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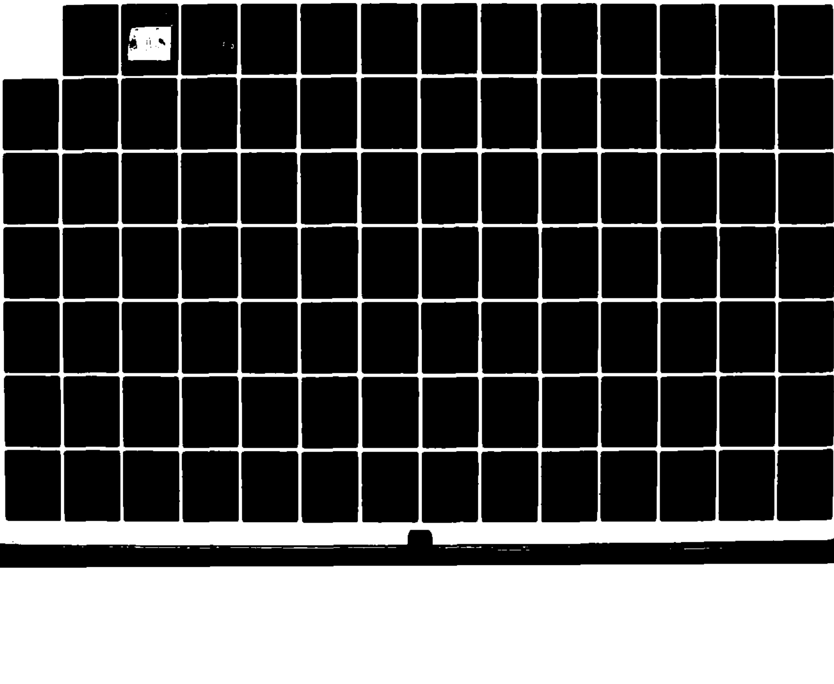

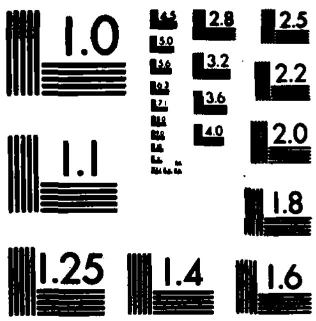

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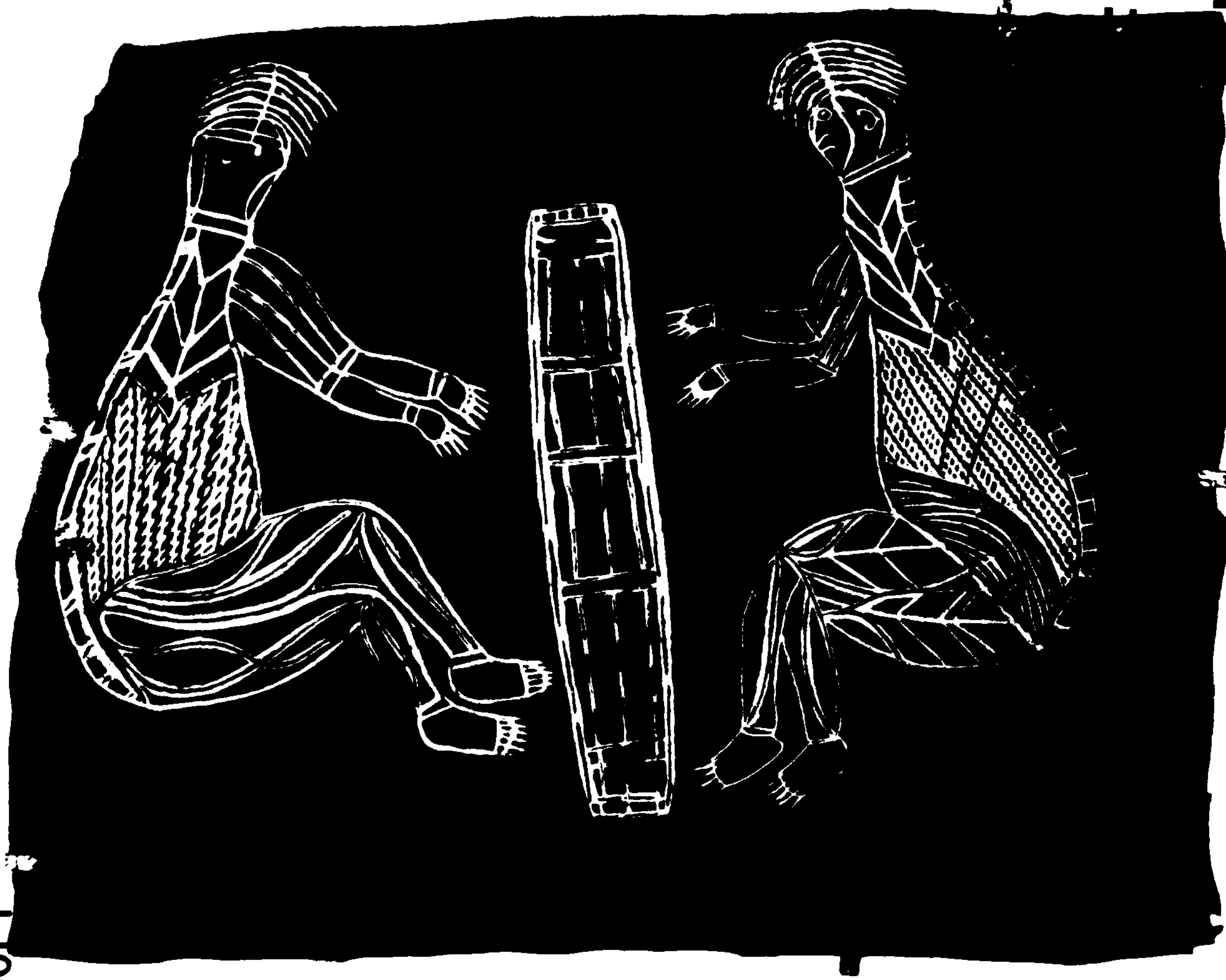
JANUARY TO MARCH 1983 VOL. 8, NO. 1

SCIENTIFIC BULLETIN

DEPARTMENT OF THE NAVY OFFICE OF NAVAL RESEARCH FAR EAST



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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ONR FE Vol 8, No 1	2. GOVT ACCESSION NO. AD-A129602	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ONR FAR EAST SCIENTIFIC BULLETIN		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Sachio Yamamoto, Director Mary Lou Moore, Assistant Editor		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Naval Research Liaison Office, Far East APO San Francisco 96503		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE January-March 1983 13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Composite materials	Special melting
Fiber systems	Metallurgical coatings
Ceramics reinforced systems	Sputtering
ICCM-IV	Vacuum evaporation
Vacuum metallurgy	Thermal evaporation

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

This is a quarterly publication presenting articles covering recent developments in East Asian (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Far East,

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19. Key Words (cont.)

People's Republic of China
Quantum Electronics Application Society (QUEAS)
Lasers
Quantum Electronics
Beijing
CSIRO
Materials research
Australia
Nuclear waste disposal
SYNROC
Supersonic nozzle beams
Laser probing techniques
Multiphotonionization (MPI)
Molecular beams
Spectroscopy
III-V compounds
Devices
MIS
Japan
Nuclear physics
Nuclear spectroscopy
Japanese atomic energy research
Yamada Science Foundation
Graphite materials
Carbon fibers
Carbonaceous mesophase
Biocarbons
Needle coke

20. Abstract (cont.)

with certain reports also being contributed by visiting stateside scientists. Occasionally a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.

CONTRIBUTORS

Milton Birnbaum is a physicist and senior scientist in the Electronics Research Laboratory of the Aerospace Corporation in Los Angeles, California. Dr. Birnbaum has served as a consultant to the Brookhaven National Laboratory, Republic Aviation Corporation, and the Local Electronics Corporation, respectively. Dr. Birnbaum's research interests include accelerator design, neutron binding energies, electron paramagnetic resonance, laser physics, optics, and semiconductors.

Jim E. Butler is a research chemist at the Naval Research Laboratory at Washington, D.C. He is currently a visiting scientist at the Institute for Molecular Science located at Okazaki, Japan. Dr. Butler's research interests include photochemistry, chemical kinetics, and energy transfer and chemiluminescence.

Michael J. Koczak is Professor of Materials Engineering at Drexel University, Philadelphia, Pennsylvania. Dr. Koczak is currently on the scientific staff of ONR Far East. His specialties include physical and powder metallurgy, composite materials and ceramics.

Derek L. Lile was born in Cardiff, South Wales, on 24 June 1943. He obtained a bachelor's degree in electrical engineering and a master's degree in solid state electronics from the University of Wales in 1964 and 1965, respectively. Following this he spent three years at Imperial College (University of London) leading to the award of the Diploma of Imperial College and a Ph.D. degree in materials science. Since emigrating to the United States in 1968, Dr. Lile has worked for the Navy Department as a research physicist at their Corona and San Diego (Naval Ocean Systems Center) laboratories and currently holds the position of Supervisor as Branch Head overseeing the work of the Device Physics Branch. His professional expertise encompasses areas of semiconductor and device physics, particularly as these relate to the transport and surface properties of materials.

Seikoh Sakiyama, Science Advisor of ONR Far East, has had considerable industrial experience in laboratory chemistry, electronic instrumentation, and quality control methodology. His interests include computer science, linguistics, and energy technology.

Gertrude Scharff-Goldhaber is a physicist at Brookhaven National Laboratory in Upton, New York. Dr. Scharff-Goldhaber has served as a consultant at the Argonne National Laboratory and the Los Alamos Scientific Laboratory, respectively. Her research interests include ferromagnetism, photoneutrons, spontaneous fission neutrons, variable moment of inertia law and parity violation in electromagnetic transitions. Dr. Scharff-Goldhaber is a fellow of the American Physical Society.

Jim Zimmer is Principal Scientist in Materials Science with the Aerotherm Division of Acurex Corporation, Mountain View, California. He conducts government-funded research and development on the analysis and characterization of graphitic composite materials for use in hyperthermal environments. Dr. Zimmer's special interest is in the study of the disclinations present in the microstructure of these graphitic materials and their relationship to the physical properties of these materials. This research is being funded by the Office of Naval Research.

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Cover: A bark painting by an Aboriginal Australian artist. Bark painting is the practice of decorating nonwoven cloth with figurative and abstract designs by scratching or painting. In Australia, styles of bark painting vary according to location. This painting is several hundred years old. Courtesy of the Information Attache, the Australian Embassy, Tokyo, Japan.

MATERIALS ENGINEERING RESEARCH IN AUSTRALIA

Michael J. Koczak

INTRODUCTION

The materials and metallurgy research efforts in Australia are centered primarily at government research institutes and universities. Australia is endowed with abundant natural resources, i.e., coal, iron ore, bauxite, uranium. As a result research efforts at large industrial companies, e.g., Broken Hill Proprietary (BHP), emphasize mineral processing and beneficiation. The following review primarily examines activities apart from industrial ore processing being conducted at government research institutes and universities. The research laboratories, i.e., governmental, university, and industrial are listed below:

Government

- CSIRO - Advanced Materials Laboratory
- CSIRO - Division of Manufacturing Technology
- Australian Atomic Energy Commission (AAEC)
- Aeronautical Research Laboratories
- Materials Research Laboratories

University

- Melbourne University
- Monash University
- University of New South Wales
- Wollongong University

Industry

- John Lysaght Research and Technology Center

Information concerning metallurgy/materials activities can be obtained from the professional material/metallurgy societies in Australia listed below:

Australasian Institute of Metals (AIM)
191 Royal Parade
Parkeville, Victoria 3052

Australasian Institute of Mining and Metallurgy
P. O. Box 310
Carlton South, Victoria 3053

Institution of Metallurgist-Australian Region
Dr. Chris Weaver, Secretary
Materials Research Laboratory
P. O. Box 50
Ascot Vale, Victoria 3032

In a future *Bulletin* article, the chemistry research activities shall be reviewed.

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION (CSIRO)

CSIRO is chartered by the Commonwealth of Australia to provide the following functions:

- scientific research and application of results,
- overseas scientific liaison,
- research training and funding,
- research association support,
- maintenance of instrument standards, and
- publication and dissemination of scientific information.

The organization of CSIRO is shown in Figure 1 detailing the five major institutes and the associated divisions. The bulk of funding, e.g., 90 percent, is provided by the Australian government, with the balance being provided by local government, trusts, and industries, i.e., the Rural Industry Research Trust Funds. The expenditure of funds, e.g., A$210 in 1980/81, is detailed in Table I, with approximately 34% to rural industries; 16% in mineral, energy, and water resources; 25% in manufacturing industry and technology and the remaining 25% in community interest activities. The goal and objectives of the individual divisions and the contacts are provided courtesy of CSIRO in Table II and information concerning the individual division activities, can be obtained by writing directly to the Institutes listed.

RESEARCH IN MATERIALS ENGINEERING - ADVANCED MATERIALS LABORATORY (CSIRO)

The materials research activity at CSIRO is conducted at three locations:

- Advanced Materials Laboratory
  CSIRO Division of Materials Science
  506 Lorimer Street
  Fishermen's Bend, Victoria 3027, Australia

- Catalysis and Surface Science Laboratory
  CSIRO Division of Materials Science
  University of Melbourne
  Parkville, Victoria 3052, Australia, and

- Division of Manufacturing Technology
  Melbourne Laboratory
  P. O. Box 71
  Fitzroy, Victoria 3065, Australia.

Other institutes, i.e., the Institute of Energy and Earth Resources and the Institute of Industrial Technology, have studies in minerology, textile physics respectively, and information can be obtained by contacting the institutes directly.

The Advanced Materials Laboratory, formerly the "Engineering Ceramics and Refractories Laboratory," major theme over several years has been the development of zirconia. The laboratory has joined with Nilsen Sintered Products, Pty., Ltd. in a joint research and development program in the development of stabilized zirconia. As a result, Nilsen is currently marketing partially stabilized zirconia powders products for application which include: hot and cold extrusion dies, diesel engine, valve guides die inserts. Zircon containing 10% zirconia has been developed by passing zircon through a plasma furnace and produces a powder ~15 μm in diameter. The material, designated as D210 in a consolidated form, has similar thermal shock resistance to commercial clay bonded zirconia, but has double the fracture toughness, eight times the strength with a lower level of porosity.

In the industrial development and study of partially stabilized zirconia, CSIRO has a long history,[1-7] with patents awarded in 1974, papers on transformation toughened ZrO_2 in 1975 and production with Nielsen in 1980. Dr. Michael Murray of CSIRO reviewed the efforts in the ZrO_2 area with specific improvements being sought in the areas of thermal shock resistance, strength, and fracture toughness. Studies are involved with oxides of lower valance, e.g., Ca, Mg, or Y, such that the cubic phase is formed and stabilized at the sintering temperatures, e.g., 1500° C-1700° C. The variation of heat treatment temperatures provides for an alteration in properties. High temperature heat treatments (T > 700° C), achieve a zirconia structure with higher hardness which is useful for applications such as tappets, valve guides. At lower heat treatment temperatures (T < 400° C), good thermal shock properties are developed and are useful for extrusion dies. The intermediate temperature heat treatments produce ceramic structures which have a combination of low wear coupled with good thermal shock resistance. These zirconia materials are being considered as prototypes for adiabatic diesel engines, e.g., cylinder liners, piston caps.

In addition to zirconia efforts, studies on solid state electrolytes,[8-10] which can be used to monitor oxygen concentrations in hot gases and molten metals above 700°C. Low temperature zirconia oxygen sensors are being developed with an extension of the temperature range down to 300°C. The modification to extend the low temperature range include firing Pt electrodes at low temperatures, alteration of electrode geometry from a pellet to a disc, and utilizing scandia instead of yttria to improve the ionic conductivity. Problems associated with oxygen sensors included leaks associated with thermal cycling and variations in thermal coefficients of expansion between the alumina and sensor components as well as low temperature performance. In addition, zircon based refractories as well as other basic refractories are being examined to include silicon carbide.

Crystallographic studies,[11-14] are being undertaken involving fluorite structures which contain long range ordered superstructures. Compounds which have been determined include $Ca_2Hf_7O_{16}$, $CaHf_4O_9$ as well as pyrochlores ($A_2B_2O_7$), zirconolite $Ca_2ZiTi_2O_7$ and calzirite $CaZi_5Ti_2O_{16}$. In addition, studies on tungstates, $Ln_{10}W_2O_{21}$ and $Ln_{14}W_4O_{33}$ is being jointly investigated with D. J. M. Bevan at Flinders University. The zirconolite structure, $CaZiTi_2O_7$ has been proposed as a constituent material of SYNROC, in order to immobilize radioactive wastes in solid solution. The minerals involved in the SYNROC scheme which include hollandite, perovskite, and zirconolite is being designed to accept various radioactive cation wastes based on the variety of cation sites available in the structure. A listing of selected publications on zirconia,[1-7] oxygen probes,[8-10] and crystal chemistry of pyrochlore, fluorite related structures [7, 11-14] is provided.

For further information contact:

Dr. Michael J. Murray
CSIRO Advanced materials Laboratory
506 Lorimer Street
Fishermen's Bend, Victoria 3207, Australia

RESEARCH IN MATERIAL ENGINEERING - DIVISION OF MANUFACTURING TECHNOLOGY (CSIRO)

In an effort to maintain and promote the manufacturing industry in Australia, the Division of Manufacturing Technology of CSIRO was established. The aim of the program is to develop new and improved methods for the production of high precision engineering components. The division was created in April 1980 with the establishment of two laboratories in Melbourne and Adelaide with a total staff of ninety people. A problem associated with government research laboratories concerns the perception that it concentrates excessive effort on basic research and little effort is devoted to innovative development programs. In order to alleviate these concerns, the Division of Manufacturing Technology is attempting to strike a symbiotic balance and assist the area of manufacturing technology.

In Australia, 90 percent of the manufacturing companies employ fewer than one hundred people, consequently, CSIRO is attempting to assist small manufacturers in order to produce quality goods economically coupled with energy and weight savings. The current effort has focused on metallurgical manufacturing processes to include die casting of nonferrous materials, casting of ferrous materials, machining, welding and integrated manufacturing. The methods adopted to interface with manufacturing organizations include:

- discussions with companies in a common technology area,
- establishment of research collaborative agreements,
- licensing of patents or "know-how" for development and marketing,
- *ad hoc* consultation and contracting research.

The studies at the Melbourne Division of Manufacturing Technology involve both short-term efforts in manufacturing processes coupled with longer-term developmental work in robotics.

The studies by T.H. Siauw in pressure die castings involve computer-aided thermal design analysis which combine flow, geometric and thermal analysis steps in order to predict die geometry and gating based on the heat contents, e.g., liquid, solid and latent heat of fusion of the die casting alloys.[1] Additional studies by A. J. Davis involve design of runners and proportioning of gates[2] as well as studies on cost estimating in foundaries by T. H. Siauw.[3]

The study of integrated engineering manufacture involves several areas to include: development and application of flexible manufacturing systems, application and interaction of robots with other manufacturing devices, development of VLSI circuits for vision interpretation and control and computer-aided design. The robotics effort is carried out by R. W. Gellie and A. J. Holzer[4, 5] and the facility has two industrial robots, i.e., Unimate Puma 600 and a Machine Dynamics Pick and Place robot (built in Australia) as well as an Automatix industrial vision system. Since the Australian manufacturing industry composed of small firms concerned with batch on "job shop" types, therefore, the robotics program and operations must perform with a repertoire for products and functions. Products must be manufactured with the same production equipment, and flexibility is required. In order to be cost effective, the investigators at CSIRO indicate that vision capability is the most important sensory capability, since part identification and orientation are essential for these applications. Initial interactions with Australian industries have involved continuous path robots and robots with grippers capable of accurately measuring, weighing, and inspecting components.

In the area of machining and tribology, R. H. Brown, N. Gane, and G. Lorenz are examing the performance of new cutting tools, the machinability of materials and polishing of hard materials. Of note, is the study of wear of magnesia partially stabilized zirconia cutting tools considered under two conditions: continuous turning tests to assess tool wear and an interrupted cutting test to assess chipping and fracture.

For comparison, similar tests were performed with alumina and two types of tungsten carbide tools. In general, the softer zirconia tools show greater wear; however, in interrupted tests, there was no evidence of large-scale fracture as seen with alumina tools.[6] Current studies are assessing SiAlON, tungsten carbide, i.e., p10, P40 grades, cubic boron nitride, zirconia, tungsten-carbide-cobalt, alumina-titanium carbide and alumina-zirconia composite cutting tools.

In summary, the Division of Manufacturing Technology is attempting to assist Australian industries in the areas of materials processing and production. The traditional areas of machining, casting and machining involve processing improvements resulting from CSIRO-industry interactions. The relative efficiency of the newly organized government-industry program in manufacturing is difficult to assess since the CSIRO laboratory/industry interaction are in the embryonic states. The efforts in computer-aided design and robotics are also in the initial stages and the level of industry interaction and acceptance shall determine the performance success of the program. Additional areas of research are detailed in Table III.

For furture information contact:

R. H. Brown, Chief
Division of Manufacturing Technology
CSIRO
175 Johnston Street
Fitzroy, Victoria 3065, Australia

AUSTRALIAN ATOMIC ENERGY COMMISSION (AAEC)
LUCAS HEIGHTS RESEARCH LABORATORIES

The Australian Atomic Energy Commission, located at Lucas Heights, Sutherland, New South Wales has programs in five research and development fields: nuclear technology, nuclear fuel cycle, health and environmental science, application of radioisotopes and radiation, and nuclear science. Table IV provides an outline of the research programs. The AAEC is the only nuclear laboratory in Australia and therefore must provide a range of services. Australia provides 15% of the free world's uranium supply as well as having abundant supplies of coal. These circumstances have allowed Australia to have abundant domestic nonnuclear energy resources; however, it must also have competence in processing nuclear fuels for its export market. As a result, the domestic nuclear power program is given a very low priority, however, research on nuclear fuel cycle does receive the commitment of resources based upon export market considerations.

For further information contact:

Director
AAEC Research Establishment
Private Mailbag, Sutherland
New South Wales 2232, Australia

The staff at AAEC numbers 1040 with 270 on the scientific staff, with a balance of 90% research and service of 10%. Informal liaisons program exist with the Naval Research Laboratory (NRL) in the area of heavy steel section A533B plate material and embrittlement, Lawrence Livermore Laboratory and the National Research Institute for Metals in Japan in the SYNROC area. Support provided by AAEC involves interactions with universities and the Australian Institute for Nuclear Scientists and Engineers, e.g., grants for Ph.D. students and postdoctoral fellows.

SYNROC PROGRAM FOR NUCLEAR WASTE DISPOSAL

Alternative approaches are being considered for the disposal of high level nuclear wastes (HLW), e.g., borosilicate glass, crystalline minerals. In 1978, Professor A. E. Ringwood proposed the utilization of barium hollandite ($BaAl_2Ti_6O_{16}$), perovskite ($CaTiO_3$) and zirconolite ($CaZiTi_2O_7$) as minerals which would accept in solid solution elements of high level radiactive waste products. The material has been termed SYNROC. The mixture of three minerals have solute atom sites which are will accept specific ions. For instance, the perovskite structure will readily accept americium, curium, plutonium and strontium, the hollandite structure serve as a solid solution host for barium, cesium, molybdenum, rubidium and ruthenium and the zirconolite structure can accept cerium, neptunium plutonium, zirconium, uranium and rare-earths. As a result of the varying solid solubility levels of minerals, SYNROC compositions are tailored based on the composition of HLW to be accepted.

The current studies in the SYNROC processing program involve four topics:

- fabrication development and process scale up,
- aqueous leaching tests,
- accelerated radiation damage testing, and
- thermophysical property measurements.

The processing scheme is shown in Figure 2 and involves ball milling of fine oxide powders, addition of HLW nitrate slurry, at level of 10-20 wt.%, spray drying, calcining and three process options in hot pressing, e.g., hot pressing in-can and hot pressing in an unsupported stainless steel canister. Plans are being formulated to design and construct a nonradioactive pilot plant involving the process as outlined in Figure 2 with an operational capability in 1984 and a production capacity of 20 kg/month

The studies on leaching have indicated that SYROC C is more resistant *vs.* borosilicate glass over the temperature range of 45°C - 300°C. The leach rates for cesium are the highest while Ti, Zr, and Al are very resistant to leaching. Radiation damage studies on SYNROC are being conducted, since radiation induced changes in volume and microstructure can effect mechanical properties and leach rates. Studies utilizing a high flux reactor and fast neutrons, i.e., $\sim 4.8 \times 10^{20}$ n/cm^2 (>1 MeV), have been conducted or SYNROC B and SYNROC C containing 10 w/o HLW. At high neutron levels, e.g., 2×10^{20} n/cm^2 volume increases, e.g., 4%, are noted with surface microcracking. These radiation levels have corresponded to simulated ages of 10^4 to 2×10^5 years.

The advocates of the program indicate that the SYNROC method will allow faster disposal at greater depths at higher ground temperatures, e.g, 100°C. The relative costs of the French borosilicate process *vs.* the SYROC scheme are not available and may become clear based upon pilot plant start up and operation in 1984. Studies are also proceeding in the preparation of SYROC B utilizing an alkoxide process, since a more intimate mixture can be obtained without ball milling to produce a powder with greater reactivity, lower sintering/pressing temperatures, and a reduced level of contamination during preparation.

Metallurgical studies by K. Snowden involve radiation-creep interactions in 321 and 310 stainless steel and zircalloy. K. Veevers is examining refractory metals, e.g., Mo, Ta, Nb in order to generate a data base with regard to creep and fatigue properties up to temperatures of 750°C. M. Ripley is involved in the mechanics aspects on materials behaviors with studies on elastic/plastic interactions, compliance techniques for J_{IC} interactions and the effects of flaws in pipelines and cylinders.

In addition to the efforts in the materials engineering areas, Table IV details the activities with regard to nuclear technology, nuclear fuel cycles, health and environmental science, radioisotopes, and nuclear science. The AAEC has an active, well-equipped laboratory which places emphasis on the nuclear fuel cycle as well as the health and environmental science areas. The specific area of high level waste management is addressed by the SYNROC program. The AAEC is maintaining a level of expertise in engineering and science as related to the nuclear fuel processing and nuclear safety.

AERONAUTICAL RESEARCH LABORATORIES (ARL)

The Aeronautical Research Laboratories in Melbourne, Australia, has five research divisions to include mechanical engineering, propulsion, structures, aeronautics and materials. The materials division has a staff of 50, with three research and three applied groups. The research groups in the materials division involve chemical properties, mechanical properties, and a structures group which includes nondestructive inspection. The applied groups include reliability and analysis, metals and nonmetals with research efforts involving about 20% basic and about 80% applied. Studies involve a Battelle-DARPA funded program involving correlation crack propagation via acoustic emission monitoring and magnetic particle studies. Additional international joint studies involve low cycle fatigue studies of titanium alloys as well as evaluation of high temperature aluminum alloys. Studies on corrosion involve water displacing paints, the use of sulfonates, surface active agents, and programs involving sodium metaborates. Specific attention is given to corrosion to aluminum alloys in high chloride, low pH environments utilizing scanning impedance measurements.

Composite materials research involve repair techniques, i.e., "crack patching" utilizing boron/epoxy and graphite/epoxy composites with the design of the "patch" based upon finite element analysis of the repair required, in order to provide for the appropriate composite geometry and strength, e.g., cross ply, volume fraction. Additional studies involve low cycle fatigue on disc sections utilizing eddy current inspection techniques and mechanical property studies on Rene 95, IN 100, Waspalloy and INCO901.

Additional technical information can be obtained from:

Dr. N. E. Ryan
Aeronautical Research Laboratories
506 Lorimer Street
Fishermen's Bend, Box 4331
Melbourne, Victoria 3001, Australia
Telex: ALR 39391, Telephone: 03-647-7511

MATERIALS RESEARCH LABORATORIES

The Materials Research Laboratories (MRL) a component of the Defense Science and Technology Organization is located in Maribyrong, Victoria, Australia, and provides for a technology and support base for the Australian Defense Force. MRL is composed of four divisions: metallurgy, organic chemistry, physical chemistry, and physics with several groups within each division as detailed in Figure 3. With an annual budget of A$10.6 million, it supports of staff of 570 scientists, technicians, and support people. The metallurgy division is headed by Dr. Leonard Samuels and is composed of groups in mechanics, electrochemistry, high temperature properties, manufacturing technology which includes composites, welding, casting and machining, ammunition metallurgy and metals characterization. Specific research topics include fracture in low and medium alloy steels, corrosion of metals in marine environments and high temperature oxidation and hot corrosion. The organic chemistry division led by Dr. Peter Dunn is particularly involved in polymer matrix composites with separate groups in structural adhesives, textiles technology, polymer research and an elastomers/plastics group. Studies are focused upon environmental deterioration, stabilization, adhesive bounding, flammability as well as mechanical and chemical properties of organic and glass fibers.

DIVISION OF METALLURGY

The six groups in the Division of Metallurgy are involved in basic and applied research programs. The metallurgical mechanics group is involved in high strain deformation, as well as fatigue studies in high strength steel. Additional studies involves relations of gaseous environment on corrosion fatigue.[1, 2] The electrochemistry group is involved in corrosion, metal finishing, and cathodic protection. Techniques have been developed for computerized corrosion monitoring in order to detect the initiation and growth of corrosion coupled with a determination of the mechanism.[3] Additional studies involve the role of impurities on the activities of anodes and cathodes and corrosion of zinc electroplate in order to improve in-service storage conditions. The high temperature properties group headed by Dr. N. A. Burley has involved basic studies in gas-metal reactions coupled with the stabilization of protective oxide films. Specific research involved Pt modified alumide protective coatings for nickel base superalloy turbine blades proved to be superior *vs.* conventional aluminide coatings.[4] Studies are also involved in the areas of precision grinding,[5, 6] acoustic emission correlation, and fracture processes.[7, 8]

Special facilities involve high temperature mass spectrometry, Auger electron spectroscopy and thermogravimetric measurements. Long-term basic research is involved in thermodynamics stability measurements of high temperature compounds. The welding and casting group has studies in electroslag refining and are also involved with the thermochemistry of the molten slag, factors controlling the profile of the molten pool, and resulfurization reactions. With regard to international/technology programs, "The Technical Cooperation Program" (TTCP), provides for the establishment of technical panels in several areas of technology between Australia, Canada, Great Britain, New Zealand, and the United States. The individual panels provide for information exchange in specific technical areas, e.g., metallic, organic, ceramic materials, surface wear, etc., so that program planning can be coordinated with regard to similar research efforts. In summary, the staff and facilities of MRL provide a strong materials support effort for the Australian government in terms of both personnel and facilities.

Inquiries regarding the research effort should be addressed to:

Chief Superintendent
Materials Research Laboratories
P. O. Box 50
Ascot Vale, Victoria 3032, Australia
Telegrams: MARELABS MELBOURNE
Telephone: (03) 317222

THE UNIVERSITY OF MELBOURNE

- Department of Mining and Metallurgy

The Department of Mining and Metallurgy at the University of Melbourne has been historically a strong department. However, with the combined effects of decreased student enrollment, a sagging economy, and a depressed mining and metal industry, the department shall be absorbed by the Departments of Chemical and Mechanical Engineering. Many of the research topics shall continue in the areas of mining, mineral processing, extractive metallurgy, and physical metallurgy; however, the department is scheduled to terminate as a unit. The current research topics at the department involve four major areas of interest to include:

- mining with regard to rock mining and cutting operations and the time dependence of stress strain behavior by W. E. Bomford

- mineral processing studies by J. E. Carr which involve hydrophobic solids and behavior of fine particles in floatation systems, e.g., sodium sulphite as a depressant in mineral sulphide floatition systems

- in extractive metallurgy, studies by G. M. Willis involve lead oxide-iron oxide silica slag, systems at 1200°C as well as iron-cobalt-silica and metal sulfide systems

- physical metallurgy research is primarily concerned with ferrous alloy systems with studies concerning iron-titanium-manganese alloys, precipitation studies of niobium carbide and titanium nitride in high-strength low-alloys steels as well as dry rubbing wear studies in cast iron by D. W. Barland and R. J. Haezel.

MONASH UNIVERSITY

- Department of Materials Engineering

Monash University, established in 1961, has seven faculties to include Arts, Economics and Politics, Education, Engineering, Law, Medicine, and Science. The population profile has an enrollment in excess of 14,000 students and a full-time staff of 2850. Enrollment in the Faculties of Science and Engineering is approximately 2800 and 1100 respectively. The academic staff numbers total 1048 with 179 members of staff with solely research responsibilities. The student, faculty, and physical plant growth over the last twenty years has resulted in a university with a capable educational and research staff. The Faculty of Engineering has been traditionally established with Departments in Chemical, Civil, Electrical, Materials and Mechanical Engineering.

The Department of Materials Engineering research interests is well-balanced with research in specific areas of metals, ceramics, and polymers. The metal research area emphasizes aluminum alloys, welding and stress corrosion, fatique, fracture, and metal forming. The ceramics area concerns metastable phases in ceramic systems, alumina based powders and plasma spray coatings. With regard to polymeric systems, a theme of the study is the mechanical properties and the applicability to engineering functions. In addition, specific polymeric research involved environmental stress cracking, methods of design for viscoelastic materials, structure of polyethylene and PVC.

Of particular note is the research in the ceramics area by Dr. Reg McPhearson and studies involving mixed oxide structures. Studies of zircon-zirconia systems produced by plasma dissociated zircon was recently reported.[1] In addition, several alumina based, e.g., Al_2O_3-SiO_2, Al_2O_3-Cr_2O_3, Al_2O_3-TiO_2 powders have been prepared by plasma techniques. The technique of preparation of submicron powders involve mixed halide gases injected into an oxygen plasma or an oxy-hydrogen flame. The studies involve amorphous powder production via plasma condensation and microstructural studies of spinodal decomposition processes. Similar studies on plasma dissociated zircon produced material containing 24 w/o SiO_2 produced an equilibrium structure of 25% ZrO_2-75% zircon.[1,2] Polmear has examined stress corrosion cracking in Al-Zn-Mg alloys and microstructural and property changes associated with heat affected zones in welded aluminum alloys.[3,4] In metal forming studies, Thomson has been defining forming limits in cold rolled sheet steel as well as edge cracking in hot rolled Al-Mg alloys.[5,6] Polymeric studies has been carried out by Cherry,[7,8] Brown,[9,10] and Stachurski[11,12] with particular emphasis on environmental stress cracking and crazing by Brown; environmental fracture of adhesive joints by Cherry; material selections for engineering applications by Stachurski.

UNIVERSITY OF NEW SOUTH WALES

- School of Metallurgy

The University of New South Wales located in Sydney has an active materials research program with topics in several areas to include: corrosion and environmentally assisted fracture, extraction and refining, mechanical metallurgy, phase transformations, structure and texture determinations of deformed and recrystallized materials, ceramic engineering and welding. Research support for programs is obtained from the Australian government; e.g., Australian Research Grants Committee, Australian trade or research associations; e.g., Foundry Research Association, Australian Welding Association or from Australian industry; e.g., Broken Hill Proprietary (BHP), Imperial Chemical Industries (ICI) Australia, Ltd. As a result of the diverse funding base, research topics range from fundamental studies in order-disorder reactions to applied studies of welding in pipeline steels. In physical and mechanical metallurgy, the notable studies include the work by M. Hatherly and coworkers in the area of microstructure and texture development in copper and copper alloys after rolling and deep drawing operations to high levels of strain, e.g., $e_t \sim 2.5$. Professor Hatherly recently completed a monograph entitled, *An Introduction to Texture in Metals*, which reviews experimental techniques for texture determination, development of rolling and annealing textures, properties and texture control, and practices. L. H. Keys and K.R.L. Thompson are examing fatigue and corrosion behavior of low alloy steels as well as fatigue and stress corrosion cracking in Fe-Ni-Cr alloys to determine the initiation and crack propagation rates. D.J.H. Corderoy and M. McGirr are combining in finite element analysis to determine rolling contact stresses as well as lateral and longitudinal fictional shear forces. D.J.H. Corderoy specializes in the mechanical behavior and finite element area specifically in the area of welding, rolling, and microscopic stress distributions in metals. Specifically, finite element analysis is utilized to obtain a solution to a stress field intensity factor, with various root geometries being modelled and correlated with experimental crack growth rates. Additional studies by H. Muir involve wear resistance of austenitic manganese steels and a study of the Bauschinger Effect and the initiation of fatigue damage. Ceramics research is being conducted by E. R. McCarthney in the following areas:

- Ti-Si-O-N, comparison of the thermodynamic stabilities with experimental findings,

- reaction sintering, modification of alumina ceramics by additions of manganese and titanium, allowing a reduction in the firing temperature from 1600°C to 1300°C without loss of room temperature strength and wear resistance, and

- development of ceramics for use in surgical endoprostheses.

The work of G. Wallwork is in the area of corrosion and high temperature oxidation. In an alloy development study, a low cost replacement for stainless steel, e.g., an iron aluminum alloy is being developed. In marine environments, Wallwork has examined steels and established that sulphides are the prime cause of localized corrosion in mild steel. Studies are continuing on desulphurized steels and the effects of minor alloying additions. Additional studies by Wallwork include corrosion inhibitors as well as the effect of stray electric currents on the corrosion of underground installations. Studies on transformation are carried out by several members of staff:

- D.J.H. Corderoy, Fe-Ni-Mo steels examining Ms Temperature;
- J.S. Bowles, morphology and precipitation studies in Cu-Cr alloys and growth mechanism in Cu-Au II plates.

