. LORENTS, and H. HELM, SRI International--A fast beam of He_2 a-state molecules produced by electron capture of He_2^+ in cesium were two photon ionized by collinear photon beams from tunable lasers. Single photon transitions to intermediate states excited with a low power tunable laser were photo-ionized with a second strong time delayed laser beam of fixed wavelength. The resulting diatomic ions were detected as the first laser was scanned to obtain an absorption spectrum from the various ro-vibrational levels of the a state to the higher Rydberg states in the triplet manifold. Spectra in the 23-25000 cm^{-1} range are dominated by a-$e^3\Pi_g$ and a-$g^3\Sigma_u^+$ transitions but several strong as yet unidentified transitions also appear. High Rydberg states of He_2 were studied by exciting, with the first laser, a transition to the $c^3\Sigma_u^+$ and with the second laser pumping Rydberg states lying above the ionization limit. Analysis and interpretation of these spectra in terms of the structure of He_2 is underway and will be presented.

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SESSION FA: IONIZATION
Wednesday morning, 18 October 1989
Rickeys Hyatt, Camino Ballroom C at 8:00 A.M.
S. K. Srivastava, presiding

FA-1 Measurements of Electron Impact Ionization Cross Sections. R. S. FREUND, AT&T Bell Laboratories - As the principal collision process which sustains electrical discharges, electron impact ionization is of pervasive importance in gaseous electronics. Recently, molecular beam methods have provided accurate measurements of absolute partial ionization cross sections for atoms, molecules, and free radicals from threshold to several hundred eV, the energy region most important in gaseous electronics. Measurements are now available for single ionization of 43 atoms (almost all except the transition metals and rare earths), for double and triple ionization of many of the same atoms, and for ionization and dissociative ionization of several dozen molecules and a half dozen free radicals. This talk will review these recent measurements with an emphasis on species important in semiconductor plasma processing.

FA-2 Theoretical calculations for electron impact ionization of metastable states of rare-gas targets.* J. B. Mann, A. L. Merts, and G. Csanak, Los Alamos National Laboratory, Los Alamos, NM 87545--Electron impact ionization of metastable states of rare-gas atoms is of considerable scientific and practical interest for usage with the modeling of excimer lasers. We shall review the theoretical methods used in the past for the calculation of electron impact ionization cross sections of metastable atomic targets. This review shows that in the past, only plane-wave (Born) or binary-encounter type of theories were used for these problems. We shall present numerical results from distorted wave approximation (DWA) calculations for the ionization of the 2^1S and 2^3S states of helium as well as for the ionization of the $2p^53s$ configuration of neon, the $3p^54s$ configuration of argon, and the $4p^55s$ configuration of krypton. DWA calculation results will also be presented in some cases using the "maximum interference" DWA. Our results will be compared to other theoretical results and to the available experimental data.

*Work performed under the auspices of the USDOE.

FA-3 The Identification of Recombination Product Excitation States*, J.B.A. MITCHELL, F.B. YOUSIF and P. VAN DER DONK, The University of Western Ontario, T.J. MORGAN, Wesleyan University -- The dissociative recombination of molecular ions leads to the formation of atomic and radical fragments in a variety of states of potential and kinetic excitation. Two techniques for identifying product excitation states are currently under development in the merged beam laboratory at UWO. The first employs a time and position sensitive detector[1] to directly measure the kinetic energy and hence to deduce the potential energy of the products of diatomic molecular ion recombination. The second uses field emission detection to selectively ionize products formed in high principal quantum number states. Progress in the implementation of both these techniques will be discussed.

*Work supported by USAFOSR and Canadian NSERC.
1. D.P. de Bruijn and J. Los, Rev. Sci. Instrum. 53, 1020, 1982.

SESSION FB: LASER PHENOMENA
Wednesday morning, 18 October 1989
Rickeys Hyatt, Camino Ballroom D at 8:00 A.M.
L. A. Schlie, presiding

FB-1 Argon Ion Laser excited at the lower hybrid Frequency, R.W. BOSWELL and PEIYUAN ZHU, PRL, RSPhysS, Australian National University - Lasing action has been observed on the 488 nm line of the AII system in a 5 cm diameter rf excited magneto-plasma. The gain is strongly peaked at magnetic fields for which the excitation frequency is equal to the lower hybrid frequency. The radial plasma density and gain profiles are very similar and have a full width half maximum of 1 cm. Theoretical analysis suggests that the rf antenna excites an m = 1 helicon (whistler) wave which is highly landau damped and can produce an excess of electrons with ~ 20 eV energy, near that required to produce a population inversion in the upper 4P state of the 488 nm transition. The phenomenon appears similar to that observed in Tokamaks employing whistler waves for current drive.

FB-2 X-ray photoswitched argon and neon discharges, H. BRUNET and B. LACOUR, Laboratoires de Marcoussis/CRCGE and V. PUECH, S. MIZZI, S. PASQUIERS, M. LEGENTIL, LPGP Université Paris-Sud, FRANCE - The electric properties of X-ray phototriggered discharges in pure argon and neon have been investigated both theoretically and experimentally. The apparatus consists of a high pressure discharge cell ($1 \times 1 \times 50$ cm^3) connected to a storage capacitor charged a few µs before the application of the preionization pulse. The discharge breakdown is induced by a X-ray preionization pulse, 5 ns FWHM. The delay times from the onset of phototriggering to gas breakdown are reported as a function the X-ray dose, reduced electric field E/N and gas pressure. A computer model integrating the time dependant equations for the electron and heavy particles kinetics and for the driving electrical circuit has been developped. The experimental versus theoretical comparison is satisfactory. It has shown the importance of background gas impurities, especially in neon discharges.

FB-3 Determination of the Ion Temperature in a He^+Ne-Laser Discharge from Gain Measurements at Different Axial Modes, J. MENTEL, N. REICH, F. GERAT, AEEO, Ruhr-Universität Bochum, FRG - A cw He^+Ne-laser pumped by the positive column of a glow discharge is tuned by a birefringent plate on different laser lines which are emitted in the TEM_{00}-mode. The distance of the different axial modes is 217 MHz or less. They are tuned across the gain profile of the laser lines by the statistical variation of the resonator length. The different axial laser modes are recorded as intermediate frequencies in the GHz-region by a fast photodiode and a spectrum analyzer. Variable losses are inserted into the resonator by a pair of Brewster plates. From the dying out of the axial modes with increasing losses, gain profiles are determined. The measured Doppler profiles of different blue and green laser lines correspond to an ion-temperature of 1500 K.

FB-4 Laser Action in the Flowing Afterglow of a Hollow Cathode Discharge, B. Wernsman and J. J. Rocca, Electrical Engineering Department, Colorado State University-Previously, we reported CW laser action by electron-ion recombination in the 1.43 um line of CdI in the flowing afterglow of a negative glow plasma.[1]

Here, we report laser action in ArI, PbI, PbII, SnII, ZnI. NeI and H_2 in the supercooled afterglow plasma of a hollow cathode discharge. The CW ArI 1.27 um laser line and the pulsed PbI and ZnI transitions at 1.31 and 1.315 um are excited by three-body electron-ion recombination. The addition of H_2 sharply increased the laser output of the recombination laser lines by contributing to the cooling of the plasma. Variation of the laser characteristics as a function of the discharge parameters will be discussed.

[s]This work was supported by AFOSR grant 87-0290.

[1]Jorge J. Rocca, Appl. Phys. Lett., 47, 1145, (1985).

FB-5 Plasma Breakdown Behavior of Hydrogen Azide (HN_3) Gas Mixtures†. M. W. WRIGHT‡, L. A. SCHLIE, and C. A. DENMAN, Advanced Laser Technology Division (WL/ARDI), Kirtland AFB, NM 87117-6008.–Recent plasma and chemical kinetic studies of hydrogen azide gas mixtures have indicated their potential use in hybrid electro-chemical, high energy laser systems. To investigate the pertinent reaction schemes present, electrical breakdown experiments have been performed on mixtures of inert gases and hydrogen azide. As in the attachment studies done previously, strong $N_2(C - B)$ ultraviolet emission was observed in Ar/HN_3 mixtures and to a lesser extent with Kr and Xe Various geometries of the test region, ranging from a point-to-point discharge to a point-to-plane configuration were utilized. Under conditions involving a discharge region surrounded by a gaseous volume, detonation occured whereupon the pressure increased in direct proportion to the amount of HN_3 present. Mass spectrometric analysis indicated the decomposition of HN_3 to H_2 and N_2 which stoichemetrically agrees with the observed pressure increase. Transient spectra suggests that the detonation follows a chemically activated chain reaction rather than being electrically or photo-induced. Other possible applications of these azide gas mixtures are chemical flashlamps in which the detonation acts as a photolytic pumping source.
† Funded by the Air Force Office of Scientific Research.
‡Dept. of Physics, UNM, Albuquerque, NM 87131.

FB-6 The Effect of Return Currents in Electron-Beam Excited KrF Lasers*. Mark J Kushner, University of Illinois, Urbana, IL -- Space charge injected by the beam current in an electron-beam excited laser must return to the ground plane. The "return" current is driven by electric fields generated by the injected space charge. In large aperature laser systems (> 10's cm) the return current fields can exceed many Td. As a result electron impact rate coefficients of the bulk plasma and the spatial distribution of power deposition are altered. These devices then functionally resemble e-beam sustained discharges. The effects of return currents on the performance of fusion class electron beam excited KrF lasers are theoretically investigated. For these devices as much as 10-30% of the power near the walls is redistributed by the return currents and the electron temperature increases from 1.5 eVto as much as 2.5 eV. As a result low energy threshold processes, such as F_2 burnup, are significantly effected.

*Work supported by Los Alamos National Laboratory.

FB-7 Microstreamers as a Termination Mechanism in KrF Discharge Lasers*. Mark J Kushner, University of Illinois, Urbana, IL -- The performance of electric discharge excimer lasers is typically limited by issues related to discharge stability rather than kinetics. Recent experimental observations of the premature termination of optical pulses in XeCl and KrF lasers while power is still being deposited have suggested microstreamers as a possible cause. In this paper the termination of optical pulses in a KrF discharge laser is theoretically investigated with a multidimensional computer model The model simultaneously simulates both the bulk plasma and microstreamers by integrating the hydrodynamic conservation and laser kinetics equations. We find that disruption of the optical homogeneity of the medium from index variations resulting from microarcs terminate the laser pulse while only a few percent of the discharge power is being dissipated in the microstreamers.

*Work supported by the National Science Foundation.

SESSION GA: ARCS AND GLOWS
Wednesday morning, 18 October 1989
Rickeys Hyatt, Camino Ballroom C at 10:00 A.M.
V. A. Godyak, presiding

GA-1 Investigation of Dielectric Barrier Discharge UV-Lamps.* M. NEIGER, H. MUELLER, K. STOCKWALD and V. SCHORPP LTI, U. of Karlsruhe, FRG.--Dielectric barrier discharges in excimer gas mixtures are capable of producing narrow bard uv output with efficiencies of the order 10 %.[1,2] The measured dependence of current, uv output and efficiency on discharge parameters can be approximately described by a simple one-dimensional model of the individual microdischarge. However, space resolved measurements of uv emission within the gap exhibit large inhomogeneities which require a fully 2-dimensional modelling approach.

*Work supported by the German Ministry of R&D (B M F T).
[1]V. Schorpp, K. Stockwald and M. Neiger, 41st GEC (1988) Minneapolis, paper GA-6.
[2]H. Mueller and M. Neiger, 41st GEC (1988) Minneapolis paper E-26.

GA-2 Excitation of Resonance Lines and Formation of Excimers in Various Mercury / Rare Gas Mixtures. B. ELIASSON, B. GELLERT and U. KOGELSCHATZ, ASEA BROWN BOVERI, Corporate Research, 5405 Baden, Switzerland - We report on measurements and theoretical predictions of the intensities of the mercury resonance lines at 185 nm and 254 nm which have been excited in a silent discharge.
The calculations are based on our theory of microdischarge formation in silent discharges and include the solution of the stationary Boltzmann equation for the breakdown fields of such current filaments. The mercury emission was investigated in Xe, Kr, Ar, Ne and He. The total gas density, the gap spacing as well as the mercury partial pressure were varied within wide limits. The most intense radiation was found in a mercury/xenon mixture in qualitative agreement with theory. We have also determined an equivalent Boltzmann temperature from up to 8 excited Hg levels. It decreases with rising Hg vapour pressure confirming the theoretical model. Furthermore we measured line profiles for mercury mixtures with Xe, Ar, and He at various mercury temperatures. The highly resolved line profiles demonstrate the effects of optical thickness as well as excimer formation, e.g. $HgXe^*$.

GA-3 Time Resolved XUV Emission from Highly Ionized Capillary Discharges. J.F. Schmerge, J.J. Rocca and H.C. Marconi, Electrical Engineering Department, Colorado State University-We have studied the extreme ultraviolet emissions from a lithium hydride capillary plasma 500 um in diameter and several cm in length. The capillary is excited by a short (50-100 ns FWHM) pulse and single shot spectra with a temporal resolution of approximately 5 ns are obtained. Analysis of the data shows simultaneous line emissions from highly ionized (LiIII, OVI) and singly

ionized (OII) species. This is consistent with the existence of a hot core plasma (Te > 25 eV) surrounded by a cooler (Te < 5 eV) plasma near the walls, in agreement with a model of a capillary plasma[1] in which ablation of the capillary wall material is assumed to form a high density plasma layer surrounding a less dense and hotter core. Diffusion of ions from the core plasma into the cooler boundary might lead to an annular region of high recombination in which extreme ultraviolet amplification might occur under optimized plasma conditions[2].

*This work was supported by NSF grant ECS-8606226.
[1]R.A. McCorkle, Appl. Phys. A, 26, 261, (1981).
[2]M.Marconi and J.Rocca, Appl.Phys.Lett., 54, 2100, (1989).

GA-4 Electric Field and Emission Profile Measurements in a Hydrogen Discharge at Low Pressures, B. N. GANGULY, J. R. SHOEMAKER and A. GARSCADDEN, Aero Propulsion and Power Lab, WPAFB, Ohio -- Spatially resolved electric field (E) and emission (I) profiles have been measured in an obstructed low current dc H_2 discharge, 2.5 cm diameter electrodes, all but the front surfaces dielectric shielded and 0.65 cm interelectrodes spacing. Stark splitting of polarization dependent $H\alpha$ and $H\beta$ lines was used to measure E. The axial E was high and approximately constant over the entire interelectrode space. The radial variation of E and I show that the discharge is almost annular. $H\alpha$ spectra indicate that except in the anode spot region heavy particle excitations exceed electron impact excitations and that the kinetic energy of much of the excited atomic hydrogen was greater than 250eV. For these conditions (E> 3Kv/cm) the $H\beta$ Stark emission measurements yield electric fields with absolute accuracy better than 6%.

GA-5 Plasma-enhanced Photoemission from the Cathode in a Low Pressure Discharge, M. B. SCHULMAN and D. R. WOODWARD, Philips Lighting Company, Lynn, MA -- Plasma-enhanced photoemission has been reported as an in situ method for electrode surface diagnostics in rf processing plasmas.[1,2] We have used this non-intrusive method to study the effect of the plasma sheath on the emission properties of an oxide-coated tungsten-filament cathode in a low-pressure discharge lamp. Pulsed low-power laser beams at several wavelengths were used to induce photoemission from the cathode. The photoelectron pulses were detected as optogalvanic signals. The technique is shown to provide spatially and temporally resolved information on the effective work function of the cathode, which is influenced by the accelerating electric field at the cathode surface. The conditions under which thermionic emission become significant can also be determined.

[1]G.S. Selwyn, B.D. Ai and J. Singh, Appl. Phys. Lett. 52, 1953 (1988).

[2]S.W. Downey, A. Mitchell and R.A. Gottscho, J. Appl. Phys. 63, 5280 (1988).

GA-6 Temperature Measurements in a Non-Equilibrium Thermal Plasma, T. Owano, M. Gordon, and C.H. Kruger, Stanford University -- Emission measurements of temperature and electron density have been made in a quartz reactor downstream of a 50 kW induction plasma torch at atmospheric pressure. Absolute and relative intensities of 8 argon lines, and the argon recombination continuum, have been separately interpreted to investigate non-equilibrium effects in a thermal plasma and their influence on temperature measurements. The data indicate non-equilibrium resulting from radiation escape and diffusion of electrons to the cooled walls. The results are interpreted in terms of a model of the bound and free electrons in partial-equilibrium at the Boltzmann temperature from relative line intensities. The partial-equilibrium hypothesis is supported by both the data, including the recombination electron-density measurements, and by calorimetric and total radiation source strength measurements. In contrast, absolute line-intensity and continuum temperatures based on LTE considerations depart from the Boltzmann temperature by as much as 1,000 K and are inconsistent with energy-balance requirements. These techniques have been applied to the diagnostics of a non-equilibrium discharge induced in the reactor by means of an auxiliary electrode.

GA-7 Liquid Cooled, High Power (≤5.4 KW), cw Hg UV Lamps,++ L. A. Schlie, R. D. Rathge, and E. A. Dunkle**, Advanced Laser Technology Division, Weapons Laboratory (WL/ARDI), Kirtland AFB, NM 87117-6008--The performance of high power Hg vapor discharges (24 cm x 0.5 cm i.d) excited by cw, low ripple (<10%) microwaves (2.45 GHz) and cooled with an excellent UV transmitting liquid (di-methyl polysiloxane) is discussed. Very high volumetric power loadings (> 300 w/cc) in low pressure Hg vapors (≅15 torr) produce stable, uniform plasmas emitting intense UV radiation ($\lambda \geq 2400$ A). Using this liquid coolant, reliable operation of these type of lamps for high power UV emitters is possible. In an attempt to better understand these plasmas and establish the conditions for optimum UV emission, several investigations were performed. These include electron density measurements, UV intensity versus input microwave power, along with detailed electron Boltzmann kinetics analysis including high fractional excited state densities and electron-electron interactions. In addition, kinetic modeling of the excited states density is presented plus with a discussion of resonant trapping for the Hg 2537 A radiation. A discussion of the use of these lamps for cw photolytic atomic iodine lasers at 1.315 microns will be presented. ++ Funded by the Air Force Office of Scientific Research, Bolling AFB, D.C., ** Rockwell Power Services, 2021 Girard Ave, Albuquerque, NM 87117

SESSION GB: ELECTRON AND HEAVY PARTICLE COLLISIONS

Wednesday morning, 18 October 1989
Rickeys Hyatt, Camino Ballroom D at 10:00 A.M.
D. C. Lorents, presiding

GB-1 Laser Probing of Ion Mobility, Velocity Distributions and Alignment Effects in Drift Fields, S. R. LEONE, JILA, NIST and U. of Colorado, Boulder, CO 80309-0440 -- A single frequency dye laser is used to probe the velocity distributions and alignment effects of ions in a well-characterized drift field of a flowing afterglow. The velocity distributions of Ba^+ in Ar and He are analyzed in terms of "moments" to obtain: (a) the mobility, (b) the average "temperature," or broadening of the Doppler velocity distribution in directions both parallel and perpendicular to the field, and (c) the "skewness" of the distribution, a measure of the degree non-Boltzmann character. Polarization studies on molecular ions, N_2^+ and trifluor benzene cation, reveal that the ions become aligned by collisions due to the directed velocity and the anisotropy of the interaction potential. These results are discussed in terms of current theoretical formulations, which relate individual cross sections to the steady state transport results.

*Staff Member, Quantum Physics Division, National Institute for Standards and Technology.

GB-2 Termolecular Ion-Atom Association,* M. R. FLANNERY and M. S. KEEHAN, Georgia Tech--A theory of termolecular association, $Rg^+ + Rg + Rg' \rightarrow Rg_2^+ + Rg'$ of atomic rare gas ions in various rare gases is proposed. The $Rg^+ - Rg$ association is assumed to proceed via $Rg_2^+ - Rg'$ collisions. Ab-initio $Rg^+ - Rg$ interactions are used. Various simplifications to the proposed theory are investigated. Results are in good agreement with measurements.

*Research supported by AFOSR-84-0233.

GB-3 Ionization Cross-section of N_2O. C.B. FREIDHOFF and P J CHANTRY, Westinghouse STC, Pittsburgh, PA 15235--The mass-resolved positive ions formed from N_2O have been measured from their thresholds to 500 eV. Thresholds for the ions N_2O^+, NO^+, O^+, N_2^+, and N^+ are measured to be 12.88, 14.70, 15.20, 17.25, and 19.50 eV, respectively. The individual cross-sections are derived from the relative signal strengths by reconciling their sum with the measured total ionization cross-section. Weighting factors accounting for the effect of ion collection efficiency of the fragment ion kinetic energies are used in the summation. Above 30 eV, this procedure indicates a substantial contribution to the total from ion products not measurable in the present experiment. Previous work[1] suggests that these ions result form delayed fragmentation of metastable $N_2O^{+(*)}$.