WOLLONGONG UNIVERSITY

- Department of Metallurgy

The Department of Metallurgy at Wollongong University is located in New South Wales, Australia, south of Sydney. Since it supplies students to extraction and mineral processing industries, the research areas are balanced between the traditional physical/mechanical metallurgy areas and mineral processing. In ore extraction, studies by M. Standish involve influence of particle size and distribution on fluid flow in packed beds in order to improve reaction efficiencies. In physical metallurgy, N. Kennon has examined copper-based shape memory alloys and T. Chandra has examined the effects of niobium carbonitrile precipitates on recrystallization in 0.07 Nb steels. Ultrahigh speep annealing of steels is also being studied in order to improve formability in deep drawing operations as well as provide for an increased speed of operation in continuous annealing lines. In terms of research support, the Australian steel industry has provided financial support for graduate projects. Recruiting of Australian students is difficult. As a result, a number of Malayasian and Indonesian students are attracted to the graduate research program.

JOHN LYSAGHT RESEARCH AND TECHNOLOGY CENTER

The research and technology center of John Lysaght in Port Kembla in New South Wales, Australia, is divided into four functional groups:

- steel technology,
- coating technology,
- process engineering, and
- process physics .

John Lysaght provides steel sheet and strip products, e.g., electrical steels, coated and laminate products. It supports a research staff of one hundred and twenty, 50 per cent being scientist/technicians who are involved in process and product development studies. The steel technology group is concerned with forming and mechanical property evaluations in nonoriented electrical steels as well as coated/uncoated steel grades. Fe-3w/o Si steel strips are being monitored utilizing dc permeability and core loss measurements. In addition, steel strip evaluations are also being conducted utilizing eddy current thickness gauge techniques and line trials proceedings. Studies of steel strip elastomer laminate composites materials are being evaluated based upon their sound damping capability with applications involving ribbed panel structures, fire walls, and saw blades.

A major application in steel strip coating is a Zn-55 w/o Al coating which is produced by a hot dip coating process. Studies on the corrosion resistance, strength, and formability of coating steel strip materials is a major concern and several papers review their activity. The studies in steel strip processing involves analytic and production studies of rolling, annealing, and pickling operations. In addition, the process physics group is involved with gas/steel interactions during annealing, decarburizing, and denitriding operations. The studies in the corrosion resistance of steel plate involve impedance and electrochemical measurements of pointed steels as well as passivation studies of zinc and zinc alloys.

In summary, John Lysaght Research and Technology Center has a very directed effort to the understanding of steel strip process control coupled with an understanding of galvanized, painted and elastomer coating interactions on cold and hot rolled conventional and electrical steels.

Additional information can be obtained from:

John Lysaght Australia Limited
P. O. Box 77
Port Kembla, New South Wales 2505, Australia
Telex: 29014, Telephone: 74-0422

TABLE I (+)

PERCENTAGE EXPENDITURE FOR CSIRO RESEARCH PROGRAMS

Rural industries		
Agriculture	26.2	
Forestry	3.8	
Fishing	3.6	33.6%
Mineral, energy, and water resources		
Mineral resources	6.1	
Energy resources	7.8	
Water resources	2.3	16.2%
Manufacturing industries		
Resource-based manufacturing industries	13.5	
Technology-intensive industries	5.5	
Industrial machinery and equipment	1.3	
Standards	5.1	25.4%
Community interests		
Knowledge and management of the natural environment	16.9	
Tertiary industry	6.3	
Public health	1.6	24.8%
		100%

(+) Courtesy of CSIRO

TABLE II

INSTITUTE OF CSIRO(+)

INSTITUTE OF ANIMAL AND FOOD SCIENCES

Director: K. A. Feguson
Limestone Avenue, Campbell, A.C.T., or
P.O. Box 225, Dickson, A.C.T. 2602
Tel. (062) 48 5211 Telex 62003

.Objectives

The Institute conducts scientific and technological research aimed at improving the efficiency of livestock production, the management and productivity of Australia's fisheries resources, the conservation of its marine ecosystems, and the quality and safety of human foods; and at obtaining a better understanding of the relationships between human diet and health.

The Institute's activities include research on:

- control of animal diseases,
- nutrition, reproduction, genetics, and management of livestock,
- marine ecosystems and the ecology and population dynamics of the ocean's harvestable resources,
- methods of processing, handling, and storing meat, fish, dairy foods, fruit, vegetables and grain,
- identification of nutritive imbalances and deficiencies in the diets of Australians and investigation of their effects on human health, and
- molecular and cellular biology and its application in the livestock and pharmaceutical industries.

INSTITUTE OF BIOLOGICAL RESOURCES

Director: M. V. Tracey
Limestone Avenue, Campbell, A.C.T., or
P.O. Box 225, Dickson, A.C.T. 2602
Tel. (062) 48 4211 Telex 62003

.Objectives

The Institute conducts scientific and technological research aimed at improving the management and productivity of Australia's land, soil, water, agricultural, pastoral, and forestry resources and the management and conservation of Australian ecosystems.

The Institute's activities include research on:

- application of the plant science to the management and utilization of crops, pastures, forests, and native ecosystems,
- introduction, selection and breeding of plant material as a basis for developing pasture plants and forest trees,

- control of insect pests of plants and animals, and of weeds and plant diseases, with particular emphasis on research aimed at reducing dependence on chemical control,
- biology of native and introduced animals in the context of conservation and pest control, and
- assessment and management of land, soil, and water resources in agricultural, pastoral, forested and near-urban areas.

INSTITUTE OF ENERGY AND EARTH RESOURCES

Director: I. E. Newnbam
9 Queens Road, Melbourne, Victoria 3004
Tel. (03) 268 7201 Telex 30670

.Objectives

The Institute conducts scientific and technological research relating to the more effective definition, utilization, and management of Australia's energy and earth resources.

The Institute's activities include research on:

- locating, evaluating, defining, and characterizing Australia's energy and earth resources, and
- planning their recovery, development, and effective use, consistent with the minimization of environmental stresses.

INSTITUTE OF INDUSTRIAL TECHNOLOGY

Director: W. I. Whitton
Limestone Avenue, Campbell, A.C.T., or
P.O. Box 225, Dickson, A.C.T. 2602
Tel. (062) 48 4211 Telex 62003

.Objectives

The Institute conducts scientific and technological research and development aimed at increasing the efficiency, competitiveness, and scope of Australian secondary and tertiary industries in relation to both national and international markets.

The Institute's activities include research on:

- purification of water and waste waters,
- industrial microbiology,
- substitute liquid fuels,
- novel processes and products for application in industry and agriculture,
- utilization of forest and other lignocellulose resources,
- building and design of urban communities,
- safety and comfort in both domestic and industrial environments,
- properties and usefulness of wool as a textile fiber, and
- new and improved technology in metals manufacturing.

INSTITUTE OF PHYSICAL SCIENCES

Director: J. R. Philip
Limestone Avenue, Campbell, A.C.T.,
P.O. Box 225, Dickson, A.C.T. 2602
Tel. (062) 48 4211 Telex 62003

.Objectives

The Institute conducts scientific and technological research in the physical, chemical and mathematical sciences aimed at meeting the needs of Australian industry and increasing understanding of the physical environment.

The Institute's activities include research on:

- application of the physical sciences to industrial problems,
- maintenance of the national standards of measurement,
- development of scientific and industrial instrument techniques,
- properties of industrial materials and development of improved materials and chemical and physical processes,
- climate, weather, and atmospheric transport of pollutants and other entities,
- physics of interactions between soil, water, plants, and atmosphere,
- radiophysics and its application to astronomy, navigation, and communication,
- the physical and chemical oceanography of the Australian marine environment, including air-sea interaction,
- application of mathematics and statics to problems in industry and science, and
- development of advanced computer systems and the provision of CSIRONET services.

(+) Program outlines in Table II was provided through the courtesy of CSIRO

TABLE III

CSIRO ACTIVITIES
DIVISION OF MANUFACTURING TECHNOLOGY+

.Melbourne Laboratory

Arc technics
- development of pulse welding equipment
- control and application of pulse welders
- arc hardening
- applications of the arc

Die casting
- analysis of fluid and thermal flow
- computer-aided design of dies
- thermal control of dies
- casting performance and strength of components
- development of new zinc alloys
- application of advanced materials in die casting equipment

Machining and tribology
- tap performance characteristics
- nature of chipping in interrupted cutting
- performance of new cutting tools
- machinability of materials
- polishing of hard materials

Integrated engineering
- development and application of flexible manufacturing systems
- application and interaction of robots with other manufacturing devices
- development of VLSI circuits for vision interpretation and control purposes
- computer-aided design

.Adelaide Laboratory

Welding
- methods of producing hard-faced materials
- manufacturing methods for welding consumables
- performance of welding consumables

Sheet metal forming
- design of forming dies
- material behaviour in forming

Ferrous casting
- casting wear resistant materials
- machinability of cast components
- microstructure of hard materials
- generating phase diagrams for various alloy systems

Energy management

- design principles for heat treatment furnaces
- survey of energy use in heat treatment

Product design

- sheep shearing cutter action and cutter grinding methods
- microelectronic design for manufacturing applications: signal monitoring, control systems
- forming of welding consumables
- a tube bending device

+ Courtesy of CSIRO

TABLE IV

RESEARCH PROGRAMS AT AAEC

Nuclear Technology

Fission and Fission Reactors
- Operation and safety of Hifar

Fusion Physics and Technology
Fusion Materials

Nuclear Fuel Cycle

Enrichment
- Centrifuge enrichment
- Enrichment science

Waste Management
- SYNROC
- Waste treatment and disposal

Health and Environmental Science

Uranium Environmental Studies
Isotope Hydrology
Radiation Biology and Biophysics
Occupational Health Research

Application of Radioisotopes and Radiation

Medicine and Biology
- Nuclear and radiation medicine
- Irradiation research and technology

Industry and Research
- Industrial applications
- Radiation detection, measurement, and standards

Nuclear Science
- Nuclear physics
- Nuclear applications
- Materials science

Services
- Computing services
- Instrumentation services
- Environmental services
- Materials service
- Isotope service

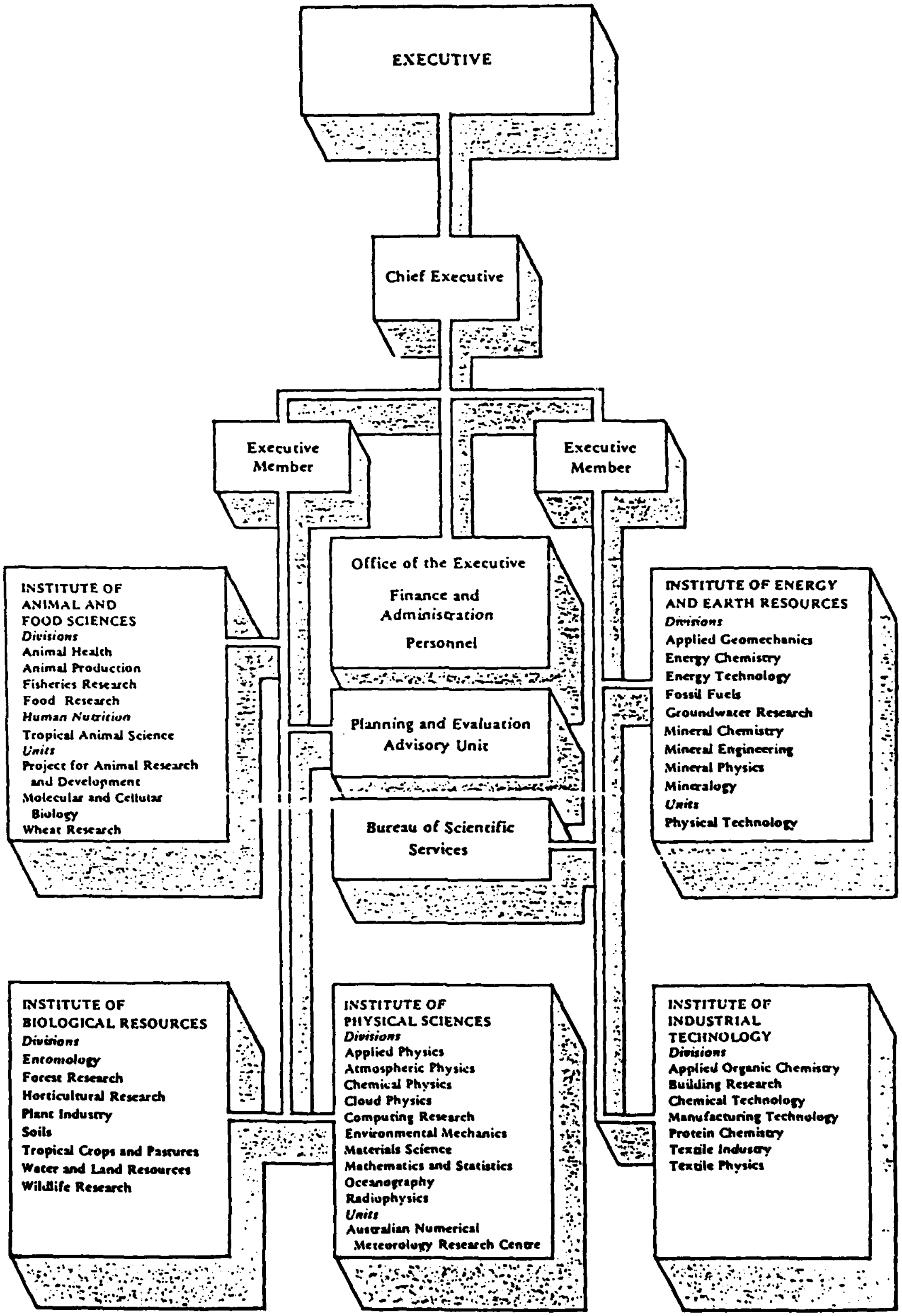

Figure 1. Organization of CSIRO (Courtesy of CSIRO)

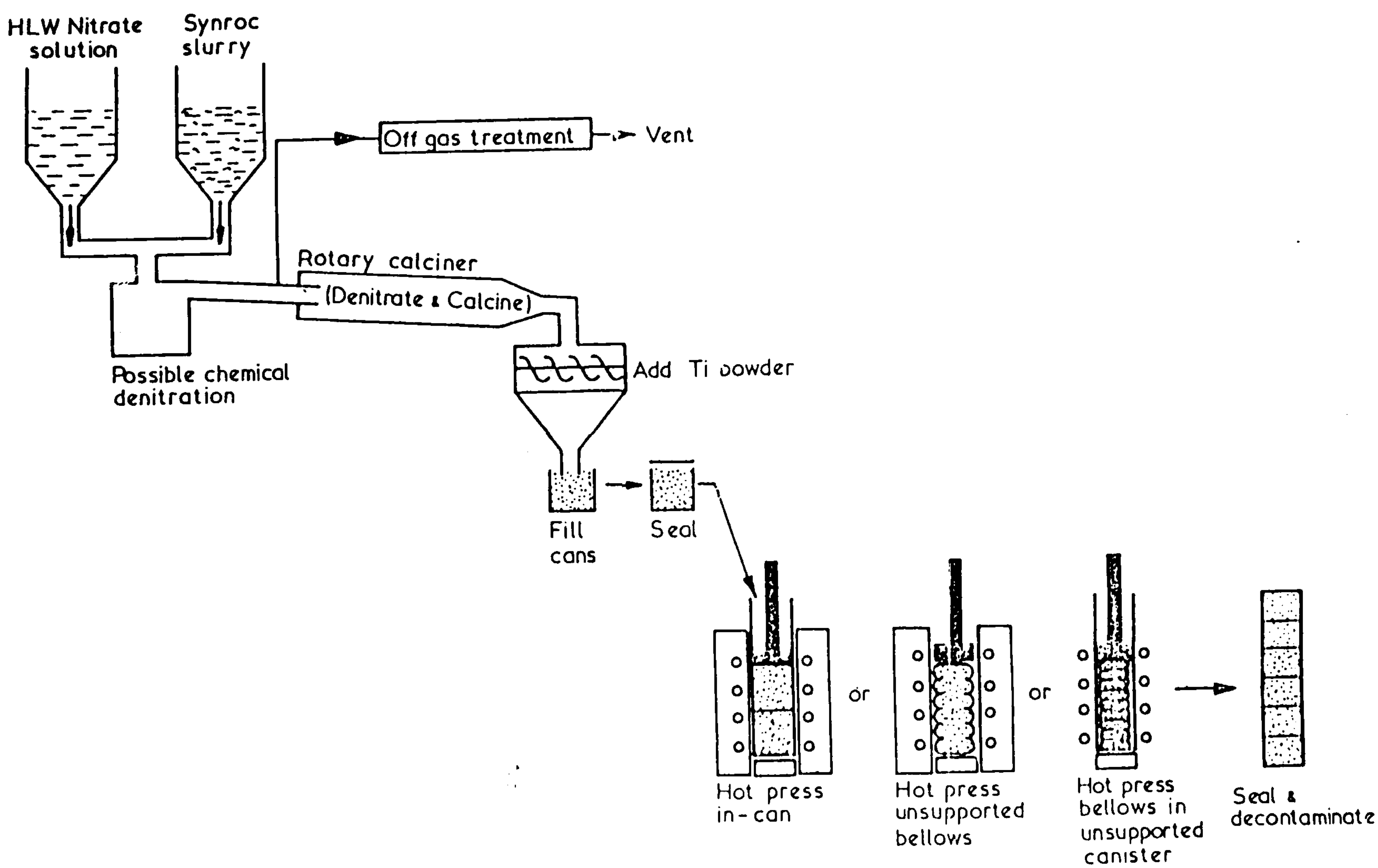

Figure 2. Processing Scheme for SYNROC (Courtesy of AAEC)

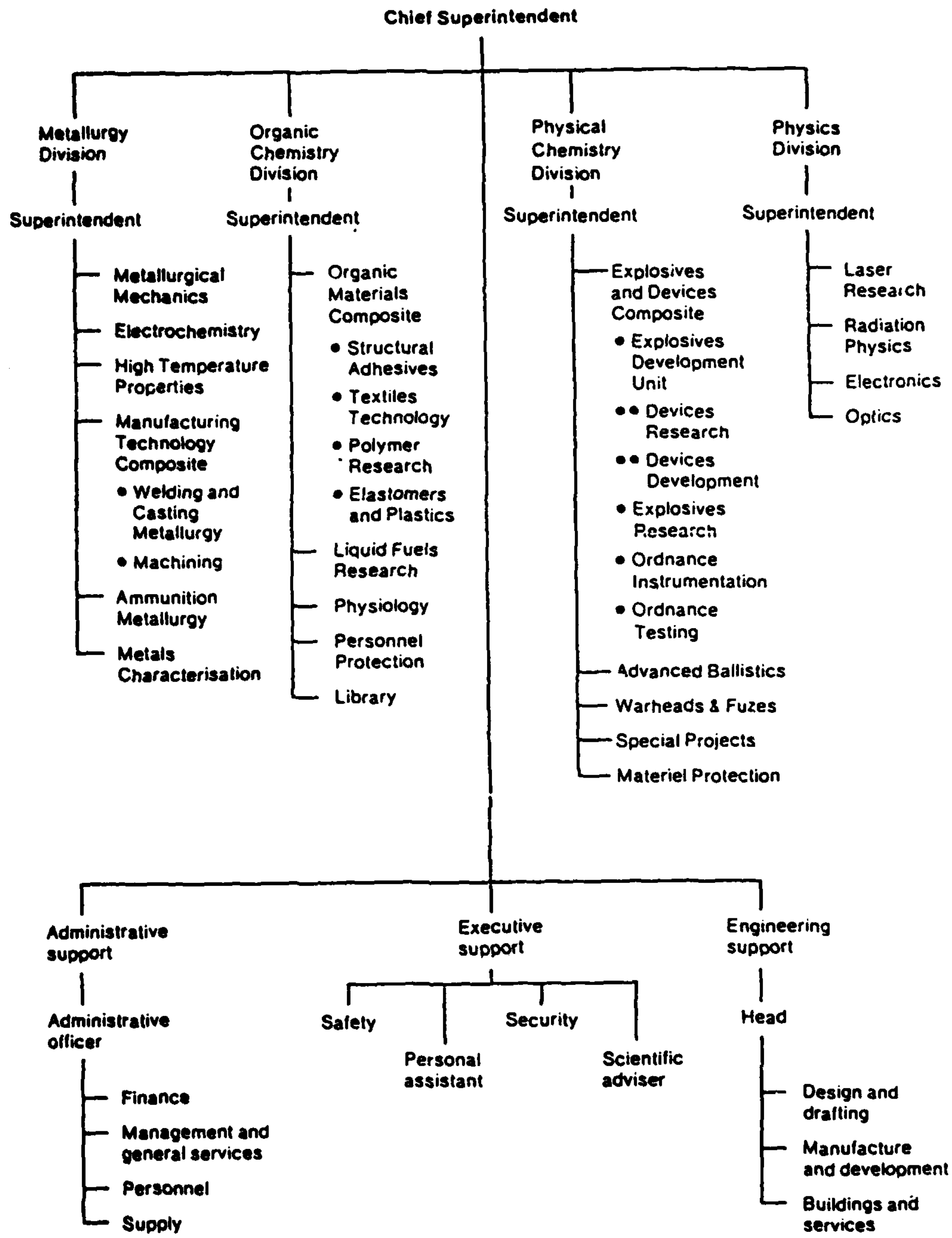

Figure 3. Research Organization of Materials Research Laboratory

REFERENCES: Advanced Materials Laboratory

1. "The Significance of Microstructure to the Fracture Toughness of Partially-stabilized Zirconia," Swan, M. V. (with Hannink, R.H.J.). 5th Int. Conference on Fracture, Cannes, France, April 1981.

2. "Material Development and Evaluation of Partially-stabilized Zirconia for Extrusion Die Application," Swan, M. V. (with Garvie, R.C., Hannink, R.H.J., Hughan, R.R., and Marmach, M.). British Ceram. Soc. London, December 15-17, 1981.

3. "Microstructural Changes During Isothermal Aging of a Calcia Partially-stabilized Zirconia Alloy," Hannink, R.H.J.. Johnston, K.A.. Pascoe, R.T., and Garvie, R.C. *Advances in Ceramics, 3*, 116-136 (1981).

4. "Crack Branching in Transformation-toughened Zirconia," Kirchner, H.P., Gruver, R.M., Swain, M.V. and Garvie, R.C. J. Amer. Ceram. Soc., *64*, 529-533 (1981).

5. "Microstructural Changes during Isothermal Aging of a Calcia Partially-stabilized Zirconia Alloy," Hannink, R.H.J. (with Johnston, K.A., Pascoe, R.T., and Garvie, R.C.). 1st International Conference on the Science and Technology of Zirconia Materials, Cleveland, Ohio, June 16-18, 1980.

6. "Fracture Mechanics Study of a Transformation Toughened Zirconia Alloy in the $CaO-ZrO_2$ System," Garvie, R.C., Hannink, R.H.J., and Urbani, C. *Ceramurgia International, 6*, 19-24 (1980).

7. "Zirconolite, $CaZr_xTi_{3-x}O_7$ Structure Refinements for Near-End-Member Compositions with x=0.85 and 1.30," Gatehouse, B.M., Grey, I.E., Hill, R.J., and Rossell, H.J. Acta Cryst. B, *37*, 306-312 (1980-81).

8. "Oxygen Sensors," Bannister, M.J., McKinnon, N.A., and Hughan, R.R. Patent Application Nos: West Germany - P 2754522.8; Japan - 146208/77. Patent Nos: Australia - 513,552; Britain - 1,575,766; United States - 4,193,857; Canada - 1,112,438.

9. "Oxygen Sensors," Bannister, M.J. Patent Application Nos: Australia - 47828/78; Britain - 7919671; Canada - 329100; West Germany - P 2922947.8; Japan - 069529/79. Patent No: United States - 4,240,891.

10. "Development, Properties, and Applications of the $SIRO_2$ Oxygen Sensor," Bannister, M.J. (with Carrett, W.G., McKinnon, N.A., Stringer, R.K., and Kanost, H.S.). Australian Institute of Physics Conference, Melbourne, August 24-29, 1980.

11. "The Crystal Chemistry of SYNROC," Russell, H.J. RACI Solid State Division Symposium on Structural and Surface Aspects of Inorganic Solids, The Flinders University of South Australia, August 27-28, 1981.

12. "Pyrochlore-related Phases in the Lead Oxide-tantalum Oxide System," Scott, H.G. RACI Solid State Division Symposium on Structural and Surface Aspects of Inorganic Solids, The Flinders University of South Australia, August 27-28, 1981.

13. "Zirconolite-A Fluorite-related Superstructure," Rossell, H.J. *Nature, 283*, 282-283 (1980).

14. "Ordering in Anion-deficient Fluorite-related Oxides," Rossell, H.J. *Advances in Ceramics, 3,* 47-63 (1981).

REFERENCES: Division of Manufacturing Technology (CSIRO)

1. "Computer-aided Thermal Design Analysis of Dier Used in the Pressure Die Casting Process," T. H. Siauw. *Aust. Mech. Eng. Trans.* (1981)

2. "Feeding of Castings from Paris of Tapered Tangential Runners," A. J. Davis. Papers G-T81-014, Proceedings 11th International Die Casting Congress and Exposition, Cleveland, Ohio, June 1981.

3. "A Computerized System for Cost Estimating in Foundaries," T. H. Siauw. *Die Cast Bulletin, 37,* 13 (1981).

4. "Some Critical Areas in Robotics Research," A. J. Holzer. *Computers in Industry, 2, 3,* 199 (Oct 1981).

5. "An Australian Manufacturing Cell," R. W. Gellie and A. J. Holzer. Proceedings of the 52nd ANZAAS Congress, Section 43, *Robotics,* May 1982. Macquarie University, New South Wales, Australia.

6. "The Wear and Fracture Resistance of Zirconia Cutting Tools," N. Gane and R. H. J. Hannik. Conference on Lubrication, Friction and Wear in Engineering, Instit. Engrs. Aust. Publin *80/12,* Melbourne, (1980).

REFERENCES: Materials Research Laboratory

1. "Structure and Properties of Free Machining Steel after Deformation to High Strains," R. L. Aghan and J. Nutting. *Metals Technology, 8,* 41 (1981).

2. Automatic Corrosion Monitoring of Metals in Solution," L. F. G. Williams, J. Electrochemical Society, *127,* 1706 (1980).

3. "Corrosion Research at Materials Research Laboratories," L. F. G. Williams. *Corrosion, 36,* 264 (1980).

4. "Surface Modification Concepts for the Enhancement of the High Temperature Corrosion Resistance of Gas Turbine Alloys," N. A. Burley. Report *MRL-R-798* (1980).

5. "Procision Grinding without Spark-out," S. K. Dean and E. D. Doyle. Proceedings of International Conference on Manufacturing Engineering, Melbourne (1980).

6. "An Insight into Grinding from a Materials Viewpoint," E. D. Doyle and S. K. Dean. Annuals of *CIRP 29,* (2), 571 (1980).

7. "Acoustic Emission Associated with Fracture Processes in Structural Steels," G. Clark, D. J. Corderay, N. W. Ringshall, and J. F. Knott. Proceedings of Conference on Elastic Waves and Microstructure, Oxford, (1980).

8. "Multiple Cracking in Thick Wall Pressure Vessels," G. Clark and M. E. deMorton. Fracture, *15*, R17 (1979).

REFERENCE: Monash University

1. "Zircon-Zirconia Ceramics Prepared from Plasma Dissociated Zircon," R. McPherson, B. V. Shafer, and A. M. Wong. J. Amer. Cer. Soc., *65*, 4, C-57 (1982).

2. "The Structure of Al_2O_3-TiO_2 Powders," M. J. J. Gani and R. McPherson. J. Mat. Sci., *15*, 1915-25 (1980).

3. "Effect of Silver on Tensile and Fatigue Properties of an Aluminium-magnesium Alloy," I. J. Polmear and K. Boyapati. Fifth International Conference on the Strength of Metals and Alloys, Aachen, 1231-6, (1979).

4. "Microstructural Changes Associated with Recrystallisation in the Heat Affected Zones of Welded Aluminium Alloys," I. J. Polmear. Proc. First Riso Int. Symposium on Metallurgy and Materials Science, Denmark, 177, (1980).

5. "Edge Cracking in Hot Rolled Aluminium Alloys," P. F. Thomson and N. M. Burman. Materials Science and Engineering, *45*, 95-107, (1980).

6. "The Development of Thickness Nonuniformities Leading to Failure in Sheet Metals," P. F. Thomson and P. U. Nayak. Mem. Sci. Rev. Met., *77*, 303-312, (1980).

7. "Polymer Surfaces," B. W. Cherry. Cambridge, (1980).

8. "The Stability of Fracture in Epoxy Resins," B. W. Cherry and K. W. Thomson, J. Mats. Sci., *14*, 3004-5, (1979).

9. "Fracture of Slightly Plasticised Polyvinyl Chloride," H. R. Brown and G. Stevens. Mats. Sci., *13*, 2373, (1978).

10. "Measurement of Craze Density by Quantitative Transmission Electron Microscopy," H. R. Brown. J. Mats. Sci., *14*, 237-9, (1979).

11. "Designing with Plastics," Z. H. Stachurski. Seminar on New Trends in Automotive Plastics, S.A.E., Melbourne, (1978).

12. "Application of Fading Memory Theory to Design with Viscoelastic Structure," Z. H. Stachurski. First National Conference on Rheology, Brit. Soc. of Rheology, Australian Branch, Melbourne, (1979).

THE SEVENTH INTERNATIONAL CONFERENCE ON VACCUM METALLURGY, SPECIAL MELTINGS, AND METALLURGICAL COATINGS

Michael J. Koczak

INTRODUCTION

The Seventh International Conference on Vacuum Metallurgy sponsored by the Iron and Steel Institute of Japan was held at Keidanren Kaikan, Tokyo, Japan from 26 November 1982 to 30 November 1982. The conference's focus was divided into the areas of special meltings and metallurgical coatings. In the area of special melting techniques, developments centered on vacuum techniques, although some nonvacuum ladle processes were also discussed. The sessions topics are provided in Table I. The concurrent sessions on metallurgical coatings involved studies on vacuum evaporation, diffusion coatings, plasma processing and sputtering. The metallurgical coating session topics are provided in Table II. In summary, 78 papers were presented in the area of special meltings and 99 papers on topics concerning metallurgical coatings. A strict definition of a metallurgical coating was undefined; as a result, a wide variety of coatings and processing approaches were considered with applications involving mechanical wear, corrosion, electronic, solar, and fusion energy applications.

The proceeding of the conference are available in two separate volumes involving metallurgical coatings and special meltings from:

The Iron and Steel Institute of Japan
Keidanren Kaikan, 3rd Floor
Otemachi 1-9-4, Chiyoda-ku
Tokyo 100, Japan
Telex: 02228153, ISISTK J
Telephone: (03)-279-6021

METALLURGICAL COATINGS

A historical perspective of the coatings was provided by C. Hayashi of the ULVAC Corporation. The four basis systems for vacuum coatings are provided in Figure 1, i.e., thermal evaporation, sputtering, ion plating and plasma chemical vapor deposition, and Table III provides for a brief summary and comparison of four vapor coating processes. Hayashi also commented in a general review, the development of a new industrial process is influenced not only by technological factors, but possibly more importantly by social and international trade and business impacts. As a result, the economic feasibility of an industrial process, e.g., a coating or plating process, can be modified by these influences as shown in Figure 2, and the development of a innovative idea is hindered by economic inertia, management conservation and authority in an older technology.

As shown in Table II, the coatings session involved a wide variety of coating processes including vacuum evaporation, chemical vapor deposition (CVD), physical vapor deposition (PVD), plasma spraying and sputtering. The materials examined included elemental coatings, e.g., carbon, silicon, alloys, e.g., NiCr, carbides nitrides, borides, e.g., SiC, TiN, B_4C and inorganic compounds, e.g., $CoCrAl_4$, Nb_3Ge, Li_2TiO_3, for superconducting applications. The direct utilization of coating science in industrial applications was very evident in terms of application to superconductors, wear resistant surfaces, and energy applications.

The area of superconductors and related films was reviewed in an invited paper by R. Smoekh of Cambridge University; he compared sputtering and chemical vapor deposition (CVD) in the preparation of A15 compounds, e.g.. Nb_3Ge and B1 superconductors, e.g., NbN. Smoekh noted that sputtering shall continue to produce novel compounds, e.g., $PbMo_6S_8$, $ErRh_4B_4$, however, the sputtering rates can not achieve production levels obtained by CVD for A15 superconductors, i.e., Nb_3Ge. Several papers were presented on the sputtering, electron beam coevaporation and continuous chemical vapor deposition of Nb_3Ge films. Additional studies on superconducting films at the National Research Institute for Metals, Tanaka *et al.*, utilized $NbCl_5$ and $GeCl_4$ gases for *in situ* reaction studies. The stoichiometry and film structure was found to be a function of the Nb/Ge gas ratio and the substrate temperature. Studies concerning the oxidation response of Nb_3Ge films as well as antioxidation films were presented by H. Ihara and coworkers. The surface of Nb_3Ge was observed to rapidly oxide forming Nb_2O_5, ~1 μm in thickness. In addition, Si and Y_2O_3 film ~2 nm in thickness were investigated as antioxidation coatings. Thin films of δ-NbN 6.5 - 390 mm in thickness were produced by dc magnetron sputtering. A linear relation existed between log Tc and the inverse grain size. Also, the critical temperatures, Tc, decreased with decreased film thickness, e.g.. 15.5 K at 390 nm *vs.* 8-10 K at 6.5 nm thickness. Additional reported studies, involved superconducting oxide thin films produced by radio frequency sputtering, e.g., (BPB) $BaPb_{0.7}Bi_{0.3}O$, $Ba(Pb_{0.7}Bi_{0.3})_2O_5$, (LTO), Li_{1+x}, $Ti_{2-x}O_4$ structures. The BPB films prepared had a Tc > 9 K and a resistivity of 3 X 10^{-3} Ω.cm, at 15 K while LTO films had a Tc of 11 K and a resistivity of 4-9 x 10^{-4} Ω.cm at 15 K.

Papers considering ion plating and vacuum evaporation considered plasma deposited TiN, InN, and TiC films. Application for TiN coating are specifically involved with cutting tools where a high hardness. chemical stability, and wear resistance is required. The physical, optical properties and stoichiometry of the films were influenced by the color temperature of the plasma flame. Studies by K. Inagawa at ULVAC examined the deposition of TiC coatings on ferrous substrates. substrate temperatures from 350°C to 700°C were utilized, with high substrate temperatures producing larger grain sizes coupled a more stoichiometric compound. The microstructure of 20 μm thick film exhibited a columnar structure with a grain size of 11-16 nm.

Studies on Si_3N_4 examined the high temperature mechanical properties produced by CVD. The structure of the Si_3N_4 was dependent upon the substrate temperature ranging from amorphous to crystalline based on the substrate temperature as well as the total gas pressure. Low gas pressure coupled with low deposition temperatures resulted in amorphous structures. Transitions to crystalline structures occur with increased deposition temperatures and higher total gas pressures. Studies by Doi *et al.* at Sumitomo Electric investigated CVD and PVD of TiC, TiCN, TiN, and Al_2O_3 on various heat resisting steels. Additional studies on TiC, TiN, and Ti(C, N) studies by Enomoto *et al.* examined the TiN microstructure as well as the frictional response. The best wear resistance was achieved by films of higher nitrogen contents and TiN coatings producing the best wear resistance.

In an invited paper, N. J. Archer of the Fulmer Research Laboratories reviewed chemical vapor deposition (CVD), PVD (physical vapor deposition) and PACVD (plasma assisted chemical vapor deposition). The advantages sited for chemical vapor deposition include quality of the coating coupled with adhesion; however, limitation involves substrate heating. With low substrate temperatures PVD processes are advantageous, particularly for wear resistant coatings. Table IV provides for a comparison of materials which can be deposited via CVD, PVD, and PAVD processes. In a second invited paper, N. Iwamoto of Osaka University discussed the problems associated with high quality plasma are spraying and cited the following considerations:

- physical and chemical considerations of the particles in flight, e.g., viscosity vaporization, and oxidation behavior,

- pretreatment and surface roughness of the substrate particularly with ceramic coatings on metal substrates,

- thermal dilation and exfoliation of the coating, and residual stresses upon cooling.

Y. Arata and coworkers, also from the University of Osaka, reviewed ceramic spraying in Japan with specific attention directed at Al_2O_3, Al_2O_3-TiO_2 and ZrO_2 coatings with typical applications involving solid fuel nozzles, e.g., $Al_2O_3 ZrO_2$ graded coatings for gas turbine combustion chambers, e.g., ZrO_2, Cr_3C_2, propellor and shaft sealing, e.g., Cr_2O_3, high wear fabric guides, e.g., Al_2O_3. For coating bond strength assessments, a blast erosion test was devised and correlated with coating hardness. With regard to problem areas in ceramic spray coatings, porosity of the coating, inspection techniques, and adhesion were noted as particularly critical. Industrial studies at Kawasaki Heavy Industries by Akikawa and coworkers examined the several ZrO_2 based coatings ZrO_2-MgO and ZrO_2-Y_2O_3 coating utilizing a variety of bond coats, e.g., NiAl, NiCr, CoMoCr, NiCrAlY, CoCrAlY, CoNiCrAlY. The NiCrAlY and CoCrAlY bond coats coupled with an 8% yttria, partially stablized zirconia overcoat performed best in burner rig simulations.