1. J.L. Olivier, R. Locht, and J. Momigny, Chem. Phys. 68, 201 (1982).

GB-4 Doubly Differential Cross Sections of Secondary Electrons Ejected from Gases by Electron Impact. 25-250 eV on O_2.* T. W. SHYN and W. E. SHARP, University of Michigan, Space Physics Research Laboratory--We have measured the doubly differential cross sections of secondary electrons ejected from molecular oxygen by electron impact. A modulated crossed-beam method was used. The incident energies used were 25, 50, 75, 100, 150, and 250 eV. The energy and angular range covered for the secondary electrons were from 1.0 eV to one half of the incident energy and from 12 to 156°, respectively. Singly differential cross sections and total ionization cross sections have been obtained from the doubly differential cross sections. The present results are compared to the previous measurements by Opal et al. (J. Chem. Phys 55, 4100, 1971) and considerable discrepancies are found.

*This work was supported partially by NSF-Aeronomy.

GB-5 Gas Phase Acidities of HPO_3 and HPO_2. A A VIGGIANO, R.A. MORRIS, AND J.F. PAULSON, GEOPHYSICS LABORATORY, IONOSPHERIC PHYSICS DIVISION, M. HENCHMAN, DEPT. OF CHEMISTRY, BRANDEIS UNIV., T. MILLER AND A.E. STEVENS MILLER DEPT. OF CHEMISTRY, UNIV. OF OKLAHOMA -- Proton transfer reactions usually proceed rapidly when exothermic and usually have no barriers to reaction. Proton transfer reactions have been used extensively to determine the gas phase acidity scale. However, the acidities of strong acids have proven difficult to measure. No acidities greater than that of HI have been measured, although some ordering of higher acidities has been made. We present here data on the gas phase acidities of HPO_3 and HPO_2, the former being a stronger acid than HI. The data were obtained by measuring the rate constants for the endothermic proton transfer reactions of PO_3^- with HI and of PO_2^- with HCl as a function of kinetic energy in a variable temperature selected ion flow drift tube. The rate constants are found to increase with increasing kinetic energy, and quasi-activation energies are derived. The activation energies are converted to endothermicities using a procedure derived from calibration against reactions of known endothermicities.

SESSION J: POSTERS
Wednesday afternoon, 19 October 1989
Rickeys Hyatt, Camino Ballrooms A and B at 1:30 P.M.
Y. K. Bae, presiding

J-1 Measurement of the I/V Characteristics of a Symmetric RF Discharge in Argon, R. B. PIEJAK, V. A. GODYAK, GTE Laboratories Inc., Waltham, MA -- I/V characteristics have been measured in a low pressure electroded RF discharge driven symmetrically at 13.56 MHz. The voltage was measured directly across the electrodes and the current was compensated for stray and fringe capacitance. The phase difference between V and I was measured very accurately by comparing the phase coefficients from a fast Fourier transform of the voltage and the current. These measurements provide accurate data of the equivalent resistance and capacitance of the discharge as well as the phase shift and impedance characteristic. Based on these measurements, the average plasma density and the sheath thickness are calculated. The current, resistance, capacitance and phase shift are shown versus discharge voltage for various gas pressures.

J-2 A New Fast Algorithm to Calculate Oscillatory Steady-States of a rf Plasma Using the Continuum Model, E. GOGOLIDES, H.H. SAWIN, and R.A. BROWN, MIT, -- Calculation of steady-states for rf plasmas using a continuum model is a very time consuming task, if the differential equations are integrated in time. Moreover criteria for determining steady-state are poorly defined, due to long transients in the bulk of the plasma. As a result of these constraints wide application of continuum models has been limited. We present here an algorithm which improves the convergence time of the continuum model between 2 to 3 orders of magnitude. We integrate in time for only one cycle and construct an objective function which contains the difference between the variables before and after the integration. We then proceed to zero that function, i.e. directly calculate the oscillatory steady-state. The technique when combined with parameter continuation methods, enables parametric studies of rf discharges to be carried out fast and on a regular workstation. In addition transients can still be followed in time, if desired, since the time integrator is preserved in the algorithm.

J-3 Comparison of CF and CF_2 LIF and Actinometry in a CF_4 Discharge, L. D. BASTON, J.-P. NICOLAI, and H. H. SAWIN, MIT- Relative ground state CF and CF_2 concentrations have been measured in a CF_4/Ar discharge using both laser induced fluorescence (LIF) and actinometric techniques. These measurements have been used to assess the validity of actinometry for CF and CF_2 in a CF_4 discharge. LIF detection of CF and CF_2 was achieved using CF ($A^2\Sigma$-$X^2\Pi$) and CF_2 (A^1B_1-X^1A_1) systems respectively. Actinometric measurements were obtained by monitoring the plasma induced emission (PIE) intensity of CF^* ($B^2\Delta$-$X^2\Pi$) at 202.4 nm, CF_2^* (A^1B_1-X^1A_1) at 251.9 nm, and Ar^* at 750.4 nm. The plasma conditions of the CF_4/5% Ar discharges studied ranged from 0.5-1 Torr pressure, 0.5-1.75 W/cm^2 power, 1.0 cm electrode separation, and 13.56 MHz RF excitation frequency. Application of actinometry for monitoring CF and CF_2 species concentrations in situ in a plasma is useful for studying kinetic mechanisms and rates, and has been previously reported.[1] Our results indicate that CF actinometry represents the relative CF concentration as measured by LIF in a CF_4 discharge under the studied conditions. CF_2 actinometry scales linearly with the relative concentration of CF_2 as measured by LIF.

[1]R. d'Agostino, et.al., Plasma Chemistry and Plasma Processing, 2(3), 213 (1982).

J-4 Spatial Profile Measurements of Plasma Species in Radio-frequency Glow Discharges.* P.J. HARGIS, JR. and K.E. GREENBERG, Sandia National Laboratories -- Spatial distributions of plasma species in a discharge were measured by imaging laser-induced fluorescence (LIF) radiation onto a gated multichannel diode-array detector. Spatial profiles, across the gap between the parallel-plate electrodes, were measured by exciting LIF with a vertical sheet of laser light. The LIF was imaged onto the entrance slit of a spectrometer and detected by the multichannel detector which replaced the exit slit. LIF from a static gas fill (~3 mTorr) of napthalene (without a discharge) was used to correct the measured spatial profiles for nonuniformities in the laser beam and optical detection system. The spatial resolution of the system was measured by imaging the light emitted from a 100-μm diameter optical fiber placed in the center of the discharge chamber. 1024 point profiles with a spatial resolution of 0.3 mm were typically recorded in 10 to 100 s, depending on signal intensity. Examples of this technique, including measurements of the spatial distributions of CF_2 in CF_4, CF_4/O_2, CF_4/H_2, and CF_4/Ar discharges, will be presented.

*This work performed at Sandia National Laboratories supported by the U.S. Department of Energy under contract no. DE-AC04-76DP00789.

J-5 RF Frequency Dependence of Plasma Parameter Axial Profiles in a Helium RF Plasma, K.Terai and T.Kaneda, Tokyo Denki Univ. Tokyo, Japan, J.S.Chang, McMaster Univ. Hamilton, Canada.--The effect of RF frequency on the plasma parameter axial profiles in a parallel plate capacitive coupling RF helium plasma was experimentally investigated. The electron temperature Te and plasma density N were determined by axially movable electrostatic double probes. The results are obtained for the gas pressure from 0.4 to 10 torr, the RF power from 5 to 30 watt and the RF operating frequency from 300 kHz to 13.56 MHz. The results show that: (1) the Te profiles are inversely proportional to the N profiles; (2) the Te and N profiles in lower RF frequencies were observed to be always a symmetric compared with 13.56 MHz; (3) the Te and N profiles become nonmonotonic when gas pressures exceed 2 torr for 13.56 MHz RF discharges; (4) nonmonotonic Te and N profiles were observed for 300 kHz RF discharges; (5) the Te in a central region of RF discharge has a nonmonotonic pressure and RF power dependencies for all RF frequencies.

J-6 Particle Kinetics in Plasmas--ALAN GARSCADDEN, Wright Research & Development Center, OH, 45433--Particle contamination in etching and deposition plasmas is a serious problem accounting for many wafer rejections. Estimates are made of the various effects due to these particles in low pressure processing plasmas. Macroscopic particles (0.1-10 microns diameter) act like very low mobility negative ions in their transport properties and also as surface recombination sinks of charged species and of radicals. The particles are at floating potential and are electrostatically trapped in balance with gravitational and thermophoretic forces. Many of the gases form negative ions, with large electron affinities and these have very long residence times and can contribute to cluster formation. External sources of particles, such as aerosols and sputtering, also will be causes of contamination. Vertical electrodes that are immediately immediately reduced to zero- or negative bias on switch-off are recommended to reduce substrate contamination.

J-7 RF Discharges at Very Low Neutral Pressures. N. HERSHKOVITZ, M-H CHO, A. VENDT, University of Wisconsin-Madison--We show that by taking advantage of surface multi-dipole fields, rf glow discharges can be maintained down to pressures at least as low as 5×10^{-5} torr. To our knowledge, this is well below the lowest previously reported rf glow discharge minimum operating pressure. Large effective electrode separation and good plasma uniformity can be achieved by making use of surface multi-dipole magnetic fields. Discharges employ only one conventional electrode. The line cusps replace the other electrode. Two different types of rf powered electrodes were explored -- conventional plates (diam. = 15 cm) and rods (diam = 0.64 and 1.3 cm). The powered electrodes were located sufficiently far from the magnets that the magnetic field could be ignored. Our experiments employed a second plate electrode. This plate was grounded and differs from the powered electrode in that it was located within the surface magnetic field. Adjustment of the separation of this plate from the magnet plane permits continuous variation of the maximum surface magnetic field (B_s) seen by plasma allowing continuous variation of the effective loss area at the electrode.
Work supported by the NSF ECS-8704529.

J-8 A Kinetic Discharge Model Applied to the RF Reference Cell* T. J. SOMMERER, W. N. G. HITCHON, and J. E. LAWLER U. of Wisconsin.--A kinetic description of discharges based on propagators (Green's functions) has previously been used to describe the electrons in the cathode fall of a helium dc glow discharge[1] and both the electrons and ions in a helium rf discharge.[2] We will present the predictions of this model for one pressure of the initial calibration conditions of the "RF Reference Cell"[3]: 0.1 torr argon, 200, 400, 600, and 800 V peak-to-peak applied voltage at 13.56 MHz, and a 2.54 cm gap. We will predict the I,V characteristics, as required for calibration of the Reference Cell, along with particle densities and other moments of the distribution function, and will investigate the nature of the heating of the discharge electrons.
*Supported by the AFOSR.

[1]T. J. Sommerer, W. N. G. Hitchon, and J. E. Lawler, Phys. Rev. A 39 6356 (1989).

[2]W. N. G. Hitchon, T. J. Sommerer, and J. E. Lawler, Proceedings of the Seventh IEEE Pulsed Power Conference, Monterey, CA, June 11-14, 1989 (in press).

[3]Proposed at the Forty-First Annual Gaseous Electronics Conference, Minneapolis, MN, October 18-21, 1988.

J-9 Cylindrical Magnetron Reactive Sputtering for Hermetic Coatings on Fluoride Glass Fibers.* Z. YU, P. A. SMITH and G. J. COLLINS, Colorado State University, D. W. REICHER and J. R. McNEIL, University of New Mexico, B. HARBISON and I. AGGARWAL, Naval Research Laboratory -- Low temperature (<50°C), high speed coating is required for hermetic protection of fluoride glass fibers, which have broad transmittance range (0.3-7μm) and low optical loss (<0.01dB/Km). A cylindrical magnetron operated in the reactive sputtering mode has deposited AlN and MgO coatings on fluoride glass fibers. The fiber is located along the longitudinal axis within the reactive plasma, formed near the cylindrical cathode. A Mg cathode in a He-Ar-O_2 discharge is used for MgO deposition. While an Al cathode in a N_2 discharge is used for AlN coatings. Deposition rates of 1000Å/min and 500Å/min have been observed for MgO and AlN, respectively. Uniform thickness and full coverage of the film on the fiber is seen from electron microscope pictures. MgO and AlN films have been proven hermetic by measuring the growth of O-H band absorbance in the coating with water exposure.

*Work supported by the Naval Research Laboratory Contract #N00014-87-C-2044.

J-10 The Feasibility of Using Neural Networks and Other Optimization Algorithms to Obtain Cross Sections from Swarm Data*, W. L. MORGAN, Kinema Research, Monument, CO 80132—I will discuss preliminary findings on the use of neural network algorithms to obtain electron impact cross sections from measured drift velocities, characteristic energies, and other swarm data. I will discuss, in addition, results that I have obtained on model systems and on real atoms and molecules using creeping simplex and simulated annealing optimization algorithms.

*Research supported by the Wright Research and Development Center, Wright-Patterson AFB, Ohio.

J-11 Space and Time Variation of Stochastic Heating in a Capacitive rf Discharge, B.P. WOOD, M.A. LIEBERMAN AND A.J. LICHTENBERG, University of California, Berkeley — Low pressure (< 100 mTorr) capacitive rf discharges are widely used in the electronics industry. It has been shown[1,2] that stochastic heating by the oscillating sheath is the main electron energy deposition mechanism. We give an analytical model of the sheath motion which is then related to the space and time variation of the electron energy distribution and to the ionization rate in the discharge. Since the sheath motion and therefore the energy deposition is strongly nonuniform in space and time, ionization waves are found to emanate from the sheath and to propagate into the bulk plasma. We compare these results to particle-in-cell computer simulations and to experimental data.

1. M.A. Lieberman, *IEEE Trans. Plasma Sci.* 16, 638 (1988); 17, 338 (1989).
2. V. R. Misium, A.J. Lichtenberg, and M.A. Lieberman, *J. Vac. Sci. Technol. A* 7, 1007 (1989).

J-12 Measurement of Target Ion Current in Plasma Source Ion Implantation. M. SHAMIM, J. T. SCHEUER AND J. R. CONRAD, Plasma Source Ion Implantation Group, University of Wisconsin – Average current per pulse to the target during Plasma Source Ion Implantation (PSII)[1] has been measured. Measurements were made for graphite, Cu, Al, and 304 Stainless Steel targets in spherical, cylindrical and planar shapes in H_2, He, N_2 and Ar plasmas. The target bias was varied from 15 to 40 kV and the density was varied from 10^8 to 10^{10} cm^{-3}. These parameters were chosen to investigate the effects of secondary electron emission at the target, ion mass, geometry and plasma density on the PSII process. The measured current has been found to be higher than that predicted theoretically.[2]

[1] J. R. Conrad, J. L. Radkte, R. A. Dodd and F. J. Worzala, J. Appl. Phys. 62, 4591 (1987).

[2] J. T. Scheuer, M. Shamim and J. R. Conrad, Gaseous Electronics Conference, Palo Alto, October 17-20, 1989.

J-13 Temperature of a High Pressure Mercury Discharge, J.T. DAKIN and R.P. GILLIARD*, GE Lighting, Cleveland, OH -- A variety of experimental techniques are used to determine the temperature in a high pressure mercury discharge. The arctube has a bore of 2.35 cm, a gap of 9.0 cm. and operates at a power of 1000 W with an estimated pressure of 4.6 atm. The apparatus and some experimental results have been described previously. [1] Here the emphasis is on sources of error, and comparison of temperatures determined with different techniques. A Boltzmann plot showing the relative densities of the mercury atomic states is presented, and the degree of Local Thermodynamic Equilibrium is addressed. Implications for experimental studies involving measurement of temperature in mercury-dominated discharges are discussed.

1) J.T Dakin and R.P. Gilliard, J. Appl. Phys., 60, p. 1281 (1986).

* current address ILC Technology, 399 Java Dr., Sunnyvale, CA

J-14 Temperature and Na-density distributions in an ac Hg-NaI discharge plasma*, A. PALLADAS+, D. KARABOURNIOTIS and A. TSAKONAS, Physics Dep't., Univ. of Crete, Iraklion, Crete, Greece.
- Time and space resolved emission measurements of the optically thin Hg 577- and Na 616-nm lines were conducted with a computer-automated system, in horizontal planes, of a high-pressure mercury arc discharge, containing sodium iodide as an additive. The purpose of these measurements was the determination of the time modulated plasma temperature as well as the density of sodium neutral atoms in the discharge, assuming LTE conditions. The temperature radial profiles and the arc pressure, were obtained from this experimental data, using the Hg 577-nm line. The Na-density radial profiles were then obtained, using the Na-616 nm line.

*Work supported by the Greek Ministry for Research and Technology.
+also with Centre de Physique Atomique, Univ. P. Sabatier, Toulouse, France.

J-15 Production of S_2F_{10} from Negative Glow Corona in SF_6,* R.J. VAN BRUNT, J.K. OLTHOFF, and J.T. HERRON, NIST, I. SAUERS, ORNL—Disulfur decafluoride (S_2F_{10}) is formed in high-pressure electrical discharges by reaction between SF_5 radicals produced by dissociation of SF_6. The production rates for S_2F_{10} in SF_6 during continuous glow-type negative point-plane discharges have been measured as a function of discharge current using a gas chromatograph-mass spectrometer. The yield curves for S_2F_{10} production are found to be linear, thus suggesting that the production mechanism is much faster than any destruction mechanisms. The magnitudes of the measured S_2F_{10} production rates are found to agree satisfactorily with predictions based on a zonal model of the discharge chemistry which takes into account the influences of O_2 and water vapor contamination. The model predicts that S_2F_{10} production will increase with increasing water vapor content and is relatively unaffected by changes in O_2 content, provided $([O_2]/[SF_6])<2\%$.

*Supported by U.S. Department of Energy.

J-16 A Kinetic Model of a DC Discharge, D.J. Koch and W.N.G. Hitchon, U. of Wisconsin-Madison,--- A self-consistent model of a DC discharge is presented. This model utilizes a Green's function solution[1] to a kinetic equation which calculates the motion of all charged particles in the discharge. The model yields ion and electron densities that are consistent with the potential, ionization and excitation rates. Results are given for an argon DC discharge. A plasma chemistry submodel for a DC silane discharge is also presented. This chemistry submodel uses dissociation and ionization rates calculated by the charged particle submodel to find densities and and reaction rates of various gas phase neutral species.

[1] W.N.G. Hitchon, D.J. Koch and J.B. Adams, J. Comp. Phys., (1989) in press.

J-17 Deterministic Chaos in Electrical Discharges in Gases, D. HUDSON, NSWC -- This work expands on the results of Braun et. al.[1] concerning observation of chaotic currunts in DC discharges. The work of reference 1 is extended to more complex gases and gas mixtures. Improvements in the apparatus allow determination of gas pressure and electrical and optical diagnostics. It is observed that while some gases such as He follow a well defined path from smooth discharge via sinusoidal current perturbations, period doubling etc. to chaos, others such as CO_2 transition directly from smooth discharge to chaotic perturbations. Results of observations on various gases as well as any illuminating insights into their behavior will be presented.

[1]T. Braun, J.A. Lisboa, R.E. Francke and J.A.C. Gallas, Phys. Rev. Lett. 59, 613 (1987)

J-18 Spectroscopic Diagnostic of a He-Cd⁺ Laser Discharge, Th.Wengorz and J.Mentel, AEEO, Ruhr-Universitat Bochum, FRG -- The intensity of He-lines emitted from a positive column He-Cd⁺ laser discharge is measured end on by an afocal imaging optics in absolute units. Using Kirchhoff's law population density ratios are determined from the intensity of optical thick lines. The corresponding temperatures are approximately equal to electron temperature. For further investigations the He-Cd⁺ laser is operated by the discharge on the 441.6 nm laser line in TEM∞-mode. The different axial modes tuned across the gain profile by statistical variation of the resonator length are recorded as intermediate frequencies by a fast photodiode and a spectrum analyzer. The vanishing of the different axial modes with increasing losses inside the resonator is measured. Taking into account the isotope shifts and hyperfine splittings of Cd⊓441.6 nm laser line emitted by cadmium of natural isotopic abundance gain profile and ion temperature are determined. On the basis of the temperature measurements and the radial profiles of line emission coefficients comments are made upon the radial diffusion of Cd-atoms and Cd-ions in the discharge.

J-19 Streamer to Arc Transition in N_2, S.K. DHALI and A. RATA BOOSHANAM, Southern Illinois University -- The numerical results of a streamer-to-arc transition model is presented for nitrogen at atmospheric pressure. The streamer phase of the calculation is performed by solving the electron and ion continuity equations along with the Poisson's equation[1]. The plasma density ($\sim 10^{14}cm^{-3}$), the radial dimension (1/e radius of $\sim$ 0.41mm), and the reduced electric field (E/N of 233 Td) are then used as initial condition for a transient glow model[2]. The glow model, which includes gas heating, neutral gas dynamics, and electron-molecule and molecule-molecule collisions is solved in the radial dimension. Discussions on the plasma density, arc radius, and gas temperature and pressure are presented.