Additional sessions considered carbon deposition, specifically diamond films (~7 μm) produced by Matsumoto and coworkers at NIRIM, on diamond, silica, silicon and molybdenum substrates. Studies utilized Raman spectroscopy, hardness measurement, and electron diffraction studies to characterize the optical, mechanical, and crystal structure characteristics of the deposited layer. Other studies on carbon films involved laser Raman studies on laser evaporated, ion bombarded, and ion beam sputtured films using graphite and diamond source materials. Epitaxial diamond films were produced on natural diamonds, while utilizing silicon, silica, and molybdenum substrates, a polycrystalline diamond structure was obtained. Good adhesion was obtained with diamonds, molybdenum, and silicon, while silica/diamond bonding was poor.

In the area of solar energy materials, studies involving amorphous silicon were presented by workers from Hiroshima University; the Electrotechnical Laboratory in Ibaraki, Japan; Kanazawa University; Tokyo Institute of Technology; and the Fuji Electric Research and Development Center. Hydrogenated amorphous silicon (a-Si H), possesses a high optical absorbtion coefficient in the visible region, good photoconductivity, and coatings of 1 μm films can be produced. A paper concerning the applications was provided by Sakai and coworkers at Fuji Electric which demonstrated the ability to produce via glow discharge techniques hydrogenated amorphous silicon films with areas of 100 cm^2 with a conversion efficiency of 6%. The 400 cm^2 cell produced conversion efficiencies of 4.1%, while smaller 1.2 cm^2 cells produced conversion efficiencies of 7.8% under AM1 (100mw/cm^2) illumination. The studies were conducted with a variety of substrate materials, e.g., glass, stainless steel, and SnO_2-In_2O_3 (ITO) coated glass. Additional studies on silicon, involved plasma anodization of silicon at the University of Tokyo by T. Sugano and M. Fukuyama. Nitriding studies of silicon, and characterization of silicon oxide layers were also considered by workers at the University of Tokyo. G. L. Harding of the University of Sydney, discussed magnetron sputtered devices for selective solar absorption for solar thermal collectors. Amorphous hydrogenated silicon, carbon, and silicon-carbon semiconductor coatings are being investigated with regard to low cost photovoltaic cells, and the results produced of magnetron sputtered films were compared with films produced by RF glow discharge techniques.

SPECIAL MELTINGS

The vacuum melting and refining processes have been developed and commercialized and has provided for improved cleanliness, workability, and mechanical properties, as shown in Figure 3. An excellent introductory lecture was presented by T. Ohtake of Nippon Steel Corporation who analyzed the effects and relationships between the refining process (e.g., reduced levels of oxide, in sulfide, phosphorus, and nitrogen), the effects on the steel property, Figure 4 (e.g., lower level of surface defects, improved formability, and deep drawing improved fatigue strength) and a salutary follow-on effect with regard to structural reliability, safety, and facility of construction. The process control under controlled rolling conditions was also considered and the development of various property combinations with processing schemes was discussed. Progress in vacuum induction melting (VIM) and vacuum arc melting was reviewed by W. Sutton of Special Metals. Its influence on the superalloy industry was provided. In advanced alloy systems, vacuum melting is considered the primary means of melting. As a result, the improvements in vacuum melting techniques have resulted in an improved alloy cleanliness and performance, Figure 5. Of particular note was the developed capability of the People's Republic of China in horizontal electroslag refining/casting to produce ferrous ingots two meters in diameter and five meters in length. Papers involving ladle techniques, vacuum arc melting and other melting approaches can be obtained directly may be obtained from the Iron and Steel Institute of Japan.

Several papers were presented in the session on Advanced Technology of Metal Powder Production with an invited paper by R. Ruthardt and coworkers from Lybold Heraeus. Several combinations of metal powder production can be considered with various techniques utilized for the melting process, e.g., induction heating electric arc, plasma, electron beam with alternative routes for the metal disintegration process, e.g., rotating electrode process, ultrasonic, etc. Suggestions were put forward that a combination of election beam melting techniques coupled with rotational atomization could be utilized for powder production utilizing ingot chips and provide for a low cost means of powder production. The properties and applications of ultrafine metal powders was discussed by E. Fuchita and coworkers of the R&D Corporation of Japan. Although production is on a small-scale experimental basis on several metal systems, Fe, Co, Ni, Ag, Pb, Ti, Mg, Cu, Al, and Si production of some powders have reached several tons. The process involves a low pressure gas evaporation process producing powders 10 nm-1000 nm in diameter. The individual particles combine into a chain structure. Questions regarding oxidation rates, stability, and thermal effects of the powders remain to be answered. However, the fine elemental and alloy powders can be utilized for magnetic tapes, catalysts, and pastes. In a second paper on ultrafine powders, Takai and coworkers from the University of Tokyo reported on evaporation in R.F. discharge plasmas producing fine InN and GaN powders, 30 nm in diameter.

The products and materials in the program proceedings included: ultrafine powders (30 nm) in magnetic alloys, e.g., Fe-Co, Fe-Ni, as well as elemental powders Ni, Cu, Ag, Fe, Co, Au by the Vacuum Metallurgical Company, Ltd., Sanbu-gun, Chiba, Japan; amorphous strip equipment for processing in vacuum or atomosphere as well as an arc melting/metal evaporation facility to produce ultrafine powder by the Daia Vacuum Engineering Company, Koto-ku, Tokyo, Japan. A large capacity, e.g., two-ton plasma melting furnace for titanium alloys by Daido Steel Company, Ltd. of Nakaku, Nagoya, Japan, ESR (1.65 m diameter), VAR (30 tons) and VIM (35 tons) furnaces produced by Fuji Industries, Chuo-ku, Kobe, Japan; vacuum furnace and coating equipment by ULVAC, Chuo-ku, Tokyo, Japan and sputtering equipment by Showa Shinku, Company, Ltd., Sagamihara, Kanagawa Prefecture, Japan.

SUMMARY

The metallurgical coating sessions revealed the developing area of coating processes as influenced by technological limitations processing, material limitations as well as economic constraints. Of particular interest were the developments in amorphous and crystalline superconducting compounds and the variations of Tc and stoichiometry with varying processing techniques. The developments in plasma spraying are maturing with numerous alloy modifications being considered and studies being carried out on the relative hot corrosion and oxidation response coupled with techniques to automate the plasma spraying process for a more uniform coating thickness. The area of carbon films appears to be of keen commercial interest with the question and possibility of producing coherent, hard "diamond" films on metallic and glass substrates. The studies in amorphous silicon for solar energy applications has received attention in terms of solar receptors, however, loss of conversion efficiency with large area receptors appears to be a current and persistent concern.

The special melting sessions involved advances in special melting, as applied to vacuum, ESR, VAD, VOD techniques with regard to process and chemistry control. These techniques have provided for improvements over conventional steel making practices. The continued efforts in these areas have resulted in alloy steels with improved properties coupled with increased processing economies.

TABLE I

SESSION TOPICS IN SPECIAL MELTINGS

- Advances in Vacuum Melting Technology
- Physical Chemistry of Vacuum Induction Melting
- Advanced Technology of Metal Powder Production
- Zone Melting for High Quality Material
- New Application for Analytic Chemistry
- Plasma Technology and Applications, I and II
- Powder Technology
- Ladle Metallurgy, State-of-the-Art
- New Process by Ladle Arc Furnace, I and II
- Mathematical Model of ESR
- Physical Chemistry of ESR
- Advances in Vacuum Arc Melting
- New Applications of Vacuum Arc Melting
- Advances in Electron Beam Melting
- VAD/VOD, State-of-the-Art
- VOD/AOD Advances in Equipment and Operation
- RH, State-of-the-Art
- DH, Advances in Equipment and Operation
- New Technology of ESR, I and II
- Energy Savings and Heat Transfer of ESR
- Advances in Process Control of ESR

TABLE II

SESSION TOPICS IN METALLURGICAL COATINGS

- Superconductors and Related Films
- Vacuum Evaporation and Ion Plating
- Mechanical Properties, Basis, and Applications
- CVD and PVD for Mechanical Wear and Corrosion Applications
- Electrical and Optical Properties
- Plasma Spraying, I and II
- Properties and Characterizations of Carbon Films
- Structural Analysis
- Amorphous Film
- Protective Coatings
- Plasma Surface Treatment
- Surface Characterization of Metals by Glow Discharge
- Sputtering Technique and Sputtered Films
- Energy Conversion and Plasma Wall Interaction, I and II

TABLE III

Comparison of Vapor Coating Processes+

		Thermal Evaporation	Sputtering	Ion Plating	Plasma CVD
Material Vapor	Metal	Yes	Yes	Yes	Halide
To be coated	Alloys($M_A M_B$)	$P_A \sim P_B$	Yes	Possible	Plus Hz
				Metal vapor	Metal vapor
	Compounds	$P_{EVAPN} > P_{DISSN}$	Yes	Plus gas or vapor	Plus radicals or gas
Impinging particle energy		$\lesssim 0.4$ eV	$\lesssim 30$ eV	$\lesssim 1000$ eV	$\lesssim 0.1$ eV
Narrow angle incidence		Possible	No	Possible	No
Deposition rate		$\lesssim 75$ μ/min	$\lesssim 2$ μ/min	$\lesssim 50$ μ/min	
Adhesion to clean substrate		Good	Excellent	Excellent	Good
Backside coating		No	No	Little	Yes
Pin Holes of $\lesssim 3$ μm size		Size and numbers reflect cleanliness of the system and the process, provided substrate surface is smooth and homogeneous			
Boundary of substrate		Clear	Migration	Gradient	Rather clear
Surface and deposit		Under SEM	Observable	Phase	
Without thermal diffusion			Under Auger		
Microstructure of deposit		Should be controllable at least in principle, from random (amorphous?) to crystalline			
Problem area in case		Reaction of deposit materials by crucible or boat	Limited rate of deposition		
Advantage in practice		High speed coating, low voltage and & safety	Steady continuous operation easy and automation	Still early to define	

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TABLE IV

PROCESSES, COATINGS, AND APPLICATIONS

PROCESS	COATINGS	APPLICATION
CVD	Titanium Carbide Titanium Nitride Tungsten Carbide Chromium Carbide Zirconium Carbide Hafnium Carbide Aluminum Oxide Boron, Nitrogen, Carbon Diffusion	Wear/erosion Resistance Sliding wear parts, cutting tools, extrusion dies, punches, dies, carbide tips
CVD	Tantalum Tungsten Silica Silicon Nitride Silicon Carbide Aluminum, Chromium Diffusion	Corrosion Resistance Chemical, medical equipment, burner parts, heating elements
CVD	Boron Nitride Tantalum Nitride Silicon Nitride Boron Carbide Silicon Carbide Titanium Carbide Zirconium Carbide	High Temperature Ceramics, Hard, barrier and oxidation coatings
PACVD	Aluminum Oxide Silicon Oxide Titanium Oxide Boron Nitride Titanium Oxide Boron Nitride Silicon Nitride Titanium Nitride Silicon Carbide Titanium Carbide Arsenic Molybdenum Nickel Silicon	Passivating Films Dielectrics, wear, antireflectance coatings, semiconductions

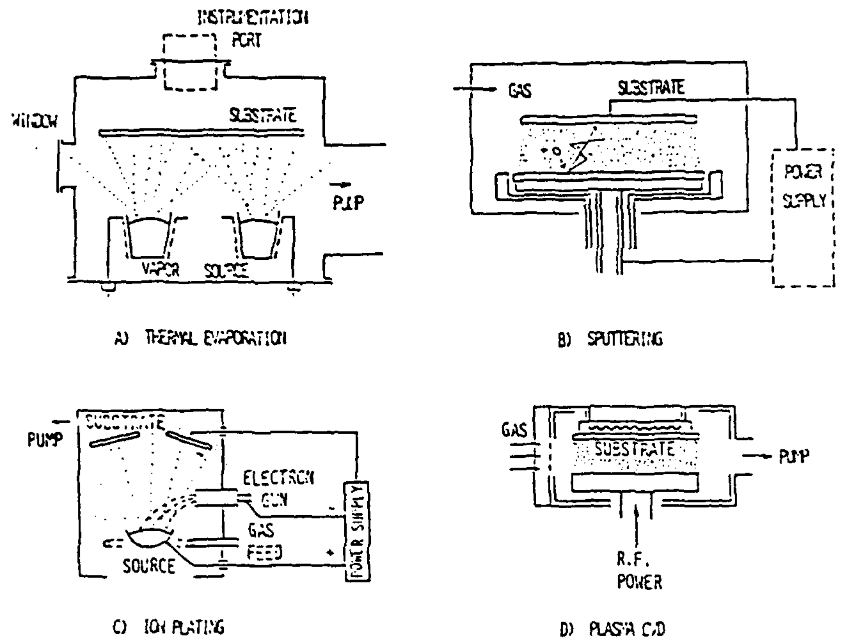

Figure 1. Schematic of Vapor Coating Processes+

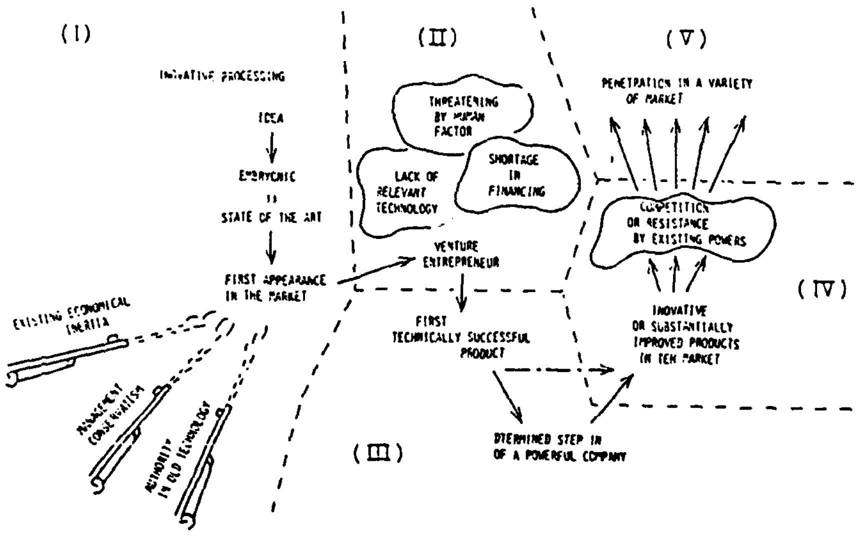

Figure 2. Sequence of Growth of An Innovative Processing Idea+

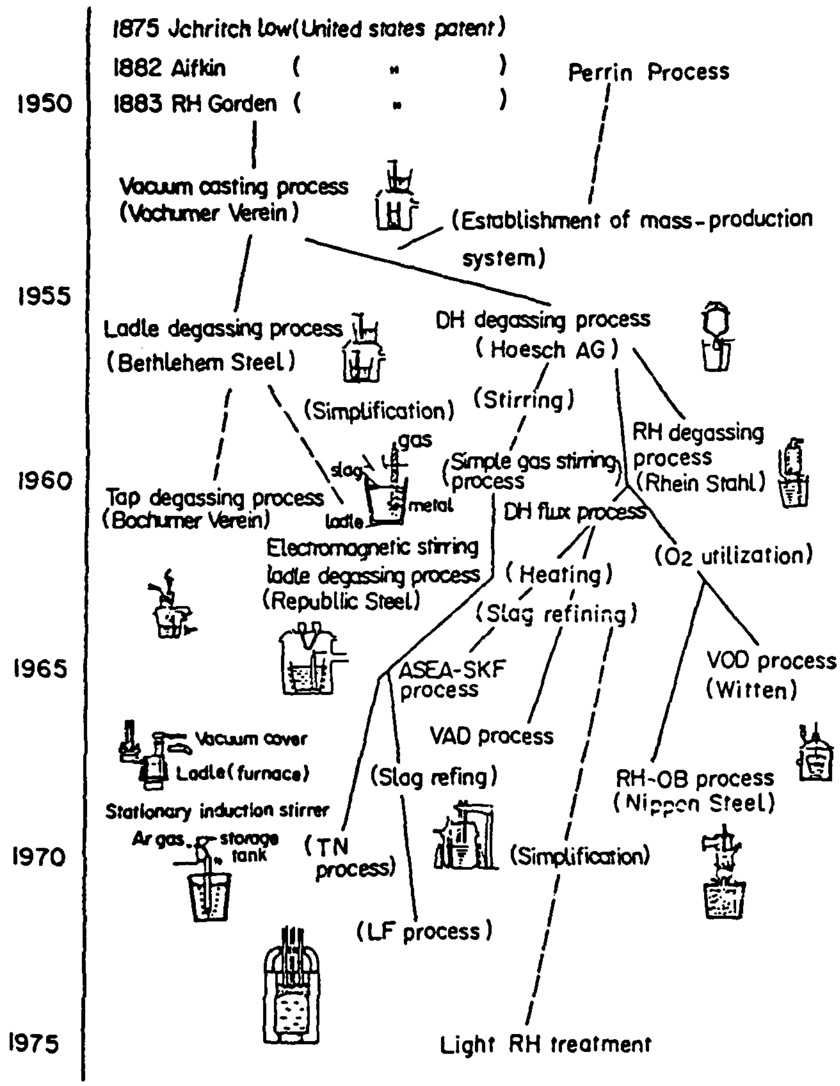

Figure 3. Historic Development of Vacuum Refining+

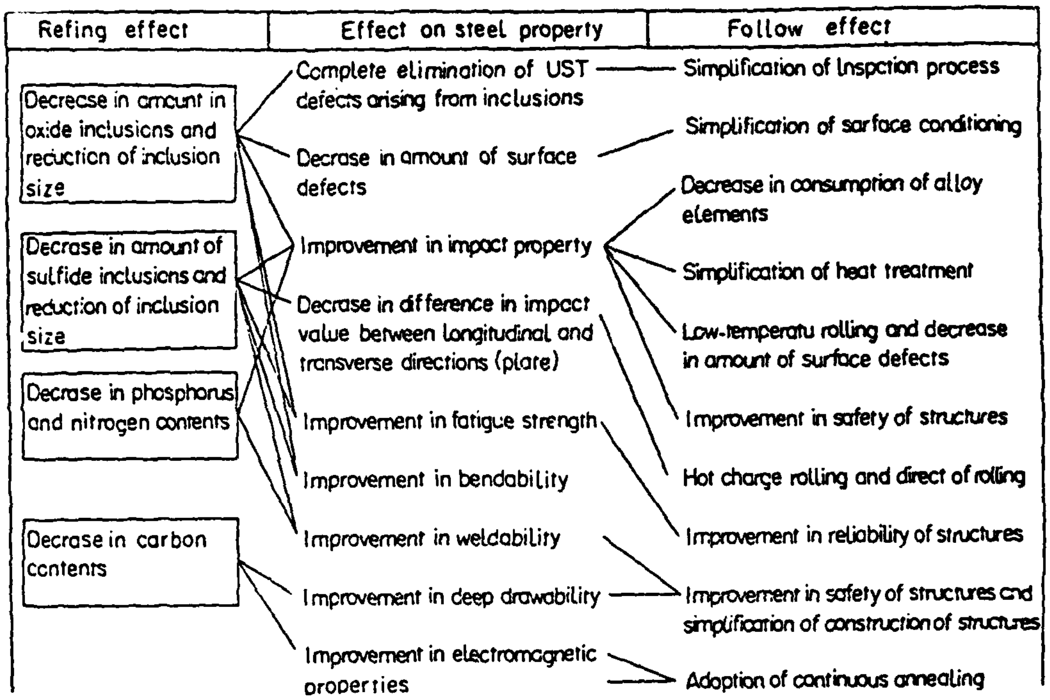

Figure 4. Relationships between Refining Effects Processing and Steel Properties+

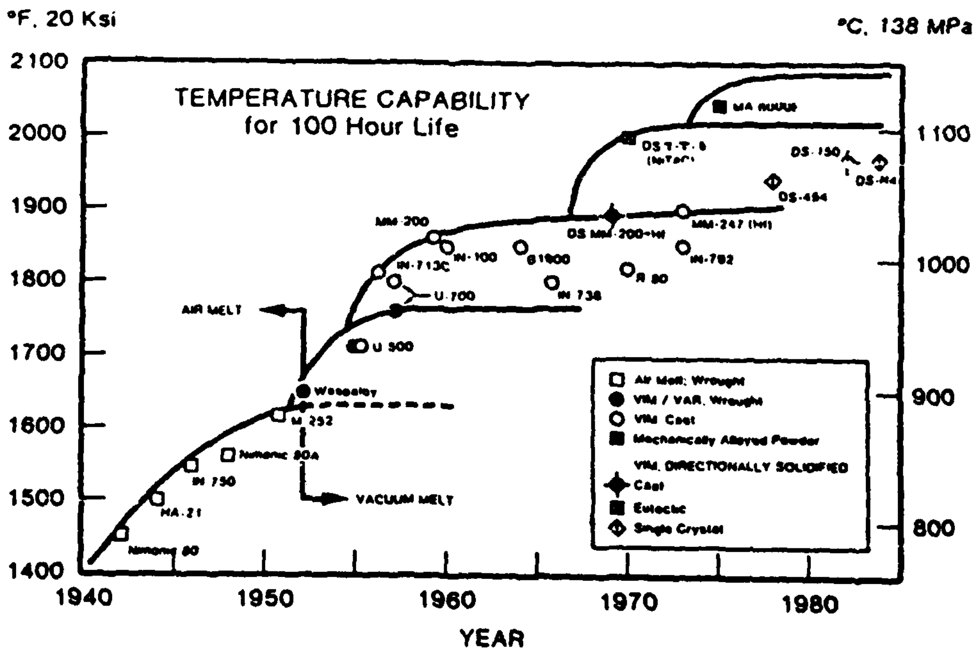

Figure 5. Developments in Superalloy Cability+
Via New Alloy and Processing Developments

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FOURTH INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS (ICCM-IV)

Michael J. Koczak

INTRODUCTION

The recent developments in composite materials was addressed at the Fourth International Conference of Composite Materials (ICCM-IV) in Tokyo, 25-28 October 1982. It was cosponsored by the Japan Society of Composite Materials (JSCM) and the Metallurgical Society of AIME (TMS-AIME). The previous conferences were held in Paris (ICCM-III), in August 1980; Toronto (ICCM-II) April 1978; and Boston, April 1975. The proceedings of the conference, *Progress in Science and Engineering of Composites*, Volume I and II are available from the Japan Society for Composite Materials, c/o Business Center for Academic Studies, 2-4-6, Yayoi, Bunkyo-ku, Tokyo 113, Japan, or from the Metallurgical Society of AIME. P.O. Box 430, 420 Commonwealth Drive, Warrendale, PA 15086. The scope of the conference was directed to composites applications and evaluation and included a wide variety of topics as indicated in Table I with concurrent sessions and workshops.

The composite systems considered involved a range of fiber systems, i.e., glass, aluminum oxide, carbon, silicon carbide, etc., in primarily resin and metal matrix applications. However, with regard to the ceramics reinforced systems, there was interest in glass fiber reinforced concrete, carbon fiber reinforced titanium carbide and silicon nitride composite structures.

The exhibition associated with the conference was composed of industrial and academic exhibits which included: fiber products, i.e., particularly graphite fibers, e.g., Toray Industries, Toho Beslon Co., Ltd., and Mitsubishi Rayon; equipment manufacturers for composite processing, e.g., Daia Vacuum; composite component manufacturers, e.g., Mitsubishi Heavy Industries, and Toyota Motor Corporation as well as resin manufacturers, e.g., Showa High Polymer Co., Ltd.

Historically, the initial applications of composite material structure emphasized aircraft structures, i.e., light weight, high stiffness, and strength applications with properties tailored by appropriate fiber volume fraction and stacking sequence. Recently, there is greater consideration of composite structures in the commercial sector, i.e., industrial equipment, sports and automotive applications. As a result, keen competition exists between the fiber manufacturers of carbon, oxide, carbide, and nitride systems to provide fibers which may be easily processed while maintaining the high initial fiber strength and stiffnesses.

CONFERENCE SUMMARY

The conference gathered engineers and scientists in the areas of fiber and resin chemistry, mechanical and metallurgical engineering, as well as structural designers. Approximately two-thirds of the five hundred conference participants were Japanese, with the major foreign delegations representing the United States, France, the United Kingdom, Russia, and the People's Republic of China. The conference had two hundred and fifty contributed papers with 100 papers being received from Japan and the balance from overseas contributions. The fourth ICCM conference provided for a greater emphasis upon the reliability, design, application, and more complex mechanical property evaluations, e.g., fatigue, buckling of composite systems. This emphasis is demonstrated in the session and specific workshop topics, Table I, involving testing and reliability, impact and applications of composites to more demanding structural designs and higher temperature environments.

The conference's orientation was directed toward the areas of design application with greater interest in mechanical property evaluation with less emphasis in resin system and fiber developments. Specific physical and mechanical properties, e.g., buckling, fatigue, creep, visco-elasticity, impact and environment effects; electrical properties received particular attention with individual sessions. Additional sessions were directed to hybrids structures, natural fibers, biomechanics, and concrete applications.

CONFERENCE GENERAL LECTURES

The general lectures that provided for an overview of the composite field are listed in Table II. In the opening lecture, Tsuyoshi Hayashi reviewed composite activities in Japan. In terms of the division of composite activities, Hayashi divided the composite field into three areas:

- glass fiber reinforced plastics (GFRP),
- advanced composite materials (ACM), and
- diversified functional composites (DCM).

GFRP materials represented the largest composite sector with polyester resins representing a 90% share of the market. The largest market for GFRP materials involved housing materials (34% in 1980), marine (21%), tank and containers (11%), industrial equipment (10%), construction materials (9%), with transportation (2%), and other miscellaneous requirements (13%) providing for the balance. Although GFRP systems have the largest market share, carbon fiber reinforced plastics (CFRP), aramid fiber reinforced plastics, i.e., Kelvar FRP follow in market share order. Several composite structures were displayed and demonstrated the capability of manufacturing large-scale structures from GFRP, CFRP, and Kevlar materials. These structures included: chimneys having diameters of two to three meters and lengths ranging from one hundred to two hundred meters, farm ponds or resevoir tanks having capacities of 3000 m^3 as well as large tanks and vessels for chemical processing produced from GFRP materials. In addition, trailer cars, carbon reinforced long span bridges, and B767 fairings are also in the production stage in Japan. In terms of promising areas, T. Hayashi indicated that electrical applications, show interest, since 10% of the total plastics production (8.2 million tons in 1979) in Japan is in this area. In terms of FRP production (0.25 million tons) or 8% was consumed by electrical and mechanical industries. In terms of FRP manufacturing processes there has been greater emphasis on processing via molding compounds and a decreased utilization hand lay-up and spraying operations.

As part of a national program in Japan, in 1982, Hayashi indicated the Ministry of International Trade and Industry (MITI) formulated six working groups in the following areas:

- high performance ceramics,
- advanced composite materials,
- advanced alloys with controlled crystalline structures,
- high performance plastics,
- synthetic metals, and
- synthetic membranes, separation technology.

In the advanced composite working group, the goals involves development of FRP (fiber reinforced plastics) with properties of 2350 MPa at 250°C and FRM (fiber reinforced metals) with properties of 1470 MPa at 450°C.

General lecturers, N.J. Hoff of Stanford University and A. Kelly of the University of Surrey respectively, provided rather historic overviews of the applications of composites to aircraft structures and to engineering applications. The area of advanced composite materials (ACM) in Japan, with particular emphasis on polyacrylonitrile (PAN)-based carbon composites, was examined by M. Tatsuhana of Toray Industries with the production capacity of PAN-based carbon fibers manufacturers as provided by M. Tatsuhana shown in Table III. The high performance PAN-based carbon fiber system has high stiffness, high strength and has application in uses of automotive components, i.e., drive shafts, leaf springs, robotic manipulators, x-ray components, radio telescopes and antennas, boat and marine reinforcement and electromagnetic shielding. With regard to the aramid fibers, the applications involve tire cord (70%), ropes and cable (15%), composite structure, e.g., marine (12%) and miscellaneous other (3%). Silicon carbide fibers development was spurred by the late Professor Yajima and is currently being commercialized by Nippon Carbon with a SiC fiber plant of one ton/month.

CONFERENCE SUMMARY

- Technical Sessions

For convenience the session had been classified into areas of materials developments, i.e., new reinforcements, fillers matrices, short fiber composites, metallic and ceramic matrix materials; processing of composite structures, i.e., interface and surface considerations; mechanical property considerations including buckling, fatigue, fracture, impact, creep and viscoelastic; environmental effects as well as design and applications. In terms of topic coverage, 18% of the papers were in the area of design, fabrication, and testing, 18% in metal and ceramic matrix composites, 43% in mechanical, physical, and chemical properties, 6% on interfacial phenomena and 6% on constitutents.

The major emphasis of ICCM-IV was related to mechanical property evaluation. In the area of FRP composites, structural and mechanical analysis studies regarding anisotropic laminate structure, hybrid, sandwich plate structures as well as structural analysis of filament wound pressure vessels were discussed. Impact response and damage received special attention in a workshop and four sessions, with emphasis on the utilization of FRP materials for complex automotive and aerospace structures and their response under rapid tensile and impact loading conditions. Studies by T. Fukuda and coworkers examined the processes leading to laminate failure under complex loading conditions. A fault-tree mathematical model to describe the damage process was developed. High velocity tensile response of glass fiber and carbon fiber systems was examined by K. Kawata, *et al.* High velocity ductility was demonstrated in glass/polyester systems; in contrast, high velocity tension brittleness was shown in carbon/epoxy systems. Impact damage tolerance was assessed by M. W. Wardle in a comparison of aramid, glass, and carbon/epoxy systems. The performance as measured by strain energy to failure in tension was found to be highest in Kevlar 29 and E-glass. Studies at Deutsche Forschungs-und Versuchsanstalt für Luft-und Raumfahrt (DFLVR, German Aerospace Research Establishment) by K.K. Stellbrink examined the damage tolerance of carbon fiber laminate structures with various stacking sequences and provided a comparison of damage *vs.* undamaged composites under tension and compressive fatigue loadings. They found that compressive response was more sensitive to near invisible damage *vs.* tensile fatigue loadings. D. Hull reviewed composite failure mechanisms under automotive crash conditions with a wide variety of energy dissipative processes and failure modes being observed, e.g., delamination, elastic bending, fiber fracture, etc. Since a large number of energy absorbing processes are available, coupled with a complex mode of loading, the relative contribution of each mechanism was difficult to quantify. Studies involving impact loading of structural members, e.g., box beams, GRP tubes and GRP ship structures were examined in subsequent sessions. Additional sessions on damage and fracture considered the failure mechanisms of more conventional laboratory specimens in mixed mode loading conditions.

There were eight sessions in the metal matrix composite area involving interfacial considerations and mechanical property evaluations. The interfacial studies characterization of graphite/aluminum composites, i.e., Al_4C_3 carbides, were provided in papers by Shorshorov *et al.* and A. Okura. The prospects for metal nitrides as an interfacial barrier coating was examined by I. Shiota *et al.* utilizing titanium and chromium nitrides via ion plating processing. Utilizing stainless steel and pyrolytic carbon substrates, the chromium nitride coating appeared to separate easily, while the titanium nitride coating adhered more tightly. The interfacial adhesion process in boron and silicon carbide reinforced aluminum was carefully researched by E. Fitzer and G. Jacobson of the University of Karlsruhe. The B-B_4C coated boron fiber maintained fiber strength following high processing temperatures, e.g., 600°C, while degradation of the fiber properties of uncoated boron occured at 530°C. The higher processing temperature resulted in higher transverse strengths, lower impact, and longitudinal strengths, and lower creep rates for unidirectional boron/aluminum (1100) and silicon carbide/aluminum (1100) systems. Only limited work was presented on *in situ* composites and involved eutectic SnSe-$SnSe_2$, Mo-TiC, Cu-In, and Ti-Ti_5Ge_3 systems.

Studies in aluminum matrix systems involved studies by Y. Abe of Sumitomo on 85%Al_2O_3-15%SiO_2 fiber with aluminum-5wt.%Ca alloys and pure aluminum matrix systems. With regard to commercial application of Al_2O_3 fibers, the industrial exhibit by Toyota Motor Corporation demonstrated an automotive application of an aluminum metal matrix composite, e.g., Al_2O_3-SiO_2 fiber with an aluminum matrix, e.g., SAE 321. The top ring groove of an automotive piston was reinforced with a FRM ring with claimed improvements in wear and seizure resistance. Studies on processing of silicon carbide/aluminum utilizing the coreless Yajima fiber was conducted by S. Kohara of the University of Tokyo. Nippon Carbon introduced Nicalon, a 10 µm diameter β-SiC fiber which is available in continuous filaments, chopped fiber, and woven fabrics which is reportedly compatible with aluminum matrix systems. Nippon Carbon has an agreement with Dow Corning for marketing the Nicalon SiC fiber in the United States as well as a joint program with Rolls Royce for the research and development of SiC composites for engine applications. A summary of the physical and mechanical properties of various fibers is provided in Table IV. A study of plasma sprayed graphite/aluminum composites was presented by A. Okura and H. Asanuma of the University of Tokyo.

In the areas of composite applications, there were two sessions on interface and surface treatment which examined a number of composite systems including ultrahigh molecules weight polyethylene reinforced epoxy, carbon fiber reinforced polyesters, polyester fiber reinforced rubber as well as compling agent effects. The studies on interfacial stresses and delamination included papers on free edge delaminations, as well as factors which alter interlaminar fracture energy. In a paper by A. J. Russell and K. N. Street, the interlaminar fracture energy for graphite epoxy laminates was primarily effected by temperature, moisture content and ply orientation in the delamination plane. For mode I and mode II conditions, loadings were considered over a temperature range from -50°C to 100°C. Low temperature/dry conditions provided low fracture energies while high temperature, wet conditions achieved greater toughness. General sessions on joints and bonding examined structural assemblies including lap joints in tubes and aircraft tail structures, and was addressed in the general lecture by R. J. Schkekelmann. He indicated that the stress/strain relationships between the adhesive and the composite matries resin must be examined particularly at the edges of adhesively bonded joints.

The session involving practical considerations of fabrication and processing reviewed several structures: including skin/spar structures by Y. Satakani and Y. Yamaguchi of Mitsubishi Heavy Industries, carbon fiber/carbon structures by S. Kimura *et al.* of The Tokyo Institute of Technology, and three dimensional weaves by F. Ko of Philadelphia College of Textiles. T. Nakagawa of the University of Tokyo provided an alternative, i.e., "vibropunching" to conventional composite drilling, machining, and punching operations. The vibratory punching operation resulted in smoother interior surface finishes in Kevlar and carbon fiber reinforced systems. The process appears attractive from the initial laboratory studies, however, questions of tool life and wear remained to be assessed.

The sessions concerning design and application contained a wide assortment of high performance products produced from composite materials and included: graphite/epoxy tubes for aerospace application, Kevlar reinforcement for aircraft structures, composite designs for helicopter rotors blades, stiffeners for large GRP ships, wing boxes, pressure vessels and retaining rings for large generators.

In summary, the conference touched on many themes in composite materials research and application with good balance of engineering application and analysis-spurred economic driving forces. Information concerning composite activities in Japan can be obtained from the following sources.

- Japan Society for Composite Materials (JSCM)
  c/o Business Center for Academic Societies Japan
  2-4-16 Yayoi, Bunkyo-ku, Tokyo 113, Japan

Activities in Japan include: a yearly symposium on composite materials held in Tokyo, Japan; a quarterly publication, *Journal of JSCOR*, bimonthly study meetings held in Osaka and Tokyo. International activities have included joint conferences on composites materials with the U.S. and U.S.S.R. The 2nd U.S.-Japan Joint Conference on Composite Materials is planned to be held in the United States on 6-8 June 1983.

- Japan Society for Materials Science
  FRP Committee
  Osaka Municipal Technical Research Institute
  Morinomiya, Joto-ku
  Osaka 536, Japan

Local activities include a bimonthly meeting and publication of booklets on composite materials as well as computer-aided design of composite materials. International activities involve workshops and round table discussions.

- Japan Reinforced Plastics Society
  Maruzen Building
  3-15-15 Ginza, Chuo-ku
  Tokyo 104, Japan

A annual meeting is held in either Osaka or Tokyo involving research in FRP composites. In addition, a monthly bulletin, *Reinforced Plastics* is published.

For information regarding standardization and testing of composite structures, contact:

Japanese Standards Association
4-1-24 Akasaka, Minato-ku
Tokyo, Japan
Telephone: (03)-583-8001

and

Technical Committee
Japan Carbon Fiber Manufacturers' Association
c/o Torayca Technical Department
Toray Industries
2-2 Nihonbashi-muromachi
Chuo-ku, Tokyo, Japan
Telephone: (03)-245-5745

In addition, general and specific information on science and technology in Japan can be obtained from the Japan Information Center of Science and Technology (JICST) which processes and disseminates domestic Japanese and international information. For further information contact:

Japan Information Center of Science and Technology
2-5-2 Nagata-cho, Chiyoda-ku
Tokyo, Japan

or

Japan International Center of Science and Technology
C.P.O. Box 1478
Tokyo, Japan
Telephone: (03)-581-6411

It should be noted that many of the local meetings and publications are in Japanese and translation service would be required.

TABLE I

CONFERENCE SESSION TOPICS

- Reinforcements
- Matrices and Fillers
- Interface and Surface Treatment
- Interfacial Stress and Delamination
- Joint and Bonding
- Mechanical Properties of Composites
- Buckling
- Damage and Fracture
- Fatigue of Composites
- Creep and Viscoelasticity
- Impact
- Environmental Effects
- Physical, Chemical, and Electrical Properties
- Short Fiber Composites and Inclusion
- Hybrids, Natural Fibers, and Biomechanics
- Ceramics and Concrete
- Interface and Its Interaction in Metal Matrix Composites
- Metal Matrix Composites
- Testing
- Fabrication and Processing
- Design and Application
- Status and Overview of Composites

COMPOSITE WORKSHOP TOPICS

- Impact--Energy Absorption by Composites
- Fiber Reinforced Metal and Fiber Reinforced Polymer
- Design and Fabrication, Present and Future
- Testing and Reliability of Composites
- Potential of Composites, Economy, and Energy Saving, etc.

TABLE II

General Composite Lectures

Speaker	Topic
T. Hayashi	Scala Lecture: Composites in Japan
A. Kelly	Composites in Engineering
G.S. Springer	A Model of the Curing Process of Epoxy Matrix Composites
R.A. Signorelli	High Temperature Composites--Status and Future Directions
N.J. Hoff	Composite Materials in Aircraft Structures
R.J. Schliekelmann	Adhesive Bonding and Composites
M. Tatsuhana	ACM Reinforcement Fiber Production and Its Application in Japan

TABLE III

Production Capacity of PAN-based Carbon Fibers (Tons/Year)

	Manufacturer	Trade name	Capacity (1981)	Capacity (end of 1982)
Japan	Toray	TORAYCA	420	1,260
	Toho Beslon	BESFIGHT	240	900
	Nippon Carbon (Asahi-Nippon Carbon Fiber)	CARBOLON	60	180
	Mitsubishi Rayon	PYROFIL	-	120
	Sumika-Hercules	MAGNAMITE	-	-
U.S.A.	Hercules	MAGNAMITE	250	450
	Union Carbide	THORNEL	-	360
	Celanese	CELION	-	120
	Hitco	HI-TEX	115	115
	Stackpole	PANEX	25	25
	Great Lakes Carbon	FORTAFIL	15	15
Europe	Courtaulds	GRAFIL	360	360
	Sigri	SIGRAFIL	-	-
	Serofim	RIGILOR	20	20

TABLE IV

MECHANICAL PROPERTIES OF VARIOUS FIBERS

Fiber Type			Maker	Density kg/m³	Diameter μm	Strength (MPa)	Modulus (GPa)
Carbon	Grafil	AS	Courtaulds	1.82		2800	194
		XAS		1.82	9	3260	235
	Pyrofil	HTS	Mitsubishi	1.77		3000	240
		HMS		1.87		2600	340
	Torayca	T-300	Toray	1.74	8	2800	240
		T-200		1.74		2500	224
		M-400		1.84		2100	400
	Carbolon	Z-2	Nippon	1.73	6	3000	200
		Z-3	Carbon	1.77	8	2800	230
	Besfight	HT		1.77	7	3100	240
		ST	Toho	1.77	7	3500	240
		HM	Beslon	1.82	6.6	2500	350
	Magnamite	AS-4		1.77	7.9	3150	225
		HMS-4	Sumitomo	1.85	"	2400	350
		HTS-4	Hercules	1.66	"	2950	270
Boron	Acvo Boron		AVCO	2.60	100	3500	400
Silicon Carbide	SiC Filament		SNPE	3.40	100	3300	450
	Nicalon		Nippon Carbon	2.50	10	2500	180
Alumina	Saphicon		TYCO	4.0	250	2400	460
	Saffil		ICI	3.4	3.0	1000	100
	Nextel		3 M	2.5	11	1750	150
	Sumica Alumina		Sumitomo	3.2	9	2500	250
	Fiber FP		Du Pont	3.9	19	2200	390
Silica	Astroquartz		J.P.Stevens	2.2	9	700	70
			"	0.8		6500	"
			"	10		4200	"
Aramid	Kevlar-29		Du Pont	1.44	12	2800	648
	Kevlar-49		"	1.45	"	"	133
	HM-50		Teijin	1.39	12	3100	77
	Arenka Reg.		Enka	1.44	12	2600	70
	Arenka-D 930		"	1.45	"	"	132
Glass	E Glass			2.54	10	2500	77
	S Glass			2.48	"	3500	89

(Data compiled and provided by T. Furata, National Aerospace Laboratory)

JAPANESE LABORATORY VISITS

Derek L. Lile

INTRODUCTION

It was my privilege to spend the three-week period from 20 August through 11 September 1982, visiting a number of Japanese university, government, and industrial laboratories engaged in research and development in the area of III-V compound semiconductor devices. These visits were arranged so as to also permit my attendance at the International Solid State Devices Conference and Molecular Beam Epitaxy and Clean Surfaces Symposium held in Tokyo. This report will address only the laboratory visits portion of this travel however.

This was my first visit to Japan and, at least as far as the technical portion of my trip was concerned, I went with many preconceived ideas, many of which tended to be negative. Examples included the notion that I would see very little and be told even less at most industrial laboratories, and that I could expect to be overwhelmed and completely discouraged by the vastly superior facilities and technical advances made by our Japanese contemporaries. Lest it become less than clear as this report progresses, it might be good to state at the outset that I found most of my preconceived ideas to be without basis. Most certainly I found much technical competence and many well-organized research and development programs that are making rapid inroads and vast strides into many areas. However, they did not, in my opinion, appear vastly different from what one might expect to encounter during a comparable visit through the equivalent laboratories in the U.S. In addition, with minor exception, my hosts were open and frank in their discussion of their work and with one exception I was, as best I can tell, led freely into any and all of the laboratory facilities, I wished to see. This might not have been the case, of course, if I had been visiting more sensitive technical areas such as Si very high speed integrated circuits (VHSIC) facilities, but that is in the realm of conjecture.

Most certainly, industrial visits in Japan are conducted in a different fashion to what is usual in the U.S. and Europe where the guest is usually escorted in turn to the office and laboratory area of each person with whom he has any interest. In Japan, visits are conducted more as a program review for the benefit of a sponsor might be in the U.S.A. I was, in general, escorted into a spacious yet comfortable meeting room where my host would give an overview of the company and present me with a copy of their latest annual report. A prepared agenda would then be produced and, in turn, the various project leaders would come into the room to present their work in a formal fashion much as at a conference. More or less time might then be made available for individual discussion then, at the end of the day, a laboratory tour would be conducted. For many of my visits, I had been invited to present a short talk on my own work on InP MIS devices and circuits. This was interposed in the above schedule and generally lasted from one to one and a half hours.

In general, both in the industrial as well as in the university laboratories, the impression I got was of a lot of equipment, some old, some new, mixed in a somewhat random fashion. In the university laboratories, in particular, space seems to be at a premium. There does not, however, appear to be any shortage of new equipment. Interestingly, although I am not sure that this was not said in jest, I was told by one industrial laboratory that 50% of their new equipment purchases had to be from the U.S. to balance the flow of Datsun's and Toyota's! Most certainly I saw a great deal of Hewlett-Packard, Tektronix, and Varian equipment although, of course, this could well be bought simply on merit. The laboratories I visited were mostly in the Tokyo area and comprised three university laboratories (University of Tokyo, Institute of Industrial Science, and the University of Hokkaido), one government facility (Electrotechnical Laboratory), and five industrial laboratories of (Nippon Telegraph and Telephone Public Corporation (NTT), Hitachi Ltd., Fujitsu Ltd., Nippon Electric Corporation (NEC), and Sumitomo Corporation).

The descriptions of the laboratory visits which follow are given in the order in which they were conducted. Each is self-contained and attempts to give some "flavor" of the visit as well as giving the facts. In this way, it is hoped that those reading this report may more effectively identify with my overall assessment, which is that the work I saw was in general good, that the personnel are often highly competent and motivated, and that the equipment seems adequate. Sometimes the equipment even seemed lavish [Fujitsu Laboratories has three ion implanters and three molecular beam epitaxy (MBE) machines] although often this was not the case. (Hitachi does not have an MBE machine because management apparently sees no need for one at present.) However, nothing I saw indicated that the Japanese are, in general, "ahead" of the U.S. or that their approach to their goals is clear-cut and that "Japan, Incorporated" is in motion. Examples of the latter are that I was continually questioned about my opinions as to the merits of HEMTs versus MESFETs for high-speed circuitry, of the virtues of GaAs MESFETs versus InP MISFETs, and of GaInAs versus InP as a material for high-speed applications. It is clear that there are many vested interests in Japan just as in the U.S. with groups working on both MOCVD and MBE; for example, each claiming their virtues and superiority for superlattice fabrication, and with the GaAs MESFET groups eyeing the HEMT developments with distrust and less than the enthusiasm that an objective observer might exhibit. This is not to say that we can be complacent in our own attitudes, but most certainly I saw nothing to indicate that we should either be fearful of the Japanese competition or overly suspicious of their position.

UNIVERSITY OF TOKYO

The University of Tokyo is recognized quite generally as being the most prestigious university in Japan. It was originally established as the "Imperial" university by decree of the emperor but, in more recent times, has become to be known by its less formal title with the crest on the main gate serving as the only reminder of its earlier status. The university is housed in a disparate and somewhat unconnected array of fairly old buildings. I spent the first part of my visit at the Institute of Industrial Science which is somewhat remotely located in a separate part of Tokyo from the main university campus. My host was Professor Sakaki who explained to me that the institute, while enjoying the full status of the university, is somewhat decoupled from teaching responsibilities. Its main function is research and, although the staff do teach to some degree at the graduate level at the main university campus, this is by far a secondary duty. Dr. Sakaki's group's work centers on MBE growth of a variety of semiconductors including AlGaAs and GaAs. Their main contribution has been in novel device structures. The most recent of these is the insulated gate HEMT (MISFET) which they have demonstrated with effective mobilities of approximately 27,000 cm^2/v-sec at 77 K using an anodic layer of Al_2O_3 for gate insulation. Mr. Hotta, an M.Sc. graduate student, described this work to be together with their studies on more conventional modulation doping. They have also proposed one-dimensional "wire" structures for high mobility applications, but have yet to implement such geometries. The most recent proposal for a high performance transistor is a velocity modulated device where carrier control is exercised by moving a fixed density of carriers between two regions of differing mobility. Such a device would be expected to be free from transit time limitations, and hence might operate in the subpicosecond range.

Given all these innovative proposals, it is somewhat surprising to me that during our discussions, the opinion was expressed that Japanese industry tends to be quite conservative. This, I think, is quite unlike the U.S. perception of the Japanese effort and was cause for some surprise on my part.

In addition to the FET work, this group is also involved in APD development and in quantum well-laser research.

Because of my interest in DLTS, I spent some time with Dr. Ikoma who is recognized in Japan as perhaps the primary authority on this technique. Dr. Ikoma feels that DLTS on the III-V compounds is complicated primarily by the complexity of surface trap effects and that great care must be exercised in extracting surface information from data. With this as a basis, it is consistent perhaps that he seems to be less excited than most with computer control of such experiments and prefers manual data handling if a real understanding is desired. He described his own current research which is primarily in using DLTS to study semi-insulating GaAs and InP. A scanned laser beam is used on a point-by-point basis to generate a current transient which is measured as a function of temperature. In such a way a spatial profile of the materials properties may be assembled.

The afternoon was spent with Professor Sugano at the main university campus. Despite his senior position and respected authority in the area of solid state device physics within the Japanese technical community, Professor Sugano's facilities were still extremely cramped. This apparently is standard policy in Japanese universities, where expensive new equipment is juxtaposed with seemingly obsolete museum pieces in cramped quarters. Despite this, the groups seem productive. Tokyo University is no exception and a broad range of interests were described to me. Particularly relevant is the plasma oxidation work that has been investigated by this group for a number of years, and which has been used to make a variety of MISFET structures on the III-Vs.

NIPPON TELEGRAPH AND TELEPHONE PUBLIC CORPORATION

My visit was to the Musashino Laboratory in a suburb of Tokyo and my host was Dr. M. Ohmori who heads the Compound Semiconductor Device Section. This group of 30 people has the objective of developing GaAs LSI circuits for a variety of application including:

- 1.6 Gbit optical communication circuits for mobile telephones,
- satellite communications related circuits, and
- high-speed computer components including multipliers and ALUs.

By far the largest portion of their recent effort involving 20 members of the group has been the development of static RAMs on GaAs. This work began in 1981 with the development of a 16-bit circuit, progressed to 256-bit and just recently they have demonstrated a 1k-bit unit based on E-D logic (DCL) which has an access time of 6 nsec with an extremely low power consumption of 40 MW. The final objective, due for completion in 1984, is a 1.6 nsec access time. This circuit, which is the largest RAM on GaAs reported to date, has 7084 devices (6 devices per bit + drive and readout), occupies a chip area of 3.3 x 3.3 mm and employs a novel self-aligned FET fabrication process with 1.1 to 1.2 micrometer gate length. This work will be reported at the GaAs IC Symposium in New Orleans in November 1982.

Although GaAs is grown at NTT with 2" and 3" diameter by both horizontal Bridgman and LEC techniques, they are presently using material obtained from Microwave Association, Cominco, and Sumitomo with a 0.1 to 0.4 specification weight ppm of Cr. A type conversion thermal anneal qualification at 830°C is performed which eliminates approximately 50% of the material. It is poor material quality, specifically nonuniformity, which I was told is the present limiting factor in their RAM process. Threshold control for them apparently is no longer a problem.

Dr. Ohmori as well as Dr. Kurumada and Dr. Ohwada of his group were very open with me in their discussion of their GaAs integrated circuit work and, just as in the U.S., they see competition between GaAs and submicron Si. From our conversation, it is evident that the arguments and justifications are the same in both the East and the West and at NTT, where there is also a large Si group working on circuits for 1.2 to 1.6 GHz applications on board satellites, a decision on GaAs *vs*. Si is apparently scheduled for 1984.

All present work has been done by conventional contact printing, but e-beam is under investigation for possible future use. Apparently, substrate charging is a problem that they find leads to serious pattern distortion.

The subject of the HEMT was raised, but although they have some good results in this area, they do not consider it a likely candidate in the near future for LSI because of the severe surface defect problem. Current performance in their discrete devices on GaAlAs/GaAs structures grown by MBE is $g_m \approx 140$ mS/mm and $\mu = 4000^2 cm^2$/v-sec at 300 K with $g_m = 280$ mS/mm and $\mu = 45{,}000$ at 77 K for 1.2 μm values of ℓ_g.

Dr. Y. Kato, who heads up the entire Device Development Division at NTT, had originally greeted me on my arrival at the laboratory where I was introduced to Dr. Furukawa, the head of the Special Section with responsibility for the insulated gate MIS studies. This was the central interest for my visit to NTT and I spent an informative, yet all too short, session on discussing MIS studies on the III-Vs with Drs. Furukawa and Minakata.

The MIS studies at NTT are on InP, InAs, and InSb and involve a total of six people. Since Dr. Kobayashi left to take a position at Osaka University, no work has been done on the quaternary although it is expected that InGaAs will be studied in the future. The main emphasis of this work is on the development of good dielectrics with Terman C-V analysis and a simple enhancement-mode FET structure being used for evaluation. Quite reasonably, I think, Dr. Furukawa identified drift as the most critical parameter in any MIS technology and their evaluation involves such a measurement on the FET together with g_m and $_{FE}$ together with an N_{SS} assessment from the capacitance measurements.

Their approach to solving (or attempting to solve) the drift question is twofold:

- low temperature growth, and
- high temperature processing.

The former I can understand; the rational for the latter escaped me, unless it is simply a matter of "covering your bets."

To accomplish the low temperature growth they have developed a novel "electron cyclotron resonance" (ECR) dielectric growth process which they kindly revealed to me prior to publication (I was not, however, privileged to see the equipment). Using this process they have grown Si_3N_4 and intend to soon look at other materials with this technique. For high temperature deposition on InP they are looking at boron nitride grown in a hot wall system at between 400° and 500°C in the presence of PH_3. They also have hot and cold wall CVD reactors for SiO_2 and $SiO_2 + N_2$ as well as Al_2O_3 and P_3N_4.

Quite frankly in the one hour I spent discussing this work, I became quite confused as to what dielectrics they are growing on which semiconductor and by what technique. It is clear, however, that, at least from what I was told in response to my question as to which is their "best" dielectric, they are taking the shotgun approach and, by their own admission, are trying to come up with new dielectrics in the hope that one will be "the one."

Because of some confusing and seemingly contradictory publications by this group, I asked them explicitly whether they felt the native oxide on InP was desirable for good interface properties. Despite the fact, which they openly admit, that some of their data is hard to explain, Furukawa told me that he felt that the native oxide was undesirable and should be removed and furthermore he felt with a leak-tight system and the proper etching that such a native oxide free interface could be obtained.

I was not shown much data, but what I did see clearly demonstrated that their control of the interface on InP is not yet optimum.

Although neither with this visit nor with Dr. Ohmori had a tour of their laboratory space been planned; on my request both laboratories were, at least in part, shown to me. What I saw demonstrated that much of the latest equipment is available in these facilities and, in fact, I was told that there is really no problem in getting what is needed. In fact, they are apparently being encouraged to buy U.S.-made equipment to offset all the Datsun and Toyota hardware crossing the Pacific. Notable omissions in viewing their laboratory areas included the processing space for the 1k-bit RAM and the device processing and ECP dielectric system.

My last visit was with the MBE group including Mr. Tarucha and the GaAlAs/GaAs work on MQW heterostructures and Drs. Ikegami and Asaki for the P containing compounds. This latter visit was particularly rushed because it had not been planned and was inserted at the last minute at my request. I did see, however, their system which they are using to grow InGaAs and InP for laser applications. The phosphorus held at approximately 300°C. In addition, they use Mn and Be for p-doping and Sn for n-type.

HITACHI CORPORATION

Hitachi is a large and diversified company supplying products ranging from consumer items such as microwave ovens and VTRs to heavy machinery such as turbines and locomotives to semiconductor components. After Fujitsu and NEC, Hitachi is the third largest producer of computers in Japan. My visit was to the Central Research Laboratory at Kokubunji, a suburb of Tokyo, which is one of five research laboratories in this company and the one devoted to development of new materials and devices as well as new measurement equipment and medical engineering and communications and information processing systems. The laboratory, established in 1942, employs some 1200 research and support personnel in two main buildings, and is devoted to maintaining a portion of the Masushima Plain which originally surrounded the Tokyo area prior to its industrial development.

My host for the day was Dr. Kiichi Ueyanagi who had arranged visits with a number of personnel involved in their GaAs IC and electrooptic circuit development programs. As at other laboratories, Hitachi also has a Si VLSI program, however, I sensed that the competition between these techniques was not a principal issue with GaAs being seen to be clearly preferable in certain applications. In particular, the central processing unit (CPU) and main memory of large computers is believed to be one very distinct application for this technology. To this end, a project aimed at a 1k-bit static RAM is also underway at this laboratory. Like NTT, this is an E-driver, depletion load design and is expected to yield a 1 to 2 nsec access time for 1 μm design rules. This is their principal IC project, but in addition, I was told that other projects are underway including the development of GaAs analog circuitry for automobile telephones where apparently the high potential data rates are necessary. All of this work involves something on the order of 30 people.

Their device technology is conventional involving the use of commercially available Cr-doped or undoped GaAs substrates, selective I^2 of Si for channel and contacts via a photoresist mask plus liftoff for metal definition. Postimplant anneal is performed uncapped in an AsH_3 atmosphere with the sample being placed face down on a dummy GaAs slice. Capped annealing has been tried and gives similar results. Anneal conditions leading to approximately 80% activation efficiencies are 850°C for 20 minutes. The main problem they confront is nonuniformity of starting material leading to carrier nonuniformity, and hence problems with their enhancement device thresholds. Although they are not employing it at present, because of the added complexity, they have devised a buried p-type implant, which helps overcome V_{TH} variations across the wafer. They provided me a preprint of this work which will be presented at the GaAs Integrated Circuit (IC) Symposium in New Orleans in November 1982. A further problem which caused them to be very interested in the InP MIS results is reaction between their Au/Pt/Ti gate metal and the GaAs during subsequent anneal cycles. This chemical reaction, which presumably would be suppressed in an MIS design, manifests itself in a variation in threshold voltages. This problem together with that of forward gate conduction in the MESFET leads them to believe that if the drift can be solved that an MIS logic technology would be far superior to the MESFET approach. I do not believe they said this simply because I was there.

In addition to the GaAs IC developments, there is a large push at Hitachi toward optical lasers, LEDs, and detectors, and some preliminary work on electrooptic integration.

Approximately 20 people are involved on visible laser development using double heterostructure GaAlAs/GaAs devices operating to 2 GHz and 1.3 micrometer buried heterojunction structures on GaInAsP. These are all made using LPE which in some of the devices involves as much as seven layers. Approximately ten people are also working on GaAlAs LED structures for use at 0.8 micrometer.

The long wavelength components are primarily for long distance fiber communications applications whereas their visible wavelength devices have varied applications including disc readout for the consumer and computer market as well as to replace the bulky He/Cd gas laser in their high-speed (20,000 lines per minute) optical printer (ironically, the day of my visit to Hitachi, the Sony Corporation announced the marketing of consumer laser readout digital disc records for the audio market).

Dr. Hideki Matsueda described their interesting electrooptic monolithic chip development combining a GaAlAs laser and photodetector with GaAs FET circuitry. Such monolithic circuits are of use for optical repeaters and intercomputer communication as well as for intercard communication within a computer which is presently accomplished using complex wiring patterns. The circuit they have built measures 600 x 1000 micrometers and consists of a laser diode for output together with a GaAlAs photodetector which monitors the laser and provides feedback control to maintain a constant output. The leveling circuit driver controller and laser driver circuitry are integrated on chip in GaAs.

This same group is also integrating a laser with two FET-driver transistors to provide an electrooptic (light out, current in) OR logic gate, which can also be operated as an AND gate by using subthreshold values of input.

My visit to Hitachi was marked by frankness and open discussion. I was shown their GaAs IC line without having to ask and got the overall impression that they were genuinely willing to discuss their work.

FUJITSU LTD.

The "SU" in the title of this company means "communications" and this is the basis of the Fujitsu Laboratories. However, a number of years ago, because of a perceived saturation of the communications field, a decision was made to diversify and as a result communications equipment now occupies a minor part of Fujitsu's operations with computer and computer-related activities taking the major share (approximately 60%) of their business. Fujitsu is, in fact, the largest computer manufacturer in Japan followed by NEC, Hitachi, Mitsubishi, Toshiba, and Oki.

My visit was to Fujitsu Laboratories, a wholly-owned subsidiary, devoted to research and development, located in Kawasaki and employing some 800 people. Although the total interests of this laboratory are diverse, my visit was limited entirely to the Semiconductor Division whose general manager, Dr. Takahiko Misugi, was my gracious and genial host. Although, throughout my visit to Japan I was always treated in a kind and hospitable manner, I believe my day at Fujitsu was the pinnacle, as many people from Dr. Misugi on down through the organization went to great effort to make my day informative and pleasant despite the fact that they were hosting a number of other people on the same day. I left this company with the feeling that I had seen everything they are doing in my field and that a frank, honest, and forthright exchange of information had taken place. As Dr. Misugi said, "if you were here to look at our VLSI process on Si you might not see what you came for, but in GaAs ICs and related optical devices we have no reason to hide anything."

The Semiconductor Division consists of 190 people divided into three main subgroups:

- GaAs devices and circuits,
- Si LSI,
- materials growth.

Most of the day was devoted to presentations followed by discussions of those topics mutually agreed to be of most interest to me. Approximately two hours at the end of the day was devoted to a laboratory tour that was extensive. I believe I saw just about all the relevant laboratory areas including being taken inside their GaAs IC/HEMT circuit process area.

Their materials growth capability is impressive including MOCVD, chloride transport VPE as well as MBE and LPE. No bulk material is grown at this laboratory with all InP and GaAs substrates being obtained commercially.

The MOCVD systems are used for the growth of GaAlAs and the LPE reactors, of which there were seven, are used for InP and GaInAsP. Sample size, using sliding boat methods in these latter systems, are approximately 2 cm x 3 cm with excellent uniformity and surface morphology for layers one micrometer and greater in thickness. The chloride VPE reactors are devoted to GaInAs and InP and, although not yet published, I was shown data on superlattice structures of five periods of GaAlAs/GaAs grown 120Å thick per layer with excellent uniformity and surface morphology using this technique.

Interestingly, there seemed to be a lot of rivalry between the MBE group and those using the other techniques with, what I sensed, was some resentment on the part of the non-MBE scientists. It was clearly pointed out to me that the chloride VPE method is well able to make superlattice structures and that the quality of the GaInAs is far better by this method than what can be accomplished by MBE. It was acknowledged, however, that there were some present limitations on the abruptness of the interface with the VPE. The MBE group has three machines (two Varian and one home built), one from Varian just having been received within the last two weeks. At present, they are using the MBE for GaAs and GaAlAs.

Electrooptic integration for communications and repeater applications is under study and specifically two circuits are being evaluated:

- a LED plus a FET driver are being integrated using GaAlAs on GaAs to convert a voltage to light and,

- a photodiode (Au Schottky on GaAs) is being integrated with a GaAs FET amplifier to convert radiation to a voltage signal.

They are also making multiquantum well (MQW) lasers which they intend, within the next year, to integrate with FETs for driver and control circuitry on chip. The use of GaInAs on InP for such electrooptic circuitry at longer wavelength is also of great interest and seems not to be done at Fujitsu primarily because they do not have the InP FET experience.

A number of characterization techniques are being employed to evaluate their material including photoluminescence, photoconductivity, DLTS and Rutherford backscattering which, surprisingly to me at least, they are doing using their 400 keV ion implanter He^+ beam. As it was pointed out to me, this is for better than a high voltage accelerator if you want fine depth resolution near the surface which is, in fact, what is generally required by the semiconductor industry. Most certainly if you have three ion implanters, as does Fujitsu, you can certainly devote one part-time to this task.

It is well-known that the Japanese government has initiated a "supercomputer" project with three device options being considered: The GaAs NESFET, the GaAs HEMT, and Josephson junctions. Fujitsu has aggressive programs in the Semiconductor Division in both the MESFET and the HEMT and work in these areas was discussed during my visit. Fujitsu, in fact, has played a pioneering role in the HEMT development and although present work is restricted to the GaAlAs/GaAs structure, they have a direct interest in the InGaAs/InP modulation-doped combination. Work is expected to begin soon on this alternative using the chloride VP transport.

All of the high-speed device work is under the direction of Dr. A. Shibatomi who, after Dr. Misugi, took me directly under his wing and guided me kindly and competently through this very important research area. Dr. N. Yokoyama described the GaAs IC development. For LSI, they believe dimensions must be no greater than one micrometer with a compatible size of two micrometers having been chosen for all their circuits. They also use the self-aligning gate process developed at Fujitsu. Using this they have built a 4 x 4 multiplier with a multiply time of 3.7 nsec, a figure five times as fast as Si circuitry of the same gate length. They have also built a 1k-bit static RAM (everyone seems to be doing this) with a 4 nsec access time which is comparable to Si, but at 68 MW power which is one order of magnitude less than Si.

They have also completed a 6 x 6 multiplier circuit employing 600 gates on a 2.1 mm x 2.6 mm chip. These results will be presented in New Orleans in November 1982.

The HEMT work is under the direction of Dr. Abe, who clearly believes that this device is going to beat out all competitors. He may be right, but the GaAs MESFET group is quick to point out that although superior at 77 K, at RT, the HEMT is no better than their self-aligned MESFET as measured by propagation delay. Using approximately 700 Å and 500 Å of GaAlAs doped to approximately 10^{18} cm^{-3}, they are making both the depletion and enhancement structure, respectively, using MBE. E - D RO structures with 1.7 micrometer gate lengths have given 57 ps delay at 300 K and 17 ps delay 77 K. Using 1.1 micrometer gates these values reduce to 17 and 13 ps, respectively, which compares to a 300 K value of 50 ps for the MESFET. With 0.5 micrometer gates, they get g_m values in discrete devices of 380 and 400 ms/mm respectively at 300 and 77 K. Although very impressive, the value at reduced temperature is apparently not larger because of contact resistance problems. It is also believed that velocity saturation effects are limiting at the lower temperatures. Similarly, the cutoff frequency, f_T, of 35 GHz obtained for this 0.5 micrometer device at RT is not as high as the large g_m might lead one to suspect because apparently the gate C is approximately a factor of two larger in these HEMTs compared to a MESFET which tends to cancel the 2x gain in g_m. Using lower doped GaAlAs is proposed as a possible means to reduce C.

The supercomputer project is due to decide between the various options in 1985 with system completion scheduled for 1990. Dr. Misugi told me his opinion which is that the Josephson junction is not going to make it. He also feels in the short-term the GaAs FET is the only possibility. Longer-term systems may well be based on the HEMT, however.

NIPPON ELECTRIC COMPANY (NEC), LTD.

NEC's Central Research Laboratory is located close to Fujitsu, just outside Tokyo in the city of Kawasaki. The laboratory houses approximately 700 people involved in research in a wide variety of subjects related to computers and communications (C&C in the jargon of NEC).

My host for the day was Dr. Nobuo Kawamura who had very kindly arranged a comprehensive visit with a number of groups in the laboratory involved in work related to my interests.

Dr. Asamitsu Higashisaka, who supervises the GaAs FET device and circuit development first described to me their MESFET program which in contrast to the work at Fujitsu on a self-aligned gate relies rather upon a "close-spaced" configuration of the gate to the channel electrodes. Typically, they employ a 1.2 micrometer-long gate which sits 0.4 micrometer equidistant from both source and drain. Using contact lithography, they accomplished this fine geometry with an automatic registration process which relies on a wet chemical overetching of an Al metallization. This close spacing of the electrodes reduces significantly the parasitic source and drain to gate resistances which result in a more typical MESFET from the significant surface depletion of the ungated source-to-drain regions. The result of this geometry change is an increased frequency response and a reduction in power because of elimination of the parasitic I^2R losses. The increased electrode parasitic capacitances in these close-spaced structures does not appear to be limiting because presumably the primary contribution to the capacitive coupling comes from the gate depletion layer.

Using these devices, E - D design RO, and flip-flops have been made with the latter operating to 2.2 GHz. Once again the limit is set by materials variability (standard derivation in V_{TH} being approximately 54 MeV) in the commercially obtained 1.06 to 1.5 wt ppm Cr-doped substrates. In hopes of alleviating this problem they are presently preparing to grow their own bulk substrate material.

In addition, these devices are also being incorporated in their GaAs digital IC FM demodulator circuits which uses buffered FET logic (depletion FETs) at present and has a complexity of approximately 70 devices. Prescalers are also being fabricated, but at present none of their circuits are being employed in any specific application. In addition to their digital designs, Dr. Kazuhiko Honjo described their analog GaAs circuit developments which include a broadband amplifier operating over the 10 MHz to 4.0 GHz band for mobile telephone use in automobiles and a low noise amplifier for satellite broadcasting at 12 GHz. At present, the broadband design seems quite satisfactory with 16 dB of gain at a power of 170 MW and an NF < 3 dB being achieved over most of the band. The narrow band circuit is, however, not meeting the noise specifications with a 4.1 dB NF being approximately 1.0 dB too high.

Drs. Ohata and Itoh described for me their work in new devices where, for example, they are using a layer of either high resistivity O-doped or n^+ GaAlAs as a buffer on the SI GaAs for MESFET applications. They intend also to look at the HEMT using GaAlAs on GaAs as is being done at Fujitsu as well as GaInAs on InP. This is presently awaiting the growth of the ternary starting material. Of particular interest to me is the work of this group which began in 1980 on the InP MISFET. As pointed out by Dr. Itoh, InP when compared to GaAs would seem to offer the advantages of:

- higher electron velocities,
- lower ionization coefficient, and
- higher thermal conductivity as well as the now well-demonstrated superior surface properties.

Based on this, as well as their own previous work, this group has fabricated 0.8 micrometer gate length self-aligned enhancement devices using VPE n^+ material for the channel contacts and CVD SiO_2 grown at 350°C for their gate-insulator as well as for the aligning pattern. The details of their process will be presented at the GaAs meeting in New Orleans. However, they did describe the structure which is illustrated in Figure 1.

Using this approach they have seen g_m values for enhancement devices of 220 ms/mm which, apart from the HEMT, is the highest value reported for any device. This value of g_m apparently implies a room temperature value for V_{SAT} of 2.5×10^7 cm/sec which again is the highest value yet reported.

Although they were not willing to divulge the details of their surface pretreatment, they did say that it seems not to be critical to the performance of the device and further, if I understood what was said, that a minimum amount of surface pretreatment is to be preferred. Power gain measurements on these devices show some variation with roll-off being typically between approximately 3 and 6 dB per octave. The better devices show values of approximately 7.0 dB at 12 GHz and 13 dB at 4 GHz with the best devices giving an extrapolated f_{max} on the order of 50 GHz.

As yet they have not made D-FETs although this is planned. They have, however, overdriven their E-FETs to assess the use of such devices for high power applications, and I sensed they were very encouraged by their results and think this may be a fruitful area of application for MISFETs on InP. The values they obtained were 1.17 W per mm of channel width with a power added efficiency of 39% being observed at 6.5 GHz.

As yet no InP devices have been made using ion implantation although, they see the benefits of this approach and intend to use it in the near future. They do, however, use I^2 in the processing of their GaAs devices and this aspect of their technology was described to me by Dr. Hideaki Kohzu who manages this program. Perhaps one of the most interesting aspects of their process is that they activate their $^{32}S^{+}$ implants (believe this is better than Si for n^{++} implants.) using a fast, approximately two second, anneal in a lamp system where the sample is heated from both sides. The anneal temperature of 950°C is reached in approximately ten seconds with the sample being placed on a Si support with a thermocouple being attached to a dummy Si wafer to monitor the thermal cycle. Using this technique, they have obtained 75% activation of 150 keV implants with reduced spreading of the carrier profiles resulting in some 20 to 30 improvements in device g_m values. Their plans are to extend this to InP in the near term.

Although they have not as yet done any fabrication of HEMT devices they are planning to do so and although they have recently obtained an MBE system for GaAs and GaAlAs, this seems to imply that their MOCVD process is preferable. The main problem of the latter technique for modulation doping, they believe, lies in the high (15Å/sec) growth rates which limit the abruptness of the junctions they can achieve. Theirs is an atmospheric system, however, and they think that the problem may be less severe at low pressures. Based on this they have developed an "MO chloride" system which they believe, will combine the high purity advantages of chloride VPE with the superior controllability of MOCVD.

SUMITOMO ELECTRIC INDUSTRIES, LTD.

Sumitomo is a well-known business name in Japan and overseas. Most of these companies, although now independent entities, are originally descended from one company of this name. Sumitomo in Itami, on the outskirts of the industrial center of Osaka, is one of three separate plants comprising Sumitomo Electric Industries which is involved in a large variety of manufacturing operations including electric cables and brake pads for automobile use as well as the semiconductor materials with which we shall be concerned. Of the approximately 9000 employees of this company, 3000 are located at Itami and of these, 200 are involved in the III-V compound materials growth. The Itami operation is production with some developmental work. The related research is done at the Osaka plant. The third plant is at Yokohama.

My host for the day was Dr. Yasuhiro Nishida, who I knew from previous meetings. He is the manager of their Engineering Section which has responsibility for the competitive production of a variety of III-V bulk and epitaxial materials to meet consumer demand. In viewing their facility, I became convinced that if not the largest, this effort must be one of the largest devoted to these materials. Most certainly there is no III-V production capability of this magnitude in the U.S. For example, I was shown 50 horizontal Bridgmann reactors which operate on a continuous basis for the production of low EPD GaAs wafers. (LEC gives higher EPD.) Taking one week to complete a run, these units can produce up to 3" diameter-cut circular wafers oriented (100). Most demand at present is apparently for the 2" size however. In addition, I was shown their pressure LEC pullers (of which they have ten) with four being used for GaAs and two for InP (SI and n-type). They are also growing InAs although the demand here is not too great.

All their epitaxial processing is by the VPE trichloride method, although an MBE reactor and an MOCVD system are in place in their Osaka research laboratory. GaP, for visible wavelength emitters, GaAs for visible LED and laser devices, and GaAs and high resistivity buffers, grown sequentially in the same reactor, for FETs are all being marketed. The FET material, for example, is grown ten wafers at a time in a vertical reactor in which the samples are rotated to ensure uniformity. I was told that the vertical system is safer than a horizontal system.

All of this production capability is apparently barely keeping up with demand and for the last few years they have, in this area, been experiencing a phenomenal 50% growth rate. They expect this to continue with most of the demand being, at present, for the GaAs. The InP worldwide demand is apparently just approximately 5 to 7% of their GaAs sales which corresponds to 300 to 400 sq. inch a month primarily for the n^+ material for substrates for optical devices.

I particularly questioned them concerning their InP wafer polish which in the past, although of very high quality, has been mechanical and in our experience unsuitable for direct electrical device fabrication. They assured me that they were initiating chemical polishing of their wafers which they expect to be commercially available early in 1983. Apparently this has been catalyzed by a number of complaints they have received from some of their customers. Surprisingly their reluctance to do chemical polishing has in part been due to the Japanese government restrictions on the disposal of methanol.

My concern with the purity of available SI InP was shared by my host and by Dr. Masaaki Sekinobu, their R&D manager. They assured me that Sumitomo most certainly thinks InP is going to become far more important in the future and thus must be prepared in a more pure form. They do have spark source mass spectroscopy and have recently obtained a SIMS machine which they have used to characterize the Fe and other impurities in SI InP. The figures they showed me looked promising with their total impurity density by SSMS being approximately 10^{16} cm^{-3}. The net donor concentration is low enough, at present, that they believe an Fe concentration slightly less than 10^{16} cm^{-3} is sufficient for good SI properties.

UNIVERSITY OF HOKKAIDO

The University of Hokkaido, located in Sapporo, is some one and one half hours by air from Tokyo and this, by Japanese standards, is quite remote. The distance is perhaps highlighted by the fact that the geography of Hokkaido, the northernmost of the Japanese Islands, while similar to the main island of Honshu in being quite mountainous, nevertheless differs markedly over much of its area by virtue of its relatively large, and hence arable, level regions. Farming thus takes on some of the characteristics of the American Midwest with wide open spaces of relatively large fields when compared with the small cultivated plots of land typical of most of Japan.