[1]S.K. Dhali and P.F. Williams, J. Appl. Phys. 62, 4696 (1987).

[2]S.K. Dhali and L.H. Low, J. Appl. Phys. 64, 2917 (1988).

J-20 Electron Impact Vibrational Excitation of Polar Molecules,* S. ALSTON,+ G. SNITCHLER, and D.W. NORCROSS,‡ JILA, Univ. of Colo. and NIST -- The electron impact excitation of HF and HCL has been studied using a fully vibrational close-coupling (VCC) program. An exact treatment of exchange is used in the separable representation. Correlation and polarization are represented by a parameter-free model potential. Differential cross sections will be compared to recent experiments.

[1]G. Knoth, M. Gote, M. Rädle, K. Jung, and H. Ehrhardt, Phys. Rev. Lett. 62, 1735 (1989); and unpublished data.

*Research supported by National Science Foundation grant PHY86-04504.

+Present Address: Dept. of Physics, Penn. State Univ., Lehmann, PA 18627

‡Staff Member, Quantum Physics Division, National Institute for Standards and Technology.

J-21 Emission of the Fluorine Resonance Lines Following Dissociative Electron Impact Excitation of CCl_2F_2, NF_3, CF_4 and SF_6*, M. ROQUE, R. SIEGEL, K.E. MARTUS and K. BECKER, City College of New York -- We report measurements of absolute emission cross sections and appearance potentials for the fluorine $(2p^43s)\ ^{2,4}P \rightarrow (2p^5)\ ^2P^o$ resonance lines at 955 Å and 975 Å produced by dissociative electron impact excitation of SF_6, CF_4, NF_3 and CCl_2F_2. The cross sections are heavily influenced by $3p \rightarrow 3s$ cascading[1-3]. A detailed analysis of the low energy region of the cross sections revealed that different dissociation mechanisms lead to the formation of the excited fluorine atoms in the case of CCl_2F_2 compared to SF_6, CF_4 and NF_3. Partial fragmentation channels appear to play a very important role in the case of the CCl_2F_2 dissociation.

1. K.A. Blanks et al. J. Chem. Phys. 86, 4871 (1987)
2. J.L. Forand et al., Can. J. Phys. 64, 269 (1986)
3. S. Wang et al., Can. J. Phys. (1989), in press

*Supported by NSF through Grant No. CBT-8896249

J-22 Total Electron-Impact Cross Sections for Ammonia, * Ce Ma, Phillip B. Liescheski and Russell A. Bonham, Chemistry, Indiana U. Total electron impact cross sections for Ammonia were measured from 4 to 50 eV by time-of-flight experiements. The primary electron pulses (< 1ns) generated wide energy range secondary electrons by hitting a graphite coated needle at the scattering center. Both primary and secondary electrons traveled 41 cm in the gas chamber before reaching an MCP chevron detector. The electronic signals from the detector and a LeCroy 4222 PDG start and stop a LeCroy 4208 TDC. A home made fast bus, that can host up to three 4208 TDCs, provided a memory storage of 4096 x 16 bits words for each TDC channel as well as 9.2 μsec fast data transmission for all 24 channels. The gas pressure was measured by an MKS SRG. The electron transmission spectra were measured in several different gas pressures and the total cross sections were determined by using the Beer's law.

* Work supported by the NSF through grant number CHE-8600746.

J-23 Measurement of Coherence Parameters in Electron - Heavy Noble Gas Collisions*, K.E. MARTUS and K. BECKER, City College of New York -- We report measurements of the P_1 and P_2 coherence parameters for excitation of the spin-orbit coupled "$^1P_1$" and "$^3P_1$" states of Ne, Ar and Kr by electron impact. Having demonstrated that the forward excitation in the regime of intermediate impact energies proceeds via direct excitation of the LS-coupled singlet component of the excited states[1], i.e. P_1=+1, the main emphasis of our current work are measurements of P_1 for very low impact energies where deviations from unity are expected caused by the LS-coupled triplet component of the excited states which makes

its presence felt at energies close to threshold[2]. We will also present P_1 and P_2 data for small angle scattering.

1. K.E. Martus and K. Becker, J. Phys. B, 22 (1989), in press
2. K. Bartschat and D.H. Madison, J. Phys. B 20, 5839 (1987)

*Supported by NSF through Grant No. PHY-8819510

J-24 Electron-Impact Dissociation of Cl_2 Molecules* P. C. COSBY, SRI International--Dissociation of chlorine molecules by electron impact is observed in a crossed beam apparatus in which the correlated neutral fragments are detected by a position and time sensitive detector. The fast beam of Cl_2 is produced by charge transfer neutralization of Cl_2^+ in chlorine gas and the state composition of the beam is probed by photofragment spectroscopy. The absolute cross section for the production of Cl + Cl is found to rise from threshold (< 8 eV) to a maximum of 2.1 ± 0.6 Å^2 near 15 eV and decrease at higher electron energies. The translational energies of the fragments suggest that excitation to the repulsive $1^1\Pi_u$ state is the primary dissociation mechanism. Evidence is also found for predissociation to $Cl(^2P)+Cl(^2P)$ of Rydberg states converging to the ground state of Cl_2^+.

*Supported by USAF Aero Propulsion Lab, Wright-Patterson AFB.

J-25 Extreme Ultraviolet Emission from the b $^1\Pi_u$ state of N_2 Excited by Electron Impact,* G. K. JAMES, J. M. AJELLO and D. E. SHEMANSKY, JPL, and U. of Arizona — The electron impact induced fluorescence spectrum of N_2 in the wavelength range 102 to 134 nm has been measured at a resolution of 0.05 nm. Emission cross sections have been determined for the vibronic transitions of the b $^1\Pi_u \rightarrow X\ ^1\Sigma_g^+$ Birge - Hopfield I band system at 20 eV and 100 eV electron impact energy. A comparison of excitation and emission cross sections shows that, with the exception of the $v' = 1$ level, all other vibrational levels of the b $^1\Pi_u$ state predissociate with a predissociation to radiation branching ratio of between 0.98 and 1.00. Predissociation of the b $^1\Pi_u$ state alone contributes approximately 14% to the total dissociation cross section of N_2 at 100 eV. The excitation function of the b(1,2) transition at 103.28 nm has been measured from threshold to 400 eV Application of a modified Born approximation analytic model to the b $^1\Pi_u$ excitation function data yields a band system oscillator strength of 0.365.

*This work supported by the Air Force Office of Scientific Research and the National Science Foundation (grant # ATM 8715709), and NASA.

J-26 Electron-Impact Ionization Rate Coefficients at Very High Density-Normalized Electric Fields for Several Alkanes and Fluoroalkanes,* G. N. HAYS and J. B. GERARDO, Sandia National Laboratories, M. Ibrahim, Atlanta University--We report electron impact ionization rate coefficients at very high values of density-normalized electric field (E/N up to 10^5Td, $1\text{Td}=10^{-17}\text{Vcm}^2$) for several alkanes, and fluoroalkanes. The electrical properties of the former series of molecules is of interest for thin-film diamond-like deposition, for example, while those of the latter series of molecules is of interest because of their widespread use in the manufacture of microelectronic circuits as well as their use as high-voltage gaseous insulator . The measurements were made in an electrodeless cell contained in an S-band waveguide immersed in a dc magnetic field and subjected to a pulsed rf electric field at cyclotron resonance. We have previously shown that our measurements are equivalent to experiments in dc electric fields. This experimental approach circumvents complications due to electrode effects at extremely high values of E/N.

*Supported by USDOE under contract DE-AC04-76DP00789.

J-27 Electron Impact Ionization of Argon and Krypton,* R. E. H. CLARK and G. CSANAK, Los Alamos National Laboratory - The extensive Coulomb-Born ionization cross sections of Sampson and coworkers[1] have been fitted as a function of n and ℓ. The resulting fit is applied to ionization of the $3p^6$, $3p^54s$ and $3p^54p$ configurations of argon and the $4p^6$, $4p^55s$ and $4p^55p$ configurations of krypton. Comparisons are made with the binary encounter theory[2] and distorted wave approximation (DWA) of Mann.[3] A simple prescription for obtaining the differential cross section with respect to ejected electron energy is compared with the calculated DWA differential cross sections. For all integral cross sections, the inner-shell excitation autoionization contribution is included and is shown to be a significant part of the total ionization cross section.

*This work was performed under the auspices of the U.S. Department of Energy.

[1]R.E.H. Clark and D.H. Sampson, J. Phys. B, 17 (1984) and references therein.
[2]H.A. Hyman, Phys. Rev. A, 20, 855 (1979).
[3]J.B. Mann (Private Communication).

J-28 Electron Impact Infrared Excitation Functions in Xenon, C. A. DeJoseph, Jr., Wright-Patterson A.F.B., OH 45433 and J. D. Clark, Wright State University, Dayton, OH 45430 - Electron impact excitation functions over an electron energy range of 10-150eV have been measured on a number of transitions in Xenon over the spectral range of approximately 0.9-4μm. These include the 1.73, 2.03, 2.48, 2.65, 3.11, 3.27 and 3.51μm lasing transitions observed in the He-Xe and the Ar-Xe lasers. Measurements were made using a low energy electron gun designed and built in-house together with a commercially built Fourier Transform Spectrophotometer.

J-29 Electron-Excitation Cross Sections of the $4p^55p$ States of Krypton and their Pressure Dependence,* JOHN E. GASTINEAU, MICHAEL P. NESNIDAL, and TODD G. RUSKELL, Lawrence University—The energy dependence (10-100eV) of the optical emission cross sections of the ten Paschen 2p levels of krypton have been measured using the optical method. The cross sections show some pressure dependence in the range of 100 μT to 5 mT, but to a smaller degree compared to Paschen 2p emission cross sections of xenon[1]. The pressure dependence is strongest at energies above 35 eV, and cross sections below 25 eV are essentially independent of pressure effects. The higher energy cross sections for the $2p_2$, $2p_3$, $2p_7$, and $2p_9$ levels reach low pressure limits by 200 μT and the absolute apparent cross sections have thus been determined. Estimates for the other 2p apparent cross sections are obtained by extrapolation. The apparent cross sections range from 1 to $7{\cdot}10^{-18}$ cm^2.

*Supported by a William and Flora Hewlett Foundation Grant of Research Corporation and by Lawrence University.

[1]Gastineau *et al*, 39th Gaseous Electronics Conference p.90.

J-30 New Coherence Data on the Excitation of Heavy Rare Gases by Electron Impact,* P.J.M. VAN DER BURGT, J.J. CORR and J.W. McCONKEY, University of Windsor, Canada. -- We report continuing measurements of the Stokes parameters for excitation of the resonance lines of the heavy rare gases following electron impact. These will extend previous measurements reported from this laboratory[1,2] and are particularly aimed at elucidating spin-related effects such as exchange or spin-orbit interaction. Particular attention will be paid to the in-plane polarization correlation parameter from which the so-called height of the excited state charge cloud is deduced.

* Research supported by the Natural Sciences and Engineering Research Council of Canada.

1. M.A. Khakoo and J.W. McConkey, J. Phys. B 20, 5541 (1987).
2. P. Plessis, M.A. Khakoo, P. Hammond and J.W. McConkey, J. Phys. B 21, L483 (1988).

J-31 VUV Fluorescence Following Electron Impact on Discharge-Created Targets.* SHOUYE WANG and J.W. McCONKEY, University of Windsor, Canada. – An RF discharge source is used to produce a gas beam with a significant metastable content and, in the case of molecular parent species, a significant dissociation fraction. This is crossed with a magnetically-focussed electron beam which produces high currents in the near threshold region. The resultant radiation is observed orthogonal to both beams using a Seya-Namioka monochromator - channel electron multiplier combination. Data obtained as a function of incident electron energy will be presented at the Conference for N_2 and other targets.

* Research supported by the Natural Sciences and Engineering Research Council of Canada.

J-32 Practical Applications of Electrostatic Probes, N. BENJAMIN and B. CHAPMAN, Lucas Labs --The Electrostatic Probe was introduced by Irving Langmuir in order to research the ionized gaseous state of matter he called "plasma" in the 1920s. Since then, probes have been primarily restricted to research applications right up to the present day. This paper describes some of the more pragmatic features of Electrostatic Probe use, principally directed towards applications in Plasma processing for thin film and semiconductor production. We shall indicate how various practical problems of application to process may be resolved. Examples will be given of the use of a Probe for process characterization and the determination of process reproducibility, as well as it's use for determining spatial profiles in the reactor. Finally we shall discusss the potential of probes in future applications for manufacturing process control.

SESSION KA: Ar/Xe LASERS I
Thursday morning, 19 October 1989
Rickeys Hyatt, Camino Ballroom C at 8:00 A.M.
A. Garscadden, presiding

KA-1 Early Work in High-Power Xe:Ar Laser Research*, L.A. Newman** and T.A. DeTemple, U. of Illinois--The 1.73 micron line of xenon in an argon buffer has emerged as one of the most efficient and powerful electrically excited atomic laser lines. The research leading up to the discovery of these features, the post discovery experiments, and the initial identification of the underlying physical processes responsible for the strong emission will be reviewed.

*Research originally supported by the National Science Foundation and the United States Air Force WPAFB.

**United Technology Optical Systems

[1] L.A. Newman and T.A. DeTemple, Appl. Phys. Lett. 27, 678 (1975).

KA-2 Experimental Study of the e-Beam and e-Beam Sustained Xe:Ar Laser. A. Suda*, B.L. Wexler, B.J. Feldman, and K. Riley*, NRL.--Experimental studies of the electron-beam and electron-beam sustained Xe:Ar laser have been carried out to evaluate performance and provide data for kinetics analysis. Small signal gain and saturation intensity have been measured and compared with calculated values. The pulse shapes and energy in the 1.73, 2.03, 2.63, and 2.65 μm lines have been observed with nonselective and single-line cavities. Data have been taken as a function of pump rate, pressure, and xenon concentration. Various electron and heavy particle collision processes can be suggested to explain the data. The e-beam pumped laser produced 1.7 J/l at 4 atm with 2.3% efficiency. With the e-beam sustained discharge, 3.5 J/l was obtained with 3.2% efficiency and an enhancement factor of 4.5. When the e-beam pump power was reduced, the enhancement increased to 10 but the laser output dropped significantly. With the addition of helium to the Xe:Ar mixture, the 2.03 μm output increases dramatically and becomes dominant. The effects of adding krypton and neon were also observed.

* Geo-Centers, Inc.

KA-3 Fission-Fragment Pumped Atomic Xenon Laser,* G. N. HAYS, W. J. ALFORD, D. R. NEAL, D. A. McARTHUR, and D. E. BODETTE, Sandia National Laboratories--We report on laser characteristics of atomic xenon (1.7-3.5 μm), in a rare-gas buffer, pumped by fission fragments from U^{235}, under bombardment by thermal neutrons. Energy efficiency up to 3% has been reported for low-pump-rate (< 10 W/cc), long pulse (several msec) excitation of xenon utilizing this pumping mechanism[1]. We will present results of the effects of buffer gas composition and pump rate on the performance of several laser lines of interest. We find that dilution of an Ar/Xe gas mixture with helium has dramatic effects on the output spectrum, whereas dilution with neon has little or no effect.

*This work performed at Sandia National Laboratories, supported by the U. S. Department of Energy under Contract Number DE-AC04-76DP00789.

[1]W. J. Alford and G. N. Hays, J. Appl. Phys. 65, 3760 (1989).

KA-4 A Parametric Study of The Atomic Xenon Laser,* E. L. PATTERSON, G. E. SAMLIN, and P. J. BRANNON, Sandia National Laboratories -- Operation of the atomic Xe laser at average e-beam pump rates between 0.04 and 1.0 kW/cm³ with buffer gases of Ar, Ar/He, or Ne is described. The pump time for these experiments is 1 ms, providing an average energy loading of up to 1 J/cm³. The 2.6 μm transitions dominate in all cases where the laser cavity feedback is not wavelength selective (for these measurements we could not discriminate between the 2.63 and 2.65 μm lines). In all cases the laser pulsewidth (full width at 10% peak power) decreased with increasing pump power. With optics selected to favor the 1.73 μm line and the use of 0.5% Xe, laser termination occurred with an average energy loading of 0.16 J/cm³ for Ar buffer gas and occurred with an energy loading of ~ 0.25 J/cm³ for Ne buffer gas. Higher resolution measurements have shown that, with either Ar/Xe or Ar/He/Xe mixtures and pump rates up to 900 W/cm³, the 2.65 μm line dominates over the 2.63 μm line. The ratio of intensity of the 2.65 to 2.63 μm line increases with increasing Xe concentration or decreasing pump rate.

*This work supported by the U.S. Department of Energy under contract number DE-AC04-76DP00789.

KA-5 Performance Characteristics of the X-ray Preionized Xe:Ar Laser, J.E. Tucker, B.L. Wexler, B.J. Feldman, and T. McClelland, NRL -- X-ray preionization has allowed discharge pumping of the Xe:Ar laser at 4 atm pressure[1]. Increased output and pulse length have been observed with a new laser head, with 0.4 J obtained from a 40 cm long x 5 cm high discharge having a nominal 2 cm width, in a 1% Xe, 3 atm Ar mixture. This compact device also definitively demonstrates the suppression of surface flashover by electric field uniformity and shaping in the laser head. The impedance mismatch between the Marx bank and the discharge results in a ringing discharge and a modulated output. The total laser pulse length observed is inversely proportional to pressure and xenon concentration, and continues for more than 5 μs for a 0.1% Xe in 1 atm Ar mixture. With a nonselective cavity, 70% of the output occurs at 1.73 μm

and 20% at 2.63 μm. The remainder occurs in the 2.03 and 2.65 μm lines. Line competition effects have also been observed. When helium is added, the 2.03 μm line becomes dominant as the other lines are suppressed.

[1]J.E. Tucker, B.L. Wexler, B.J. Feldman, and T. McClelland, to be published in IEEE Phot. Tech. Lett., Aug., 1989

SESSION KB: BREAKDOWN AND SWITCHING

Thursday morning, 19 October 1989
Rickeys Hyatt, Camino Ballroom D at 8:00 A.M.
L. E. Kline, presiding

KB-1 Formation of Cathode Spots by Unipolar Arcing. F. SCHWIRZKE, Naval Postgrad. Sch. - Breakdown and plasma formation on electrodes is a fundamental process in pulsed power technology. The initial "explosive" plasma formation on the surface of a cathode of a vacuum diode and many other discharges is highly non-uniform. Micron-sized cathode spots form within ns. Laser produced unipolar arcs[1], UPA, ignite and burn on a ns time scale. Similar UPA craters have now been observed on the cathode surface of a pulsed vacuum diode. Field emitted electrons ionize desorbed neutrals above an emitting spot. Plasma pressure gradients then naturally lead to electric fields which ignite and drive the UPA[2]. Power dissipation for an UPA is considerably larger than for field emitted or space charge limited current flow. The high current density of an UPA provides explosive plasma formation. Unipolar arcing represents a fundamental form of discharge which contributes to breakdown and formation of cathode spots in a unique way. This report was sponsored by NRL and the Naval Postgraduate School.

[1]F. Schwirzke, Laser Induced Unipolar Arcing, in Laser Interaction and Related Plasma Phenomena, Vol 6, H. Hora and G. H. Miley, eds., Plenum Publ. Corp., New York, 1984
[2]F. Schwirzke, J. Nucl. Mater., 128 & 129 (1984) 609.

KB-2 Transport and Multiplication of Charged Particles in H_2 at Very High E/n,* Z.Lj. PETROVIĆ** and A.V. PHELPS, JILA, University of Colorado and NIST. -- Current waveforms were taken for pulsed-laser initiated, non-selfsustained discharges in hydrogen at E/n from 0.5 to 45 kTd. The change from H_3^+ to H_2^+ for E/n of 0.5 kTd to 3 kTd causes a very slow change with E/n in the duration of a single avalanche. Integrated currents yield[1] the charge that crosses the gap in electron (Qe) and ion (Qi) transit times and in vacuum (Qc). Qe/Qc and Qi/Qc ratios are fitted to equilibrium models for E/N ≤ 1 kTd and non-equilibrium models for E/n ≥ 3 kTd. Apparent secondary electron coefficients are higher than published values.[2] The ionization cross section of the non-equilibrium model is reduced to fit Qe/Qc ratios. Fits to Qi/Qc data at the higher E/n yield secondary electron coefficients which depend on E/n only as expected when secondaries are due to H_2^+ and fast H_2.

*Work supported in part by NSF.
**Permanent address: Institute of Physics, Belgrade.
[1]V.T. Gylys, B.M. Jelenković and A.V. Phelps, J. Appl. Phys. 65, 3369 (1989).
[2]M.A. Folkard and S.C. Haydon, Aust. J. Phys. 24, 527 (1971).

KB-3 Application of a Multi-Dimensional Beam-Bulk Model to Simulation of Low Pressure Pulse Powered Devices,* HOYOUNG PAK and MARK J. KUSHNER, University of Illinois, Urbana, IL--A computer model has been developed to simulate low pressure pulse power devices such as conventional thyratrons, pseudo-sparks and electron beam sources. The simulation is a 2-1/2 dimensional time-dependent continuum model using rectilinear or cylindrical coordinates. Gas pressure, gas composition, applied voltage, and geometry are user definable To account for nonequilibrium electron transport, a beam-bulk methodology has been developed. In this model the electron distribution is separated into a low energy component (the "bulk"), described by the electron continuity and energy equations, and a high energy component (the "beam") representing ballistic electrons. Results are presented for optically triggered pseudo sparks and low pressure beam sources during which we demonstrate when non-equilibrium effects must be considered.

*Work supported by Defense Nuclear Agency

KB-4 Theoretical Analyses of High Pressure Self-sustained Glow Discharges with High Switch Ratio,* W. M. MOENY, A. E. RODRIGUEZ, and J. M. ELIZONDO, Tetra Corporation, Albuquerque, --Tetra Corporation has recently developed high pressure glow discharge gas mixtures with high switch ratios, (ratio of the breakdown voltage to the glow voltage). This involved detailed engineering of excited-state ionization, attachment and recombination processes within the mixtures to achieve these results. The gas mixtures are composed of a dominant monatomic gas used as a buffer and energy donor, another monatomic is used as an electron donor, with a third one used as a secondary electron donor. A fourth gas element is added as a buffer or attacher. The gas elements were selected from those that show a coincidence in the power flow from primary metastable states to Penning ionization processes. In this paper, we describe the theoretical analyses that led to the development of these mixtures.[1]

*Research supported by SDI/IST and managed by ONR

[1]See companion paper, these proceedings

KB-5 Experimental Research on High Pressure Self-Sustained Glow Discharges With High Switch Ratio,* J. M. ELIZONDO, W. M. MOENY, J. W. BENZE, B. R. BECKES, and K. YOUNGMAN, Tetra Corporation of Albuquerque, New Mexico --Experimental measurements of glow voltage, breakdown voltage, and maximum current were made of pulsed high pressure, self-sustained glow discharges with high switch ratios, that is, a high ratio of the breakdown voltage to the glow voltage. The best results achieved to date are a switch ratio of 3.7 with a breakdown voltage of 4.6 kV per cm, glow voltage of 1.25 kV per cm, and current densities of 7-8 amps per square cm. One gas mixture was tested for lifetime performance in a closed loop, performing an excess of 700 discharges at a repetition rate of a pulse every 5 seconds. In this paper, we describe specific experiments with mixtures of nitrogen, neon, helium, argon, xenon, and CF_4.[1]

* Research supported by the SDI/IST and managed by ONR.

[1]See companion paper, these proceedings

KB-6 Streamers in N_2: New Empirical Results, F.E. Peterkin and P.F. Williams, University of Nebraska--We have obtained streak and high speed shutter photographs of streamers in a trigatron spark gap filled with N_2 at pressures around atmospheric, main gap charging voltages ranging from about 50% to 99% of the breakdown voltage, V_{SB}, and both charging polarities, producing cathode- and anode-directed streamers. The streamers propagate with a non-constant velocity which, for charging voltage near V_{SB}, ranges from ≈2 x 10^8 cm/sec initially to more than 10^9 cm/sec. Surprisingly, we find that cathode-directed streamers propagate faster than anode-directed streamers. For charging voltage near V_{SB}, cathode-directed streamers have a diameter of ≈2 mm and anode-directed streamers are somewhat thinner and have a more feather-like appearance. For lower charging voltages,

cathode-directed streamers remain well-defined, whereas the anode-directed streamers become more diffuse. We observe a jump in the main gap current when the streamer approaches the distant main gap electrode. From the magnitude of this jump and the streamer body diameter we can estimate the free electron density in the streamer to be in the range 10^{14} - 10^{15} cm^{-3}.

KB-7 Streamer Dynamics,* M-C. Wang and E. E. Kunhardt, Weber Research Institute, Polytechnic University. The dynamics of anode and cathode directed streamers have been investigated using the 2-D numerical simulation scheme of Wu and Kunhardt.[1] An analytical approach based on process competition is utilized to elucidate the transition between transient and steady-state streamer behavior. Using this approach, the fundamental dynamics responsible for the differences between anode and cathode directed streamers are examined. We have also investigated the instability of axial streamers and their transition to annular streamers. The critical condition for this instability is derived analytically and the dominant process is determined.

*Work supported by the Office of Naval Research and National Science Foundation.

[1]C. Wu and E. Kunhardt, Phys. Rev. A37, 4396 (1988).

SESSION LA: Ar/Xe LASERS II
Thursday morning, 19 October 1989
Rickeys Hyatt, Camino Ballroom C at 10:10 A.M.
A. Garscadden, presiding

LA-1 Energy Scaling of the Atomic Xe:Ar Laser, DANIEL W. TRAINOR, L. LITZENBERGER, M. McGEOCH, Avco Research Laboratory, Inc.-- The atomic xenon laser has been scaled from the 80J level reported by Basov et. al.[1] to 650J using a large two-sided electron-beam pumped device. These experiments were conducted at a pump rate temporally and spatially averaged) of 70 kW/cm^3 with energy delivered to the laser gas (spatially averaged) of 115 J/l. An aluminum primary mirror and an uncoated fused silica output coupler were aligned to form a stable flat-flat resonator. The laser cavity dimensions are 50 x 65 x 300 cm^3. Energy measurements were made with full aperture calorimeters. The temporal pulse shape of the 1.73 μm laser output was measured with a spectrally filtered germanium photodiode. The device was operated at gas pressures ranging from 20 to 40 psi with argon/xenon mixtures containing experimentally optimized xenon partial pressures. The maximum energy was obtained at an intrinsic efficiency of 0.57% A maximum efficiency of 0.85% was observed during a shorter e-beam pulse at a reduced energy output of 495J.

[1]N. G. Basov, et. al, IEEE J. Quant. Electron. QE-21, 1756 (1985).

LA-2 Time-Resolved Spectroscopic Study of Self-Sustained Discharge Pumped Xe:Ar Lasers. K.KOMATSU, E.MATSUI, S.TAKAHASHI, F.KANNARI AND M.OBARA, Dept. of Electrical Engineering, Keio U.,--The atomic Xe.Ar laser operates with multilines in the near-infrared region of the spectrum. To experimentally understand the complicated kinetics[1] involved in the excitation and quenching, the time-resolved spectroscopic measurement was carried out for a *self-sustained discharge -pumped* Xe:Ar laser. The time-resolved spectroscopy of the laser lines was performed as a function of the diluent (Ar,He), excitation rate, pumping duration and mixture pressure. The discharge laser is with a discharge volume of 2x2x50 cm^3 and a UV preionizer. The results will be compared to the direct electron-beam-pumped and electron-beam-sustained discharge-pumped Xe:Ar lasers.

[1]M.J. Kushner, M. Ohwa, T.J. Moratz: Technical Digest of Conference on Lasers and Electro-Optics, Baltimore, Maryland, (1989) p.252

LA-3 Quenching of Xenon Laser Levels ($6p[5/2]_2$, $6p[3/2]_1$) by Rare Gases,* W. J. ALFORD, Sandia National Laboratories--Quenching rates of the xenon $6p[5/2]_2$ and $6p[3/2]_1$ levels by rare gases (He Ne,Ar,Kr,Xe) have been measured. The quenching rates are obtained from the 6p fluorescence decay following two-photon excitation. Quenching by Ar is found to be much larger for the $6p[5/2]_2$ level than for $6p[3/2]_1$. Helium shows the opposite behavior: larger for the $6p[3/2]_1$ than for $6p[5/2]_2$. Quenching due to three body collisions have been observed for Ar and Kr quenching of $6p[3/2]_1$. In addition, radiative lifetimes have been measured. Results will be presented and compared to previous measurements. Quenching of the 6p manifold by rare gases may be the dominant kinetic process in determining which wavelength(s) lase in high pressure xenon lasers.

*This work performed at Sandia National Laboratories, supported by the U. S. Department of Energy under Contract Number DE-AC04-76DP00789.

LA-4 The Effect of He Addition on the Performance of the Ar/Xe Atomic Xenon Laser.* Mieko Ohwa and Mark J. Kushner, University of Illinois, Urbana, IL--Ar buffered gas mixtures for xenon lasers operate efficiently and predominantly on the 1.73 μm transition. The 2.03 μm transition is virtually absent. When He is added to an Ar/Xe mixture, the laser power obtained at 2.03 μm increases and that at 1.73 μm decreases while the total laser power remains nearly constant. This behavior is attributed to a rapid quenching of the lower level of the 2.03 μm transition initiated by He. For He addition, He/Ar/Xe mixtures have a lower electron number density at a given power deposition, and lower gas temperature for a given energy loading. The power deposition which results in the reduction of lasing due to electron collision mixing between the upper and lower levels therefore shifts to a higher value. We will discuss the possible mechanisms responsible for this behavior in He/Ar/Xe mixtures. We will also discuss extraction of high energy by comparing this system with Ar/Xe mixtures.

*Work supported by Sandia National Laboratory.

LA-5 Power and Energy Loading Effects in Scaling of the Atomic Xenon Laser.* Mieko Ohwa and Mark J. Kushner, University of Illinois, Urbana, IL--The atomic xenon laser can be efficiently operated at moderate power loadings leading to quasi-steady state lasing. At high power deposition, though, electron collision mixing between the 5d and 6p manifolds (upper and lower levels) reduces the population inversion. Optimum performance is obtained with $n_e/N \lesssim 2\text{-}3 \times 10^{-6}$. High energy loading at even moderate power deposition results in gas heating. The rate of ion association reactions, and the rate constants for dissociative recombination of diatomic ions, which populate the upper laser level, decrease with increasing gas temperature. The result is that the electron density and rate of electron collision mixing of the laser levels increase which may eventually impact laser oscillation. We will discuss the scaling of laser power and energy efficiency of the xenon laser as a function of power deposition and gas heating resulting from high energy loading.

*Work supported by Sandia National Laboratory.

LA-6 Utilization of a Commercial Discharge Laser for an Atomic Xe Laser,* W. A. Neuman and J. R. Fincke, EG&G Idaho, Inc., Idaho National Engineering Laboratory– A commercial eximer laser discharge system has been used to pump an atomic Xe laser. The line strengths and temporal behavior of the 5d → 6p laser transitions have been experimentally measured for a variety of buffer gases and pressures. Because the discharge system has a uv preionizer, the discharge behavior favored helium buffers, which result in domination of the 2.03 μm line. Line competition has been studied for mixtures of Ar/He, Ar/Ne, He/Ne and Ar/He/Ne as well as the individual buffers, at various pressures up to 2 atm. Comparison of kinetic calculations with observed experimental results will be presented. The discharge pulse width is 20 ns. Typical extracted energy on all lines is 15 mJ.

*Work performed under the auspices of the U.S. Department of Energy.

LA-7 Current Understanding and Remaining Physics Issues of the Xe:Ar(He, Ne) Laser* Mark J. Kushner and Mieko Ohwa, University of Illinois, Urbana, IL -- The high pressure (≥ 0.5 atm) atomic xenon laser (5d → 6p) has demonstrated high intrinsic efficiencies (3-5%) over a wide range of pressures and power deposition. The laser spectrum (6 major lines may oscillate) and efficiency, though, are separately sensitive functions of gas mixture, power deposition, and energy loading. Parametric experimental data obtained over the last 15 years has given insight to the important kinetics pathway for exciting and quenching the laser. Our current understanding of the operation of the xenon laser based on these results, and computer modeling, will be discussed. In particular, we will highlight the areas where we lack sufficient understanding of the kinetics to optimally scale the laser and conjecture on the potential performance of the system.

*Work supported by Sandia National Laboratory and National Science Foundation.

SESSION LB: CROSS SECTION DATA I
Thursday morning, 19 October 1989
Rickeys Hyatt, Camino Ballroom D at 10:10 A.M.
R. A. Phaneuf, presiding

LB-1 Cross Sections for Low – Energy Electron Molecule Collisions, H. PRITCHARD, C. WINSTEAD, K WATARI†, M LIMA‡, V. MCKOY, California Institute of Technology. The Schwinger Multichannel method has recently been used to study several low-energy electron-molecule collision processes with special emphasis on the effects of channel coupling. Examples to be reported include $1\pi_u \rightarrow 1\pi_g$ excitations of N_2 leading to the $A^3\Sigma_u^+, W^3\Delta_u, a'^1\Delta_u, a''^1\Sigma_g^-$, and $B'^3\Sigma_u^-$ electronic states and analogous $1\pi \rightarrow 2\pi$ excitations in CO. Cross sections for excitation of selected electronic states of H_2O at the two-channel level will also be presented along with the results of studies of polarization phenomena in elastic scattering by the polyatomics NH_3, CH_4, and SiH_4.

*Supported by NASA Ames Cooperative Agreement NCC 2-315, NSF Grant PHY- 8604242, and the Innovative Science and Technology Program of SDIO Contract DAAL 03-86-K-0140.
†Supported by CNPq(Brazil).
‡Permanent address University of Campinas, Campinas, Brazil.

LB-2 Electron Scattering from and Dissociative Attachment in Halogenated Silanes*, H.X. WAN and J.H. MOORE, Department of Chemistry and Biochemistry, University of Maryland -Total scattering cross-sections and dissociative attachment cross-sections for 0.2 - 12 eV electrons have been measured for silane (SiH_4) and the chlorinated silanes (SiH_nCl_{4-n}) and tetrahalosilanes (SiX_4). The scattering cross-sections are large, ranging from 10 to over 100×10^{-16} cm^2 in this energy range. Broad resonances associated with temporary negative ion states are observed and assigned. In contrast to the case of the halogenated methanes, the dissociative attachment cross sections are very small, even at threshold, and the scattering resonances do not give rise to enhanced dissociative attachment.

*Supported by NSF grant CHE-87-21744.

LB-3 Extreme Ultraviolet Emission from N_2 by Electron Impact: Cross Sections of the $c_4' \, ^1\Sigma_u^+$ and $b' \, ^1\Sigma_u^+$ States,* J. M. AJELLO, G. K. JAMES and D. E. SHEMANSKY, J.P.L. and U. of Arizona — Emission cross sections have been measured for each of the vibrational transitions of the $c_4' \, ^1\Sigma_u^+ \rightarrow X \, ^1\Sigma_g^+$ Carroll-Yoshino and $b' \, ^1\Sigma_u^+ \rightarrow X \, ^1\Sigma_g^+$ Birge Hopfield II band systems of N_2 excited by electron impact at 100 eV in the wavelength range 82 to 110 nm. The $c_4' \, ^1\Sigma_u^+$ and $b' \, ^1\Sigma_u^+$ states strongly perturb one another by homogeneous configuration interaction, leading to vibrational excitation cross sections with a v' dependence that is strikingly different to the variation of deperturbed Franck-Condon factors. Excitation function measurements of the c_4' (0,0) and b'(16,0) transitions have been performed from threshold to 400 eV. A modified Born approximation analytic model has been applied to these measurements yielding accurate band system oscillator strengths. Comparison of the emission and excitation cross sections shows that the $c_4' \, ^1\Sigma_u^+$ state is less than 10% predissociated; the predissocation yield for the b' state is 84%. These results represent a substantial improvement in the available data base.

*This work supported by the Air Force Office of Scientific Research and the National Science Foundation (giant # ATM 8715709), and NASA.

LB-4 Measurements of Electron-Impact Cross Section for Excitation out of the $He(2^3S)$ Metastable Level.* R. B. LOCKWOOD, F. A. SHARPTON, L. W. ANDERSON, J. E. LAWLER, and CHUN C. LIN, Univ. of Wisconsin, Madison—In this experiment metastable $He(2^3S)$ atoms formed in a hollow-cathode discharge flow out of the hollow cathode through an orifice into a vacuum collision chamber. The vertical metastable-atom beam is crossed by a horizontal electron beam of energy up to 16 eV. Radiation from the $He(n^3L)$ atoms produced by electron excitation out of the 2^3S metastable level is measured and utilized to determine the optical emission cross sections. Absolute calibration of the cross section is facilitated by a laser-induced fluorescence experiment which gives the ratio of the electron excitation cross section to the known $2^3S \rightarrow 3^3P$ optical absorption cross section. Apparent excitation cross sections and excitation functions have been obtained for several n^3L levels. The direct excitation cross sections for the 3^3P level are found to be much smaller than those for 3^3S and 3^3D.

*Work supported by the Air Force Office of Scientific Research.

LB-5 A Study of the Pais Variational Phase Shift Approximation and Its Extension Potentials with a Pure Coulomb Tail, S. R. VALLURI, Dept. of Appl. Math., U. of Western Ontario, CANADA and W. J. ROMO, Ottawa-Carleton Inst. for Phys., Carleton U., CANADA, -- The accuracy of a variational approximational scheme for calculating phase shifts in potential scattering problems that was devised by Pais[1] is investigated. Calculations indicated that the method gives fairly accurate results for all but the very lowest partial waves. The partial derivative of the phase shift with respect to the angular momentum

$(\partial\delta_\ell/\partial\ell)$ can be calculated for a variety of potentials in the Pais approximation. This is of importance since this partial derivative is directly proportional to the defections angle which has played an essential role in the analysis of 'rainbows' in heavy ion collision[2]. The Pais approximation can be of use in computational physics since the scattering processes can be formulated in terms of a Sturmian Bessel set of functions[3]. The extension of the Pais formula to the pure Coulomb potential has been studied and some simple applications have been worked out. The analysis of 'rainbows' is now under study.

1. A. Pais, Proc. Camb. Phil. Soc., 42 (1946) 45.
2. K. W. McVoy et al; Nucl. Phys. A455 (1986) 118.
3. S. Weinberg, Phys. Rev. 131 (1963) 400.
   G. H. Rawitscher, Phys. Rev. C25 (1982) 2196.

LB-6 Inelastic 3S-3P and Superelastic 3P-3S Electron Scattering,* L. VUŠKOVIĆ, T.Y. JIANG, M. ZUO, and B. BEDERSON, New York U,— We report on "time inverse" processes, the inelastic 3S-3P and the superelastic 3P-3S absolute differential cross sections for 3 and 20 eV unpolarized electron scattering by sodium over an angular range of about 0-20°. Inelastic process corresponds to electron scattering with all atomic sublevels of initial and final state present, while in the superelastic case the atoms are initially prepared by circularly or linearly polarized laser light which result in unequal initial state population. Accordingly detailed balancing cannot be directly invoked to compare the inverse reactions, and in fact our results do reveal significant differences between those processes. Experiments were preformed using crossed-beam electron and photon recoil technique[1]. Absolute cross sections are obtained[2] by a suitable analysis of deflection beam profiles taking into account all relevant beam and apparatus parameters.

*Work supported by NSF

[1]B. Jaduszliwer et al,. Phys. Rev. a 30, 1255 (1984).
[2]L. Vušković et al., to appear, Phys. Rev. A 40, XXX (1989); T.Y. Jiang et al., to be published.

SESSION MA: FUNDAMENTAL DATA FROM PLASMAS

Thursday afternoon, 19 October 1989
Rickeys Hyatt, Camino Ballroom C at 1:30 P.M.
J. E. Lawler, presiding

MA-1 Oscillator Strengths and Lifetimes from Transform Spectrometer Data, B. A. Palmer, Los Alamos National Laboratory – A Fourier transform spectrometer (FTS) has been used in the past to measure branching ratios. The FTS data can also be used to augment oscillator strengths and lifetimes because of the inherent intensity accuracy, the high resolution, and the wide spectral coverage. It does however rely on previous measurements, and this may be the limiting factor in absolute accuracy. The various analysis techniques will be discussed as well as the inherent problems, the largest being the lack of LTE in any laboratory source that works well with the instrument. The sources that are commonly used, the hollow cathode and the inductively coupled plasma, will be examined and the problems with each will be discussed. Because of the accuracy in the FTS, some of the problems with these sources can be overcome in the analysis of the data. Examples of these techniques will be given.