The University of Hokkaido, originally an agricultural college, now boasts a substantial technical faculty in both the sciences and engineering.

My visit was hosted by Professor Hasegawa whom I have known for a number of years from contacts at many technical meetings. His interests at the University encompass both Si as well as III-V compounds including both GaAs as well as InP and the ternaries and involve both materials and device studies.

Although they have had LPE work on high resistivity GaAs and InP for some time, this has now been abandoned because of their limited success in achieving the desired resistivities and their primary materials growth effort is in MOCVD. Dr. Ohno is responsible for this work which will be addressed primarily to the growth of GaAs and GaAlAs. The system is expected to be operational within a few months and will be used, in part, for the fabrication of hot electron and superlattice structures including HEMT devices. This work ties in with the government program on "nanometer devices" involving 20 universities of which Professor Hasegawa's group's contribution is in surface effects.

Their materials characterization capability includes DLTS as well as a novel microwave and optical technique for the impurity profiling of Cr-doped GaAs. The method relies on the generation of excess carriers optically whose density is then determined from a 1 GHz microwave measurement of the resulting conductivity change of the sample. This change is inversely proportional to the Cr concentration and thus permits for a noncontacting method of profiling the sample. Because the resolution is determined by the size of the light spot, it can be very high although in the present case they have restricted themselves to 1 mm. The technique has been applied to (100) wafers cut from (111) oriented horizontal Bridgeman boules of GaAs although it is expected to be equally applicable to InP.

The principal III-V device work of the group has been in MISFETs using anodic oxide layers for gate insulation. Most recently this work has resulted in the development of such an enhancement device on semi-insulating InP exhibiting an apparent effective mobility on the order of 3000 cm^2/v-sec. This is the largest value reported anywhere to date and was achieved using a double layer oxide consisting of an approximately 1200Å thick anodic layer of Al_2O_3 formed from Al plus a thin approximate 100Å underlying layer of native oxide followed by a 400°C anneal for 30 minutes. It appears that the native oxide component is essential for achieving the high mobilities reported and also leads to reduced values of drift in these structures. Mr. T. Sawada described to me how it is formed by illumination of the insulating substrate following termination of the Al oxidation which permits for additional oxide growth from the InP under the overlying and encapsulating Al_2O_3. Whatever the details of the benefits of this process, and these are not at present understood as Professor Hasegawa is ready to admit, it is evident that the process is beneficial and may lend credence to the claims recently expressed in the literature for the importance of the native oxide in the formation of good surfaces on this semiconductor.

Although preliminary, such devices, made with semitransparent gates, have shown photoconductive gains as high as 10^4. In addition, masks are being procured to allow fabrication of simple inverter structures using these high mobility devices.

Some preliminary FET results on thin n-layers of LPE InGaAs have given enhancement-mode mobility values of approximately 1000 cm^2/v-sec. Although not as high as those reported by other groups, it is felt that further work will lead to improvements in this area.

In addition to the III-V work, this group also has an interest in Si solar cell applications. Such devices are being made in an MIS configuration using annealed anodic oxides on both polycrystalline and amorphous as well as Si crystal material. The Si is prepared by CVD and the oxide process, which involves a 30 minute 450°C anneal in H_2, results in a high quality interface with N_{SS} values $<10^{11}$ cm^{-2} eV^{-1}. They feel these devices will be competitive which is not likely to be the case with compound semiconductor cells because of their high cost.

ELECTROTECHNICAL LABORATORY (ETL)

The Electrotechnical Laboratory is the largest national research organization in Japan specializing in electronics. Coming directly under the jurisdiction of MITI (Ministry of International Trade and Industry) this laboratory, much like the DoD facilities in the U.S., has, in addition to its own internal research, responsibility for advising the government on technology options and on monitoring research and development programs in industry. When we hear of coordinated government programs in Japan involving many different laboratories on some topic such as, for example, the case three or four years ago on GaAs MIS developments, then it is ETL which is the agency directing this coordination. In 1981, ETL relocated at Tsukuba City about 35 miles (and a one and one half hour train ride) northeast of Tokyo. This "Science City," which was begun in 1966 is, so far, the home for 43 research and educational institutions including Tsukuba University as well as the site for housing developments and facilities for the more than 130,000 people in the area. When completed, it is intended that many private industries will also be located in the immediate vicinity. Tsukuba Science City has been planned and built by the government for the purpose of better undertaking research and educational activities in a comprehensive and organized manner. In terms of its concentration of high-level research personnel it in many ways resembles "Silicon Valley" in the U.S.; although in terms of government organization, the North Carolina Research Triangle development is perhaps a better comparison.

In light of its recent genesis, it is not surprising that what I saw of Tsukuba was new. ETL is no exception and although much of their equipment was brought with them when they moved, the overall impression is pleasantly one of newness.

The Electrotechnical Laboratory employs some 730 members at an annual operating budget of $39 million. Its functions cover the area of solid state physics and materials, information processing, energy and standards and measurements. It is directly involved in and responsible for six national research and development projects, viz: solar energy, effective energy utilization, ultra high-speed computers, optical instrument operation and control, manufacturing and "next generation" laser applications to industrial standards development.

I was invited to visit ETL by Dr. S. Kataoka, who is head of the Electronic Devices Division. Unfortunately, on the day of my visit he was called out of town on business and thus our time together at the laboratory was brief. In his absence, Dr. H. Hashizume, who has responsibility for their GaAs device and circuit program, acted as my host. Their main effort in this area, at present, is in assessing the short channel limitations on this high-speed circuit technology. At present, their work has primarily addressed Monte Carlo modeling of such submicron structures from which they have concluded that 600 ms/mm of gate width should be possible for 0.25 μm design rules. This very large g_m because of ballistic effects, results from a carrier velocity of near 10^8 cm/sec, a value one order of magnitude above that achievable in Si. Using e-beam techniques in a converted SEM it is hoped to demonstrate such values in actual structures although somewhat larger devices made, so far, have been less successful than the modeling would predict.

Insulator studies on InSb have been addressed in the hope of developing a CCD-type device for signal processing at 77 K right at the optical detector. Their results seem to suggest the native oxide is beneficial at least when anodization or sputtering is used for the deposited dielectric. Some preliminary 4-phase, 4-bit structures have been made although electrical results, so far, are disappointing.

Analysis capabilities include Rutherford backscattering using an ion implanter beam much as was described to me at Fujitsu.

Interestingly, in addition to their advisory and monitor role, my impression of ETL was in other ways reminiscent of government in-house research in the U.S. They certainly felt they cannot, nor should they, compete with industry. Just as in the U.S., it seemed that a great concern was to identify projects and directions (perhaps high risk) where they could supplement and not be outpaced by the much larger industrial programs. In one respect, however, there did seem to be a difference and that was that salaries seemed to be decoupled from projects in contrast to the U.S. where a persons on-going employment, at least in theory, is tied in large measure to the continuation of the work.

YAMADA SCIENCE FOUNDATION: A VISIT TO JAPAN

Gertrude Scharff-Goldhaber

INTRODUCTION

The Institute for Nuclear Study (INS) International Symposium on Dynamics of Nuclear Collective Motion, was held from 6-10 July 1982, at Lake Yamanaka at the foot of Mt. Fuji. This conference was in effect a sequel to the International Conference on Band Structure and Nuclear Dynamics, held from 28 February-1 March 1980, in New Orleans, whose proceedings were published in *Nuclear Physics* A347 (1980). In addition to participating in the conference, I visited:

- the Research Center for Nuclear Physics (RCNP) at Osaka,
- the Institute for Nuclear Study (INS), University of Tokyo,
- the National Laboratory for High Energy Physics, [Koh Enerugiibutsurigaku Kenkyusho (KEK)] at Tsukuba,
- the Japan Atomic Energy Research Institute (JAERI) at Tokai,

CONFERENCE

Dr. H. Ikegami of the Research Center for Nuclear Physics (RCNP), Osaka University, who had joined our Nuclear Structure Group at Brookhaven National Laboratory (BNL) in the early sixties, informed me that the Yamada Science Foundation was willing to sponsor my trip. Simultaneously, he suggested that in addition to participating in the conference I visit a number of research laboratories in Japan, besides his own. I was invited by Dr. Naoki Onishi (INS), Chairman of the Organizing Committee of the Symposium, to deliver a talk at the conference which I entitled, "Relations between the Variable Moment of Inertia (VMI) Model and the Interacting Boson Model (IBM)."

The conference indeed provided a great deal of information on developments which had taken place after the 1980 New Orleans Conference, and many of the speakers were the same. The topics dealt with there fell essentially in three groups, namely,

- nuclear properties at and near the nuclear ground state, including the yrast band,
- classification of band structure and selection rules for interband transitions at relatively low excitations, and
- nuclear properties at high spin states, including the γ-ray continuum at very high excitations.

Japanese physicists, both in theory and experiment, were well represented at the conference.

DISCUSSION ON LABORATORIES AND LABORATORY VISITS

Three of the laboratories I was to visit, INS, RCNP, and KEK, were established by universities. Two of them bear a genetic relationship to each other since the scientists at INS, established in 1955, planned the establishment of RCNP, which was approved in 1970 and completed in 1977. The third laboratory, KEK, had its origin in the decision of the Science Council of Japan in 1962 to construct a large accelerator. After a basic study, the Laboratory for Elementary Particles was established in 1971 as the first Interuniversity Research Institute; in 1976 acceleration to 12 GeV was achieved, and research began in 1977. Finally, the fourth laboratory, JAERI at Tokai, which is the largest of the Japan Atomic Energy Research Institutes, was established by the Ministry of Science and

Technology in June 1956 for the purpose of "contributing fully to atomic energy research, development, and utilization." (Strong efforts were made to facilitate as much as possible scientific exchange between the staff members of the institutions I visited and myself.)

INSTITUTE FOR NUCLEAR STUDY (INS)

The predecessor laboratory of INS was that of R. Sagane's laboratory at the University of Tokyo. Dr. Sagane was the son of the atomic spectroscopist, Dr. Nagaoka, who in 1923 discovered hyperfine structure in the spectrum of mercury from which W. Pauli deduced in 1924 the existence of the nuclear spin. In 1937, Dr. Sagane spent a year at the Cavendish Laboratory in Cambridge, England, where he studied radioactive isotopes induced by high energy γ-radiation, resp. neutrons, from Rd Th, resp. from Rd Th-Be sources. Then, after the war, he went for several years to Berkeley where he became acquainted with the cyclotron. Before the war, Dr. Sagane inspired his student, M. Sakai, to build a special type of electron spectrometer with a large solid angle named Spiral Orbit Spectrometer (SOS). Dr. Sakai continued this project after the war. Since then, spectrometer design for charged particles has been one of the main interests of Japanese nuclear physicists. Dr. Sakai himself studied from 1951 to 1953 at the Institut Curie in Paris, at Kistemaker's laboratory in Amsterdam where he was introduced to isotope separation, and at K. Siegbahn's institute in Stockholm, where he became acquainted with the $\sqrt{2}\,\pi$ double-focusing spectrometer. He then joined Kurbatov's laboratory at Columbus, Ohio, where he was introduced to radiochemistry, electronics, and γ-γ coincidence and angular correlation measurements. Soon after his return to Tokyo and the founding of INS, whose first director, S. Kikuchi, was the discoverer and interpreter of the "Kikuchi lines" in electron diffraction patterns, Dr. Sakai was named associate professor. He was given the task of designing a large isotope separator which was built by Hitachi Limited, and of establishing a research group for the study of nuclear spectroscopy. He decided to build a sector-type double-focusing spectrometer. In this endeavor, H. Ikegami, a young assistant, was of great help. Soon afterward, T. Yamazaki, a second assistant, joined the group, and within the next few years "the three musketeers" made important contributions to charged particle spectroscopy and to the study of radioactive isotopes.

Dr. Sakai has recently retired upon becoming 60 years old, after serving 10 years as Director of INS. On this occasion he wrote his autobiography, which provides interesting information on the "heroic" period of nuclear physics. Dr. Sakai's last project, a Numatron (meaning; Nuclear-Matter-Tron) concerns an accelerator capable of producing heavy ions of several GeV/nucleon.

Dr. Ikegami left INS to work for two years at Brookhaven National Laboratory (BNL) in 1963 and was replaced by H. Ejiri. In 1964, Dr. Yamazaki left for Lawrence Berkeley Laboratory (LBL) in Berkeley, whereupon M. Ishihara joined the group. All these younger physicists have become important in nuclear and high energy physics research in Japan. Dr. Ikegami is now a research professor at RCNP. He has designed an ingenuous charged particle spectrometer (RAIDEN) cable of high resolution which yields very beautiful results in nuclear spectroscopy, and Dr. Yamazaki, now a professor at Tokyo University, studies muon spin phenomena at KEK.

Dr. Kunio Nagatani, previously of BNL and Texas A&M University, accompanied me to INS, where I met Dr. Hayakawa, who had participated in the discovery of the 1+ state in ^{208}Pb. I was received by Dr. Sugimoto, the new Director (since 1978) of the Institute, who expressed his disappointment on having just been informed that the "Numatron," planned and prepared for since 1976, in the near future at least, would not receive construction funds.

Several fine nuclear physics experiments are being carried out at INS. Recently, Tooru Kurihara carried out a $^{208}Pb(\alpha, {}^{6}He)^{206}Pb$ experiment, using 109 MeV alphas, which permitted the establishment of several new states in ^{206}Pb. The air core beta ray spectrometer built in 1967 has been considerably improved in order to carry out a precise measurement of the neutrino mass from tritium decay, or at least of its upper limit.

From the beginning a series of cyclotrons were constructed at INS. Now, most research is being carried out with the SF cyclotron, a three-sector, single dee type machine, which was completed in 1973. It permits the use of polarized beams and heavy ion beams as well as high-quality light ion beams. Both solid and gaseous ions are accelerated. Proton beams of 48 MeV are produced. Further, a 1.3 GeV electron synchrotron has been available since 1966, which allows experiments on photopion production from a nucleon, etc. At 300 MeV, electrons are injected into an electron storage ring for the production of synchrotron radiation to conduct studies in condensed matter physics.

JAPAN ATOMIC ENERGY INSTITUTE (JAERI)

At the Japan Atomic Energy Institute (JAERI) located at Tokai, the largest of the atomic institutes, I gave a talk to the nuclear physicists on "Pseudomagic Nuclei." Dr. Shikazono gave me a detailed tour of the Tandem Laboratory (built between 1975 and 1979). The Tandem, a vertical machine, 45 m high, has a terminal voltage variable between 2.5 and 20 MeV, and is capable of accelerating ions of $1 \leq A \leq 240$. It was built by the National Electrostatics Corporation (NEC) in the U.S.A. The Tandem is equipped with four different types of negative ion sources, to be used for continuous operation, and with a duo plasmotron positive ion source for the production of intense beams of pulsed protons or deuterons, mainly used for pulsed neutron work. Twelve beam extension tubes, leading to five target rooms, are available for experiments. Two computers, PDP-11/04 and PDP-11/55 serve for data acquisition and a PDP-11/70 is available for data analysis. A heavy ion TOF spectrometer serves to identify reaction products with $A < 80$ and a kinetic energy <10 MeV/amu. Dr. M. Ohshima reported to me on an experiment carried out by him and his associates on the high spin states of ^{167}Er, which were studied by γ-γ coincidence, angular distribution, and directional correlation measurements. Three new states ($21/2^+$, $23/2^+$, and $25/2^+$) were thus established. It appears that the instrumentation at the Tandem is excellent but that the planned research concerning the investigation of high spin states is still in a beginning phase. I had met one theorist, Dr. Otsuka, two years earlier at Erice. He is a coauthor of A. Arima on papers relating to the Interacting Boson Approximation (IBA). He appears to be the only nuclear theorist at the Tandem Laboratory.

From the top of the Tandem Van de Graaff tower I was given, an overview of the multipurpose laboratory at Tokai. The laboratory includes a Reactor Safety Research Center, a Fusion Research and Development Center, and a large Nuclear Data Center which cooperates with the International Atomic Energy Agency (IAEA) in Vienna.

NATIONAL LABORATORY FOR HIGH ENERGY PHYSICS (KEK)

Dr. Kasuke Takahashi gave me a tour of KEK with its 12 GeV Proton Synchrotron and its associated beam lines, including the fast extracted beam which was used for bubble chamber experiments yielding about five million pictures which led to valuable results before the bubble chamber was shut down. A sizable part of the pictures still awaits analysis. The physicists who work there include at least one American, Dr. George Igo of the University of California, Los Angeles, and many Japanese physicists from other institutions.

I received a detailed tour of the layout for the Tristan project, a 25 GeV e^+e^- collider (Phase I) as well as an electron-proton collider (Phase II). It is hoped that the missing sixth quark referred to as "top quark" will be discovered at Tristan, after the electron energy has been increased to a considerably higher value, as planned.

I also received a detailed description of the plans for the experiment on proton decay which is to be carried out in the Kamioka Mine some 300 km west of Tokyo, ~1000 m below the top of the mountain. I was shown the enormous (20") phototubes, specially developed and produced by the Hammamata Company, 1100 of which are to be installed. Experiments are to begin toward the end of 1982.

RESEARCH CENTER FOR NUCLEAR PHYSICS (RCNP)

Dr. Ikegami and I visited RCNP, Osaka, where I was introduced to Professors Kondo (Director of the Institute) and Dr. Ogata, who gave me a brief tour of the RCNP AVF cyclotron capable of producing up to 65 MeV protons. (Dr. Kondo had spent some years during the 1960s at the University of Colorado, while Dr. Ogata had spent about a year at Rutgers University.) The cyclotron is mainly used for (p,d) and inelastic proton scattering experiments. The secondary protons or deuterons are analyzed by means of an excellent spectrometer built by Professor Ikegami and associates which has a resolving power of $E/\Delta E \simeq 10^4$. With this equipment very interesting studies of excited states, especially hole states, in semimagic and doubly magic nuclei have been carried out, such as in Ni and Sn isotopes, in ^{40}Ca and ^{90}Zr. Also studied were levels in odd A Se isotopes, g-factors in ^{192}Pt and ^{194}Pt, and, quite recently, a 1+ state at 5.845 MeV in ^{208}Pb was established by inelastic scattering of 65 MeV protons in a very fine experiment by S. I. Hayakawa, *et al.* The resulting report has been submitted to *Physical Review Letters*.

Following the tour of the cyclotron, I gave a seminar on the variable moment of *inertia (VMI) model, including the discovery of pseudomagic nuclei.*

ADDITIONAL LABORATORY VISITS

At Professor Ejiri's laboratory at the University of Osaka, he and his associates carry out experiments on nuclear de-excitation in the continuum region in rare-earth isotopes. Also, various experiments on double beta decay as well as on the establishment of neutrino mass differences are planned.

At the Physics Department at Tokyo University, I was accompanied by Dr. Steven Yamamoto, who had been at Brookhaven National Laboratory (BNL) in the late '50s. He is carrying out relativistic proton scattering studies at KEK. Drs. T. Yamazaki and S. Nagamiya, members of the same department, also work mainly at KEK. Dr. Nagamiya was until recently at Lawrence Berkeley Laboratory, working at Bevalac on particle correlations in high-energy nuclear collisions, in which the concept of a "hot spot" in the target nucleus is important for the analysis of the data (see *LBL Reports* 14032-35).

COMMENTS

My whirlwind tour through Japanese nuclear and particle physics laboratories left me with the following impressions: Since the "heroic" postwar period during which Dr. Sagane and Dr. Sakai reestablished bridges with Western scientists, a second generation of leaders (now in their forties and fifties) has grown up. They are extremely hard working, knowledgeable, and experienced physicists who collaborate in planning the future of their research. They are generously supported by their government and by Japanese industries, both large and small, who have the wisdom to realize that basic research is essential for the economic well-being of their country. Some of the new leaders in research had chosen to work abroad (where they had been given well-supported positions) but were, in recent years, persuaded to return to Japan. Although they may have paid a price in terms of material well-being, they felt they would have a chance to make more significant contributions to physics in their country of birth. Others may still follow suit.

I have one strong objection to the present system, namely, to the almost complete lack of support for women scientists. In spite of the tradition that the place of a married woman is in the home, there are now a few women who have become respected physicists and whose husbands would like them to obtain positions, but so far with little success. I am referring to Dr. Sugawara-Tanabe, who was invited to give a talk at the Mt. Fuji conference; Mrs. Otsuka, who has been invited to work with Dr. Ginocchio at the Los Alamos Scientific Laboratory during this summer; and Dr. Masuko Shima, who after many years of waiting, is now at the National Science Museum at Tokyo although her international reputation is attested to by the fact that she is only the third woman representative within the 60-year history of the important subcommittee on isotopic abundances of IUPAC, following in the footsteps of Marie Curie and M. Perey who served in the thirties and forties. I believe that Japanese physics would gain a great deal if women were allowed to join its ranks.

In closing, I should like to express my warm thanks to the Yamada Science Foundation for having given me a splendid opportunity.

INTERNATIONAL SYMPOSIUM ON CARBON

Jim Zimmer

INTRODUCTION

The International Symposium on Carbon: New Processing and New Applications was held in Toyohashi, Japan on 1-4 November 1982. This was the second international carbon conference sponsored by the Carbon Society of Japan, the first being held in 1964. The number of attendees was 353 with 51 from overseas. A total of 148 technical papers were presented in both oral and poster sessions. The organizing committee included:

- Professor H. Honda, Science University of Tokyo. Chairman,
- Professor T. Tsuzuku. Nihon University, Vice-Chairman,
- Professor S. Otani, Gunma University. Secretary-General,
- Professor H. Suzuki, Tokyo Institute of Technology, Treasurer
- Professor Y. Sanada, Hokkaido University, Technical Program Leader, and
- Professor M. Inagaki, Toyohashi University of Technology, Local Arrangements Leader.

This committee deserves commendation for the well-run and technically informative symposium.

Carbon is a unique and important material. Its many uses include polycrystalline graphite for electrodes in steel and aluminum making and for the moderator in gas-cooled nuclear reactors, carbon fibers for the reinforcement and strengthening of polymers for such applications as sporting goods and airplane components, and carbon materials for endoprosthetic joints and dental implants. The topic areas of this symposium were as follows:

- New Processing

  raw materials preparation
  mesophase control
  manufacturing methods
  characterization and design

- New Applications

  nuclear carbon
  carbon fiber
  intercalation compounds
  biocarbons and potential uses

- Fundamentals

  physics
  chemistry
  technology

The technical presentations covered all aspects of carbon technology from basic research to industrial applications, as exemplified in the plenary lectures presented:

S. Ootani Gunma University Japan	Development of carbon technology in Japan
K. J. Huttinger University of Karlsruhe West Germany	Carbon materials for endoprosthetic joints
H. Juntgen Bergbau-forschung GmbH West Germany	Basic reactions and technical performance of coal gasification and liquefaction
B. T. Kelly United Kingdom, Atomic Energy Authority England	The control of irradiation damage in graphite
T. Tsuzuku Nihon University Japan	Studies on electric processes in graphite during the last decade in Japan
H. P. Boehm University of Munich West Germany	Graphite intercalation compounds: old and new problems in the chemist's view
L. S. Singer Union Carbide Corporation U.S.A.	Carbon fibers from mesophase pitch: past, present, and future
R. Setton Centre de Recherches sur les Solides à Organisation Cristalline Imparfaite France	The organic chemistry of some intercalation compounds of graphite

This report will center on the advances in carbon fibers, specifically mesophase-pitch fibers, the carbonaceous mesophase and its role in carbon materials, and the use of carbon materials for dental implants and prosthetic joints.

CARBON FIBERS

Most carbon fibers are made from the polymer precursors, rayon and polyacrylonitrile (PAN). The amount of carbon fiber from PAN produced in Japan is about 500 tons a year. These fibers offer either high strength or high modulus, depending on the level of heat treatment. The invention and production by L. S. Singer and his coworkers at the Union Carbide Corporation, U.S.A.. of carbon fibers from pitch have demonstrated that carbon fibers can offer both high modulus and strength. The precursor for these pitch fibers is either petroleum pitch or coal tar pitch which is heated to between 400° and 500°C to form the carbonaceous mesophase, a discotic nematic liquid crystal. The spinning of this orientable liquid crystal provides the high degee of alignment of the graphitic structure in the resulting carbon fiber and thus its high modulus. Essential factors for successful production of these mesophase-pitch carbon fibers are low viscosity at low melt-spinning temperaures, agitation and gas sparging of the mesophase before spinning, and removal of ash or infusible carbonaceous solids. Processing includes spinning, infusibilizing, carbonizing, and graphitizing. Elastic moduli range from 25 x 10^6 to 100 x 10^6 psi. Union Carbide now produces 250 tons a year. New applications of this low-cost carbon fiber include structures in outer space which require high stiffness and strength, and low thermal expansion.

A mesophase-pitch carbon fiber is not yet on the market in Japan. But there is much interest on the part of many researchers in Japan in understanding the spinning and production of these mesophase-pitch fibers. The precursors for these fibers are quite abundant in Japan: petroleum pitch from oil refining and coal tar pitch from coking coals used in blast furnaces for steel making. Several companies in Japan that are undertaking research on mesophase-pitch fibers are the Nippon Steel Corporation, the Kawasaki Steel Company, Tonen Oil Company, Mitsubishi Chemical Industries, Ltd., the Kureha Chemical Company, and Mitsui Coke Company.

Intercalation compounds of graphite crystals with a high degree of crystal perfection show metallic electrical conduction comparable to that of the metal, copper. The intercalation compounds formed by using graphite fibers could afford high potential for application as an electroconductive wire for high-power transmission lines or aircraft where light weight is needed. M. Endo, Shinshu Univesrsity and T. Koyama and M. Inagaki, Toyohashi University of Technology, have shown that by intercalation with HNO_3. K and AsF_5, the resistivity of a graphite fiber was reduced from 80 to less than 2 $\mu\Pi$ -cm.

Another exciting area of research in carbon fibers is the fabrication of vapor-grown carbon fibers. Professor M. Endo, Shinshu University, in conjunction with Showa Denko Company, Ohmachi, has developed vapor-grown carbon fibers by means of thermal decomposition of hydrocarbons with seeding by catalytic ultrafine particles of metals. Cylindrical substrates, seeded with iron or iron-nickel particles about 10 to 50 nm in diameter, were heated at temperatures about 1000° to 1250°C in a mixture of vaporized benzene and hydrogen gas. The resulting fibers consist of concentric stacked layers of carbon planes with a hexagonal network about the fiber axis. There is a small hollow core. This seeding method is effective in producing a large quantity of vapor-grown carbon fibers with high reproducibility and controlled dimensions. The method is applicable to an automatic production system, which could afford one of the simplest production methods for carbon fibers.

Professor M. Egashira and his co-workers at Nagasaki University have prepared vapor-grown fibers from the thermal decomposition of benzothiophene and Z-thionaphthol at 1100° to 1300°C. The sulfur in these organic molecules promotes the growth of the fibers. The particle which uncleated the growth was SiC; the Si was present in the mullite substrate. Small particles and temperatures near 1100°C produced long, thick carbon fibers with a yield of five percent.

CARBONACEOUS MESOPHASE

The carbonaceous mesophase is a liquid crystal formed during the pyrolysis of polynuclear aromatic hydrocarbons such as petroleum pitch, coal tar pitch and naphtha-cracked tar. In the temperature range of 400° to 500° C, microstructures introduced in the carbonaceous mesophase are retained in the graphitic materials formed from this liquid crystal. Thus, much research is being conducted in Japan, as well as in the United States, England, Germany, and France, on the chemistry and physics of the carbonaceous mesophase, the precursor to polycrystalline graphite and the mesophase-pitch fibers.

T. Miyazaki, Mitsusbishi Chemical Industries, Ltd., discussed the development of needle coke from coal tar pitch. Needle coke, which consists of well-developed, needle-shaped crystals of carbon, is the starting material for ultra high-power graphite electrodes. As the demand for such sophisticated electrodes increases, the critical problems of expanding the volume of production and upgrading the quality of needle coke to meet technical needs have to be solved. However, only selected heavy petroleum oil with low sulfur, low ash, and low asphaltene contents has been believed to be suitable for manufacturing needle coke. If this is to continue in the future, there will be danger in a shortage of the raw material supply to meet the sharply growing demand. In addition, the threat posed by the prevailing instability in the world oil situation urgently requires that new sources of feed stock be examined in order to ensure an abundant and stable availability of raw material. Under such circumstances, Mitsubishi Chemical Industries and the Nittetsu Chemical Industrial Company have been developing methods of manufacturing needle coke from coal tar pitch. For coal tar pitch containing a high concentration of fine, inert particles, mesophase formation and deformation to produce the required needle coke is impeded. Removal of the fine particles has been accomplished by the use of solvents to coagulate the particles to cause precipitation and separation. The graphite electrodes produced from the needle coke from coal tar pitch were of good quality and were characterized by low spalling and low graphite consumption. Such a coal tar pitch could also be used for mesophase-pitch fibers.

Related research is being done by Professor I. Mochida, Kyushu University. To utilize the precious petroleum completely, the bottoms of the barrel are expected to be converted to carbon materials such as needle coke or carbon fiber. Among various residues, the tar produced in the naphtha cracking for ethylene production consists of principally aromatic hydrocarbon, so that it is a prominent resource of carbon precursors, although it requires considerable modification because of low coking value. Acidic modification using the least amount of aluminum chloride has been accomplished for the conversion of these tars to sources for needle coke and carbon fiber precursors.

In the production of coke for steel blast furnaces, high-rank, nonfusible coals can be used as coke only if their fusibility and strength are improved. The improvement of the fusibility of such coals by adding coal tar pitch, petroleum pitch, or solvent-refined coal has been accomplished by T. Abe and his coworkers at the Kansai Coke and Chemicals Company. Important in this blending of pitch and coal is the role of transferable hydrogen. T. Obara, Hokkaido University, has shown the transferable hydrogen is influenced by Lewis acids and atmospheric oxidation and is one of the keys to controlling the carbonization reactions of coals and pitches.

BIOCARBONS

Carbon has excellent biocompatibility with the human body and thus has found application as dental implants, heart valves, and bone prostheses. Dental implants with a fine Rahmen surface are prepared by low temperature pyrolytic carbon deposition on carbon substrates. This process was developed by A. Kojima, Gunma Technical College; S. Ohtani, Gunma University; and S. Yanagisawa, the School of Dentistry, Nihon University. Preclinical tests have shown that implants in primate jaws under loading for two years performed excellently. In the surface structure of the implant, collagen fiber bundles were interwoven with the carbon implant and deeply ingrown tissue was ossified and filled all spaces of the surface structure. The implant brought about a hybrid load-transmitting system of carbon and bone. Thus, the implant can be used as an artificial replacement of the skeletal defect or loss of dentition that needs strong attachment to living tissue. The use of carbon materials for endoprosthetic joints was presented by K. Huttinger, Universitat Karlsruhe, West Germany. More than 400,000 components for heart valves have been implanted. Isotropic carbon and carbon-silica carbide composites are used, respectively, for hip joint cups and balls. The stem of the hip joint is fabricated from a carbon-fiber-reinforced carbon composite. New research has shown that for the first time tendons and ligaments can be repaired with the use of carbon fiber strands and fabrics, which provide strength for the new tendon and a substrate for new tissue growth.

PRODUCTS

New carbon products described in a poster session included a fine carbon-carbon composite for pencil lead that could be shaped as a spring with good elasticity (Mitsubishi Pencil Company, Ltd.), a high-quality needle coke with low thermal expansion (Koa Oil Company), large-sized, isotropic graphites of high-density and high-strength for nuclear, metallurgical, and electrical applications (Toyo Tanso Company) impervious graphite and carbons for electrodes for electrical discharge machining (Toyo Carbon Company), a high-density, high-strength graphite (Tohoku-Kyowa Carbon Company) and inexpensive silicon-carbide whiskers (Tokai Carbon Company). These carbon products highlight the innovative and advanced research on carbon and graphite being conducted by many universities and companies throughout Japan.

CONFERENCE ON SPECTROSCOPY AND DYNAMICS OF MOLECULES AND CLUSTERS IN MOLECULAR BEAMS

Jim E. Butler

INTRODUCTION

The 15th Okazaki Conference, Spectroscopy and Dynamics of Molecules and Clusters in Molecular Beams, was held between 15-17 November 1982 at the Institute for Molecular Science (IMS), Okazaki, Japan. Professor Nagakura (Director, IMS) opened the conference by emphasizing the "informal, friendly, and frank nature" of the discussions characteristic of the Okazaki conferences, and announced that the prospects look good for holding three Okazaki conferences per year, as compared with the two per year recently held.

The dominant theme of this conference was the opening up of diverse fields of fundamental chemical and physical phenomena to experimental investigation by the recent development of supersonic nozzle beams and laser probing techniques [particularly, multiphotonionization, (MPI)]. Supersonic nozzle expansions of a rare gas dilutely doped with polyatomic molecules can give extremely cold translational velocity distributions (relative to the other molecules in the expansion) and internal energy distributions of the polyatomic molecules. The temperatures of the distributions can range from 2 K to the temperature of the nozzle. During the expansion, extremely weak forces, e.g., van der Waals, hydrogen bonding, can cluster aggregates of the polyatomic molecules and/or the carrier gas. The degree of cluster formation can be controlled by the conditions of the expansion. After the expansion region, these molecules or aggregates are isolated from collisions, frequently with extremely cold internal energy distributions. Spectroscopy, e.g., with lasers, allows the experimental characterization of the structure and energy content of these species. In addition to nozzle beams, many other useful and ingenious experimental techniques were presented. These included rotor accelerated beams, polarized spectroscopy (LIF and chemiluminescence), MPI (multiple wavelengths), Penning ionization, laser photolysis, e^- impact and photoelectron spectroscopies.

TECHNICAL PROGRAM

- Formation and Spectroscopy of Clusters

R. E. Smalley (Rice University) presented work employing laser photolysis in the expansion region to generate radicals (e.g., CH_3O) from organic substrates; and metal atom or clusters by ablation of metal surfaces. Multiphotonionization (one and two color) was used to detect and characterize the species. Clusters of Fe, W, Ni, Cr, Cu, and Mo were reported along with the associated oxides and carbides. Initial studies of physical properties, e.g., ionized potassium with cluster size, and detailed studies of spectroscopy of Mo_2, Cr_2. and Cu_3 were also given.

K. Kaya (Keio University) reported mass selected MPI studies of hydrogen bonded complexes phenol-$(H_2O)_{n=1-3}$ and $(\text{Phenol})_{n=2,3}$. This study allows the probing of the transition between the free molecule and the solvated liquid. For n=1, only the ϕ OH-OH_2 isomer was observed, while n=2 appears to have the second water H-bonded to the phenol oxygen.

M. Faubel [(MPI)-Gottingen University] discussed in detail the design and characteristics of a high resolution (~1 MeV) crossed supersonic beams apparatus. He reported results on He-N_2 rotationally inelastic collisions and N_2 (J=0) - N_2(J=6) → N_2 (J=4) = N_2 (J=4) using e^- impact excitation of N_2^+ emission.

S. Tomoda (Institute for Molecular Science) used photoelectron spectroscopy to measure the ionization thresholds of $(H_2O)_2$, $(CH_3OH)_2$, and $(HCOOH)_2$.

S. Bei (Institute for Physics and Chemical Research) reported the formation of large clusters (10^2-10^5 molecules of H_2 or N_2) using a cooled supersonic nozzle with a trumpet shape for impedance matching.

T. Fukuyama (National Institute of Environmental Studies) discussed the optimum beam conditions to form dimers of CO_2.

N. Nishi (Institute for Molecular Science) observed NH.-H.O binary clusters, $(NH_3)_n\ (H_2O)_m$, (n,m) = 8,0 → 2,6 with the $(NH_3)_n + H_2O \rightarrow (NH_3)_nH_2O$ preferred for $n \geq 7$.

K. Kuchitsu (University of Tokyo) emphasized the "body contact" nature of Penning ionization and its value in studying steric effects and probing the exposed (first) molecular layer of surfaces. He determined the orientation of pyridine on Ag and observed an amorphous-crystalline transition for biphenyl as the temperature was raised.

- Spectroscopy and Dynamics I. Supercooled molecules

J. Jortner (Tel Aviv University) presented a diverse array of experimental results and techniques which indicate the impact nozzle beams will have on chemical physics. Using cw, pulsed, circular, and rectangular orifices which could be heated to 500 C, LIF, MPI, and absorption spectroscopies, he has been able to probe the spectroscopy of low frequency modes of large molecules, intramolecular vibrational relaxation, controlled solvation of molecules and its effect on spectroscopy and dynamics. As examples he presented data on pentacene, ovalene, tetracene, dichloro- anthracene, and tetra phenyl prophyrin.

N. Mikami (University of Tokyo) examined the spectroscopy of the $^1B_2$ state of CS_2 cooled in a jet. He found the excited state to be bent with a double minimum potential and obtained good agreement of *ab initio* calculations with the experiments. He found $R \approx 1.6$ Å, $\theta \approx 131°$, $T_{00} = 30530\ cm^{-1}$.

T. Ebata (Tohoku University) observed highly excited states of NO and rotational relaxation within them, by simultaneously observing two photon fluorescence and MPI. Delaying the ionizing laser pulse gave rotational relaxation rate constants (~1.8 x 10^{-10} cc/molec sec) comparable with the electronic quenching.

S. Tsuchiya (University of Tokyo) observed quantum beat phenomena in the fluorescence of SO_2 ($^1A_2$) excited after supersonic nozzle expansion and cooling. Using polarized excitation of individual rotational features (~0.2 cm^{-1}), polarized detection and a weak magnetic field, he determined $g_J = 0.14$.