MA-2 Atomic Transition Probability Measurements with an Inductively Coupled Plasma, W. WHALING *Caltech*, T. R. O'BRIAN, M. W. WICKLIFFE, J E. LAWLER *U of Wisconsin*, J. W. BRAULT *NOAO/NSO*. - The 1-m Fourier Transform spectrometer at the National Solar Observatory (Kitt Peak) has been used extensively by many guest scientists to measure the emission branching fractions by which atomic level lifetimes can be converted into individual atomic transition probabilities (ATP). This conventional method of measuring ATP's uses a tiny fraction (usually << 1%) of the spectral information in an FTS spectrum. The inductivly coupled argon spectral source (ICP) provides a way to make more efficient use of the immense amount of information in a typical FTS spectrum. We show that the population of excited levels in the ICP approximates closely the Boltzmann exponential dependence on excitation energy. Measured lifetime values for only a few levels spread over a wide range of excitation energy determine the excitation temperature of the ICP source. Once the relative populations of excited levels are known, it becomes possible to find the ATP *for every line that can be classified* in the ICP spectrum by simply measuring the emission line strength. Application of this method to Mo and Fe will be reported, including the computer techniques required to measure and analyze the thousands of transitions accessible by this method.

MA-3 Electron Beam Ion Traps (EBIT): A New Tool for Studying the Spectroscopy of Multiply-Charged Ions,* R. E. MARRS, Lawrence Livermore National Laboratory—An Electron Beam Ion Trap (EBIT) at LLNL is being used to produce and trap ions with up to 82 electrons removed (e.g. neonlike U^{82+}) for x-ray spectroscopy measurements. In EBIT highly charged target ions are prepared in a selected ionization stage and bombarded with a monoenergetic electron beam. The available electron energy range is presently $0.5 \leq E_e \leq 30$ keV. This technique has been used to obtain precise energy level (i.e. Lamb shift) measurements, to obtain electron-ion collision cross sections for impact excitation[1] and dielectronic recombination[2], and to study x-ray line ratios used for plasma diagnostics.

*Work performed under the auspices of the US Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

[1]R.E. Marrs et al., Phys. Rev. Lett 60, 1715 (1988)
[2]D.A. Knapp et al., Phys. Rev. Lett 62, 2104 (1989)

MA-4 Evaporative Cooling in Electron Beam Ion Traps,* B. M. PENETRANTE, M. A. LEVINE+ and J. N. BARDSLEY, Lawrence Livermore National Laboratory -- Evaporative cooling has been used successfully in EBIT to extend the containment time for neon-like gold to several hours. We have developed a computer model to elucidate the mechanisms which affect the energy and charge balance of the trapped and coolant ions. With this model we are able to self-consistently determine the (a) ion density as a function of charge state, (b) spatial extent of the various ionic species, (c) heating rate of the ions by the electron beam, (d) energy transfer from the highly-charged ions to the coolant ions, (e) energy distribution among the coolant ions, and (f) energy escape rate of the ions. Thus, for each set of operating parameters and amount of coolant, we are now able to predict the resulting number of trapped ions and their trapping times, and study the relative efficiencies of different coolants.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

+Lawrence Berkeley Laboratory

SESSION MB: CROSS SECTION DATA II

Thursday afternoon, 19 October 1989
Rickeys Hyatt, Camino Ballroom D at 1:30 P.M.
B. Bederson, presiding

MB-1 Atomic Collision Processes in the Edge Plasma of Magnetic Fusion Devices, R.A. PHANEUF, Oak Ridge National Laboratory* -- The importance of atomic processes in the hot central core of magnetic fusion plasmas such as tokamaks has received much attention over the past decade. However, it has only recently been recognized that a detailed understanding of the behavior of the cooler edge region near the physical boundary of the vacuum chamber is critical to effective plasma confinement

and heating. This region is characterized by electron temperatures in the 1-100 eV range, and relatively large densities of neutral species such as H, H_2 and hydrocarbons of the type C_aH_b. Accurate low-energy cross-section data for atomic processes such as excitation, ionization, recombination, dissociation, interchange reactions and charge transfer are required for modelling the edge plasma.[1] A survey of data needs will be presented.

*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under contract No. DE-AC05-84OR21400.

1. H. Tawara and R. A. Phaneuf, Comm. At. Mol. Phys. 21, 177-93 (1988).

MB-2 Negative and Positive Ion Formation by Electron Impact on Benzene*, A.F. FUCALORO+ and S.K. SRIVASTAVA, Jet Propulsion Laboratory, California Institute of Technology--We have utilized a crossed electron beam and molecular beam collision geometry to study the ionization, dissociative ionization and dissociative attachment properties of benzene by electron impact. A large number of dissociated fragments (both positive and negative) have been identified for the first time. Threshold energies and cross sections for the production of various fragments have been measured. Threshold energies have also been calculated from the knowledge of heats of formation and compared with the measured ones. This comparasion provides information on the bond structures of the various radical fragments. These data will be presented at the conference.

*Work supported in part by Air Force Wright Aeronautical Laboratories.

+On leave from Joint Sciences Department, Pitzer College, Claremont, CA 91711.

MB-3 Electron Collision Cross Section Needs for the KrF Laser, D.C. CARTWRIGHT and P. J. HAY, Los Alamos National Laboratory, and S. TRAJMAR, JPL CalTech -- Electron Collision processes play a critical role in the KrF laser. These processes contribute to the formation and the destruction of the excimer molecule and/or have critical importance in determining the behavior and performance of the laser system.

Although some information on electron collision cross sections pertinent to KrF laser exists in the literature, for a rather large variety of processes only fragmentary data or no information at all is available. The problem is especially serious for collision processes involving excited (mostly metastable) species. Here we briefly review the needs in general and specifically describe procedures we have used for estimating electron collision cross sections for quenching of metastable Ar and Kr and for dissociation of molecular flourine.

The estimation of quenching cross sections is based on the principle of detailed balance and results will be presented for both Ar and Kr for electrons in the zero to 2.5 eV kinetic energy range.

Estimation of F_2 dissociation cross section is based on very fragmentary electron-impact energy-loss spectra, the similarity of the F_2 and N_2 molecule and the available cross sections for electron impact excitation of N_2.

MB-4 e-CH_4 collisions in a Static-(Exact) Exchange plus Parameter-free Polarization Model. Elastic and Rotational Excitation Parameters. P. McNaughten and D. G. Thompson, Queen's Univ., Belfast, N. Ireland and Ashok Jain, Florida A & M Univ., Tallahassee,- We report differential, integral and momentum transfer cross sections for the elastic, rotational excitation and rotationally summed processes in an exact static-exchange plus nonadjustable polarization model of Jain and Thompson[1]. The inhomogeneous scattering equations are solved iteratively[2] for all the symmetries (A_1, E, T_1 and T_2) considered here. We compare our results with recent experimental data in the whole energy region (0.1 - 10 eV). The agreement with expt. data is excellant and much better than all previous calculations. In particular, our results on the total and differential cross sections are very good below 1 eV where polarization and exchange effects are very crucial.

1. A. Jain and D. G. Thompson, J. Phys. B15, L631 (1982)
2. P. McNaughten and D. G. Thompson, J. Phys. B21, L703 (1982).

MB-5 Dissociative Attachment in the Chloromethanes,* S.C. CHU and P.D. BURROW, U. of Nebraska, Lincoln--
Using a newly modified electron beam apparatus with provisions for counting the ion fragments, we have re-examined the dissociative attachment cross sections of CH_3Cl, CH_2Cl_2, $CHCl_3$ and CCl_4 at low energies. The cross sections are normalized to that for O^- from CO_2 at the 4.4 eV peak.[1] Because the cross section for CH_3Cl is so small, contamination of the gas bottles or from the gas handling method can lead to an overestimate of the low energy peak. We have found direct evidence for both these problems. Our cross section is substantially smaller than that derived recently from swarm measurements[2] and differs in energy dependence.

*This work was supported by NSF.

[1]G.J. Schulz, Phys. Rev. 128, 178 (1962).

[2]Z.L. Petrovic, W.C. Wang and L.C. Lee, J. Chem. Phys. 90, 3145 (1989).

MB-6 Temperature Dependence of the Vertical-Onset-Dissociative Electron Attachment to CH_3Cl*. P. G. DATSKOS, L. G. CHRISTOPHOROU, AND J. G. CARTER, Oak Ridge National Laboratory and the University of Tennessee - The low-energy (< 1 eV) dissociative electron attachment process in CH_3Cl exhibits a vertical onset behavior. At 300K the total electron attachment rate constant $k_a(\langle\epsilon\rangle, T)$ for CH_3Cl in N_2 is $< 10^{-14}$ cm^3 s^{-1}. As T is increased to 750K, $k_a(\langle\epsilon\rangle, T)$ shows a remarkable (by over 4×10^3 times) increase which depends on $\langle\epsilon\rangle$; two negative ion states contribute to $k_a(\langle\epsilon\rangle, T)$, at thermal energies and at ~ 0.7 eV. At T = 750K, the $k_a(\langle\epsilon\rangle, T)$ is ~ 4×10^{-11} cm^3 s^{-1}. The exceedingly small $k_a(\langle\epsilon\rangle, T)$ at 300K and the profound increases in $k_a(\langle\epsilon\rangle, T)$ with small increases in T (which may indicate infrared photoenhanced electron attachment) make CH_3Cl and its mixtures with buffer gases candidates for pulsed power switches.

*Research sponsored by the U.S. Department of Energy under Contract No. DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

MB-7 Inference of HN_3 Electron Attachment Cross Sections From Drift Velocity and Electron Attachment Rate Constant Data.++ L. A. Schlie, C. A. Denman, and M. W. Wright**, Advanced Laser Technology Division (WL/ARDI), Kirtland AFB, NM 87109-6008

Recently, it was reported that the energetic azide HN_3 molecule is electronegative. In an attempt to further understand this electron attachment process, detailed electron attachment rate constant data plus other TOF (Time-of-Flight) experimental results (V_d, D_l, and D_3) were measured over a wide range of E/N values and all of the inert gases. Such data indicates the very strong influence of this electron attachment process on such gas mixtures. In addition, the results indicate that threshold energies greater than 0.2 eV exists. Using the Boltzmann equation to describe the electron kinetics, these data are used to

infer the energy dependence of the this particular process. The algorithms used are discussed in detail.

++ Funded by the Air Force Office of Scientific Research, Bolling AFB, D.C.
** Dept. of Physics and Astronomy, University of New Mexico, Albuquerque, NM 87131

SESSION NA: POSTERS
Thursday afternoon, 19 October 1989
Rickeys Hyatt, Camino Ballrooms A and B at 3:30 P.M.
J. B. Jeffries, presiding

NA-1 Particle Simulation of a RF Discharge: Nonlocal Effects,* M. SURENDRA and D. B. GRAVES, University of California, Berkeley - A self-consistent 1D2V particle-in-cell simulation of a RF discharge will be presented. Collision effects included in the model are elastic and ionizing electron-neutral collisions using realistic differential cross sections and ion-neutral charge exchange. The detailed nature of the model is suited to an in-depth study of the RF plasma and sheath dynamics. Fluid models typically require the use of swarm parameters either in the local field approximation[1] or in an energy balance approach[2]. The accuracy of these simplifying assumptions are examined by comparing transport properties and inelastic rates predicted by the particle simulation to their local field values. Furthermore, the effects of power and neutral gas density will be discussed. Ion energy distributions at the electrode under various operating conditions are also presented.

*Work supported in part by San Diego Supercomputer Center.

1J. P. Boeuf, Phys Rev A 36, 2782 (1987).
2A. D. Richards et al., Appl. Phys. Lett. 50, 492 (1987)

NA-2 Probe Potential and Capacitance Measurements in a Symmetric Argon RF Discharge Driven at 13.56 MHz, V. A. GODYAK, R. B. PIEJAK, GTE Laboratories Inc., Waltham, MA -- The DC voltage and various RF voltage components on a wire loop probe located at the mid-plane of an RF discharge have been measured using RF probes with different input capacitance The measurements showed that the RF component on the loop probe was almost entirely composed of the second harmonic of the driving frequency. The values of RF and DC components of the probe potential were found to mainly depend upon the input capacitance of the RF probes. Measuring the potential with RF probes of different input capacitance enabled us to determine values of plasma-probe capacitance and to calculate true values of DC and RF potentials. The DC and RF probe potentials were compared with predictions from various RF electrode sheath models. The values of probe-plasma capacitance and the RF voltage are important in designing an electronic circuit for probe diagnositcs in an RF discharge.

NA-3 Electron Cyclotron Resonance Plasma Source Research at the University of Wisconsin-Madison, H. M. Persing, N. Hershkowitz, A. Wendt, D. Diebold, M. H. Cho, University of Wisconsin-Madison, Electron cyclotron resonance (ECR) plasmas have recently been used for a number of applications such as low temperature chemical vapor deposition, plasma etching, ion beams, etc. We are investigating two such sources: a commercially available source which is employed as an etcher and a device built to achieve overdense ($\omega_{pe} >> \omega_{rf}$) target plasmas with n_e=10^{13}. In both instances, we are intent on characterizing the plasma sources by measuring the radial, axial, and azimuthal distributions of density (n_e), electron temperature (T_e), and plasma (ϕ_p) and floating (ϕ_f) potentials as functions of magnetic field configuration, microwave power, and neutral gas composition and pressure. Further investigations will include measurements of the electron and ion "endloss" currents and their energy distributions. The latest results will be presented.

NA-4 Observation of Submicron Particles in RF Plasmas, K. R. STALDER, SRI International--We have observed submicron size particles in an parallel plate rf plasma. The particles were grown while etching silicon wafers in CCl_2F_2/Argon plasmas. The particles were observed in situ by a laser scattering apparatus which made vertical scans between the plates. Particles tended to stratify in the discharge, with the maximum particle density located at the lower sheath-plasma boundary. The particle sizes, calibrated against Rayleigh scattering from test gases, are less than 0.4 microns in diameter. These particles are smaller than those reported by Selwyn, et al.[1] in a similar experiment. Possible explanations for the discrepancies include differences in electrode temperatures, electrode materials and degree of discharge confinement. We have not yet made chemical analyses of the particles, but we note that they were only observed while etching silicon Nucleation, growth and transport processes in plasmas will be discussed.

1. G. S. Selwyn, J. Singh and R. S. Bennett, to be published in J. Vac. Sci. Tech. A (July/August, 1989).

NA-5 Power Absorption by Electron Cyclotron Resonance, D CARL, A.J. LICHTENBERG, M.A. LIEBERMAN, J. STEINHAUER, AND M. WILLIAMSON, University of California, Berkeley — Electron cyclotron resonance (ECR) discharges are widely used for the fabrication of integrated circuits. ECR power absorption on a magnetic beach is calculated from linear wave theory and from nonlinear single particle heating theory. The two results are found to be in reasonable agreement in the weak absorption limit where the nonlinear calculation can be performed. The calculations predict a rather sharp cut-off of absorbed power with decreasing incident power due to the plasma becoming transparent to the incident radiation. Over most power levels of interest, however, the ECR power is strongly absorbed. A simple discharge model is constructed based on these results. The theoretical results and the model are compared with experimental measurements.

NA-6 Studies of Microwave Breakdown Plasmas in Air by the Microwave Cavity Perturbation Technique,* D. J. ECKSTROM AND M. S. WILLIAMS, SRI International--We have used a 329 MHz microwave cavity to make very sensitive measurements of the electron densities and collision frequencies in air following pumping by a high-power pulsed 2.86-GHz microwave source at LLNL. The S-band source was focused through 23-cm diameter holes in the cavity endwalls. The pressure was varied from 0.01 to 30 torr, microwave pump power and pulse length were adjusted to minimum values required to produce measurable electron densities, which ranged from 2×10^5 to 1×10^7/cm^3. Threshold pump powers were slightly lower than values for critical breakdowns, and followed similar trends with pulse length (decreasing power but increasing energy with increasing pulse length). Electron density decay rates were about 10^2/sec from 0.01 to 0.3 torr and then increased linearly with higher pressures (slower than 3-body electron attachment rates in air). Collision frequencies could not be measured below 1 torr. They corresponded to calculated values for T_e = 800 K at 1 torr, decreasing to 300 K at 3 torr and 100 K at 30 torr. The latter value may reflect a contribution of negative ions to the conductivity.

*Work supported by AFGL through LANL.

NA-7 Growth of Diamond in a DC Discharge,* H. N. CHU, A. R. LEFKOW, R. REDWING, L. W. ANDERSON, M. G. LAGALLY and J. E. LAWLER, Department of Physics, University of Wisconsin, Madison, WI 53706—Diamond films have been grown using DC discharges. We have studied the growth of diamond using both a Ta spiral hollow cathode and a abnormal glow discharge using a Cu cathode. The diamond is grown on a Si(100) substrate with a feed gas of 0.5-1.0% CH_4 in H_2 at a pressure of 30 Torr, with a flow rate of 80sccm, with 150V cathode to anode potential difference, and a cathode to anode spacing of 0.5-2.0 cm. The substrate is heated resistively to 900°C. The growth rate is about 0.5 micron/hour. The diamond is identified using both Raman Scattering and a scanning electron microscope. Spatially resolved

emission measurements will be reported. We observe a glow near the cathode, a dark space, and second glow near the anode.

*Research Supported by NSF Grant No. CDR-8721545 in support of the Engineering Research Center - Plasma Aided Manufacturing.

NA-8 Generation of carbon ion beams from a small multicusp source* -- K.N LEUNG, M LOWENTHAL, W. STOCKWELL, M.D. WILLIAMS, and W.B. KUNKEL, Lawrence Berkeley Laboratory, and J.M. DAWSON, UCLA -- Carbon ion beams are used in some experiments to form diamond-like films. Negative carbon ions are required in Accelerator Mass Spectrometry applications. In most cases, the carbon ions are generated either by dissociation of gas molecules such as CO, CO_2 or CH_4 or by sputtering graphite targets with energetic Cs^+ ions. We would like to report a novel method of producing C^+ or C^- ions without the use of gases or cesium. The experiment was performed in a 7.5-cm-diam. multicusp source. A graphite hairpin filament was used to generate the background carbon vapor as well as the primary ionizing electrons. Preliminary results showed that almost pure steady-state C^+ ion beams could be obtained without employing any supporting gas for the discharge. An ample amount of C^- ions has also been observed when the source was biased for negative ion extraction.

* This work is supported by the U. S. DOE under Contract Number DE-AC03-76SF00098.

NA-9 Multi-Species Ambipolar Diffusion*, T. Gist and A. Garscadden, Wright Research and Development Center (WRDC), and W. Bailey, Air Force Institute of Technology (AFIT). An improved model of multi-species ambipolar diffusion has been developed. Previous models based on Schottky's single species ambipolar diffusion[1] require assumptions that cannot be justified from the physical situation, or can produce only numerical solutions. The new model, based only partly on Schottky's development, produces analytic solutions for a range of realistic systems, and numerical solutions are often much simpler than previously.

Development of the new model is discussed. Analytic and numerical solutions for realistic cases are presented. Validity and necessary conditions for proportionality are discussed.

*Work supported in part by WRDC and AFIT.

[1] Diffusion Theory and the Positive Column, W. Schottky, Zeitschr. f. Phys., October 1924.

NA-10 Kinetic study of electron properties in a capacitively coupled RF-discharge, G. FROMLING, Ruhr-Universität Bochum, FRG. -- The electron distribution function is investigated in the frequency range $\nu_e \lesssim \omega \ll \nu_m$ where $\nu_{e/m}$ are the collision frequencies of energy or momentum exchange, respectively.

The energy supply necessary to sustain the discharge is modeled by the reflection of the electrons at the oscillating space charge potential. Since the thermalization of these electrons occurs far from this space charge region in the energy exchange zone, the problem is nonlocal. The ultimate goal is the correction of the Boltzmann factor of the electron density and the Hertz-Knudsen formula for the electron current. We present first the numerical results.

NA-11 Electron Degradation Spectra by Subexcitation Electrons in Gaseous- and Solid-Water, H. KIMURA, M. A. ISHII,† and M. INOKUTI, Argonne National Laboratory-- Electrons whose kinetic energies are below the electronic-excitation threshold are termed subexcitation electrons. Knowledge of the behavior of these electrons is essential in radiation physics and chemistry. We have conducted a systematic study of the moderation of the subexcitation electrons in H_2O (gas and solid) using the Spencer-Fano theory and its simplified treatment, the continuous slowing-down approximation within time-dependent and time-independent representations. Our study shows that while the general shapes of two degradation spectra arising from the gaseous and condensed phases are similar, detailed structures as well as magnitudes are quite different because of additional energy-loss processes in the condensed phase.

*Work supported in part by the U.S. Department of Energy, Office of Health and Environmental Research, under Contract W-31-109-Eng-38.

†Summer student, Department of Educational Programs, ANL.