- Spectroscopy and Dynamics II. Collision Free Molecules

J. P. Simons (University of Nottingham) discussed the history and advantages of rotor accelerated beams and, in particular, beams of metastable rare gas atoms used to study reaction dynamics in a beam-gas configuration. Total cross sections for rare gas halide excimer formation as well as the product internal energy distributions were obtained. Polarization of the product emission, and the angular distribution of the scattering revealed the vector properties of the reactions.

T. Kodow (University of Tokyo) is studying the symmetry of excited states by electron impact excitation of polarized fluorescence of the parent molecules (RCN) and the angular distribution of the excited fragments (CN)*. Similar measurements on N_2 producing N atoms in Rydberg levels ($n \geq 15$) reveal the shape of the excited potential energy surface. He has observed the $B^1 \Pi_u$ state of N_2^{2+} in this manner.

K. Obi (Tokyo Institute of Technology) has observed HNO, DNO ($\tilde{A}$, $\tilde{X}$) in the Hg photosensitized nozzle expansion of Hg, $H_2(D_2)$, NO, by measuring the fluorescence spectra, LIF spectrum, and lifetimes in the 610-810 nm range. The (011)-(000) band shows a biexponential decay. Also observed was NH_2 with a rot. Temp. of 10 K and lifetimes in the range 4-10 μs. The transition moment was determined to be 0.026 $\pm$ 8 debye^2.

T. Ogawa (Kyushu University) is studying the electron impact dissociation dynamics of H_2, H_2O, CH_4 by measuring the translational energy distribution of the H* fragment.

J. Butler (Naval Research Laboratory) presented an inverted vibrational distribution of OH ($X^2\Pi_i$, v=1-4) obtained by FTIR emission from the reaction of $O(^1D) = H_2$. When combined with previous LIF results, a, bimodal vibrational distribution is observed. He suggested that the H atom abstraction channel may be more important than previously believed.

- Chemical Reactions by Molecular Beam and Laser Techniques

R. N. Zare (Stanford University) presented a number of experimental investigations of chemical reaction dynamics employing spectroscopy and molecular beams. Polarized light was used to spatially select the reactant states in the $Ca^*(^1P_1)$ + ClH reaction where the polarization characteristics of the $CaCl^*(A^2\Pi_i, B^2\Sigma^+)$ were observed. Optical-optical double resonance was used to unravel the BaI Doppler-free spectrum. The Ba + HI reaction was proposed for the controlled study reactant impact parameter effects due angular momentum constraint $\underline{L}_i \rightarrow \underline{J}_f$. Finally, strong absorption and LIF spectra of H_2(C-X, B-X) transitions in the region of 101.3 nm at a pressure of 10^{-4} Torr were presented. This was possible by the generation of tunable four-wave mixing (third harmonic generation) of a tunable dye laser second harmonic at 300 nm in a pulsed Ar supersonic jet.

K. Sakurai (University of Tokyo) discussed the characterization of the cooling in the a supersonic expansion and the design of a large crossed beam machine employing pseudo randomly chopped cw LIF with cross correlation to achieve a large duty factor with low noise in TOF measurements. LIF results of CaI in a heat pipe and beam were presented.

I. Nishiyama (Institute for Molecular Science) reported the IR photodissociation of benzene and methanol dimers with a pulsed CO_2 laser, which require one and two photons, respectively. The TOF of the fragments and the depletion of the parent species were measured. The benzene dimer dissociation rate peaked at the monomer absorption band, with a broadening of the wavelength dependence at higher laser fluences. The methanol dimer dissociation rate peaked 20 cm^{-1} higher than the monomer absorption band with a larger fluence broadening effect.

M. Baba (Institute for Molecular Science) observed that under supersonic expansion conditions the rotational structure of the first singlet state (S_1) of complex ketones could be resolved. He was able to reassign the 0-0 band of acetone.

M. Kawasaki (Miie University) reported on the TOF and angular distributions of the photodissociation of N_2O_4 at 248 and 193 nm. The TOF indicated that one of NO fragments must be in an excited state and that the translational energy was lower then statistically expected. A 193 nm excitation shifted the NO_2* emission to the red.

K. Kimura (Institute for Molecular Science) used resonant enhancement of MPI coupled with the laser polarization to determine highly excited states of neutral atoms and molecules, and also some low lying ionic states. Systems presented were Ar, Fe, NO, and NH_3.

- Ion-Molecule Reactions

K. Tanaka (Institute for Molecular Science) presented the application of threshold photoelectron secondary coincidence spectroscopy to the study of vibrationally excited ion-molecule reactions. For $O_2^+(X, v \leqq 20)$ = H_2, HO_2^+ = H was the preferred product channel with equal partitioning of the O_2^+ + HD reaction to OH_2^+ and DO_2^+.

I. Kusunoki (Tohoku University) discussed the chemiluminescence from ion beam (C^+, S^+, N^+, O^+), neutral gas H_2, D_2, NO, CH_4) reactions. Emission from CH^+, OH^+, NH^+, NO^+, and CO^+ were reported.

K. Sato (Tohoku University) reported the use of ion-impart energy loss spectroscopy using light ion beams (H^+, He^+, H_2^+) to determine the energy and spin degeneracy of the electronic states of target molecules (e.g., C_2H_4).

Y. Hatano (Tokyo Institute of Technology) used pulse radiolysis to produce atoms and radicals in ground and excited states. He also observed low energy electron attachment to O_2 producing O_2^- (v=4), and to O_2-M (M=rare gas) van der Waals complexes to give O_2^-+M.

Conference attendees were given a tour of many of the laboratories at IMS, including the 600 MeV synchrotron and storage ring which will be used as a "photon factory" for experiments when completed in 1984. All foreign visitors to the conference were unanimous in their praise and envy of the organization, capital equipment, and the research underway at IMS.

HIGHLIGHTS OF THE QUANTUM ELECTRONICS APPLICATION SOCIETY OF THE IEEE CHINA STUDY GROUP

Milton Birnbaum

INTRODUCTION

The China Study Group, comprising members of the Quantum Electronics Application Society (QEAS) of the IEEE, visited China from 31 October through 21 November 1982. Lasers and optical device physics are among the eight technical areas emphasized by The People's Republic of China (PRC). Thus, substantial efforts are in progress in these fields.

Briefly stated, the objectives of the study group were: To obtain a perspective on the status of Chinese technology in lasers and quantum electronics, and to establish contacts between experts as a means of facilitating the exchange of information. Additionally, we were to foster cooperation between the QEAS/IEEE and its counterparts in the PRC and thus to engender continuing professional liaison between the technical communities.

The itinerary of the group included visits to the major institutes and centers of research in lasers and optical device physics in Beijing, 1-8 November; Xian, 8-11 November; Shanghai, 11-14 November; Guilin, 15-17 November; and Guangzhou (Canton) 17-19 November. The members of the China study group were:

Chung L. Tang, Chairman
Richard Abrams
Michael Bass
Milton Birnbaum
Robert Byer
Cyrus D. Cantrell
Anthony J. DeMaria
C. Hammond Dugan
Christos Flytzanis
Elsa Garmire
Eugene Gordon
Pierre Lallemand
Mark Levenson
Michael M. T. Loy
John B. MacChesney
Peter Smith
Charles P. Wang

We visited many institutes and universities in Beijing (Peking) including the:

- Qinghua (Tsinghua) University,
- Beijing University,
- Beijing Institute of Optoelectronic Technology,
- Institute of Physics,
- Institute of Electronics,
- Institute of Mechanics.
- Institute of Semiconductors.

In Shanghai we visited the:

- Institute of Optics and Fine Mechanics,

- Fudan University,
- Institute of Metallurgy,
- Shanghai Laser Institute, and
- Jiaotong University.

The PRC has mounted a substantial effort in the fields of lasers, optoelectronics, and related applications. A rapid rate of progress has been maintained since the end of the cultural revolution about seven years ago. Nevertheless, much ground remains to be covered before a larger fraction of their output is at the cutting edge of current technical advances. In Beijing and Shanghai, we were shown white light HeCd lasers (~50 MW output) which, to our knowledge, are not found outside of China. At the Shanghai Laser Institute we viewed a number of cw HeNe lasers on display, notable for their high output powers--50 to 100 MW.

The lack of commercial development in the PRC has resulted in the use of institutes to manufacture lasers and other electrooptic devices, which are then supplied to other institutes and universities. In our opinion, this is not an efficient system for the manufacture and distribution of needed scientific equipment. The technical caliber of the institute staffs was high, with a Ph.D. population comparable to that of good U.S. research laboratories. We guessed that the scientific capabilities of the personnel at those institutes were not fully utilized.

Our Chinese colleagues extended many courtesies to the QEAS Study Group, which considerably enriched our experiences in China. We all look forward, in the near future, to our next visit to the PRC.

BEIJING

BEIJING UNIVERSITY (P. Smith, R. Abrams, M. Levenson, C. Tang)

There is a total of 10,000 students at Beijing University, 200 faculty members are in the Physics Department, 43 graduate students (four Ph.D. students, and the rest are in the M.S. program). There are 3000 faculty and technical staff members.

Out of 120 students in the whole of China that pass physics examinations (sponsored by an association of U.S. physics departments) about 30 go to Beijing University. Most of the physics research is conducted by the rather large faculty.

The head of the Physics Department was Professor Yue (not present). Our host was Wang Wei-li. We had particular interaction with Zhang He-yi who was interested in nonlinear interface studies and picosecond pulse experiments. He requested reprints and materials on suspension of particles.

There are four main areas of interest in the Physics Department:

- theoretical physics,
- low-temperature semiconductors,
- optics,
- magnets.

In the optics area there is work being done in:

- research in optical fiber communication,

- molecular spectral,
- solids--rare earth types.
- semiconductors,
- nonlinear optics in metal vapors, and
- spectron of solids at low temperatures (ionic crystals and semiconductors).

Four-wave Mixing

Investigators: Zia Zong-ju and Zou Ying-hua

- Experiments were being done with YAG SHG pumped Littman design dye and lasers on atomic vapors in heat pipe ovens.

- In Na with laser tuned to D lines, they observe conical emission of frequency-shifted radiation as has been reported. Quantitative explanation was not attempted, but detailed phenomenology is published.

- In K two photons access the 13S state whereupon the injection of a YAG photon produces a 4022 Å output by four-wave mixing. Tunable input for 3rd photon gives tunable output. Both results are published in the *Chinese Laser Journal*.

6900 Å DH Laser ($Ga_{.8}A\ _{.2}As$)

Investigator: Mrs. Chen Wei-xi

- CSP binary heterostructure.
- 0.2 Al content in active region.
- LPE growth (we saw the furnace).
- Lasers worked pulsed. It is not clear if they also operated cw, but if seems that they did.

With ring cavity operation, they find $\Delta\nu \alpha$ length of ring

$\ell = 200\ \mu m$	$\Delta\nu = 5$Å
$\ell = 400\ \mu m$	$\Delta\nu = 10$A

- Single mode operation.

This laser growth and characterizing above was being carried out by fourth or fifth year undergraduate students, the first study as a three-month thesis project.

Magnetooptics

We saw a spin-flip Raman laser setup using InSb using both CO and CO_2 lasers (made in the university) as pump sources. They also made a 60 KGauss superconducting magnet (Dewar and all) (cost of He \$70 m^3 at 1 atm).

Also, they are conducting studies in two-photon absorption in InSb, Faraday rotation studies, and studies of photon drag detection in p-Ge.

Clearly, this is a top university in China for physics students. They have excellent support facilities, and their undergraduate training in applied physics would appear to be at least the equal of the best U.S. universities. Their research program is ambitious and involves faculty and students. It was equal to the most current research we saw in Beijing.

QINGHUA (TSINGHUA) UNIVERSITY (R. Byer)

Qinghua (Tsinghua) University was organized in 1911. It has 17 departments and 2 000 faculty members and 9000 students. The university has a long history of sending students abroad for study. It has also emphasized technical subjects and thus might be compared with the Massachusetts Institute of Technology (MIT) in the United States. There are plans, however, to expand the subjects taught at the university to include arts, history, and languages and to become a full-fledged university in the manner represented by Beijing University. Last year, as an example of this increasing range of subjects, the Physics Department was established.

To date, Qinghua University has established an equivalent Bachelor of Science program and a Master's program. The Ph.D. program is also in its early stages. The first Ph.D. students should be graduated within the next two years.

The university enjoyed good support for its science and engineering programs. Its research and teaching are comparable to that of its closely located sister institute, Beijing University.

Technical Overview

The group visited Qinghua University on Tuesday. November 2, 1982. The visit included general discussion sessions at which it was stated that close to 15% of all high school graduates attended universities in China. Following the general discussion, the group visited the Radio and Electronics Department, the Physics Department and the Mechanical Engineering Department.

Associate Professor Zhou Bingkun showed us the experiments in progress in the Radio and Electronics Department. They included a Nd:YAG unstable resonator Q-switched Nd:YAG laser which was frequency doubled in KDP and pumped a 20 atm pressure hydrogen stimulated Raman cell. The laser was well-engineered, but produced only one-half of the output of an equivalent U.S. made laser. The Nd:YAG crystals were grown at the North China Research Institute for Electrooptics (NCRIEO) and are not yet of U.S. quality. The KD*P crystals for the Q-switch and for the SHG were grown at Shangdong University. The oscillator output was 40 mJ for a 5 mm diameter rod. The amplifier boasted the 1.064 µm output to 120 mJ. The repetition rate was only a few hertz.

In the next laboratory we were shown degenerate four-wave mixing in BDN dye by Professor Y. L. Guo, M. Y. Yiao, and S. M. Pang. The four-wave mixing experiment at 1.06 µm, which reports a 377% efficiency and time delay studies, has been submitted to the 1983 Conference on Laser and Electrooptics (CLEO).

We also were shown a GaAlAs double heterostructure diode laser within a grating tuned cavity; 1 mW of cw power was generated and the wavelength observed via a one meter grating spectrometer with a IR image converter handheld device similar to the VARO up-converter.

The final area of technology shown was fiber optic sensors by Mr. Liao. Multimode fibers were used in a Mach Zehender arrangement to observe temperature and pressure variations. A helium neon beam provided the coherent output.

The group then moved to the Physics Department building and spent time with Professor of Physics Zhang to observe a hollow cathode white light HeCd laser. The laser still had stability problems due to the discharge. However, it generated approximately 100 MW of total output power. The Physics Department is located in an old building that needs considerable work to be up to the standards elsewhere at Qinghua.

The Mechanical Engineering Department demonstrated double pulse holography of structures. The work was under the direction of Professor Chao.

During my visit two new projects were shown. They were in the semiconductor processing area and the acoustic optic microscope research.

My hosts were Associate Professors Zhou Bingkun, who will arrive at Stanford University in January 1983 for a one year stay, and Fan Chong-cheng who has visited the U.S. and Pang S. M. who studied last year at the University of California at San Diego.

The acoustic microscope operated at 120 MHz frequency and used a ZnO transducer. The resolution was 5 μm. The work was under the direction of Zhang Keqian and Chen Gelin.

The semiconductor processing included all steps up to mounting the chips. The detector-transmitter fiber optic system was designed and constructed in this laboratory.

The acoustic microscope work. the semiconductor work, and the laser work were all of 1975-1976 vintage. However, the gap in research capability is slowly closing.

I also met four students who had passed the national examination to allow them to study abroad for a Ph.D. Of the four students Lii Mei was considered the best. She will apply to U.S. universities this year.

BEIJING INDUSTRIAL ENGINEERING UNIVERSITY (M. Loy)

This is a relatively small university with a student population of 2000, and is a comprehensive engineering school. It is an institution belonging to the city of Beijing [rather than national, such as Qinghua (Tsinghua) University]. It has a total of about 100 students doing post-B.S. work leading to M.S. degrees. This university is only 20 years old. They were eager to point out that of the 20 years, nothing much happened in the ten years during the Cultural Revolution and so they consider themselves just starting out.

Technical projects were performed in a number of different departments.

- Use of holography for information storage

They constructed a homemade HeNe laser system for transmission holography, and made a random phase shifter by using a speckle pattern. They constructed pinholes by YAG laser drilling. The net result appeared to be able to store the entire page of a Chinese newspaper on a 3mm x 3mm area, by transmission holography. They said that the resolution and storage density are comparable to conventional nonlaser techniques.

- Picosecond YAG laser by active modelocking

This project is just starting. They have not measured the pulse width yet. They are setting up to do so by second harmonic generation.

- Laser Printer

They have designed and constructed a rather professional looking laser printer. Their machine, similar to laser printers of the western world, also uses xerography (selenium). It is controlled by a Z80 microprocessor. It is capable of printing 30 lines/sec, in 12 x 14 dot format. It can print 96 international standard symbols, plus 12 additional symbols, and 110 Chinese characters. The entire machine was built by the faculty members and students (at least five theses were based on this work.) The sample output (which I have) appears to have good resolution. Even though this printer is by no means world-class, I thought that for a city-run university of this size, this is a remarkable project.

INSTITUTE OF PHYSICS, ACADEMIA SINICA (R. Abrams, P. Lallemand, M. Levenson, C. Flytzanis, M. Loy, C. Tang)

The Institute of Physics is a major research and degree-granting institution with a total staff of 900. The Director is Shi Ru-wei; the Associate Directors are Qiad Xing-nan, and Guan Wei-yon. It is divided into 16 departments of which three (atomic and molecular physics, solid state spectroscopy, and laser physics) with 120 people, including 40 students, are concerned with quantum electronics. In addition, the institute operates well-equipped laboratories for x-ray analysis, NMR, electron microscopy, and chemical analysis. These laboratories service institutes and universities throughout Northern China. Finally, there is a factory to provide apparatus for use in the institute and for other customers.

Our host, Dr. T. C. Wang, is well-known in the United States because of his nine years (from 1948-57) with Professor Townes and A. D. Little at Columbia University. He heads the atomic and molecular spectroscopy program, and continues to interact with Columbia University. Among the projects visited were:

- Cesium Atom Detection Via Two Photon Ionization

An 800 mJ flashlamp pumped dye laser was tuned to the 2nd resonance line of Cs, (at 4593 Å) and the electrons thus generated were detected with an electron multipiier fabricated in-house (copy of a Mullard electron multipier). Sensitivity approached one atom per laser shot. (Aim: detect minute concentrations of Na in Si.)

- Four-wave Mixing in the Isotropic Phase of MBBA

Nd:YAG laser beams were crossed at an angle in the medium to produce an orientational grating. A dye laser beam or a beam from an independent Nd:YAG laser was Bragg scattered from the resulting spatially oscillating susceptibility. At a later time the effects of orientational grating were separated from those of thermal gratings with polarization techniques. Mr. Fu, an investigator, was aware of related work in the U.S., and intended to use his apparatus to determine the variation of the effective orientational correlation time with grating spacing and temperature. (Uses a HP 85 desk computer on line to normalize data.)

- Optical Pumping of Na

Dr. Mei Yin Hou, Ph.D., from Columbia University under Happer, showed an experiment which employed a Chinese built version (360 Yalizi Jiquangqi, made at Nanjing) of the Coherent 53 Ar^+ laser to pump a multimode Spectra Physics dye laser. A chopped circularly polarized beam pumped the Na in a low pressure NaXe cell while a very weak cw probe beam detected the absorption. The results of her experiment confirmed that the system was in the "spin temperature limit." The aim of the work is to study relaxation in the ground state of Na due to NaXe or spin exhange (NeNa) collisions.

- Optical Bistability

A hybrid bistable device consisting of a twisted nematic liquid crystal cell with applied voltage dependent upon the transmitted intensity was demonstrated. A Radio Shack computer introduced delay in the intensity →voltage feedback. This system showed a self-pulsing mode with period doubling and chaos along the lines of the Ikeda instability. The setup did not include sophisticated spectrum analyzers needed to get physics from this setup. They believe there are mechanisms that can cause chaos in addition to that of Ikeda.

- Dye Laser Development

Flashlamp pumped dye lasers designed and built in the institute were demonstrated. Relatively high repetition rates were obtained using flowing gas flashlamps. The optical setup to narrow the line was rather classical (prism beam expanders, etc.). No physics was attempted with those lasers.

- Surface SHG at 10 μm

Dr. Z. L. Chen demonstrated a remarkable experiment in which the output of a tunable CO_2 TEA laser was coupled into the surface polariton, mode of an aluminum film on GaAs with a grating on the aluminum film (at the interface). When correctly phase matched, the polariton radiated a second harmonic output detectable with a cooled InSb detector. The output depended upon the input frequency, angle, and polarization as would be predicted by a surface polariton model. Relating experiments have been performed in the visible by Y. R. Shen. The conversion efficiency was fairly good, starting from 100 kW on a 2 mm^2 spot size gets 0.5 W of S.H.

- Laboratories.

Meng Quinan was employing the institute's excellent Bruker NMR apparatus to study the motion of Li^7 ions in superionic conductors. It is a pulsed NMR machine tunable from 4 to 100 MHz, but without the high resolution devices for solids. Interesting results have been obtained on samples grown at the institute.

We also visited an extensive x-ray facility including an automatic diffractometer and a topography setup, and a recent surface analysis laboratory equipped for XPS, Auger, etc. The x-ray source was a 60 kW Japanese model employing a rotating anode. This last equipment is not set in a clean room and samples to be analyzed are prepared elsewhere so that there must be serious pollution problems.

The Institute of Physics has, in summary, strong programs employing lasers to address topics of current interest in physics. They have built most of their own laser apparatus and have developed instruments well-suited to the requirements of their technical environment. In nonlaser areas they have, however, purchased entire systems from European and Japanese manufacturers. The continuing relationship with Columbia University, and former associates at Columbia University, provides them with valuable information on current trends in the highly competitive laser science area. Professor Wang is also organizing an international conference on atomic clocks for time and frequency measurement scheduled for Hangzhou, 2-6 September 1983. He indicated that there was hydrogen master and Rb master work being done at other institutions in central China.

INSTITUTE OF ELECTRONICS, ACADEMIA SINICA (C. Cantrell, M. Bass)

The Institute of Electronics, Director, Mr. Lu Bao-wei, which belongs to the Chinese

Academy of Science, has evolved since 1978 under Mr. Lu's direction from an institute devoted to vacuum tube technology into a research and development institute for electronics in a broad sense. The institute has eleven specialized divisions in various areas of electronics, including circuits and systems; vacuum tube devices; electromagnetic theory and applications; lasers; high-resolution television; and side-looking radar. No laboratories were visited at this institute because the laboratory buildings were still under repair from earthquake damage suffered in 1980. According to a videotaped presentation this institute has developed reflex klystrons (ranging from high-power devices to highly stable devices with an average power output of 500 MW); traveling-wave tubes with an efficiency of 45-50%; millimeter-wave tubes; microwave amplifiers for space applications; gas lasers for range finding, precision machining, laser processing of materials and medical treatment. In 1980, seven research achievements of this institute were awarded first, second, or third state prizes. It was stated that in at least some of these areas, the Institute of Electronics has attained the international level of the 1970s. In certain areas, presentations by Institute of Electronics personnel, Mrs. Cao Qui-sheng, Leader of the Infrared Laser Group and Mr. Shi Dian-cheng, and Ms. Chen Chiao-chen, provided additional information which will be summarized below.

This institute appears to be a major center for the development of technology and its transfer to industry. Helium-neon and cw carbon-dioxide laser technology developed here has been successfully transferred to an electric bulb factory in Shanghai where lasers of these types are now manufactured. The transfer of technology was accomplished by training the factory personnel at the institute and by subsequent visits of institute personnel to the factory. The argon-ion laser technology developed here has not yet been successfully transferred to industry; so far several factories have been tried without success. This institute manufacturers its own laser coatings, coating equipment, and substrates, and sells coated optics internationally.

The visible light laser technology already developed here appears to be the 0.5 MW class of HeNe lasers and the under 10W class of Ar^+ lasers. The development of Ar^+ lasers is continuing, with the objective of reaching higher powers (20 W) longer life (>1000 hours) and, one speculates, ultraviolet line generation. Work has also begun to develop a Kr^+ ion laser on the basis of the Ar^+ laser technology. So far 500 MW has been obtained on all Kr^+ lines. Both the Ar^+ and Kr^+ lasers employ graphite bore tubes in quartz jackets. Other classes of visible lasers are under development. A rhodamine 6G dye laser with a three-mirror cavity (perhaps similar to the coherent 590) has been pumped by an Ar^+ laser. Work is also proceeding on a copper-vapor laser, from which they hope to obtain average powers of 40-50 W.

The infrared laser technology developed here so far appears to include the under 10W class of cw CO_2 lasers. However, an ambitious program of development of high-power pulsed infrared lasers was described.

The basic laser of this type appears to be a UV-preionized TEA-CO_2 laser. A high-pressure (8-12 atmosphere) UV-preionized CO_2 laser with a pulse length of 50 nsec, a pulse energy of 1J and a continuous tuning range of 4 cm^{-1} has been operated. Ultimately it is hoped to tune this laser over a wide range in the 9-11 μm region. At present, the cavity of this laser consists of a grating and an output coupler. The optics used for the pulsed CO_2 lasers are Ge; the window materials are $CaCl_2$ or $CaBr_2$. A line-selectable TEA-CO_2 laser has been used to pump a CF_4 laser; pulse energies of 20-25 mJ at 615 cm^{-1} have been obtained. In the videotaped presentation, a CO_2 amplifier chain made here was shown in use (at the Institute for Chemical Studies) to pump a CF laser. NH_3 has also been pumped to obtain laser action at 12.8 μm. Finally, $^{12}C^{18}O_2$ isotope lasers have been operated, with the objective of obtaining efficient emission outside the 9-M μm range of the $^{12}C\ ^{16}O_2$ laser. This is the standard line of laser development for separation of uranium isotopes using UF_6 as a working material.

Excimer lasers are also under development at this institute. Both KrF and XeF have been lased using a longitudinal discharge preionized by a radial e-beam. The pulse length is 70 nsec. It is hoped to obtain 100 J per pulse from KrF, using a system that is now under development.

The applications of lasers in medicine received considerable emphasis in the videotaped presentation and in discussions with the personnel of the institute. An Ar^+ laser has been used in conjunction with dye that is preferentially absorbed by cancer cells to facilitate the detection and destruction of cancerous tissue. This work appeared similar to work carried out with hematoporphyrin dye by M. Burns (at the University of California at Irvine) and others in the U.S.A. Numerous examples of the successful treatment of skin cancers in human patients were shown in the videotaped presentation.

BEIJING INSTITUTE OF ELECTRONICS (M. Bass, C. Cantrell)

This institute is concerned with the broad field of radioelectronics which includes lasers. Until four years ago it was only concerned with vacuum tube devices, but since then has expanded its activities into laser research and development. The institute is divided into 11 divisions which come under the broad headings of Circuit and Systems, Vacuum Tube Devices, Electromagnetic Theory, and Lasers.

The range of laser-related activities in four years is very impressive if we are to believe all that we were told. After all the building where the laser laboratories were was being "brought up to earthquake resistance standards" and so all that follows is what we were told or shown on a television tape.

This institute claims to have first worked on HeNe, CO_2 and Ar ion lasers and developed them sufficiently to have transferred their designs to industry for production. We think these are the 0.5 MW class of HeNe lasers, the under 100 W class of CO_2 lasers and the 8 W class of Ar ion lasers. The HeNe and CO_2 lasers are being produced in the Shanghai Electric Light Bulb Factory. There is still development of Ar ion lasers in progress with the objective of reaching higher powers (20 W), longer life ($\geq$1000 hrs) and ultraviolet line operation.

The institute has developed a high-pressure, tunable pulsed CO laser. It operates at 8-12 atm and uses ultraviolet preionization. The output energy is 1J broadband in a 50 nsec pulse and with a grating as a 100% reflecting mirror it can be tuned continuously from 9-11 μm. The spectral width in tuned operation has not been measured. This laser is then used to pump CF_4 and CH_3 to lase at 16 and 12.8 μm respectively. They have obtained 20-25 mJ from CF at 615 cm^{-1}. Some work is in progress using $^{12}C\ ^{18}O_2$ to obtain the precise wavelengths needed to pump UF . Far infrared lasing of D_2O and CH_3F is also being studied using the tuned laser CO_2 laser as a pump.

Based on their Ar ion laser technology work, the institute has begun to develop a Kr ion laser. So far, 500 MW on all lines has been obtained. These lasers (Ar and Kr) employ graphite bore tubes in quartz jackets. A rhodamine 6G dye laser with a three mirror resonator (sounds suspiciously like the Coherent 590) has been pumped with the argon ion laser.

The institute is working on excimer lasers. So far, KrF and XeF have been operated using a radial electron discharge. Plans are being developed for a 100 J per pulse, 70 nsec KrF laser. The existing system has achieved lasing of Xe at 1720 Å but with a small output energy.

Work on Cu vapor lasers is to be resumed in the near future. The objective is to produce a 40-50 W device.

We were shown a television tape in which the Ar ion laser was used to stimulate fluorescence "in a medicine made in China" and so detect and then destroy cancers. The "medicine" sounds like the hematoporphyrin dye used by M. Burns at the University of California at Irvine and others in the U.S.A.

In answer to a repeated question about the CO_2 laser window materials, we were told that "Ge windows were used but sometimes they employed CaCl and CaBr windows." The two Ca salts are unfamiliar to me (MB) and this warrants some investigation. We specifically asked if they did not mean NaCl and KBr and were assured that CaCl and CaBr were the materials used.

At this institute they were unaware of diamond turning as a means of preparing metal optics. We gave them a brief discussion of diamond turning.

This institute makes their own coatings and substrates. They claim to do well at making coatings because of their vacuum tube experience. That is, they have "good vacuum technology." The substrates are polished in the institute, but they do not have complete surface quality diagnostics. That is, they have interferometry, normal illumination (not Nomarski or dark field) optical microscopy and scanning electron microscopy, but no scattering or absorption measurement capabilities.

INSTITUTE OF SEMICONDUCTORS, ACADEMIA SINICA (E. Gordon, E. Garmire, P. Smith, J. MacChesney)

The Institute for Semiconductors (IS) was established in 1960. They did work in the 1960s on e-beam excited CdS. The Cultural Revolution slowed, but did not stop development. Research was stopped completely. The institute is an old building, primitive by western standards, but is scheduled to move to a new building within three years, closer to other institutes.

The institute has nine divisions:

- semiconductor materials,
  (Si and GaAs; Si defects; epitaxial growth on GaAs)
- new devices,
  (bipolar IC's)
- new processes and technology--SIC's,
- surface devices and physics,
- microwave devices and physics,
- instrumentation (support) for measuring semiconductors,
- optoelectronic devices and physics,
  [heterojunction lasers in (GaAs)(GaAlAs) and InP (InGaAsP), spectroscopy and heterojunction physics]
- physical and chemical analysis,
- semiconductor physics--surface research.

IS has about 500 university graduates; there are virtually no Ph.D.'s. Division seven, which we visited, has 60 people altogether including 45 professionals. Our host was Associate Professor Zhuang Wei-hua. She is head of the Optical Measurements Group. She was assisted by Mr. Yu Jin-zhong of the Laser and Luminescence Research Group. Professor Wang Chi-minh is head of the division--we met him in the afternoon. Our escort was:

Mr. Hong Jian (spent two years in Washington, D.C. with the Chinese Embassy)
Box 650
Optoelectronics Division
Institute of Semiconductors of the Chinese
Academy of Sciences
Beijing, People's Republic of China

We spent the morning visiting various laboratories and the afternoon was reserved for presentations by E. Gordon (fiber optics communications and lasers), E. Garmire (integrated optics), and P. Smith (nonlinear optics).

The discussions centered mostly around semiconductor lasers around 0.82 µm. They make complete packages with coupling to multimode fibers and backface monitors. They achieve coupling over 70%, sometimes as high as 90%. The packages are in DIP form using glass seals. I do not know if they are hermetic, but I think they are. This laboratory was under the direction of Mrs. Chuang Wan-yu.

The laser chips are gain guided, shallow, proton bombardment defined stripes. Typical geometry is 250 µm long by 12 µm wide. Not surprisingly the light *vs.* current characteristic showed signs of kinks and other instabilities. They were able to achieve considerable facet power before rollover which is surprising given the geometry. Room temperature threshold is ~140 mA.

They have data on intra- and interwafer reproducibility, lifetime (best is about 10^3 hours at 70°C). LPE growth is used. The apparatus is crude, but incorporates some good features such as movable furnace and good load locks. Mr. Pen described the LPE apparatus and Mrs. Chuang Wan-yu was responsible for the device work.

The work appeared to be characteristic of the U.S. state-of-the-art five years ago. They were using tungsten with shadow masks for proton bombardment. They were not facet coating. Reliability was poor, about 20 times worse than what is done in manufacture today. They had very little clear idea of what was needed for communications lasers or what direction to move to improve matters. They were making a beginning on (InP) (InGaAsP). Nevertheless, given the lack of Ph.D. professionals, the late start, and the poor facilities, they were doing remarkably well.

The spectroscopy work was well-supported by equipment from the U.S., e.g., NRC optical tables, a Spectra Physics dye laser, etc.

Mr. Wu described a semiconductor laser with a 6-layer PNPN structure. The idea seems to be able to produce a negative resistance in series with the laser which produces a bistable operation. The device was reasonably fast (3-4 nsec on time, 10 µs off time). The idea was to develop a very low threshold-current device.

Mrs. Chuang, Mr. Yu, and Mr. Pen had questions for E. Gordon on bonding, chips, phosphorus loss protection for InP, refractive-index-guided structures and how to choose structures. Mr. Yu asked E. Garmire more details of the three-mirror active/passive laser which she presented in her talk.

In division six, they are studying electron modulation on a SEM. They told us China has had a ~10 km optical communication system in operation for three years at 8.448 mbit at 0.82-0.84 μm. We saw a U.S.-made argon laser for studies of low temperature photoluminescence studying armorphous silicon and doping in GaAs. They have a dye laser which they intend to mode-lock in the coming year. They need to obtain Coumarin dye. Saw PAR boxcar and lock-in. We saw DLTS apparatus--all electronics made in China.

They have not begun to develop MOCVD or MBE, but are thinking about it.

THE INSTITUTE OF SEMICONDUCTORS, ACADEMIA SINICA

The Institute originally grew out of a semiconductor division of the Institute of Physics. It was separated from the Institute of Physics and established as an independent institute of the Academy of Science in the year 1960. The Director is Huang Kun, the Deputy Director's are Liu Ta-ming, Wang Show-wu, Lin Lan-ying and Wang Feng and our host was Zuang Wei-ho, an Associate Professor in the Laser Department.

The work of the institute has been closely connected with the growth of the semiconductor technology of China. The first germanium and silicon single crystals in the country were grown in the late fifties in the laboratory of this institute, where also the first Chinese transistor was successfully fabricated. Then in the early sixties, the all-important planar process for silicon device fabrication was successfully developed at the institute.

Following recent rapid developments in semiconductor technologies, e.g., integrated circuits, semiconductor lasers, microwave devices, etc., the institute has been expanding steadily in its fields of research and personnel. At present, the institute has a staff with nearly 500 university graduates. The present site of the institute was the old site of the Institute of Physics which had only two buildings, whereas now there are five buildings. Apart from overcrowding, the conditions of the buildings are far from being adequate for semiconductor work. It is planned to move to a new site in the suburbs of Beijing, where they hope to have greatly improved and modernized laboratories.

At present, they are striving to make up for the loss of time of the Cultural Revolution and they are taking measures to raise the academic level of their research work. In the past, the work of the institute has been largely applications-oriented. For the future more emphasis will be put on research of a more basic nature. It is envisaged that in a few years time research on the physics of materials and devices together with basic research on semiconductor physics should constitute the greater part of the work of the institute.

The research work of the institute is carried out in the following nine research divisions:

- Semiconductor Materials

(Division Chief: Liang Jun-wu)

Main fields of research: Silicon; GaAs (single crystal epitaxial), other III-V compounds and their mixed crystals; amorphous materials.

Present research topics: Origin and mechanism of defect formation in silicon crystals; growth of high purity epitaxial GaAs; dislocations and other microdefects in GaAs (physical investigation and fabrication technologies); electrical and optical properties of amorphous materials, etc.

- New Circuits and New Devices

(Division Chief: Wang Shou-chueh)

Main Fields of research: Bipolar integrated circuits.

Present topics of research: Development of two new systems of integrated logic circuits proposed in this laboratory; fabrication technology related to the development of new circuits, e.g., coplanar isolation, multilayer wiring, etc.; device-modeling related to computer-aided design.

- New Processes and New Technologies

(Division Chief: Ma Chun-ju)

Main fields of research: New fabrication technologies relevant to future IC development.

Present topics of research: Development of dry processes; ion implantation; X-ray photolithography, etc.

- Surface Devices and Device Physics

Main fields of research: Fabrication problems in connection with MOS, CMOS, and CCD circuits; physical investigation of interfacial states and traps in insulating films, etc.

- Microwave Devices and Device Physics

(Deputy Division chief: Chen Ke-ming)

Main fields of research: Device structures promising high-power levels and high-efficiency and related physical research.

Present topics of research: Si and GaAs avalanche devices; mixer and oscillators for the 4 mm microwave band; physical investigations in connection with the avalanche breakdown of high-field domains in Gunn-diode structures.

- Instrumentation

(Division Chief: Li Chin-lin)

Main responsibilities: Instrumentation work directly connected with research work undertaken under other research divisions or in connection with new instrument developments relevant to the work of the institute; calibration and maintenance of instruments and equipment in the institute.

- Laser and Luminescence Research

(Division Chief: Wang Chi-ming)

Main field of research: Semiconductor junction lasers and related device physics.

Present topies of research: Deterioration of double heterojunction laser; related spectroscopic investigation of the pnpn negative resistance laser, etc.

- Physical and Chemical Analysis

(Division Chief: Hsu Chen-chia)

This division used to be a part of the Material Division and has just been separated from the Material Division and established as a division on its own. It is intended to be developed into a well-equipped laboratory adequate for accurate physical measurements of materials and thoroughgoing analysis of connection with material and device problems.

- Semiconductor Physics

(Deputy Division Chief: Kung Mei-ying)

This is a new division just being organized. The fields of research envisioned are surface physics, spectroscopy of electronic states, and electron theory.

BEIJING INSTITUTE OF OPTOELECTRONIC TECHNOLOGY (M. Birnbaum, R. Byer, M. Levenson, and C. Wang)

The Institute Director is Song Lin-you and the head of the Testing Department is Huang Chao. There are nine departments in the institute and a total of 90 engineers out of a staff of 450.

- Laser Devices

Argon ion, Nd:YAG, Nd:Glass, and ruby lasers were shown. They appeared similar to corresponding devices in the U.S. The entire laser is constructed at the institute with the exception of the laser rods which are obtained from other sources in China. The following examples will indicate some of the devices exhibited: Nd:glass laser, output 25J/pulse, 1Hz repetition rate and 1% efficiency; Nd:glass laser, 150J/pulse, 1Hz repetition rate, 20 mm silicate glass rod, 8400J input efficiency 1.8%; pulse width 0. 5 to 1 ms. In design and appearance, it is similar to U.S. pulsed solid state lasers.

- Holography

We were shown a double pulsed ruby laser holographic system similar to those found in the U.S.

- Laser Spectroscopy (Director: Li Shaolum)

Lasers were exhibited which were similar to the coherent argon ion laser and the Spectra Physics argon ion lasers. M. Levenson observed mechanical improvements in their copy of the Spectra Physics dye ring laser. Of particular interest was the elimination of belt drives on the mounts and the positioning of the mirrors over the fulcrum for greater stability. A 50 MHz line width was reported. A nitrogen-pumped dye laser was shown in which, with various dyes, a bandwidth of 3600 Å was covered. N_2 output was 0.5 to

1 µW in a 5 nsec pulse. A synchronous pumped picosecond dye laser pumped by a frequency- doubled, mode-locked Nd:YAG laser was exhibited.

- Laser Applications in Medicine and Machining

Pulsed lasers are used for cutting, hole-drilling, and other processing required in metal fabrication. In medicine, HeNe lasers are used for acupuncture. A laser fluorescence technique is used for diagnostics and a similar technique is used to treat skin cancer by means of appropriate laser irradiation. He mentioned contact with Dr. Leon Goldman's group at the University of Cincinnati.

- Testing and Measurements (Director: Huang Chao)

Testing and measurements of laser parameters of all laser products from China and also abroad are performed. Among the parameters measured are: power output stability, beam profile beam divergence, and life. This activity is funded by a grant from the United Nations Development Program. Mr. Huang stated that laser testing will be a major activity of the institute.

- Crystal Department

They are setting up a facility to grow Nd:YAG, ruby, KDP, and other crystalline materials required for solid state lasers.

- Optical Coatings Department

This department supplies multilayer optics for the institute. Very high reflectivity mirrors are fabricated. The coatings are hard and can withstand the high peak powers and the energy loading of the most powerful lasers constructed in the laboratory.

- Information Department

This department provides information services to the institute which includes books, journals, and the other usual requirements for a scientific institute.

We guess that this department is concerned with administration of the institute. None of us has notes which explicitly state anything about the ninth department.

INSTITUTE OF MECHANICS, LASER RESEARCH LABORATORY, ACADEMIA SINICA (M. Bass, A. J. DeMaria)

Our host was Chow Quan-tie, Professor of Physics. We observed gas dynamic laser work which began in 1971. It has 10 kg/sec flow and produces 30 kW. At present they have no applications in mind. The laser used Ge windows. They commented that they would like to use ZnSe, but had none and could get none.

Work on chemical lasers was started recently, but will be set up outside Beijing because of effluent control. They are also considering building an excimer laser capable of 100 W, but they were unclear as to which gas they would use.

We saw a 3 kW cw transverse flow, transverse discharge CO_2 laser with GaAs water cooled windows. This is physically larger than the Spectra Physics or United Technologies 2-3 kW lasers. This was running while we were there and had a decent spatial mode. This laser was being applied to a number of metal working questions. We suggested that for such work they could use a metallurgist as a collaborator. We also suggested that they could use the laser to drill the holes in the gas injector plate in their mixing laser. We saw the mixing laser (a mixing laser is where you heat the N_2 thermally and inject cold CO_2 to obtain an inversion) which has not yet worked because of the problem of drilling the holes in the mixing plate.

We met Li Yuan-heng who received his master's degree under Professor Chow studying the properties of semiconductors irradiated with CO_2 radiation (~40-50 W). His work includes "Dynamic Interference Effects of Reflectance of Ion-implanted Si by Intense CO_2 Laser Radiation." By measuring the reflection as a function of time they found that the epitaxial growth rate of the ion implanted (P^+) layer of Si is not uniform during the crystallization. They also studied B diffused Si and Ge annealing with CO_2 laser irradiation.

This institute has made a shearing interferometer utilizing a 1.5 mW HeNe laser to make 1.3 μsec exposures in conjunction with a 750,000 frame per second rotating mirror camera. Because of the short exposure time they can obtain excellent interferograms with minimal stability requirements imposed on the optical system. They have used this to study:

- interaction of high intensity CO_2 pulsed laser light with targets in air,
- disintegration of urinary stones with CO_2 laser ligl t, and
- the internal fluid flow field in circular pipes.

The institute is interested in selling this developed and packaged instrument. For information, contact the Oriental Scientific Instruments Import and Export Corporation.

We felt the facilities and equipment were primitive, but the work was of high quality. The scientists were well-read and quite aware of the reported work. Their progress has been limited by facilities and time.

INSTITUTE OF CHEMISTRY, ACADEMIA SINICA (M. Loy, C. Cantrell, H. Dugan)

Our hosts were Professor Guo Chu and Zhu Qibe. The institute was founded in 1956 to conduct research in organic, analytical, and physical chemistry. At a later time there was a division into two institutes, the one concerned with organic chemistry moving elsewhere in China. The Institute of Chemistry is concerned with polymer chemistry and physical chemistry, about a 60/40 ratio. Personnel in the institute number about 400. We saw the following experiments:

- Fluorescence of dye molecules on a nanosecond time scale. Dye-solvent interaction is being studied by observing shifts in fluorescence spectra, explained as charge transfer complex formation. The dyestuff was synthesized in the institute, we were told. Equipment: Applied Photophysics Lab (flashlamp) fluorescence spectrometer, purchased two years ago.

- Broadband CARS using a domestic Nd:YAG laser, spectrograph with photographic plate detector; studying pyridine compounds (perhaps they have solar energy conversion applications in mind). Also, the study of "surface Raman spectra" at electrodes in cells is being done.

- Under construction is a photolysis experiment using a supersonic molecular beam, initially to study acetylene decomposition at 193 nm. (Their domestic excimer

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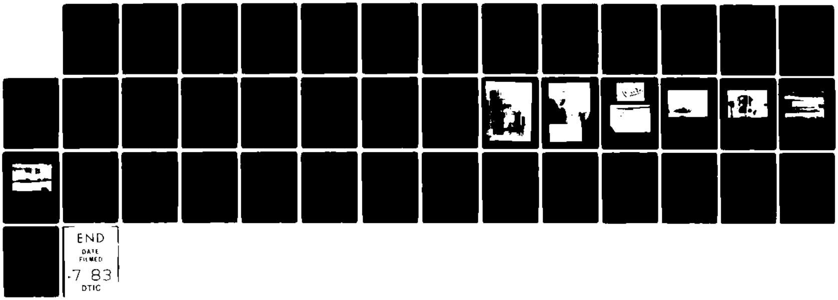

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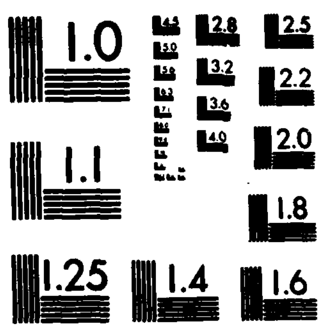

MICROCOPY RESOLUTION TEST CHART
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laser does not satisfy them.) This is in an early stage. (Collaboration is with Y. T. Lee at the University of California at Berkeley. Zhu was a student of Professor Giauque at the University of California at Berkeley.)

- Assessment: We saw the pure research aspect of the institute which cannot occupy more than about 25 people. The experiments which described items two and three above are modern and appropriate for the country's premier institute. However, they seem to be a small part of a larger operation that we did not see.

BEIJING INSTITUTE OF POST AND TELECOMMUNICATION (J. MacChesney, E. Garmire, P. Smith)

Yeh Pei-da, a member of Academia Sinica, and Professor of Microwave and Optical Communication and President of the Institute was our host. We visited the Department of Applied Physics. The head of the Department is Chen De-zhao, our host was Hsa Da-hsiung, Professor of Applied Optics and a member of the Council of Beijing Optics Society. Wa Yizun, Associate Professor, was the Optics Communication Teaching and Research Section Director. Also serving as host was Professor Zhong Bao-an.

The institute has 2000 undergraduate students, around 140 graduates students and 110 professors and 500 lecturers. It provides instruction in telecommunication technology through the Department of Applied Physics, Radio Engineering, etc. It offers bachelor's degrees and has awarded 110 M.S. degrees.

The experiments seen included a variety of measurement techniques and transmission methods including: preform profile measurements by near field, far field and Mach-Zhender methods of prism coupling as well as loss measurements. These seemed more directed to instruction than research.

From the questions asked it is judged that they are aware of the literature--both on fiber making and on systems built or planned in the United States.

It was learned that the Chinese had three optical systems in operation. These were 3-4 km links, providing 120 channels using 0.85 μm lasers operating at 8 MHz. These were installed, or first installed, in 1979. We learned of another 12 km fiber link in use for phone conversations in the Beijing area.

We were met by Mr. Zhong Bao-an, who has a student doing an experiment on a y-branch modulator in the $LiNbO_3$ and would like to make a hybrid bistable optical device. They showed us a demonstration with 50% modulation with 2V half-wave voltage--waveguide channels were 5 μm wide, so not a single mode waveguide. The laser used to demonstrate was a large Chinese-made HeNe. In the same room were an rf sputter system and a e-beam sputter system. They had diffusion pump vacuum systems. They had also made sputtered glass waveguides.

They have a mask maker made at Qinghua (Tsinghua) University which uses laser interferometric alignment. We asked to see their mask aligner, but they did not show it.

They have an investigator doing LPE of GaAlAs DH lasers on semi-insulating substrates to integrate with a FET. She is using cleaved or chemically etched mirrors. In an experiment recently completed she fabricated LOC material with an active and passive cavity. It was not clear what the threshold was.

They obtain their semi-insulating substrates from the "Color Metal Institute." This title is as opposed to "Black Metal"--iron. A more appropriate title would be "Precious Metal Institute."

We also met a Professor Hsu, who does research in holography and image processing.

We were guests in the Department of Applied Physics--the director was Professor Chen De-zhao. We gave a talk to about 50 students and 15 faculty members. They wanted to know about applications for bistability and integrated optics.

We were told there was LPE in InP, but we were not taken to see it because of the shortage of time. The physical building was adequate, two layers of cleanliness were achieved by changing shoes twice. Not beautiful, but care kept in cleanliness.

BEIJING GLASS RESEARCH INSTITUTE

Chia Zin-te, is the Director of the Institute and Wen Ngon is manager of the fiber optics division. The institute which is part of the Beijing Glass Factory, appears to be responsible for development work on optical fibers, optical glasses, laser windows, optical coatings. The work engaged in is determined by the Optical Source Committee of the Beijing government.

Optical fiber development is being done here, and at Shanghai, Guilin, and Wuhan. Here, at least, MCVD is used for preparation. Spectal loss (0.1 - 1.5 μm) is at respectable level ≈1 dB/km 1.4 - 1.5 μm, but very high OH^- level. Reported bandwidth for systems using this fiber is 400 MHz-km. System works at $\lambda = 0.85$ μm but where fiber loss is in 3-4 μm region, so OH^- does not matter. They are considering working on single mode fiber, but have not yet done so. Four fiber cable cells cost $5 per meter.

Their preparative equipment is primitive. Although reactant flows are controlled by "breadboard" computer-operating Brooks electronic flow controllers, and there is an attempt at automatic temperature control using some type of servo-acting valve, they do not have it under control. There is piping of tygon and teflon--again crude and unsatisfactory to produce low loss fiber. I would place their preparative capabilities as state-of-the-art circa 1975. Deposition was said to be at the rate of 1 km/4 hours; much lower then even a 1975 rate.

Fiber drawing is accomplished using a graphite resistance furnace. They use an Anritsu diameter monitor and a crude plastic-metal coating cup which exhibits no obvious means of alignment. Silicon is used for coating. Pulling is carried out using tractor wheels on furnace-cured silicon coating.

Measurement includes--attenuation which employ homemade apparatus employing incandescent light and chopper, and bandwidth use of Anritsu--equipment for measurement.

Profiles are measured again by Anritsu apparatus using reflected laser beams. Data is, I guess, stored and printed by a TRS 80-3 computer. This apparatus looks current by virtue of being imported.

The institute's other activities include growth of halide crystals CuF_2 LiF, etc., by Stockbarger and Chralkowski methods for "window" application. Equipment is homemade, but appears well-engineered and adequate. They also work on optical coatings--antireflection and other. They have a large 3 m diameter coating tank with allocated pumping, electron beam evaporation, and other equipment.

It is difficult to assess their knowledge of the literature because of the language difficulty. However, they seemed generally unaware of what has been published on MCVD, especially the more recent and fundamental publications.

BEIJING VACUUM ELECTRON DEVICES RESEARCH INSTITUTE (C. Wang, A. DeMaria)

The Beijing Vacuum Electron Devices Research Institute (BVEDRI) was founded in 1957 as part of the Ministry of Industrial Electronics to develop microwave devices such as traveling wave tubes, klystrons, etc. They started their laser development programs in 1964, but did not obtain a charter for the area until 1967. The Chief Engineer of the Institute is Dr. Han C. Hu, P.O. Box 749, Beijing. He is also President of the Administration Committee of Vacuum Electronics Society of the Chinese Institute of Electronics. Dr. Hu is a graduate of the University of Illinois where is studied from 1942 to 1947. He went back to China in 1948. In 1970, BVEDRI became aware of the importance of CAD in microwave tube development for studying nonlinear interactions. They acquired a 6912 model computer made by Beijing University. (Rumor is that Beijing University purchased the PDP-11, copied it, and distributed 200 copied models throughout China). The institute was slowed down by the Cultural Revolution, but not closed down as were the universities.

The institutes' staff who took part in the discussions with A. DeMaria and C. Wang were Han C. Hu, Zhang Bing-rong, Su De-xing, Zhang Fu-quang, Zhu Yi-bin, Pan Cheng-zhi, Cao Song-E, Li Yi-mei, Shen Hong-lin, Liu Xue-ming, Zhang Li-gong. We visited the Gas Laser Laboratories and saw the following facilities.

- Tunable CO_2 Laser

  Tunable from 9.17 μm to 10.8 μm with a grating. Operated at 20 Torr at 8 W and in the TEM_{00} mode. The laser was H_2O cooled and operated attached to a oil diffusion pump vacuum station.

- CO_2 Waveguide Laser

  We were shown a BeO_2 tube CO_2 waveguide laser that had 2 W output with flat end mounted mirrors and 1 W output with a grating. The bore waveguide diameter was 1.5x1.5 mm and was ~15 cm long. They have obtained 4 to 5% efficiency and 100 hours of sealed-off lifetime. Since they use epoxy adhesive, they cannot expect much better. The model we saw also was attached to an oil diffusion pump vacuum station.

- TEA Laser Pumped FIR

  We saw a TEA tunable 20J/pulse, multiple line TEA CO_2 laser which put out 5J/pulse in a single line. The CO_2 laser was UV preionized and operated at 300 Torr pressure. The discharge volume was 4cm X 4cm X 9cm long. This laser used a grating to select the appropriate CO lines to pump a D_2O FIR laser which in turn operated at 86 cm, 116 m and 385 μm. They were obtaining approximately 0.01% efficiency conversion of CO_2 pump energy into FIR radiation. All these laboratory lasers were fabricated out of transparent plastics.

They did not inform us as to the reasons for setting up these experimental arrangements. Neither of the three devices were packaged in any way from a product-oriented viewpoint.

In general, we found the staff to be well-read and up-to-date on recent developments. Their progress is hampered by a lack of equipment.

NORTH CHINA RESEARCH INSTITUTE OF ELECTROOPTICS (NCRIEO) (R. Byer)

The NCRIEO is located on the road to the Beijing Airport. It is a large institute with approximately four four-story buildings. The Director is Zhang Lian-hua who is also Vice-Chairman of the Optical Society of China, and Vice-Chairman of the Beijing Institute of Electronics. The Vice-Director is Mr. Mei who visited the U.S. last year along with Dr. Zhang. Dr. Zhang obtained his Ph.D. in the United States in the 1940s at the University of Illinois.

NCRIEO emphasizes solid state laser devices for ranging applications. Photographs are not allowed in the institute. The supporting technologies include crystal growth, optical and crystal fabrication, optical coating, and laser engineering.

My connection with the institute is through a very talented solid state laser engineer, Mr. Sun Yung-lang, who spent two years in my laboratory at Standord University. Sun returned to the institute in August 1982 and has received permission to begin a Md:YAG product development effort with the goal of selling laser products to both China and U.S. markets. The laser product will most likely be a small TEM_{00} mode pulsed or cw Nd:YAG source. Expected announcement of the product is at the Conference on Lasers and Electrooptics/International Quantum Electronics Conference (CLEO/IQEC) to be held in Anaheim, California, in June 1984.

- Technical Overview

I visited the crystal growth faculty. It consisted of a single Czochralski growth station that could produce 20 mm diameter Nd:YAG boules up to 15 cm in length. Other crystals that have been grown included ruby, Nd:SOAP, Nd:YLF, Nd:YALO, $LiNbO_3$, KDP and other garnet crystals doped with various rare earths. The effort is small, but has led to products that are for sale to the West.

We have tested their Nd:YAG and Nd:Cr:YAG crystals at Stanford University and found that the quality is not yet up to U.S. standards.

We visited a number of laser device experiments including an unstable resonator Nd:YAG source with SHG in 3 cm of KDP. Performance is similar to that achieved at Quinghua (Tsinghua) University and is limited by the relatively poor crystal quality available. The research is limited in scope to some ruby and mostly Nd:YAG sources.

The optical coating and fabrication facilities are good, but not state-of-the-art. The typical coating tank is 16 inches diameter. Optical components can be hard on soft coated. No data on damage threshold was available. Polka dot output couplers for unstable resonators and dielectric polarizers were also being coated.

Considerable interest was shown in slab geometry solid state laser design. There was little interest in single axial mode Nd:YAG sources. Discussions also showed that U.S. and Russian literature was being read and that new unstable resonator designs were being tried.

The level of technical work at NCRIEO was not up to the standards at either Quinghua (Tsinghua) University or the Beijing Institute of Optoelectronics. It is interesting to note that considerable parallel effort is underway within an institute and between institutes. The Russian model of independent stand-alone institutes is alive and well in Beijing and in China.

Discussions centered on possible products for sale outside of China. The institute does not have in place a management structure for production. It does not know what procedures must be followed for exporting a product or even what bureau in Beijing to contact. It does not have established procedures for setting product prices except to look at U.S. prices and decrease by 10%. The lack of middle management and organization was recognized, but a method to remedy the situation was not forthcoming. Until recently, the institute's performance was evaluated by the value of the product produced. This led to production of a few very expensive items. Sales and return on investment were not understood. This is slowly changing and profit is now being applied as the measuing stick. However, no standard method of calculating profit to the institute yet exists.

It is clear that the lack of people trained in business administration and accounting will impede progress toward an efficient method of goods production and distribution. What products to produce is also a complicated committee-evolved procedure that leaves no room for innovation, but demands minimizing the risk as perceived by the committee and institute. This in turn leads to considerable safety in reproducing research done elsewhere rather than striking out in a new direction. "The stalk of wheat that stands higher than the rest will be the first to be noticed and cut off," is an old Chinese saying that has implication in how the institutes plan their research and product development.

The evening discussion also led to the fact that of the foreign currency earned by sales of products, only 15% is retained by the institute. This is perceived as too small an amount to act as an incentive for boosting foreign sales.

There was also considerable discussion on the quality of Chinese products. The feeling was that perception of top quality was very important and that product evaluation standards must be set and rigorously abided by to insure proper quality standards. An example is recent interactions with NCRIEO to understand Nd:YAG rod performance tests in preparation to possible U.S. sales of Nd:YAG rods. This also led to a discussion of Chinese advantages in product sales abroad. It was agreed that labor intensive products such as Q-switches, fiber couplers, optical components had the most margin for profit. How to establish a market and to produce products on schedule was not resolved.

LUDA (DARIEN)

LUDA (DAIREN) INSTITUTE OF CHEMICAL PHYSICS (LICP) (M. Loy)

I visited LICP 30 October-1 November before joining the delegates in Beijing. Luda (Darien) is a city at the southern tip of Manchuria, about two hours flying time east of Beijing. Luda was under Japanese rule from 1905 to 1945, and then Soviet rule till 1950. The institute dates back to 1908 (started by the Japanese Railroad Corporation).

At present, LICP has 1000 people, about half of them technical people. Half of the institute is doing laser-related chemical physics work, the other half are doing analytic chemistry work (ESCA, SIMS, LEED, NMR, and Fourier Transform IR Spectrometer, gas chromotography). I visited the laser-related areas. LICP is probably the institute with the best equipment, both in quality and quantity, that I have seen in China. They purchased lasers (Ar^+ lasers, quanta-ray YAG laser, N_2 pumped dye laser, ring dye lasers, etc.) from both inside and outside China. They also have very good supporting electronics and optical equipment such as Boxcar Integrator (PAR), OMA-2 (PAR), J-Y Spectrometer, photon counting equipment (PAR) and a MINC computer for laboratory automation work. They are also planning to purchase a larger computer such as the IBM 370/148 for theoretical computation work.

LICP's director is Professor Lou Nan-quan, who, in addition to his heavy administrative task, is also actively engaged in chemiluminescence and LIF studies using a crossed molecular beam (the only one in operation in China at this moment, while there are plans for more at the Institute of Chemistry in Beijing and Fudan University in Shanghai). The deputy directors are Professor Zhong Cun-hao (graduate work at the University of Michigan) who is in charge of the laser area and Professor Tao Yu-sheng (a student of Harold Johnston while he was at Stanford University) in charge of areas in reaction kinetics. These three directors are all relatively young (in their 50s), all active in research, and appear to work well as a team to run LICP.

Experiments that I saw include laser Raman spectroscopy, optogalvanic spectroscopy, tunable diode IR laser spectroscopy; they have a Laser Analytics diode laser system, dissociative attachment of Cl_2 and recombination of Ar^+_2, high temperature atomic beams for dimer spectroscopy, and the crossed-molecular beam experiments. They also did cw HF/DF laser work in the past, but are not continuing in that area.

Compared to the other institutes and universities, LICP impressed me as the one with the best planned direction in their research program. They have also made the decision not to spend time building lasers, and have gotten the funding to purchase modern equipment so they are now in a good position to really get on with doing world-class science. If the present leadership continues on its course, I think they will be able to do that in a few short years.

In talking with people in the Institute of Chemistry in Beijing, I got the impression that LICP is generally recognized as one of the best run institutes in the Academy of Sciences. However, due to its location, LICP is rather isolated and difficult to get to. They are rather weak in electronics and computers and cannot get help as easily as other institutes in Beijing.

XIAN

NORTHWEST UNIVERSITY (J. MacChesney, R. Byer, H. Dugan, M. Levenson)

Our hosts were Mr. Lu Tsu-kuo, Lecturer in Physics, Honorary Chairman of the Physics Department; Dr. Y. S. Chiong (Ph.D., University College, London); and the Director of the University: Mrs. Gau.

This university was established 45 years ago by academics fleeing the Japanese. After the war, it fell upon hard times, but now has 3000 students and 800 faculty and staff. The physics faculty numbers 90 of whom 15 rank as professors. Dr. Shu Shen-jin heads the laser section of the Physics Department and mentioned research in laser spectroscopy, laser devices, and nonlinear optics. We had no chance to visit the laboratories because the bulk of our half-day visit was spent giving three one-hour talks to about 100 assembled scientists. Also present was Mr. Gong Zu-tong, Director of the Provincial Optical Society of Xian. Other nonlaser research mentioned was in solid state physics, theoretical physics, statistical physics, and microelectronics. Given the nature of the visit, it is impossible to evaluate this institution.

- Discussion on solid state lasers with 12 people representing Northwest University and other institutes, and R. Byer.

The discussion took place at the Xian Benmin Hotel and centered on solid state laser engineering. Mr. Shang acted a translator for the discussion. Prior to the discussion a written list of questions was presented to us for consideration. Questions of interest included:

- What was the status of the development of small size Nd:YAG laser sources?

- What was the progress in the development of $Nd:LaP_5O_{14}$ crystalline lasers and how did they compare with Nd:YAG?

- What was the comparison of alexandrite as a laser material?

- How can Nd:YAG lasers be frequency stabilized; for example, by electronic line narrowing, injection locking, intracavity etalons or regenerative amplification?

- What are design features for unstable resonator oscillators?

I asked, in turn, about Northwest University. The university has 3000 students of which 300 study physics. The Physics Department also grants M.S. and Ph.D. degrees. The areas of research include laser spectroscopy, nonlinear optics, picosecond pulse generation, applications of tunable lasers and semiconductor physics.

Professor Zhang Ji-kue answered my questions and asked questions about chaos, superradiance and two photon lasers. He was very bright and knowledgeable about recent literature. His English was marginal.

- Technical Discussion

The technical discussion covered questions that were given above. At the beginning, the topics discussed were frequency stabilization of Nd:YAG lasers. I reviewed electronic line narrowing and injection locking and recent work on <1 MHz linewidth Nd:YAG by Sun Yung-long while he was at Stanford University.

We then discussed, at length, unstable resonator design and I outlined the classical magnification = 3.3 Byer-Herbst design, a newer laser magnification design (filled in beam resonator) and the use of a radial birefringent filter as a spatial filter within the unstable resonator.

Slab geometry solid state lasers were briefly discussed as was the comparison of Chinese YAG crystal quality to U.S. quality.

SHANGHAI

FUDAN UNIVERSITY (R. Byer, C. Cantrell, M. Loy)

We were met by Wang Zhao-yong and by other professors of the Chemistry Department. Wang is the Chairman of the Physics Department. He has studied for one year under Art Schawlow (1981) at Stanford University, and therefore knows U.S. university structure. Also, in his department is Professor Zhang who met the entire group and Dr. Lee who also studied at Stanford University for one year under Dr. Hansch.

After the initial discussion we visited both the physics and chemistry laboratories where laser research is important. The students were not in the laboratories, but were attending lectures by P. Smith and C. Flytzanis.

We saw surface enhanced SHG studies, CARS studies of flame temperature and liquids using a Nd:YAG pumped dye laser CO_2 TEA laser induced fluorescence spectroscopy with a N_2 laser pumped dye laser probe, and in chemistry a CO_2 TEA laser photodissociation study effort.

The quality of the work was high. The work had been selected in scope and was much more focused than in my visit of two years earlier. Measurements were now being made to understand physics and not just to demonstrate laser experimental capability. The scientists seemed to sense where they were making a contribution to new knowledge. This was not the case two years ago. The visits to foreign laboratories by the faculty has proven to be good in a number of ways. These include understanding of where efforts should go to make contributions on a limited budget; the focusing of effort to a few key areas; an appreciation of where world-level science is relative to current Chinese university science and the ability to communicate across international boundaries.

Discussion with Professor Wang also led to an understanding of sources of funding in China for university-based research. Unlike institutes which have large predetermined budgets, universities must seek funds from three sources: the Ministry of Education, local municipal funds, and from the equivalent to the National Science Foundation in the U.S. which in China is administered by the Academia Sinica. Funds are distributed by a proposal review process. The system is new, and this is the first year it has been in effect. The overall result of writing proposals and seeking funds is, however, positive. The universities are more directed and selective in areas of research than institutes.

An area of difficulty at universities is excess faculty in every department. The faculty trained during the Cultural Revolution are treated differently due to their lack of formal training. Some departments are trying to re-train faculty by having them formally take and pass courses and exams. Other departments request that faculty members remain current in their field by self-study. The problem also exists in the U.S., but not to the degree generated by ten years of imposed nonintellectual activity.

Mr. Wang asked specific questions following our visit. One of these was what could Fudan University do to improve on its present course. Following one visit and discussions, we replied that the actions taken thus far of focusing research efforts, sending faculty and students abroad to study, and seeking research funds by proposal are in the right direction. Improvements in the quality of science over the past two years is evident. Future improvements could be expected in the future if the situation remains stable from outside political or economic changes.

FUDAN UNIVERSITY (K. Dugan, C. Flytzanis, P. Lallemand, P. Smith and C. Tang)

The group was met by Professors Wang Zhao-yong and Zhang Zhi-ming respectively, Chairman of the Physics Department and Director of the Laser and Optics Laboratory.

In the subsequent general presentation of the department which took place in the reception hall, the group was presented to Professor Xie Xi-de, newly appointed President of the University and to Professor Li Chang-lin of the Department of Nuclear Chemistry.

From the general presentation and discussion that followed it became clear to the visitors that Fudan University is among the two or three top institutions of the People's Republic of China with very selective enrollment (one out of ten applicants) both at the undergraduate and graduate level. At present, a particular emphasis will be made at the graduate level to attract students from as wide a class of institutions as possible and broaden the scope of the graduate program. It was stressed that in this new policy, Professor Xie Xi-de played a very important role and the department was very confident about its success; being a specialist of surface physics, she was influential in promoting this field across the various departments of the university.

The visitors were very much impressed by the general discussion and the maturity of research activity in the department. The general feeling that emerged, and which was reinforced by the subsequent laboratory visit, was that Fudan University is competitive with any top institution of the United States, Canada, and Europe, and in the future will play a dominant role in educating top scientists, elaborating, formulating, and innovating research programs appropriate to the Chinese reality and distinct to the ones conducted elsewhere.

The organization structure of the university is as follows:

Founded in 1905, and reorganized after 1952.

- Departments (16)

  Foreign Languages and Literature
  Chinese Language and Literature
  History
  Journalism
  Philosophy
  Economics
  International Politics
  World Economy
  Mathematics
  Physics
  Chemistry
  Biology
  Nuclear Science
  Computer Science
  Management Science
  Electronic Engineering

- Research Institutes Affiliated with the University (7)

  Institute of Mathematics
  Institute of Genetics
  Institute of Modern Physics
  Institute of Electric Light Sources
  (development of lamps through the gas discharge processes)
  Institute of World Economy
  Institute of Chinese Linguistics and Literature
  Institute of Historical Geography

- Curriculum

Undergraduate: four year program towards B.S. or B.A. degrees
Graduate: program for M.S., M.A., and Ph.D. degrees in certain fields

- Number of faculty members

Total: about 2300
Professors and associate professors: about 400

- Number of students in the fall of 1982

Undergraduates: about 5600 (tuition waiver)
Graduates: about 400
Day students: 252 (tuition paid by students)
Visiting faculty members: 210 (for advanced studies from other Chinese universities)
Foreign students: about 132

The visit in the laboratories was very enriching and refreshing. It was concentrated in the laser physics and chemistry activity; first in the Physics Department and then in the Nuclear Chemistry Department.

- Physics Department. The main emphasis in laser physics here is in nonlinear optics, and in particular:

CARS - spectroscopy,
surface nonlinear optics,
picosecond techniques,
IR - photodissociation.

A sample of experiments was shown to the visitors in the following sequence:

.Infrared Photodissociation

$$HBr + Cl \rightarrow HCl + Br$$
$$CCl_3F \rightarrow CCl_2F + Cl$$
$$CClF + Cl$$
$$CF + Cl$$

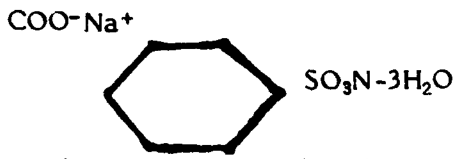
A TEA-laser was used and the products were detected by absorption spectroscopy. In the second reaction, the presence of CClF as an intermediary was evidenced by careful time-delayed spectroscopical analysis at 3665 Å using a N_2-pumped dye laser. The concentration of CClF reaches a peak delayed by ~ μs from the start of the photoreaction. The pressure dependence of this time delay was carefully studied and accounted for theoretically with rate equations; by extrapolating to zero pressure (no collisions), the delay was determined to be 634 nsec.

.CARS Spectroscopy

A completely operational CARS spectrometer was setup for taking CARS spectra of different molecules. A KDP-doubled YAG laser (repetition rate ~10 Hz, power ~30 MW and stability 10%) was used to pump a dye and also deliver a fixed frequency for the CARS spectroscopy.

Detailed experiments were performed in N_2 (1 atm, at T=500°C and 835°C) and accounted for theoretically by assuming the same lifetime for all rotational levels. The spectrum was taken up to the line Q(40). Presently the CARS-spectrum of nitrobenzene vapor was taken at different temperature. The results are of excellent quality, but are used mainly as a test for the viability of the setup which subsequently will be used for diagnostics of combustion.

In this experiment, a new nonlinear crystal for second harmonic generation was also tested with the chemical structure



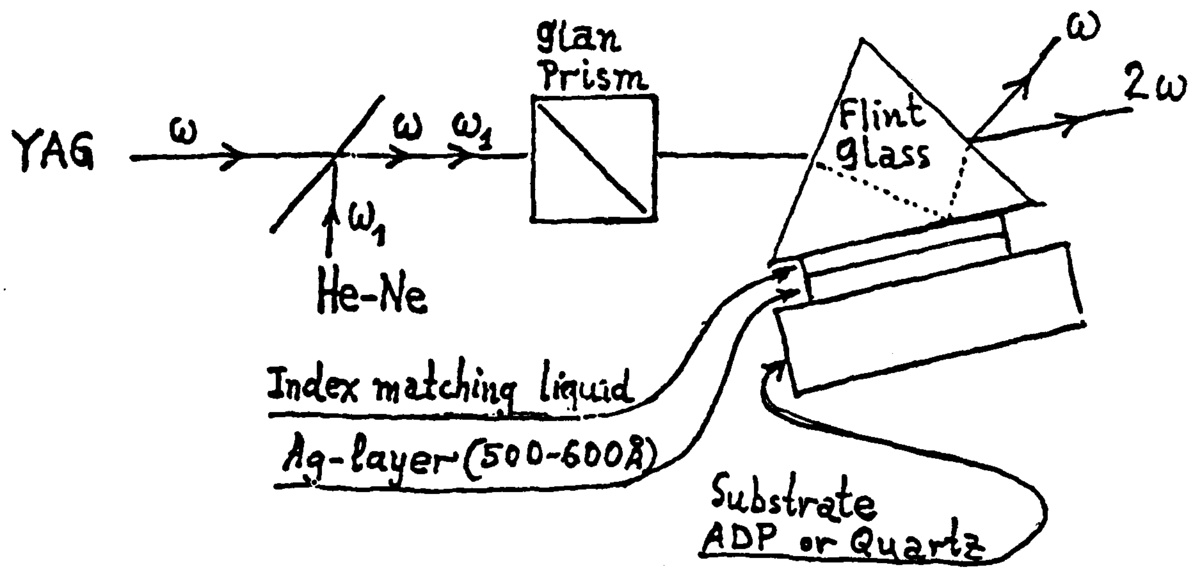
Its SHG efficiency was higher than KDP's, but the crystal suffered from prolonged exposure to a high repetition laser source.

.High Resolution Spectroscopy

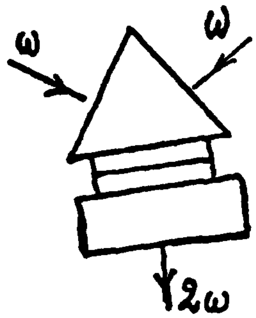
A fully equipped Ar-pumped dye ring cavity was setup for high resolution spectroscopy. The laser was made in the Laser Technology Institute at Shangai. Experiments have not started yet.

.Second Harmonic Generation by Surface Plasmons

The experimental set-up was:



An other geometry is also used



At resonance (by turning the angle of incidence of the input laser) one gets an enhancement factor of 200 to 400.

The use of the index matching liquid was for convenient angle of entrance. The main observations were that the second harmonic

- is independent of the bulk.
- is strongly dependent on the surface and its state,
- it showed a thickness dependence, and
- it could be used for surface diagnostics.

.Determination of Thickness and Dielectric Constant of films by ATR Spectra (attenuation of total reflection)

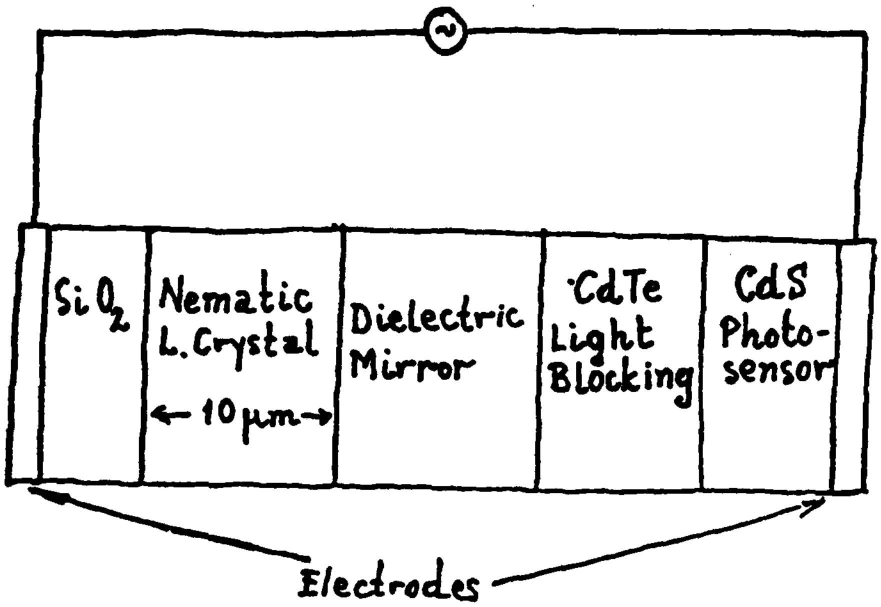
The setup is fully operational and uses a HeNe laser; it is similar to the one proposed by Otto. The ATR-spectra were taken by scanning the angle of incidence. The laser source will be replaced by tunable dye laser to allow for the measurement in a wide class of materials; the frequency each time will be tuned at the reflection peak of the film.