NA-12 Model of Plasma Source Ion Implantation in Planar, Cylindrical and Spherical Geometries, J. T SCHEUER, M. SHAMIM and J. R. CONRAD, Plasma Source Ion Implantation Group, University of Wisconsin -- A model of transient sheath propagation has been developed and applied to Plasma Source Ion Implantation.[1] This model assumes that the transient sheath obeys the Child-Langmuir law[2] for space charge limited emission at each instant during the propagation. The model predicts the final sheath extent and average current to the target during each high negative voltage pulse for planar cylindrical and spherical geometries.

[1] J. R. Conrad, J. L. Radkte, R. A. Dodd and F. J. Worzala, J. Appl. Phys. 62, 4591 (1987).

[2] I. Langmuir, Phys. Rev. 21, 419 (1923); I. Langmuir and K. Blodgett, Phys. Rev. 22, 347 (1923); I. Langmuir and K. Blodgett, Phys. Rev. 24, 49 (1924).

NA-13 Generalized Sheath Condition for Emitting and Reflecting Walls K.-U RIEMANN, Ruhr-Universität Bochum, FRG. In the asymptotic limit of a small Debye length ($\lambda_D \to 0$) the problem of the plasma boundary layer is splitted up into the separate problems of a collision free sheath and quasineutral presheath. For the case of completely absorbing walls the well known Bohm "criterion" [1] formulates a necessary condition for a stationary sheath. We reinvestigate the problem of sheath formation accounting for emitting and reflecting walls and find a generalized sheath condition. By a kinetic analysis of the presheath we show that this condition is usually fulfilled marginally and connected with a sheath edge field singularity on the presheath scale. An analogous result was obtained earlier for absorbing walls. [2]

[1] E. R. Harrison and W. B. Thompson, Proc. Phys. Soc. London 74, 145 (1959).

[2] K.-U. Riemann, Phys. Fluids B1, 961 (1989).

NA-14 A Micro-Pyrometer System for Measuring the Temperature of F-Lamp Electrodes, A AWADALLAH and A.K. BHATTACHARYA, GE Lighting, Cleveland, OH A Micro pyrometer capable of measuring time-resolved temperature profiles of the hot spot on the electrode of a fluorescent lamp is described. The system has a spatial resolution of .0008 inch in diameter and is capable of following the temperature excursions of the hot spot over 60 Hz AC frequency. It is capable of measuring temperatures as low as 1000° K. The instrument is simple to construct and easy to operate. It was used to measure the temperature variations of the cathode spot as a function

of the phase of the lamp current and a temperature averaged over 60 Hz. The hot spot temperature was fairly constant in the cathode and anode half cycle. The average hot spot temperatures of an electrode surface covered with emission mix in F40W lamps operating on reference and 2-lamp rapid start ballasts were consistently measured in the range of 1400-1500 K.

NA-15 Mercury Pressure Effects on Convection in Horizontal Discharges, M.E. DUFFY and P.Y. CHANG, G.E. Lighting — A three-dimensional convection model has been developed and used to investigate horizontal, high pressure mercury vapor arcs. The model solves the coupled momentum, mass continuity, energy and electric field equations. The numerical approach is capable of handling irregular geometries of offset electrodes as well as curvature of arctube. The effects of mercury pressure on arc centering and wall temperature are reported by both the theoretical model and by measurements of curved arctubes with offset electrodes and varying dose weight. Aquadag spot temperatures on the arctube wall verify qualitative model predictions. Line of sight arc intensity measurements show the effect of increased buoyancy with higher mercury pressure. A similar trend is also obtained from the model. The data are used to set a geometry dependent model parameter approximating the effect of radiation absorption by the cold gas surrounding the arc.

NA-16 Short-Gap Breakdown in He: the Effect of Impurities*, J.P. NOVAK and R. BARTNIKAS, IREQ, Varennes, Québec, Canada --The experimental arrangement consisted of a pyrex glass vacuum chamber and two stainless steel electrodes of 5.08 cm diameter with the edges rounded to a 0.32 cm radius, separated by a 0.48 mm gap; limit pressure was below 1×10^{-4} Torr and before experiments the gap was degased by a glow discharge. Working pressure was 760 Torr with relative pressure of the added dry air between ≈ 0 and 3×10^{-3}. The evaluated breakdown voltage U_{br} of the mixture was 250, 259, 268, 285 and 309 V for the relative pressures ≈ 0, 10^{-4}, 3×10^{-4}, 10^{-3} and 3×10^{-3}, respectively. The initial current increase (recorded up to about 500 µA) was very nearly exponential. The inverse time constant of the current rise as measured at the voltage $U_{br}+10$(V) was 0.051, 0.15, 0.26, 0.47 and 0.96 μs^{-1} at the corresponding relative pressures as above. In the near proximity of the breakdown voltage (measured up to about U_{br} + 25 V), the inverse time constant was approximately a linear function of the overvoltage with the slope rapidly increasing with the relative pressure of the air.

* This work was supported by CEA (Canada).

NA-17 Line Broadening in Laser-produced Oxygen Plasmas*, L.S. Dzelzkalns and W.A.M. Blumberg, Geophysics Laboratory (AFSC), P.C.F. Ip and R.A. Armstrong, Mission Research Corp., W.T. Conner and C.C. Lin, U. of Wisconsin -- Ultra-broad spectral lineshapes have been measured in the short- to medium-wavelength IR for laser-produced oxygen plasmas. Atomic oxygen emissions were observed in the GL LINUS facility in which O_2 at pressures of 30-190 torr was irradiated with a pulsed Nd:YAG laser with peak laser intensities of $(1\text{-}10)\times10^{12}$ W/cm^2. Time-resolved spectra were obtained over the wavelength range 1.5-8.5 microns. The IR observations are being analysed using a line broadening theory which treats the interactions of the emitting oxygen atom with both the plasma ions and electrons. The effect of the ions is calculated in the quasi-static approximation using perturbation theory and the electron broadening is obtained from impact-parameter calculations of electron collision cross-sections. The method will be applied to our observations of oxygen atom Rydberg state emissions to determine the relative importance of ion versus electron broadening.

*Supported by the Air Force Office of Scientific Research and the Defense Nuclear Agency.

NA-18 Time Dependent Solution of Boltzmann Equation in Self-sustained XeCl Discharges Coupled to Plasma Chemistry and Circuit Equations, C. GORSE and M. CAPITELLI, U. of Bari, Centro Studio Chimica Plasmi (CNR) --Time dependent Boltzmann equation, including electron-electron and superelastic collisions, coupled to plasma chemistry and circuit equations has been solved for a self-sustained XeCl discharge. The main results can be summarized as follows 1) the time dependent solution of Boltzmann equation is necessary during part of the temporal evolution specially when the electric field drops to small values 2) superelastic vibrational and electronic collisions play a non negligible role during the laser action. The accuracy of the code has been tested by comparing theoretical results with the corresponding experimental ones obtained in the National Laboratory of Frascati, showing in general a satisfactory agreement for the behaviour of laser output i) versus charging voltage (30 V_o 50kV) at fixed pressure (P=3atm) ii) versus pressure (1.5 P 3 atm) at fixed charging voltage (V_o=45kV).

NA-19

Study of UV and VUV fluorescence of high pressure rare gases excited by dielectric controlled discharge : third continuum of Argon *, C. Cachoncinlle and J.M. Pouvesle, CNRS/University of Orléans, France, and F. Davenloo, J.J. Coogan and C.B. Collins, The University of Texas at Dallas--We report the observation of the third continuum of Argon centred at 188 nm (FWHM ≃ 20 nm) in plasmas excited in high pressure (100 to 4000 torrs) Argon and Argon-reactant gas mixtures by fast high voltage pulses in a dielectric controlled discharge. The effect of various reactants, such as He, Xe, N_2 and H_2, on the fluorescence yield and decay has been studied leading to the determination of the corresponding rates. In contradiction to what has been reported previously *(1)*, under our discharge conditions, the presence of large amounts of helium doesn't affect significantly the argon fluorescence in that domain. This and other experimental results necessitate a reexamination of the last assingment *(1)* of the origin of this third continuum to a transition between $Rg^{2*}Rg$ and $Rg^{*}Rg^{*}$ molecules. Analysis is presently in progress.

* Work supported in part by NATO grant n° 890508.
(1) H. Langhoff, Optics Comm., 68, 31 (1988).

NA-20

Model of electrons, ions, and fast neutrals in H_2 at very high E/n, A V PHELPS, JILA, University of Colorado and NIST. -- Previously assembled[1] cross sections and swarm coefficients for electrons, H^+, H_2^+, H_3^+, H, H_2, and H^- in H_2 are used to model the current growth and spatial dependence of light emission for low current discharges in H_2 at very high E/n. At E/n < 1000 Td the H_3^+ ion is dominant, but for E/n > 3000 Td H_2^+ ions are dominant. The H^+ to H_3^+ ratio[2] increases with E/n to about 30% at 1000 Td. H^- ions can be neglected. At E/n > 10 kTd the predicted excitation of Balmer-α emission is primarily by fast H_2 and fast H. The predicted spatial dependence of the H_2 $a^3\Sigma_g^+ \rightarrow b^3\Sigma_u^+$, near UV transition by electrons peaks sharply near the cathode and is very small elsewhere. This result is inconsistent with measurements[3] for D_2 and

with initial data[4] for H_2. We propose that this UV excitation is caused by fast H or H_2 collisions with H_2.

[1]A.V. Phelps, Int. Conf. Physics of Electronic and Atomic Collisions, New York, July, 1989.
[2]J Fletcher and H. A. Blevin, J. Phys. D 14, 27 (1981).
[3]B M Jelenković and A V. Phelps (unpubli ed).
[4]Z.Lj. Petrović and A.V. Phelps, 1989 Gaseous Electronics Conference.

NA-21

Density Measurement of the Metastable $Hg(6^3P_2)$ in a Hg-Ar Low-Pressure Discharge. P. MOSKOWITZ, GTE Products Corp., Danvers, MA 01923 -- The radial density distribution and absolute density for the 6^3P_2 metastable level of mercury in the positive column of a low-pressure mercury-argon discharge has been measured using the modulated linear absorption (MLA) method.[1] The 6^3P_2 level is one of three closely spaced levels ($6^3P_{0,1,2}$) that play a crucial role in the operation of a fluorescent lamp. Knowledge of the metastable state density can aid in the validation of models for fluorescent lamps. In the MLA technique, the output of a tunable dye laser is split into pump and probe beams. The pump is 100% modulated, and saturates the atomic transition of interest, while the weak probe intersects the pump at right angles inside the discharge. Synchronous detection of the probe yields pinpoint density information at the intersection zone, obviating the need for Abel inversion of the data. This reduces the error propagation and inherent uncertainties associated with Abel inversion. Model predictions and experimental results[2] for the density of $Hg(6^3P_2)$ have recently appeared in the literature. Densities measured under varying discharge conditions are compared with these published results.

1 P.Moskowitz, Appl.Phys.Lett.50(14),891(1987)
2 J.T.Dakin and L.Bigio, J.Appl.Phys.63,5270(1986)

NA-22

Study of Negative Ion Formation by Electron Impact on Dichloromethane, Toluene, Xylene and Trichloroethane,* C. TIMMER and S.K. SRIVASTAVA, Jet Propulsion Laboratory, California Institute of Technology -- A crossed electron beam and molecular beam collision geometry has been employed to study the process of negative ion formation from the above molecules. Cross section data on these molecules are not readily available. It is found that both dissociative attachment of electrons and polar dissociation are responsible for the production of negative ions. In the case of dichloromethane and trichloroethane, the cross sections are very large for the appearance of Cl^- (masses 35 and 37). Cross sections for the production of the various negative ions from toluene and xylene are small. The various negative ion spectra and cross sections will be presented at the conference.

*Work supported in part by Environmental Protection Agency.

NA-23

Plasma Line Broadening in Molecular Spectra in D.C. Glow Discharges. W T CONNER and R C WOODS, U. of Wisconsin-Madison--Certain nearly degenerate molecular states can be perturbed by the modest plasma densities in glow discharges. We have studied the millimeter wave rotational spectra of the *l*-doublets of HCN and HCO^+ in excited states of their bending vibrations. These transitions are much broader and weaker than their unperturbed counterparts, due to their fast Stark effect. This broadening was measured as a function of plasma density. Models of this effect based on the impact and quasi-static limits have been developed. The impact approximation is favored, for both ions and electrons, on theoretical grounds and is supported by the data. Surprisingly, the quasi-static model simulates the observed spectra fairly well too. We have also applied both models to atomic oxygen, see the poster *Line Broadening in Laser-produced Oxygen Plasmas* by L. S. Dzelzkalns et.al.

NA-24

Stark Broadening in High Pressure Helium Plasmas -L.W. Downes, S.D. Marcum and W.E. Wells, **Miami University, Oxford OH,** and J.O. Stevefelt, **GREMI, Université d'Orleans, France.**--We have investigated the electron, atomic (2^3S) and molecular ($2^3\Sigma$) metastable densities in high pressure (100 - 4000 Torr) helium plasmas during the discharge and afterglow periods of a long pulsed (900 ns) electron beam discharges (250 KeV, 10 A/cm^2). Using the broadening of the 388.9 nm ($2^3S \rightarrow 3^3P$) line and removing the pressure broadened and instrument (gaussian) components, we have found the lorentzian that fits the Stark broadened spectrum. Those fits suggest electron densities in the range of 10^{14}-10^{15} cm^{-3}. Metastable densities were also determined from the lorentzian fit to the lines. We present the results of the study along with the pressure broadening parameters for high pressure helium plasmas. Comparisons with calculated densities from a kinetics model of such plasmas are also presented and discussed.

NA-25

The Effect of Radiative Cascade on Cesium Excited State Populations in Thermionically Assisted Ar-Cs Discharges,* M.L TACKETT, S.D. MARCUM, **Miami University, Oxford, OH,** B.N. GANGULY, **AFWAL, WPAFB, OH** -- A model has been constructed that allows calculation of cesium excited state densities in low pressure (0.1 Torr Cs, 2 Torr total pressure) Ar-Cs discharges that use a heated cathode (700-1200 K). The model assumes that the dominant creation processes are electron impact excitation from the ground state and radiative cascade from higher levels while destruction is by spontaneous emission. Results are reported for the range $Ne=10^8$-10^{11} cm^{-3} and $Te=2000$-4000 K. The model indicates cascade contributions to excited state densities in the range of 30% for a number of cesium levels. Predicted emission spectra show similar cascade contributions to line emission intensities and agree well with measured spectra. Electron temperatures and densities based upon comparison of predicted and measured spectra are presented and discussed.

*Work supported by U.S. Air Force (WPAFB).

NA-26

A Study of the Influence of $^3P_2$ population of Mercury on the Electron Temperature in a Hg-Ar rf discharge, L. Maleki, B. Blasenheim and G. Janik, Jet Propulsion Laboratory-- We have studied the influence of laser irradiation on the line emission of an rf excited mercury-argon discharge. The discharge is produced by inductively coupling rf power to a closed cell containing a small amount of Hg and Ar at 1 Torr of pressure. The laser excites the 7 $^3S_1$ level of mercury from the $^3P_2$ metastable level. The influence of the depletion of the metastable population on the discharge parameters is determined through monitoring changes in the intensity of lines present in the discharge emission. By examining this effect we have determined that: 1) electron impact excitation from $^3P_2$ level is the dominant mechanism for the excitation of upper levels in neutral mercury, but not in the singly ionized mercury or neutral argon; and 2) depletion of metastable population by laser light closes the excitation channel mentioned above and thus increases the electron temperature in the discharge.

The Research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.

NA-27

Multiply Charged Noble Excimers, P D HAALAND and R A DEEMER, Air Force Institute of Technology - Radiative charge transfer from He^{++} to He has been experimentally probed by Johnson *et al.*[a] and theoretically characterized by Cohen *et al.*[b] The quantum constraints on radiative charge transfer from heavier multiply charged ions are less well defined. We report the results of ab

initio electronic structure calculations for the reaction of Ne^{2+} with Ne:

$$Ne^{2+} + Ne = [Ne_2^{2+}] \xrightarrow{h\nu} 2Ne^{+}.$$

Potential energy surfaces, transition moments, and the implications of radiative charge transfer kinetics for the extraction of stimulated vacuum ultraviolet radiation will be described.

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[a]R. Johnson and M. Biondi, Phys. Rev. A18, 194 (1978)

[b]J. Cohen, J. Wadehra, and J. Bardsley, Phys. Rev. A18, 996, 989 (1978)

NA-28 Global Potential Energy Surfaces of H_2Cl^+ and Comparison with Experiments Th. Glenewinkel-Meyer, P. Knowles[1], Ch. Ottinger, P. Rosmus[2] and H.J. Werner[3] MPI für Strömungsforschung, Göttingen, FRG

The three lowest H_2Cl^+-PES of A'-Symmetry were calculated using the ab-initio MCSCF (CAS) and MR-CI approaches. The Gaussian basis set for the H atom consisted of 10 s-functions (Huzinaga) and additional 4 p- and 2 d-functions; for the Cl atom a slightly modified and augmented Partridge 17-12 basis set was used combined with additional 4 d- and 2 f-functions. This set was contracted to Cl [7s,7p,4d,2f], H [7s,4p,2d]. The calculations were done pointwise for H-Cl distances ranging from 2 to 6 bohrs at 0.2 bohr intervals. For different C_s geometries, e.g. ∢ HClH = 90° and ∢ HClH = 175°, the behaviour of the three PES was studied. In particular, the presence and location of conical intersections was investigated.

Experiments done in our group on luminescent charge transfer of $H^+ + HCl(X^1\Sigma^+)$ were compared to the theoretical results. The observed high rotational excitation of the product $HCl^+(A^2\Sigma^+)$ at low collision energies is due to an avoided crossing which allows the reaction to take place only in a bent configuration, with an HClH angle somewhere between 60° and 100°.

[1]U.Cambridge, UK; [2]U.Frankfurt, FRG; [3]U.Bielefeld, FRG

NA-29 Formation of XeCl and Xe_2Cl During Three Body Recombination of Xe_2^+ and Cl^-, W. L. MORGAN, JILA, Univ. of Colorado & NIST and Kinema Research, Monument, CO 80132 and D. R. BATES, Queen's University of Belfast--Recent measurements[1] have shown XeCl to be a product of the three body recombination of the xenon dimer ion and the chlorine negative ion. This is in contrast to the conventional wisdom where we would expect the molecular ion to simply recombine to form Xe_2Cl. We have performed many body Monte Carlo simulations of the trajectories of Xe-Xe^+ and Cl^- as a function of pressure in a xenon buffer gas in order to study the recombination process. We find for low pressures that enough energy is gained between collisions with the background gas to rotationally excite and eventually dissociate the Xe_2^+ ion; this leads to XeCl being a more probable recombination product than it might otherwise be.

[1]S.P. Mezyk, R. Cooper, and J. Sherwell, submitted to J. Phys. Chem.

NA-30

Radiation Trapping under conditions of Low to Moderate Optical Depth,* T. COLBERT and J. HUENNEKENS, Lehigh U. --We have studied trapping of resonance radiation under conditions of moderate to low line-center optical depths in sodium argon mixtures. We report measured effective radiative decay rates which are compared to predictions of the Post and the Milne theories of radiation trapping. These theories are expected to be valid for lineshapes with low to moderate line-center optical depths, where the Holstein theory of radiation trapping is expected to break down. The experiment is performed under conditions where the radiation trapping is dominated by either the Doppler-broadened Gaussian or by an impact-broadened Lorentzian lineshape function. The measured effective radiative rates agree well with rates predicted by the theories over the range of low to moderate optical depths.

*Work supported by GTE Laboratoies Inc., General Electric Corporate Research and Development, and the National Science Foundation under grant PHY-8451279.

NA-31

Collisional Relaxation of $NH(^3\Sigma^-, v=1\text{-}2)$ by N_2 and H_2,* D. J. FLANAGAN, S. J. LIPSON, J. A. DODD, and W. A. M. BLUMBERG, Geophysics Laboratory (AFSC), J. PERSON and B. D. GREEN, Physical Sciences Inc.,-- The rate constants for the relaxation of vibrational levels v=1 and 2 of $NH(^3\Sigma^-)$ by N_2 and H_2 have been measured. Vibrationally-excited NH was produced by the $N(^2D)+H_2$ reaction in N_2/H_2 mixtures irradiated by a pulsed 35 keV electron beam in the GL LABCEDE facility. Time-resolved spectra of NH fundamental band emission were observed using a slow-scanning Michelson interferometer. Time-resolved histories of the populations of NH vibrational levels v=1-3 were obtained using a synthetic spectral fitting code. Rate constants for the relaxation of vibrational levels v=1 and 2 by N_2 and H_2 were determined from the population histories by kinetic modeling. Additional kinetic analysis was required to infer the effects of quenching by beam-created N and H atoms. These results are important for predicting the IR spectra of NH produced by combustion processes.

*Supported by the Air Force Office of Scientific Research.

SESSION NB: NOVEL PLASMAS

Thursday afternoon, 19 October 1989
Rickeys Hyatt, Camino Ballroom D at 3:45 P.M.
C. B. Fleddermann, presiding

NB-1

Relativistic Plasmas Produced by Intense Lasers,* J. N. BARDSLEY and B. M. PENETRANTE, Lawrence Livermore National Laboratory -- The quiver motion of electrons in the focal regions of intense lasers can be disturbed significantly by space-charge forces and spatial inhomogeneities in the laser field. Independent-electron simulations of these effects have been performed[1], and a multi-electron particle-in-cell code has been developed. These codes are being applied to analyze laser-induced nuclear reactions, the production of high-order harmonic radiation, and the use of short-pulse lasers to pump short-wavelength recombination lasers.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

[1]J. N. Bardsley, B. M. Penetrante and M. H. Mittleman, Phys. Rev. A 40 (1989) in press.

NB-2

Wide Area Disc Shape Plasma Source for Energy Assisted CVD,* Z. YU, T. SHENG, H. ZARNANI, B. PIHLSTROM and C. J. COLLINS, Department of Electrical Engineering, Colorado State University, -A wide area disc shape plasma source up to 20 cm in diameter is generated by a ring cathode electron beam. VUV photons, excited species, and radicals created from the disc plasma can all assist dissociation of chemical vapor deposition feedstock reactants via volume photo-absorption and sensitized atom-molecule collisions, respectively. In addition, the excited radical flux and VUV impingement on the film may also assist heterogeneous surface reactions and increase surface mobility of absorbed species. Microelectronic thin films including amorphous silicon, AlN and Si_3N_4 have been deposited at temperatures between 100°C-400°C. The deposited films

show significant improvement over other photo-assisted CVD processes in the film quality, low substrate temperature and the maximum deposition rates achieved.

*Work supported by National Science Foundation, Naval Research Laboratory and Applied Electron Corporation.

NB-3

Plasma Processes in Soft Vacuum Electron Beams Used for Microelectronic Film Processing, G. J. COLLINS, Colorado State University -- Soft vacuum (0.05 ~ 3 Torr) glow discharge generated electron beams are employed to create a large area plasma for assisting chemical vapor deposition (CVD) of microelectronic thin films, zone melt recrystallization, hardening of polymer films, and pattern definition in polymer films. The electron beams are operated on both a continuous and a pulsed (20-100 nsec) basis. The electron beam spatial intensity and energy profiles have been quantified from generation in the cold cathode sheath to impingement on the substrate surface for each unique application. The properties of electron beam assisted CVD films are cataloged and compared to conventional plasma assisted CVD films. Zone melt recrystallization silicon films are compared to those using conventional strip heaters. Submicron features (~ 0.5 μm) from a stencil mask have been transferred into PMMA by the pulsed electron beam. Pulsed electron beam hardening of AZ-type resist patterns were also achieved with hardened resist patterns stable to the temperature up to 350°C.

NB-4

Electron Beam Generation by Electron Bombardment Induced Cathode Emission,* B. SZAPIRO, C. MURRAY, and J.J. ROCCA, Electrical Engineering Department, Colorado State University-We have demonstrated that intense pulsed electron beams can be created by multiplication of a lower current density primary beam impinging on a high electron yield target. A 17 A electron beam of 1 us pulse width was generated from a 2.5 A beam bombarding an activated Ag-Mg alloy target 2.5 cm in diameter at an energy close to that required for maximum emission of secondary electrons. The surface activation technique for Ag-Mg is similar to the one used for photomultiplier tubes, providing reproducible yields greater than 5 that remain stable under bombardment by the intense (A/cm^2) primary beam. The maximum electron beam current densities were limited by the onset of electron current oscillations probably associated with the development of beam-plasma instabilities.

* Work supported by Wright Research and Development Center.

NB-5

The Effects of adding Xe to a H_2 Discharge. A.A. Mullan, University of Ulster, Coleraine, N. Ireland and W.G. Graham, Queen's University, Belfast, N. Ireland

Recently in attempting to understand the basic processes producing negative hydrogen ions in intense ion sources and in trying to optimize the total negative ion production, small percentages of other gases have been added to the hydrogen discharges and the changes in the extracted positive and negative ion concentrations monitored[1]. We have now measured the plasma parameters and the relative positive and negative ion concentrations in a hydrogen multipole filament driven discharge with additional small percentages of Xe gas. The main features of the present results are the increased electron density, electron temperature and plasma potential when Xe is added. This latter effect is important in interpreting our mass spectrometry data.

1. K.H. Leung et al. Rev. Sci. Instrum. 56, 2097 (1985) and S.R. Walther et al. J. Appl. Phys. 64, 3424 (1988).

NB-6

Removal of SO_2 from Flue Gases Using Combined Plasma and Optical Processing.* Jeanne H. Balbach, Mark J. Rood and Mark J. Kushner University of Illinois, Urbana, IL. Combined plasma photolysis (CPP) is a method that has the potential to remove SO_2 from flue gases at lower capital and operating costs, with a higher degree of safety, and higher electrical efficiency than current methods. CPP consists of a device that produces a pulsed discharge in the flue gases ($Air/H_2O/SO_2/NO_x$ $=90/10/10^{-3}/10^{-3}$) followed by irradiation with UV photons. The irradiation photolyzes O_2 producing $O(^1D)$. Further reaction with H_2O forms OH radicals which react with SO_2 to form H_2SO_4. This acid reacts with NH_3 to make a particulate material which is easily removed with filters. The plasma chemical reactions that occur between the gas phase radicals and SO_2 as a result of CPP are numerically simulated. The results of the model are compared to experimental results.

*Work supported by Advanced Environmental Control Technology Research Center.

NB-7

Plasma Oxidation of SO_2 in Flue Gas,* S.K. DHALI and I. SARDJA, Southern Illinois University -- The experimental results of the removal of SO_2 from a synthetic flue gas using a dielectric-barrier discharge will be reported. The dielectric-barrier discharge is an efficient means for producing atomic oxygen by electron impact. A high voltage line transformer is used for power, and the discharge geometry is co-axial. The following reactions accounts for the reduction of SO_2 concentration in the flue gas:

$$SO_2 + O \rightarrow SO_3$$

A typical measurement shows a 65% reduction in SO_2 concentration for a sample gas of 6400 parts per million of SO_2 in air. We will report the results of SO_2 removal for different flows, gas mixtures, and applied voltage. Also, we will report the results of emission and spectroscopy of atomic oxygen.

*Work supported by DOE.

SESSION P: CROSS SECTIONS I WISH I KNEW

Thursday evening, 19 October 1989
Rickeys Hyatt, Camino Ballrooms C and D at 7:30 P.M.
C. C. Lin, presiding

P-1

Cross Sections of Great Interest to Aeronomy and Astrophysics,* J. P. Doering, Dept. of Chemistry, Johns Hopkins U. -- The need for electron impact cross sections in aeronomy and astrophysics arises from the ubiquitous nature of electron collision processes. In environments as different as the thermospheres of the planets and supernova remnants, excitation by electrons is controlled by the interaction of the ambient electron energy distribution with the available atomic and molecular species. The ambient electron energy distribution is in turn produced by the balance of electron production and loss functions where the production mechanism can be either photoionization or impact of high energy particles accelerated by electromagnetic fields. Understanding of the loss function requires knowledge of electron inelastic cross sections and emission cross sections are necessary to predict the observed radiation. Cross sections can be divided into those which are possible, very difficult, or probably impossible to measure in the laboratory depending on the nature of the species excited Present work will be reviewed and examples of each class will be given to stress the need for cooperative experimental and theoretical work.

*Work supported by NSF Grant ATM-8605992.

P-2

Cross-sections I Wish I Knew in Discharge Light Sources, JOHN F. WAYMOUTH, 16 Bennett Rd, Marblehead, Mass 01945. Highly sophisticated computer models are available for most electric discharge lamps.

In low pressure discharge lamps, such as the Hg-RG fluorescent lamp, and the low-pressure sodium lamp, most of the ionization and much of the excitation of upper energy levels occurs stepwise via resonance or metastable states. There is very little experimental data on the necessary cross-sections. Similarly, in some parameter ranges, associative ionization is significant; only a few of the cross-sections are known. In metal halide high-pressure discharge lamps, diffusion of molecules, radicals and atoms through mercury vapor controls species concentrations in the arc. There is no experimental data on diffusion coefficients. To calculate rate processes for which cross-section data is absent, models use everything from quantum-theoretical calculated values to outright guesses.

P-3

Electron-Molecule Collision Cross Section Needs for Etching Gases*, KURT H. BECKER, City College of New York -- It is the objecuve of the presentation to give an assessment of the electron impact cross section needs for molecules that play an important role in the areas of plasma etching and deposition. Two aspects will be addressed. Firstly, an attempt is made to identify and categorize those target molecules for which cross section data are needed most regularly. Secondly, the current availability of cross sections and the future needs for particular types of cross sections will be discussed in detail for each molecule.

* Work supported by NSF-CBT and PSC-CONY.

P-4

Cross Section Needs for Modeling Etching and Deposition Discharges, L. E. KLINE, Westinghouse STC, Piitsburgh, PA 15235 -- Many gases are used in plasma processes for microcircuit fabrication. Plasmas are used for both etching and thin film deposition. The gases used include halogens, freons, silanes as well as the rare gases and H_2, N_2, NH_3, N_2O and O_2. Cross section data is available for H_2, N_2 and O_2. Recent cross section, swarm and discharge dissociation measurements and theoretical studies have provided cross sections for HCl, Cl_2, CH_4, CF_4, SiH_4, CCl_2F_2, SF_6, C_2H_6, C_2F_6, Si_2H_6 and N_2O. The available data suggest that electron impact neutral dissociation, where the dissociation products are all in their ground electronic state, is a key channel in for chemical activation of N_2, O_2, CH_4, CF_4, SiH_4, SF_6, and N_2O. The neutral dissociation rate is comparable to or larger than the dissociative ionization rate for these gases. Neutral dissociati... is also likely to be important for many of the other feed ga... used in plasma etching and deposition. The limited availabl... data and the data needs for this important process will be reviewed.

P-5

Cross Sections and Moments of Importance A. GARSCADDEN, Wright Research and Development Center, Wright-Patterson AFB, OH--The relevance of, and need for low energy electron collisional cross sections for plasma processing applications are illustrated by their influences on the electron energy distribution function (EEDF) and the subsequence excitation, dissociation and ionization rates. Low energy ion collisions such as dissociative charge transfer are also important in plasma reactors. In many situations there is a need for information on the cross sections of the principal products of dissociation, the volatile products of surface reactions, and of complex molecules used in processing. Adding to the difficulty is the fact that one is really interested in data for excited gases, especially vibrationally excited gases. Self-consistency tests of the data are emphasized, especially when the cross sections are derived from different experiments. In order to maintain contemporary relevance to the technology, the need to measure other non- traditional moments of the distribution function is outlined.

P-6

A Status Report on the Availability and Needs of Electron Impact Cross Sections for Modeling Plasma Deposition *Mark J. Kushner, University of Illinois, Urbana, IL -- Reliable electron impact cross sections for momentum transfer, attachment, electronic and vibrational excitation, dissociation and ionization are prerequisites for developing models of plasma deposition systems. We will briefly review the availability of cross sections for deposition of silicon and carbon films. Gas mixtures containing silane, disilane, methane, and higher hydrocarbons, and typical additives (e.g., H_2, N_2O, O_2, NH_3, PH_3, BH_3) will be discussed. The availability and need for partial cross sections and cross sections for electron-radical processes will also be discussed.

*Work supported by the National Science Foundation.

SESSION QA: SINGLE WAFER PLASMA PROCESSING

Friday morning, 20 October 1989
Rickeys Hyatt, Camino Ballroom C at 8:00 A.M.
J. H. Keller, presiding

QA-1

ECR and Other High Density Plasmas for Single Wafer Plasma Processing, W.M. Holber and J. Forster, IBM T.J. Watson Res. Ctr. and East Fishkill, -- The trend in plasma processing for semiconductor applications has been towards higher plasma density, lower neutral pressure operation This is driven by several different requirements. Single wafer operation requires far greater rates than for batch tools - in order to maintain reasonable throughput for manufacturing. Submicron features require tighter control over etch and deposition profiles. Finally, more delicate and complex structures require that the energy of ion bombardment be minimized. The challenges of higher plasma density, lower neutral pressure, and lower ion energies have been addressed primarily through the use of magnetized plasmas - both in the MHz and low GHz frequency regime. Particular emphasis will be placed in this talk on Electron-Cyclotron-Resonance (ECR) plasmas, operating at 2.45 GHz. Results obtained in a divergent magnetic field ECR system will be reported. It has been found that plasma densities up to 10^{12} cm^{-3} can be achieved with uniformities required for single-wafer processing. Several unique features of such plasmas will be discussed.

QA-2

RF Excited Diffusion Plasmas, R.W. BOSWELL, PRL, RSPhysS, Australian National University - With appropriately designed extended antennas rf power from 2 to 20 MHz can be used to create large volumes of high density plasmas at low pressures ($< 10^{-2}$ Torr). Peak densities of $\sim 10^{14}$ cm^{-3} at a few 10^{-3} Torr argon have been achieved in 5 cm diameter sources With larger sources coupled to a diffusion chamber surrounded by permanent magnets, ion current densities of a few ω A cm^{-2} uniform over a 20 cm substrate have been measured in O_2, SF_6, CHF_3 and $SiCl_4$. Etch rates for Si, SiO_2, GaAs, Al and resist are between 0.5 and 1.0 μm min^{-1} for gas pressures of $\sim 10^{-3}$ Torr and rf powers between 500 and 1000 watts. The substrate bias voltage can be varied independently of the plasma density thereby minimizing ion induced damage. The system can operate without metalic containments The theory and operation of this type of plasma will be reviewed.

QA-3

Low Pressure RIE using an RF Plasma Source with Surface Magnetic Confinement - A. Wendt, M. H. Cho, N. Hershkowitz, and H. Persing, University of Wisconsin, Madison. Reactive ion etching (RIE) of silicon in CF_4-O_2 and SF_6 plasmas using an RF, capacitively coupled, multidipole magnetic confinement plasma system will be reported. Our investigation of RIE at low pressures ($\sim 10^{-4}$Torr) addresses processing concerns as microelectronic devices become smaller, faster, and packed more densely on an IC. Etch rates and trench etch profiles will be presented for a range of processing and plasma conditions (etch chemistry, pressure, flow rate, plasma density, and substrate bias). Etching of Si has been carried out with Al, SiO_2, and photoresist etch masks with feature sizes as small as 0.8μm. Attention will be given to the advantages and limitations of low pressure etching.

*Work supported by NSF

QA-4

Characteristics of Inductively Excited Discharges with a Drift Space , P. Bletzinger and M. E. Dunnigan, Wright Research and Development Center WPAFB.OH For applications in plasma etching and thin film deposition the parallel plate reactor does not offer separate control of plasma density and ion energy. This can be achieved with a microwave exciter (ECR) and an added DC or rf drift field. We have investigated a simpler system using an inductor (3" dia. by 3" length) over a section of a 2" dia. glass tube with electrodes spaced 2" away from the inductor ends. With one tube, permanent magnets in multipole configuration were placed inside the inductor. Using the electrodes with an applied sweep voltage, the collected current peaks at .3 Torr, decreasing slowly at higher pressures but increasing monotonically with power (40mW/cm^3 max). Using time averaged double probes will allow more accurate electron density measurements and permit measurements at higher power We hope to also report on time resolved single probe measurements.

QA-5

RF Induction/Multipole LPSWE System, J. H. Keller IBM - E. Fishkill, Hopewell Jct., NY -- A low pressure single wafer etching system has been designed and tested. The plasma is inductively excited with 13.56 MHz rf power and the wafer is rf biased. This gives independent control of the plasma density and ion energy. The wafer is electrostatically clamped and cooled with helium. The plasma is surrounded in the radial direction by a multipole magnetic field which confines the plasma electrons thus producing a uniform plasma. Ion densities of approximately 5 x 10^{11} /cc and ion currents of 1 amp over a 125 cm wafer have been achieved in both electropositive and electronegative gases, in the 1 to 20 mTorr pressure range [1]. Uniformities of 7% (3 sigma) and etch rates of over 1 micron / min have been achieved for both Si and SiO_2. RF induction is a very simple and efficient means of producing high plasma densities. It is competitive with both Magnetron and ECR type plasmas but does not have the problem of a magnetic field at the wafer. In the rf induction mode (no rf bias power) the floating potential and plasma potential are typically 13 and 30 volts respectfully.

[1] Ajit Paranjpe, to be published.

SESSION QB: COLLISIONS BETWEEN ATOMS, MOLECULES, AND IONS

Friday morning, 20 October 1989
Rickeys Hyatt, Camino Ballroom D at 8:00 A.M.
J. R. Peterson, presiding

QB-1

IR Excitation Cross Sections from Fast O-Atom Collisions,* G.E. CALEDONIA, B.L. UPSCHULTE, R.H. KRECH, and B. CLAFLIN, Physical Sciences Inc., and G. BURGESS, MIT/Lincoln Laboratory -- Experimental measurements of the cross sections for vibrational excitation of molecules by energetic oxygen atoms have been successfully performed A crossed molecular beam apparatus utilizing both a supersonic target molecular beam and a fast O-atom source was developed for these measurements. The fast O-atom source is generated by focusing a high power pulsed CO_2 laser into a nozzle containing expanding molecular oxygen. Inverse Bremsstrahlung absorption of the 10.6 μm radiation produces a laser breakdown of the O_2: dissociation, and ionization occurs very rapidly. The nozzle expansion is tailored to provide sufficient time for ion-electron recombination but insufficient time for atomic recombination. Instantaneous fluxes of 10^{22} atoms/cm^{2}s with velocities variable throughout the 6 to 10 km/s range have been obtained. The target molecular beam was generated from a pulsed free jet expansion. A calibrated radiometer, utilizing an InSb detector and bandpass filters, viewed the collision perpendicular to the intersecting beams. A circular variable filter (CVF) radiometer was used to provide spectral bandshapes. Measurements were performed with CO, CO_2, CH_4, and H_2O target beams in the single collision regime. Cross section and reaction path observations are discussed.

*Th s work was sponsored by the Department of the Army under contract number F19628-85-C-002 The views expressed are those of the author and do not reflect the official policy or position of the U.S. Government.

QB-2

The Dependence of Spacecraft Glow On the Spacecraft Velocity, R.E. MEYEROTT AND G. R. SWENSON, Lockheed Palo Alto Research Laboratory -- The extent to which spacecraft glow depends on the spacecraft velocity, and hence the kinetic energy of the ramming participants to the spacecraft surface recombination reactions, has a large impact on the difficulty in conducting laboratory simulations. If the dependence on the kinetic energy is minimal, as suggested by Kofsky and Barrett, then much of the previous work on recombination catalyzed by laboratory substrates can be applied with any little modification. However, if the kinetic energy is an important part of the glow producing mechanism, laboratory reactors will require intense sources of atoms and molecules with kinetic energies of up to ~10eV. Such sources are difficult to constrict.

The pseudo-continua red spacecraft glow in the 0.4 to 0.8μm is believed by many investigators to be due to the surface recombinations of O and NO atoms to form excited NO_2. However, this glow has a spectral distribution that does not completely agree with that produced by three body gasseous recombination or by low energy surface recombination. A model for the N_2 Lyman-Birgel-Hopfield spacecraft glow will be presented in which the upper state of the LBH bands is populated by radiation transition from higher levels. The higher levels are populated as a consequence of the high kinetic energy of incident N atoms The model predicts additional radiations that are associated with the LBH glow. The application of this model to the red glow will be discussed.

QB-3

Ion and Fast Neutral Excitation in N_2 at Very High E/n,* V.T. GYLYS** and A.V. PHELPS, JILA, University of Colorado and NIST. -- Measurements are made of the pressure dependence of the time integrated emission of the 1st and 2nd positive bands of N_2 at 670 and 337 nm and the 820 nm line of NI following a photon initiated, pulsed discharge through N_2 at E/n = 52 kTd. The pressures are 10 to 35 mTorr, i.e., well below the 60 mTorr at breakdown. The photocurrent pulse is $\approx$ 10 mA for $\approx$ 10 ns. The emission is normalized to the time integrated 391 nm emission of the N_2 1st negative band which is excited only by electrons.[1] The 337 to 391 nm emission ratio is proportional to the N_2 density at low pressures as expected for 337 nm excitation in N_2^+ collisions with N_2, but increases more rapidly at higher pressures as is consistent with efficient excitation of

N_2 by fast N_2. The relatively rapid increase with pressure of the ratios of 670 nm and 820 nm emission to 391 nm emission are not yet understood.

* Supported in part by Lawrence Livermore Laboratories.
** Now at Rockwell International/Rocketdyne Division, Canoga Park, CA.
[1] V.T. Gylys, B.M. Jelenković and A.V. Phelps, J. Appl. Phys. 65, 3369 (1989).

QB-4

Rotational excitation of N_2^+ in N_2 at E/n ≈ 100 Td*, JACEK BORYSOW§ and A.V. PHELPS, JILA, University of Colorado and NIST. -- The rotational temperature of N_2^+ ions in N_2 drifting in an electric field is measured using the absorption of $A^2\Pi(v = 2) \leftarrow X^2\Sigma(v = 0)$ lines near 780 nm. The ions are in a pulsed, positive column discharge with 1.5 Amp cm^{-2} current, 10 μs duration, and 0.3 torr pressure. A single-mode, tunable diode laser source propagates parallel to the electric field with an absorption S/N > 10^5:1 for 1 μs resolution. Densities of rotational levels with quantum numbers up to 20 obey Boltzmann distributions with temperatures of 360 ± 15 K during the discharge and 305 ± 15 K in the afterglow The change in temperature determined from the higher levels is 57 ± 2 K. The E/n from Doppler profiles[1] and N_2^+ drift velocities is = 105 ± 5 Td. The ion drift energy corresponds to a temperature of 1200 ± 80 K during the discharge. The results yield the ratio of rotational excitation to charge transfer collisions.

*Supported in part by the Wright Research and Development Center.
§Now at Michigan Technological University, Houghton, MI.
[1] J. Borysow and A.V. Phelps, Bull. Am. Phys. Soc. 34, 293 (1989).

QB-5

Energy Transfer in the $B^2\Pi$ State of NS, INGRID J. WYSONG, JAY B. JEFFRIES, and DAVID R. CROSLEY, SRI International--Quenching and vibrational energy transfer in the $B^2\Pi$ state of the NS free radical have been studied using temporally and spectrally resolved laser induced fluorescence in a low-pressure discharge flow reactor. The collision partners were He, Ar, H_2, N_2, O_2, SF_6, CO_2, and N_2O. Total removal cross sections show an oscillatory behavior with v' in the range of unperturbed levels, v'=4-7, for all colliders studied save O_2 where a nearly monotonic increase is seen. Significant vibrational transfer occurs for H_2 and the polyatomics; the rates vary little with v'. Δv=2 transfer occurs with the polyatomic colliders for v'=5. Time-resolved fluorescence traces from the perturbed v'=3 and 8 levels differ from the unperturbed levels and from each other. v'=3 is perturbed by quartet states and shows "gateway" transfer behavior, whereas v'=8 is perturbed by a doublet and shows efficient interelectronic transfer for all rotational levels.

Supported by the Air Force Office of Scientific Research.

QB-6

Temperature Dependent Quenching of NO $A^2\Sigma^+$ and $B^2\Pi$ by H_2O, GEORGE A. RAICHE, GREGORY P. SMITH, and DAVID R. CROSLEY, SRI International -- Quenching cross sections for electronically excited nitric oxide have been obtained from measurements of the pressure dependence of time decays of laser-induced fluorescence. The temperature range 300-750K was covered using a heated flowing gas cell, gas temperatures were measured using rotational excitation spectra. Results in $Å^2$ are given in the table. Although the sizes of the cross sections suggest the influence of attractive forces, only for H_2O collider is there a decrease with increasing temperature (i.e., collision velocity).

Collider	300K: NO	O_2	H_2O	750K: H_2O
$\sigma_Q(A^2\Sigma^+)$	37	21	103	34
$\sigma_Q(B^2\Pi)$	46	3	17	5

Supported by the U.S. Army Research Office.

SESSION RA: RF DISCHARGES: MODELS AND EXPERIMENTS

Friday morning, 20 October 1989
Rickeys Hyatt, Camino Ballroom C at 10:00 A.M.
M. A. Liebermann, presiding

RA-1

An Experimental System for RF Discharge Physics Research, V.A. GODYAK, R. B. PIEJAK, B. M. ALEXANDROVICH, GTE Laboratories Inc., Waltham, MA -- An experimental system has been designed and built to comprehensively study the electrodynamic and plasma characteristics of capacitively coupled electroded RF discharges at low gas pressures. The system consists of a glass discharge cell, a vacuum station, a controllable gas flow system for precise gas flow, a tuneable matcher coupler with voltage, current and power sensors, a two channel precision RF power meter, a wideband RF source and RF amplifier and a data acquisition, processing and display system based on a multi-channel waveform analyzer connected to a PC. A previously developed plasma probe diagnostic station has been modified for plasma density and electron energy distribution measurements in this system. The following range of RF discharge parameters can be studied with this system: gas pressure .001-10 Torr, RF power, .01-100 watts, RF frequency .5-150 MHz.

RA-2

Frequency effects in a RF Discharge* M. SURENDRA and D. B. GRAVES, University of California, Berkeley - A study of frequency effects in a RF discharge using a self-consistent particle-in-cell simulation is presented. Electron-neutral interactions are included through realistic differential cross sections for both elastic and ionizing collisions. The importance of secondary electron emission at the electrode in sustaining low frequency discharges (in particular, below the ion plasma frequency) is discussed. At higher frequencies, where the RF sheath velocities can be appreciable, electron heating (stochastic heating or wave riding) by the moving sheaths plays an important role. The different heating mechanisms at the high and low frequencies influence the time dependent behavior of the electron energy distributions. The effects of frequency and pressure on spatial and temporal profilesof the ionization rate are also presented.

*Work supported in part by San Diego Supercomputer Center

RA-3

DC Self Bias Formation in Symmetric Parallel-Plate RF Glow Discharges, J.W. BUTTERBAUGH* and H.H. SAWIN, Massachusetts Institute of Technology - The formation of DC self bias in well-confined, symmetric, parallel-plate RF (13.56 MHz) glow discharges has been investigated. At narrow spacings of 3-4 mm and pressures of 2-6 torr, stable discharge operation in CF_4 is obtained with either a positive or negative self bias on the capacitively coupled powered electrode. It is believed that the presence of negative ions are important in the formation of this electrical asymmetry since the same effect can be observed with a gas feed of 96% Ar and 4% SF_6 The energy and flux of positive ions striking the grounded electrode has been measured by orifice sampling and retarding grid analysis and correlates with the magnitude and sign of the self bias of the powered electrode. Spatially resolved plasma induced emission has also been measured from a small amount of Ar added to the CF_4 discharge indicating the most intense glow nearest the electrode with the higher DC potential.

*IBM Burlington, Resident Study Program

RA-4

The Spatial and Temporal Variation of Plasma Parameters in an rf Discharge. C.A. Anderson, University of Ulster, Coleraine, N. Ireland and W.G. Graham, Queen's University, Belfast, N. Ireland. - Our time resolved Langmuir probe technique has been extended to higher frequencies and used to study the spatial

variation of plasma parameters in a rf discharge operating at frequencies of up to 1 MHz. This time resolved technique can be used to investigate the fundamental processes driving the parallel plate discharge. The dependence of the plasma parameters on the gas used, gas pressure, rf frequency and method of driving the electrodes has been studied. Measurements of the electron energy distribution function shows the electron distribution to be non Maxwellian and time dependent. It is found that time averaged measurements tend to overestimate all the plasma parameters particularly the electron temperature and plasma potential when compared with measurements made using the time resolved technique.

[1]C.A. Anderson, W.G. Graham, and M.B. Hopkins. Appl. Phys. Lett 52, 783 (1988).

RA-5

Ion Bombardment Angle and Energy in Argon rf Discharges, J. LIU, G.L HUPPERT, and H.H SAWIN, M.I.T. -- The measured ion angle distribution shows that a significant portion of bombarding ions impinge at angles greater than 10° from the surface normal, even at pressures below 20 mtorr. The ions with large incident angles have lower energies than those incident perpendicular to the surface. Monte Carlo simulations of the sheath kinetics predict the trends shown in the experimental data for ion energy and angle distributions. Fine structures in the ion energy distribution were observed below 50 mtorr and are attributed to charge-exchange collisions in the sheath. The average energy can be correlated directly to the applied voltage across the electrodes for measured plasma pressures up to 500 mtorr.

RA-6

Particle Modeling of an ECR Reactor,* R. K. PORTEOUS and D. B. GRAVES, Chemical Engineering, U. of California, Berkeley -- The high frequencies and plasma densities which characterize an ECR reactor challenge conventional particle modeling techniques. The electrons must be followed on a timescale of the plasma and cyclotron periods ($< 10^{-9}$s) while the plasma as a whole comes to equilibrium in 10^{-4}s (around the mean ion residence time). The particle flux to the walls depends on sheaths 0.1 mm thick which in turn depend on the ion diffusion in the whole chamber.

A 2D3V model of a cylindrical ECR reactor has been developed. Electric fields are calculated self-consistently with the motion of ions and electrons, while localized ECR heating is introduced heuristically. Electrons are strongly confined by a uniform axial magnetic field whereas ions are only weakly magnetized. Both electrons and ions may have elastic and inelastic collisions with neutrals. Innovative techniques to handle the disparate time and length scales are introduced. Results showing the effect of the microwaves on the electron velocity distribution will be presented.

*Work supported in part by IBM.

RA-7

Two-Dimensional Simulations of RF Glow Discharges,* J. H. Tsai and C. Wu, Electrical Engineering Department, Auburn University.--Self-consistent two-dimensional numerical simulations of rf glow discharges have been carried out in nonattaching (N_2) and attaching (SF_6) gases using a single moment fluid model. The More Accurate Flux Corrected Transport[1] and Reconstructed Fast Fourier Transform techniques[2] have been used to solve the fluid and Poisson's equations, respectively, in the presence of large gradients and dynamic range. The Glow discharge in SF_6 has been observed to be considerably different from those in N_2. The results obtained further illustrate the radial-axial flow dynamics of charged particles.

*Work supported by CRAY Research, Inc.

[1]E. E. Kunhardt and C. Wu, J. Comput. Phys. 68, 127 (1987).

[2]C. Wu and E. E. Kunhardt, J. Comput. Phys. 83, (1989) (in press).

SESSION RB: OPTICAL DIAGNOSTICS

Friday morning, 20 October 1989
Rickeys Hyatt, Camino Ballroom D at 10:00 A.M.
J. T. Dakin, presiding

RB-1

UV Emission from a Discharge in N_2O and Electron Detachment T H TEICH, Swiss Federal Institute of Technology, Zürich. - Determination of discharge parameters/-swarm coefficients for gases in which unstable negative ions are formed may present considerable difficulties, particularly when detachment rate coefficients are high as, for instance, in N_2O where the secondary ion NO^- is the principal electron donor. Some access to rate coefficients may be gained from the measurement of local light emission from suitable excited states[1]. For N_2O, such states were assessed by means of spectrally resolved synchronized single photon counting applied to emission from a Trichel pulse corona discharge. The dominant emission is found to originate from $NO(B^2\Pi, v'=0)$ and is indirectly excited, probably via formation of $O(^1S)$; the relatively slow decay corresponds to a quenching density of the order of $3 \cdot 10^{17}$ cm^{-3} for a B state natural lifetime of 2μs. Besides emission NO ($B \rightarrow X$), there are minor shares of emission from $N_2O^+(^2\Sigma)$ and $N_2(C^3\Pi)$; the latter emission $N_2(C \rightarrow B)$ occurs promptly and with a fast decay and should thus give access to local electron density data useful for discharge parameter determination.

1 M.J. Brennan and T.H. Teich, Proc. 9th Int. Conf. Gas Discharges and Their Applications, Benetton Editore, Padova 1988, pp. 343-346.

RB-2

Gas Temperatures from Vibrational Temperatures, M. PASSOW, M. L. BRAKE, and P. LOPEZ, Dept. of Nuclear Eng., U. of Michigan -- Gas temperatures (Tg) of low pressure (0.5 - 100 Torr) microwave (2.45 GHz) discharges in nitrogen can be estimated from measurements of the vibrational temperature (Tv). The dependence of Tv on Tg is calculated by modeling the excitation and de-excitation mechanisms of the vibrational levels. Included in the model are electron excitation, V-V and V-T transfer. The model shows that at low electron densities (10^{10}-10^{13} #/cc) and low Tv's (<4000K) that Tv and Tg are equal. At higher temperatures (≳8000K), Tv is equal to the electron temperature. The Tg's predicted by this model (1000K-2000K) for Tv's measured in a low pressure microwave discharge (5000K - 15,000K) match the measured rotational temperatures very well. Thus, estimates of Tg can be made from Tv and the relationship between the two, without having to go to the extra work to measure the rotational temperature.

RB-3

Temperature Profiles in N_2 and N_2-Ar DC Discharges Using Coherent Anti-Stokes Raman Spectroscopy (CARS). P. P. YANEY and B. L. Epling,* U. of Dayton**; S. W. KIZIRNIS, USAF Aero Propulsion Lab. -- Spatially resolved CARS measurements provided non-equilibrium rotational and vibrational temperature profiles in glow discharges stabilized by glass electrode caps which constrained the discharge to about 10 mm diameter. Both axial and radial profiles were determined. The doorknob-shaped Ni-Fe electrodes were spaced 14 mm. Nominal conditions were 40 Torr total pressure, 0.08 A/cm² and E/N= 60 Td. The influence of gas flow rate and changes in the Ar-to-N_2 ratio were studied. The temperatures were obtained from computer fits to spectra recorded with a narrow-band, scanning, folded BOXCARS system. The length of the control volume (dia. ≈ 20 μm) was measured to be 1 mm by scanning a 6 mm by 0.38 mm Ar jet through the

beam crossing in air. A computer model of the laser beam geometry agreed with these results.
* In partial fulfillment of the requirements for the M.S. degree in Electro-Optics.
** Supported by USAF Contract F33615-86-C-2722.

RB-4

Time Resolved Two-Dimensional Emission Spectroscopy of a LF Asymmetric H_2 Discharge -- B. N. GANGULY, J. R. SHOEMAKER, and A. GARSCADDEN, Aero Propulsion and Power Laboratory, WPAFB, OH. -- Two dimensional emission intensities of $H\alpha$ and the 540-550nm H_2 molecular band have been measured in a 0.75 Torr H_2 discharge with 4:1 electrode area ratio, driven at 50 kHz, using a time-gated (400nsec) intensified CCD imaging system. The 18mm diameter photocathode (570 X 380 pixels) allows temporal and spatial resolutions simultaneously of the entire powered discharge volume, including behind the electrodes. Nearly symmetric sheaths and negative glows about the front and back surfaces of either powered electrode are observed for abnormal glow discharge conditions. The emission profiles show that the discharge is focussed to the anode, especially when the large electrode is cathode and that there is also simultaneous excitation on both sides of the anode. Decay of the cathodic cycle shows bright plasma regions "trapped" behind the cathode. The presence of strong atomic and molecular excitation in the sheath regions indicates a highly collisional sheath for electrons and ions.

RB-5

Emission spectra of laser produced plasmas used in producing high T_c thin films. H.F. Sakeek, W.G. Graham and T. Morrow, Physics Department, Queen's University, Belfast, Northern Ireland. The emission from plasmas created during KrF laser ablation of high temperature superconducting material (Y $Ba_2Cu_3O_7$) has been studied. The aim is to obtain a fundamental understanding of the laser ablation process and to correlate the elemental abundance in the plasma with the stoichiometry of the thin films produced. Currently the spatial variation of the emission lines and its dependence on laser power is being investigated. The effect of operating in an oxygen environment will be studied.

RB-6

Imaging of Laser-Produced Plasmas Using Planar Laser-Induced Fluorescence, P. H. PAUL, M. A. CAPPELLI and R. K. HANSON, Stanford University -- Planar laser-induced fluorescence (PLIF) provides a powerful, non-invasive technique for probing complex, high-speed flowfields with excellent spatial and temporal resolution. We report recent PLIF imaging of Ba and Ba^+ in a laser-produced plasma, obtained by focusing a XeCl laser onto a barium target in vacuo. PLIF imaging is performed using an intensified CCD array and an excimer-pumped dye laser We discuss the application of laser ablated films to the formation of dense focused neutral atomic beams.

*Work supported in part by AFOSR, Aerospace sciences directorate

RB-7

Opiogalvanic Line Profile of Cu Autoionization Levels, R. SHUKER and M. HAKHAM-ITZHAQ, Physics Dept., Ben-Gurion University, and A. BEN-AMAR, NRCN, Beer-Sheva, Israel -- Autoionization levels are generally very broad, long lived and have characteristic asymmetric line profile, the well known Fano-shape.(1) We present measurements of the lineshape of autoionization levels of Cu atom using pulsed optogalvanic technique(2), whereby a discharge response to changes in the level population and electron distributions induced by laser absorption is utilized as spectroscopic tool. We use a 15 nsec, 7 GHz linewidth pulsed dye laser to scan the transition profile of two autoionization transitions of copper. A one cm^{-1} tuning of the dye laser is used across the broad transition profiles The results exhibit the characteristic Fano-shape for these transitions This demonstrates the usefulness of this technique in the study of lineshapes and line-profiles.

(1) U. Fano and J.W. Cooper. Phys. Rev 136A, 1364 (1965)
(2) A. Ben-Amar et al., J. Appl Phys Rev. 54, 1473 (1983)

AUTHOR INDEX

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CALENDAR OF MEETINGS

September 1990

General Meetings

Place	Meeting Dates	Deadline Dates
San Antonio, TX	21–24 January 1991	1 October 1990
Cincinnati, OH	18–22 March 1991	30 November 1990
Washington, D.C.	22–25 April 1991	11 January 1991
Indianapolis, IN	16–20 March 1992	
Washington, D.C.	20–23 April 1992	

Separate Divisional Meetings

Place	Division	Meeting Dates	Deadline Dates
Urbana-Champaign, IL	Nuclear Physics	25–27 October 1990	Past
Cincinnati, OH	Plasma Physics	12–16 November 1990	Past
Ithaca, NY	Fluid Dynamics Physics	18–20 November 1990	Past
Cincinnati, OH	High Polymer Physics	18–22 March 1991	16 November 1990
East Lansing, MI	Nuclear Physics	24–26 October 1991	
Tampa, FL	Plasma Physics	4–8 November 1991	

Sectional Meetings

Place	Section	Meeting Dates	Deadline Dates
Poughkeepsie, NY	New York	19–20 October 1990	
New Haven, CT	New England	19–20 October 1990	5 October 1990
Bowling Green, OH	Ohio	2–3 November 1990	19 October 1990
Texas City, TX	Texas	8–10 November 1990	
Atlanta, GA	Southeastern	15–17 November 1990	Past

Topical Conferences

Place	Conference Name	Meeting Dates	Deadline Dates
Minneapolis, MN	6th Interdisciplinary Laser Science Conf.	16–19 September 1990	Past
Asilomar, CA	Interdisciplinary Conf. on Electrified Interfaces	16–21 September 1990	
Pacific Grove, CA	7th Intl. Symp. on Capture Gamma-Ray Spectroscopy & Related Topics	14–19 October 1990	
Urbana-Champaign, IL	43rd Gaseous Electronics Conference	16–19 October 1990	Past
Aachen, Federal Republic of Germany	SPIE Intl. Conf. on Physical Concepts of Materials for Novel Optoelec. Device Appl.	27 October–2 November 1990	Past
San Diego, CA	35th Annual Conf. on Magnetism and Magnetic Materials	29 October–1 November 1990	Past
Denton, TX	11th Intl. Conf. on the Application of Accelerators in Research & Industry	5–8 November 1990	Past
Denver, CO	IEEE Conf. on Neural Information Processing Systems— Natural and Synthetic	26–29 November 1990	Past
Monterey, CA	Intl. Symp. on Heavy Ion Inertial Fusion	3–6 December 1990	Past
Brighton, UK	Joint Mtg. of the 15th Texas Symp. on Relativistic Astrophysics and the 4th ESO-CERN Symp.	16–21 December 1990	
Washington, DC	Washington Materials Forum: Superconductors & Semiconductors	28 February–1 March 1991	10 December 1990
San Francisco, CA	1991 Particle Accelerator Conf.	6–9 May 1991	3 December 1990
San Jose, CA	1991 Conf. on Physics Computing	10–14 June 1991	
Williamsburg, VA	7th Top. Conf. on Shock Compression of Cond. Matter	17–20 June 1991	
Annapolis, MD	14th Conf. on Numerical Simulation of Plasmas	4–6 September 1991	
Munich, Federal Republic of Germany	8th Symp. on Turbulent Shear Flows	9–11 September 1991	15 November 1990
Darmstadt, Federal Republic of Germany	1991 Intl. Conf. on Ion Sources	30 September–4 October 1991	
Budapest, Hungary	4th European Conf. on Applications of Surfaces and Interface Analysis	14–18 October 1991	