.The Design and Fabrication of Wedge Ring Detectors for Optical Power Spectrum Analysis.

In hybrid optical power spectrum analysis systems. the wedge ring array detector functions as an optical to electrical interface device for sampling the optical spatial frequency information for further processing by digit computer. The detector designed and fabricated in the laboratory consists of 32 semicircular rings for detecting the radial information and with 32 wedge-shaped sections for the directional information in the spectrum. The detector is made on a silicon wafer; diameter is about 32 mm with carefully controlled diffusion process in order to obtain uniformity in response and sensitivity. The average responsivity is about 0.5 mA/mW for the wedges and annular rings of the corresponding areas: the time constant is about 150 μs. The spatial bandwidth could be up to 100 cycles with an optical transform lens of 240 mm focal length irradiated by the HeNe radiation of 6328 Å.

.Liquid Crystal Photovalve for Data Processing

A well designed photovalve. Size 1.5x2.5 cm^2



Its response time, ~300 msec, is limited by the thickness of the liquid crystal layer. The uniformity can be further improved. Threshold intensity 3 μW/cm^2; to appear in *Optics Letters*.

.Mode-locked Ar-laser

This set up will be used for the study of short transients in some complex molecules; in the process of completion.

- Nuclear Chemistry Department

The highlights of the activity in photochemistry were shown to the visitors. The laboratory is in the process of being modified and equipped with a new generation of lasers and modern diagnostics for spectroscopical analysis, surface enhanced photochemistry, and molecular beam instrumentation.

.TEA laser in the process to be modified to deliver square light pulses of 20 ns duration. This will be achieved by inducing the laser action in the TEA laser with the output of a cw CO_2 laser through a fast Pockels cell.

. Excimer laser XeCl to pump a dye laser (200 mJ, 3 Hz repetition rate).

.Molecular photodissociation of NH_2. $NH_3 + O_2$, C_2F_4. CF_2HCl ...

.Molecular beam experiments in the process to be completed. It will use a China-made vacuum pump.

.Surface photochemistry of SF_6. A CO_2-beam is focused on a surface in order to study the threshold energy for photodecomposition. The process shows isotope selectivity and can be used for isotope separation.

.Infrared Fourier spectrometer

A fully equipped, computerized Brucker infrared Fourier spectrometer with resolution ~ 0.06 cm^{-1}.

The hosts showed us the campus (student dormitories and club. library) and explained the main organization of the university and the recruiting procedure. They also showed us the new physics building where all research activity will be transfered by the end of 1983 allowing the present building to be used as a physics laboratory for students and for teaching purposes.

The lectures of C. Flytzanis and P. Smith were presented in the Physics Department lecture room with a large audience without an interpreter. Subsequently, the speakers met with small groups of the audience and elaborated on specific aspects of their activity. The scientists participating in these informal discussions were extremely well-prepared and in the process of elaborating new lines of research in nonlinear optics and nonlinear optical devices. They also explained the organization of the department. The whole department meets once a month to listen to reports concerning fields of research activity which eventually could be developed in the department or is related to an existing activity. The choice of these subjects is made several months before the date scheduled for the presentation by a scientific committee. Besides these department meetings each group met once a week to discuss the progress of an experiment, related literature. and instrumentation.

The organization of seminars with outside speakers is still in its infancy, but it will be made a priority once the transfer to the new physics building is completed.

The group was impressed by the general atmosphere in the laboratories; it is similar to top Western institutions. The presentations were done in excellent English by the active scientists who seemed to be motivated, independent, and extremely well-informed concerning similar work done elsewhere.

The general feeling that emerged from this visit is that Fudan University is a wholly matured institution with immense potential for future advancement and scientific exchange with institutions for mutual benefit.

JIAOTONG UNIVERSITY (E. Garmine, J. MacChesney, G. Gordon)

All three visitors gave talks--only E. Garmine visited any laboratories--that of Associate Professor Chen Yi-xin in integrated optics. His title is also Executive Head of the Department of Applied Physics. Jiaotong University was established as a technical engineering school in 1921. There are 5000 students in a four year program and 400 graduate students. There are 1600 faculty members with 300 professors and associate professors. Applied physics is one of 13 departments and is responsible for all physics courses--that department began in 1977. Enrollment in that department is 35 undergraduate students and 15 graduate students. Areas of research besides integrated optics are holography and "laser techniques and applications." Professor Pan was a visiting scientist with W. S. C. Chang at the University of California of San Diego and is doing a wide range of integrated optics research of a relatively primitive sort. They are copying the rf spectrum analyzer developed here several years ago, but they have a long way to go. They have done some nice work. and so far unpublished research on ion exchange waveguides in $LiNbO_3$ in the presence of an electric field. They are studying Ge avalanche photodiodes, since they can fabricate them in their laboratory and have made a SAW Bragg optical deflector with 6 μm fingers. They showed me their clean room, mask aligners, bonders, etc. Simple, but adequate for research purposes.

They were studying optical damage, but clearly did not understand the science behind what they do and are not familiar with the literature or other research in China. They are setting up LPE for III-V integrated optics research. Looks like a good average laboratory for an American university, but much less understanding of what device physics is.

SHANGHAI CERAMIC INSTITUTE (R. Byer)

The Shanghai Ceramic Institute grows melt-grown crystals including a wide variety of oxide crystals of use in laser devices. Also grown are mica, diamond, and crystal quartz.

The Czochralski growth stations are stainless steel enclosed, of the same design as seen in Beijing at the Beijing Optical Factory. The crystals pulled included many old favorites such as $LiNbO_3$, $BaNaNb_5O_{15}$, $SrBaNb_5O_{15}$, $KNbO_3$, BSO, BGO, YAG, and ruby. Boule sizes were typically 20-25 mm diameter by 10 cm in length. There were no new materials and there did not appear to be an effort to invent new materials.

The crystal growth group was under the direction of He Chong-fau, Associate Professor, Deputy Head of the Department of Crystal Growth.

The crystals from this institute are available in the U.S. through the C. P. Wang Company, Global Technology. A ruby crystal of poor quality and a $BaNaNb_5O_{15}$ crystal, not yet tested, are at Stanford University in my group. A $LiNbO_3$ crystal is at University of California at Berkeley with Y. R. Shen.

The $LiNbO_3$ with 1% MgO doping is not of good quality and does show optical damage. The group did not know of the research under Professor Hau Kai at Chengdu Southwest Technical Institute, P. O. Box 238, Chengdu, People's Republic of China, which has produced high quality photorefractive-damage-free $LiNbO_3$.

This group is production oriented and is not current in crystal growth technology. With two growth stations and poorly regulated local electrical power in Shanghai, it cannot produce large high quality materials. There are steps being taken to correct the power problem. The lack of research will slow progress in the growth of improved crystalline material.

One impressi e experiment shown to the group was an acoustro-optically Q.-switched internally doubled Nd:YAG laser. The SHG crystal was $BaNaNb_5O_{15}$. The output in the green was approximately 500 MW average power. The laser and doubler were originally shown in May 1980 to the scientists of the quantum electronics meeting. It has not changed since then. The current U.S. product is two W average power in the green and the next generation is 10 W average power.

Although an impressive visual demonstration, the experiment is equivalent to work done in the U.S. in 1970-72.

SHANGHAI INSTITUTE OF OPTICS AND FINE MECHANICS (M. Bass, C. Cantrell, A. DeMaria, M. Levenson)

The Shanghai Institute of Optics and Fine Mechanics (also known familiarly in China as Jia-din) was founded in 1964 by drawing from the Changchun Institute of Optics and Fine Mechanics and the Beijing Institute of Electronics. The Director is Professor Gan Fu-xi, and the Vice-Directors are Professor Deng Xi-ming, and Professor Wang Shi-jiang.

The basic objectives of the institute are: exploring fundamental problems in laser science: developing laser techniques; and opening up laser applications. There are 1400 workers at the institute, including 600 scientists. The institute has 14 departments:

- high energy,
- gas lasers,
- advanced gas lasers,
- far-infrared lasers and optical frequency standards,
- small- and moderate-sized solid state lasers and their applications,
- laser glasses,
- laser crystals,
- laser pumping light sources,
- technical optics,
- mechanical design,
- electronic techniques,
- laser physics, and
- semiconductor lasers.

The institute also has its own workshop for pilot production of lasers and optical products. The primary research areas of the institute include various types of lasers, laser materials, laser components and related devices, laser physics, optical information processing, optical frequency standards, and laser fusion.

The laser fusion program was started in 1975. They have constructed a six beam Nd^{3+}: glass system which uses ED-2 (i.e.. a silicate glass). They recognized that this glass was not the best for such a system, but it was the only glass available for them. The system uses an actively mode-locked YAG laser oscillator from which a single pulse is selected, and then amplified by a YAG amplifier. The final glass stage uses 70 mm x 50 cm long glass rods. Each one of the six beams can provide 10J in a 100 psec pulse on a target held on a pedestal. With a 1 nsec pulse, they can obtain 15 J per beam.

The beam divergence is less than 1 mrad with 75% of the contained in less than 1 milliradian. By our standards, this is not good performance.

Dr. Lin heads the group. He just returned (i.e., three months ago) from a two year visit to the Rutherford Laboratory in England. Their present glass system is not expandable. Our inquiries regarding laboratory amplifiers resulted in vague answers. Dr. Lin stated they can achieve 400 to 500 shots per year if they work hard on the system. The room in which the system was enclosed was so dusty that we doubt they can even obtain this performance. The system was not in operation when we visited.

They have also initiated some work on the CO_2 TEA laser for fusion research. The system utilizes UV preionization in the oscillator and amplifiers. The last stage amplifier was in processes of being final tested and utilized an e-beam. They were utilizing an aluminum foil (rather than titanium) to separate the e-beam and laser chambers.

Mr. Zhou Fu-hsin has assembled a CARS apparatus consisting of a doubled quanta ray-type YAG laser and a Littman-type dye laser. He has used this apparatus to study CARS and cascaded four-wave mixing ("HORSES" and "HORAS") type interactions in organic liquids and calcite. The detection of sixth order HORAS by this group has been reported at the VICOLS Conference (*Laser Spectroscopy V*, edited by A. R. W. McKellar *et al.*, Springer-Verlag, 1981. The lasers appear powerful enough for more current CARS experiments in gases, discharges, and flames. The detection system consisting of a tandem ½ m monochrometer and photomultiplier also would be more than adequate. One hopes that this equipment will be applied to topics of interest in spectroscopy and engineering rather than used to demonstrate nonlinear effects observed previously by Compaan and Klauminzer.

SHANGHAI INSTITUTE OF LASER TECHNOLOGY (SILT) (E. Gordon, R. Byer)

The Shanghai Institute of Laser Technology, (SILT) was founded in 1971. Its purpose is to develop laser devices and to investigate laser applications in industry and medicine. The institute develops and sells laser products to the Chinese market. Some of the devices are available for export.

SILT employs approximately 500 people divided equally between research and development and factory production. One of its Vice-Directors is:

Nie Bao-cheng
Yue Yang Road
Shanghai, People's Republic of China
Phone 374 454
Cable 1538

SILT occupies two buildings in Shanghai. The building space and supporting equipment is adequate. The production rate is small by U.S. manufacturing standards. The Vice-Directors of SILT, Mrs. Nie and Weng, are aware of U.S. laser status. They are also aware of their own product development and application goals and direct SILT to maintain a rather narrow, but effective line of products and applications. The institute stands out as well-organized and well-managed.

The institute was established with the goal of working on laser applications and producing laser products. Very small-scale manufacture is carried out with ultimate manufacture carried out in a Shanghai factory. The factory is a separate organization.

The products being developed are HeNe, CO_2 and HeCd lasers. Applications study areas are color center lasers, optical disc memory, industrial uses of the laser, holographic interferometer.

Typical HeNe lasers were well-packaged, 100 MW output and life of 10^4 hours. Similar statements for HeCd and CO_2 are appropriate. The typical white light HeCd was displaced. None of this is high technology. A useful dating of the work is given by the following example. One individual was systematically filling a discharge tube with gas, pulsing it and looking for new laser lines. Typically, gases were Cl, O, N, B. This reminds me of the 1965 era. They did have a good monochromater and had seen some new transitions in HI which were published in the *Journal of Quantum Electronics*.

We saw some optical disc work using a Ar^+ laser (10 MW) for writing and a HeNe laser for reading. Disc speed was 2 rps using Te film (400 Å) on glass for writing. Holes were 1 μm with 2 μm track spacing. Hole formation was not well understood and both evaporation or melting plus pull back were still under consideration.

Pockels cell modulators with both perpendicular and parallel field configurations were being designed. Nothing special. A cavity dumped HeNe laser using an internal acoustooptic modulator was exhibited. Its purpose was to reduce low frequency, flicker noise in the laser output. Noise at 450 Hz was reduced by 50 dB.

Apparatus for Doppler measurement of velocity down to 1 mm/sec was exhibited. It had no new concepts. One of the applications was for blood velocity flow.

Most, if not all, of the work exhibited a strong pattern. It is duplicative, prosaic, and low technology. However, the Chinese are determined to be self-sufficient in all aspects of the technology. This is a good learning experience for them.

At the present time, the quality of the components leaves much to be desired. Thus, sales are essentially internal to China. Not until they can produce high quality products do they plan to sell externally.

TECHNICAL AREAS

During the visit to SILT we were given a tour of both buildings and all laser experiments in operation. The A.O. modulator and E.O. modulator development is under Fan Yuan-xuan who is studying for two years at Stanford University in R. Byer's group. The products are vintage 1971-75. A ring electrode KDP (not deuterated) modulator is being developed. It is not fluid encased.

The HeNe laser looks well-developed in the small power range, 1-10 MW. The 50 MW laser is one-half the output of a similar U.S. manufactured laser (the Spectra Physics Model 125). The institute does not make an argon ion laser. It recently purchased a Spectra Physics model 165 argon ion laser for optical memory studies. SILT would like to become the service institute for U.S.-made lasers in China.

The SILT sealed off CO_2 laser technology is well-advanced with 60W per meter of output. One device was purchased for testing in the U.S.

Also produced are a HeCd laser (250 MW), a white light laser, and a N_2 pumped dye laser. All devices were standard. There are no solid state lasers at SILT.

The institute has a good staff and good management. It is among the best in China in its limited area of laser production and applications of lasers.

One piece of new research was the investigation of pulsed ion discharges for new laser lines. The work, coauthored by C. C. Chou and published in the July 1982 *Journal of Quantum Electronics* has resulted in more than 30 new lines in the UV in Cl, O, S, Ti discharges.

GUANGZHOU (CANTON)

ZHONGSHAN UNIVERSITY (R. Abrams, M. Bass, R. Byer, C. Cantrell, A. DeMaria, C. Dugan, C. Flytzanis, E. Gordon, P. Lallemand, M. Loy, C. Tang)

Zhongshan University was founded by Dr. Sun Yat-sen (for whom the university is named) in 1924. At the present time it is one of the "key" universities in China, like Beijing University and Fudan University. Persons visited were: Professor Gao Zhao-lan, Head of the Laser Laboratory and Professor Li Xie-jun, Vice-Chairman of the Physics Department. The university academic departments are divided among two colleges, the College of Literature and the College of Science. The science departments include:

- mathematics,

- physics,
- chemistry,
- geology, and
- computer science.

There are 190 faculty members in the Physics Department, including six professors, 11 associate professors, and 90 lecturers; the remainder are assistant professors. Among the 5000 students at the university, there are 500 undergraduate and 31 graduate students in physics. At the present time graduate work is almost entirely at the master's level. There are only a few Ph.D. students, and these are directed by the full professors as a group rather than by a single faculty member. There are two kinds of subdivisions in the Physics Department here: teaching/research groups, which educate students, and laboratories, which exist primarily for research. The groups are in the areas of theoretical physics, optics, metal physics, semiconductor physics, and ferroelectric materials; the laboratories are in the areas of laser physics and gravitational waves.

As in all the other laser laboratories at universities and scientific institutes that we visited in China, safety precautions were notably absent. The hazards of high voltage and laser light were particularly acute: high voltage leads and laser electrodes were unprotected, and laser beams propagated in and outside the laboratories at eye level and without adequate protection against specular reflection. If a greater consciousness of the need for safety precaution does not develop, China's investment in the education of its young laser scientists will be jeopardized.

The laser laboratory was started in 1969, at a time when China could not easily obtain lasers from other nations. In its first years this laboratory manufactured HeNe, CO_2, Ar^+, HeCd, N_2, and solid state lasers, with help from the Shanghai Institute of Optics and Fine Mechanics. HeNe lasers are still manufactured here. Precision instrumentation purchased from Japan, Western Europe, and North America supplements the scientific instruments made in China.

Several experiments using Ar^+ lasers built here are under construction, including laser resonance Raman spectroscopy, and studies of biological molecules using an actively mode-locked dye laser pumped by an Ar^+ laser.

CHENGDU

THE SOUTHWEST TECHNICAL PHYSICS INSTITUTE (R. Byer)

I had requested to visit this institute due to interaction with Professor Han Kai when he visited Stanford University in April 1982 for four weeks. The visit yielded a sample of $LiNbO_3$ doped with 5% MgO that was of very high optical quality and showed <u>no</u> photorefractive optical index damage. The crystal has been used for SHG of Nd-YAG <u>and</u> phasematches at 116° C. It has recently been carefully studied by R. Rice of McDonnell-Douglas in St. Louis. The study has verified the absence of optical index damage. Rice calls this crystal "The Star of China."

My visit to Chengdu could not be arranged in time despite efforts by the institute codirectors. It is being set up for next year after the Laser Symposium to be held 6-9 September 1983 in Guangzhou, People's Republic of China.

The Technical Institute was established in 1958. It employs 600 people.

Approximately 130 are trained scientists and engineers. About 50-100 people work in the factory.

There are four areas of research and development at the Technical Institute. They are the crystal growth area, the optical detector area, the laser device area, and the laser range finder area.

In the crystal growth area, which is considered by Professor Han Kai to be the most advanced in China, Nd:YAG, CDA, and $LiNbO_3$ are grown. Recently work has been started on alexandrite and on new nonlinear crystals for harmonic generation of Nd:YAG. In 1983, a scientist from the institute will visit the Stanford University Materials Science Department and study with Professor R. S. Feigelson.

In the optical detector group the work is directed toward high speed detectors. To date silicon APD detectors have been built with greater than 500 MHz bandwidth.

The laser devices group designs and builds Nd:YAG, CO_2 waveguide, CO_2 TEA, and ruby lasers. Work is also done on efficient SHG of Nd:YAG using $LiNbO_3$. One goal is to produce a small laser system for laser range finding applications.

My information came from extensive discussions with Professor Han Kai during our two day stay in Guilin. Professor Han Kai flew from Chengdu to Guilin to have the opportunity to have technical discussions.

One note of concern expressed by Professor Han Kai was that the Southwest Technical Physics Institute should not be confused with the similarly named Southwest Physics Institute. Thus, the P.O. Box 238, Chengdu, is essential in the address.

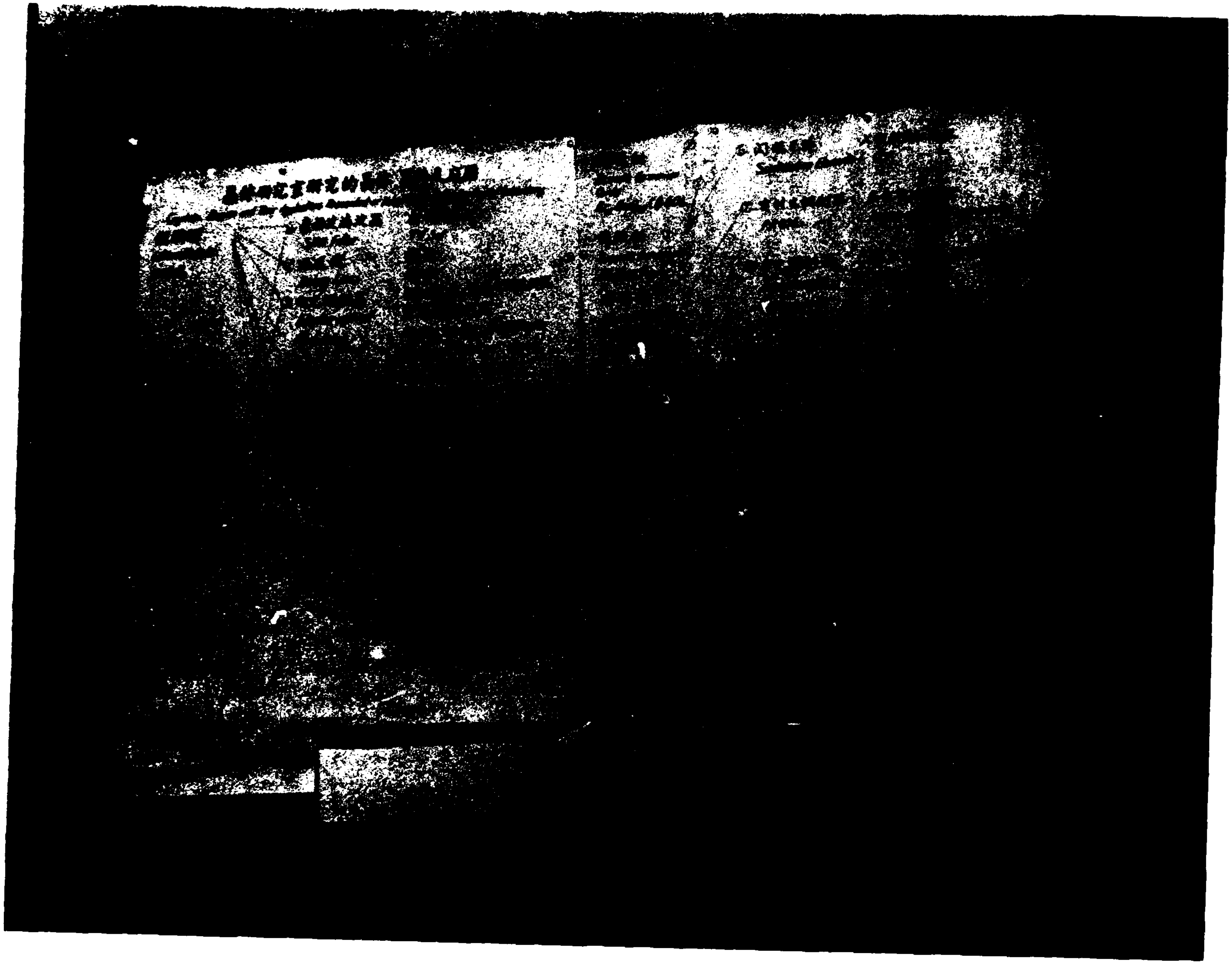
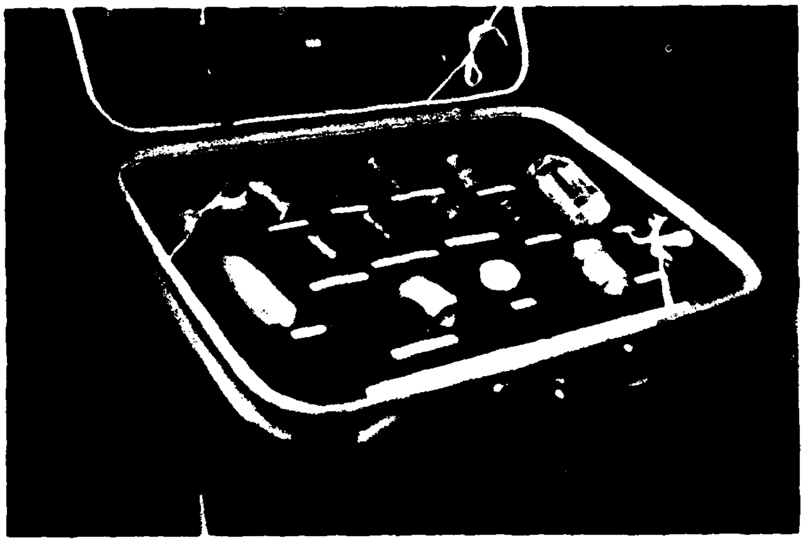


Photo 1. Wall chart listing crystals grown and their applications, Institute of Ceramics, Shanghai.

Photo 2. Buildings of the Institute of Ceramics, Shanghai.



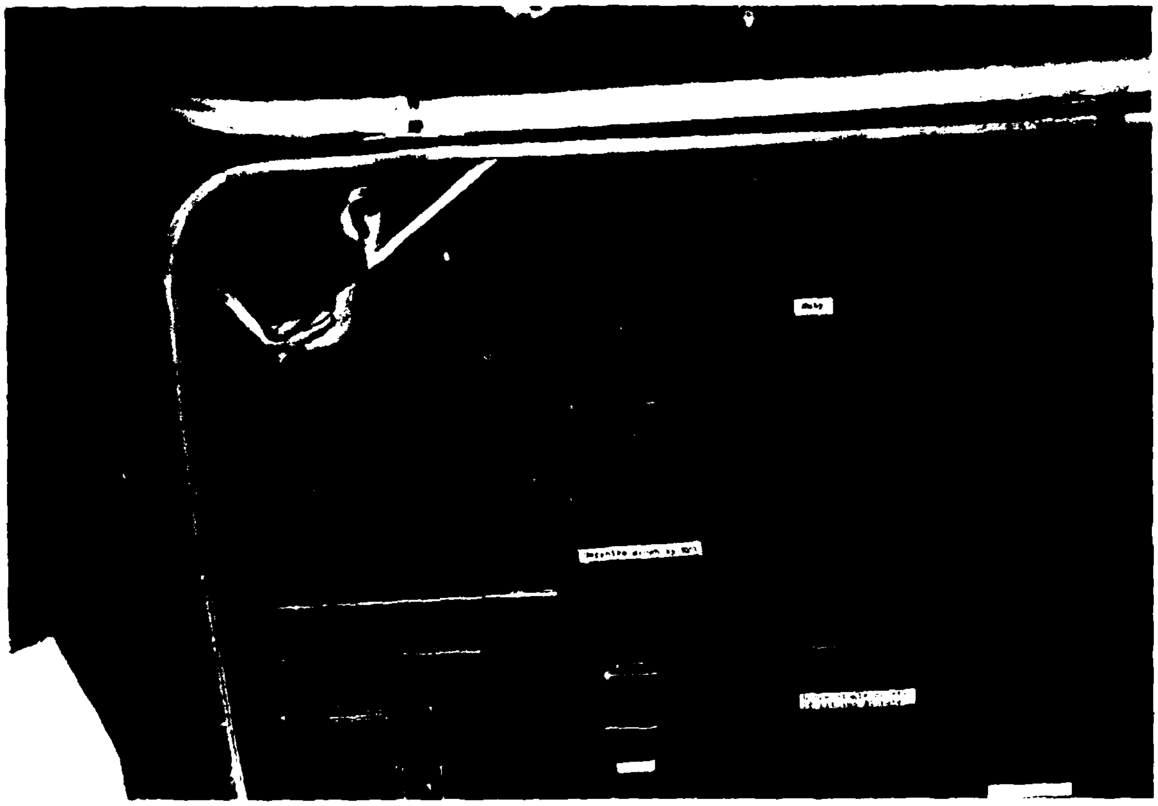


Photo 3. Sample case of crystals, grown at the Institute of Ceramics.

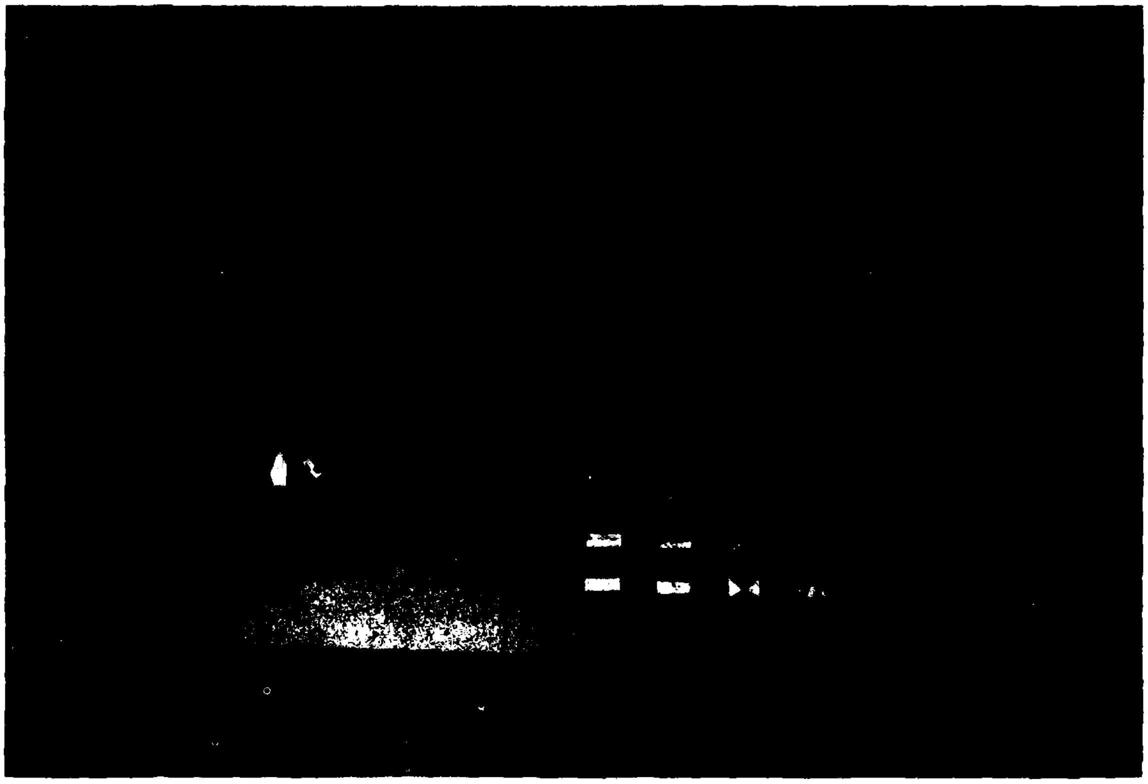


Photo 4. Six-beam laser fusion system, Shanghai Laser Institute.

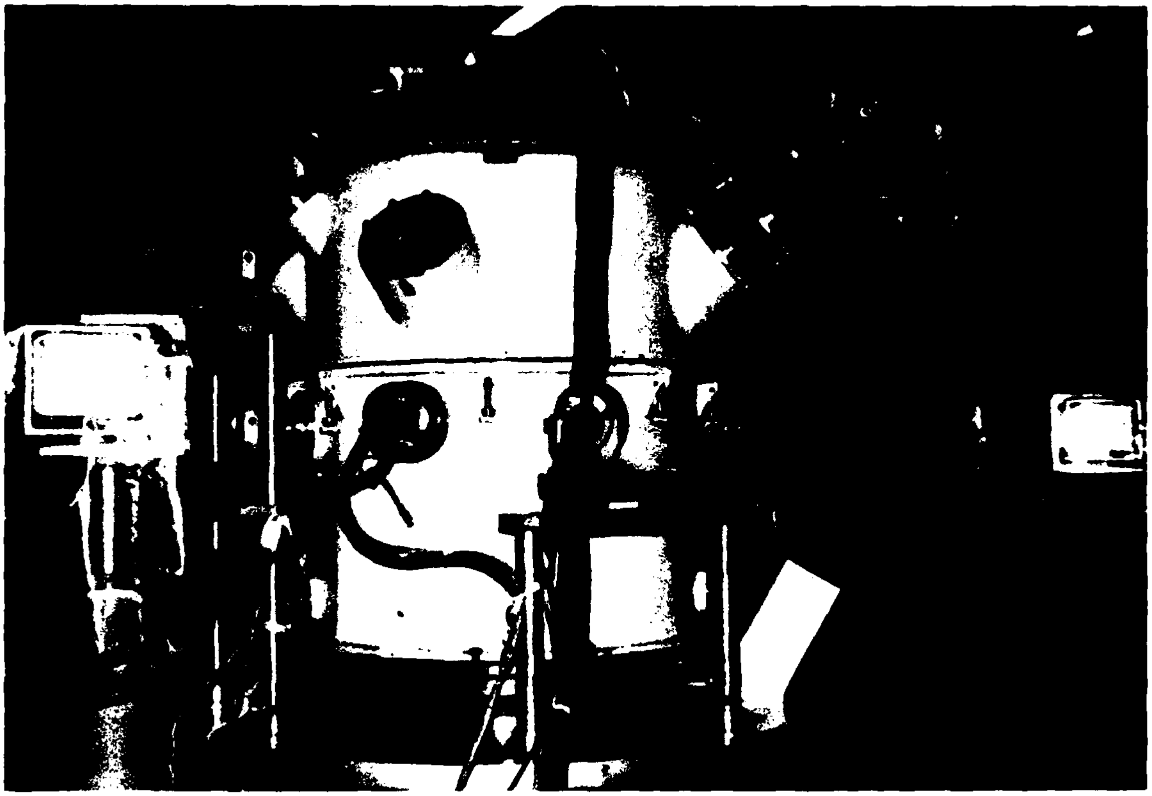


Photo 5. Vacuum irradiation chamber, laser fusion system; Shanghai Laser Institute.

Photo 6. Nd: glass laser rods, Shanghai Laser Institute.

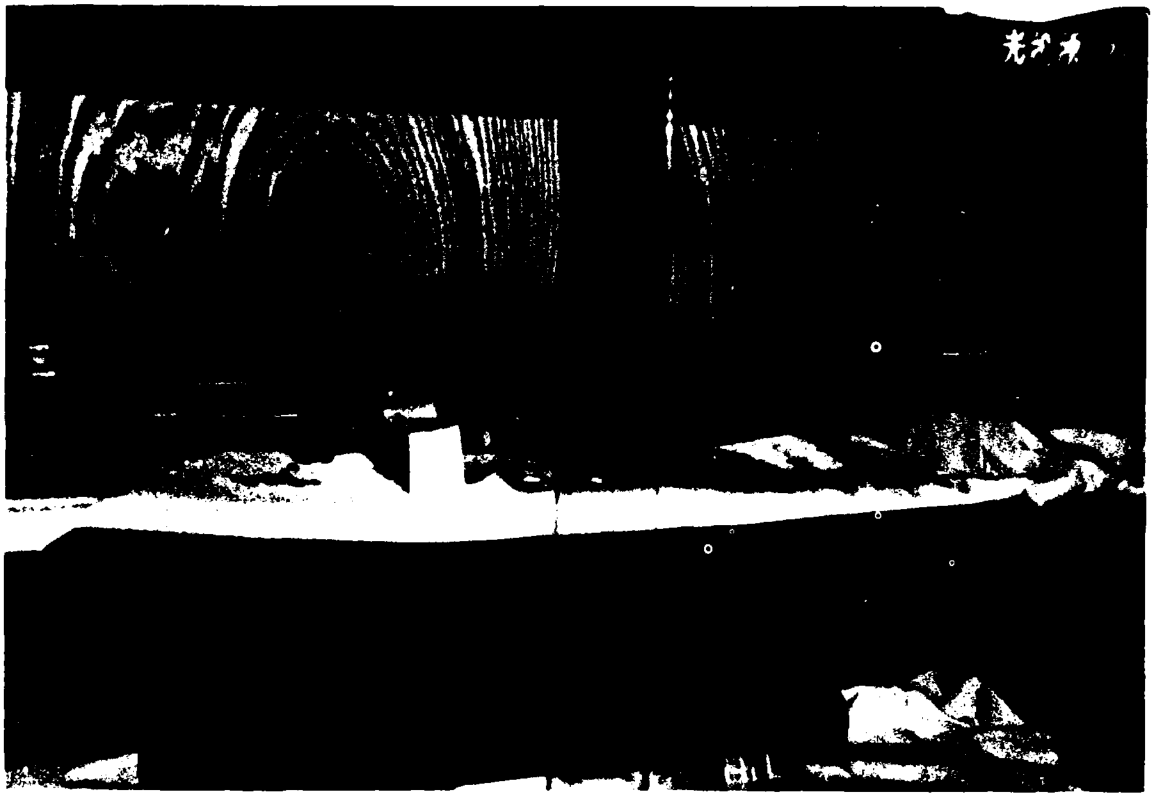


Photo 7. Flash lamps for Nd: glass laser amplifiers, Shanghai Laser Institute.

INTERNATIONAL MEETINGS IN THE FAR EAST

1983-1986

Compiled by Seikoh Sakiyama

This list will be updated and augmented in future issues of the *Scientific Bulletin*. The assistance of the Australian Academy of Science and the Japan Convention Bureau in supplying a list of meetings in their countries is deeply appreciated. Readers are asked to notify us of upcoming international meetings in the Far East which have not yet been included in this report.

1983

Date	Title	Site	For information, contact
April 20-22	First International Symposium on Molten Salt Chemistry and Technology	Kyoto, Japan	Dr. Y. Ito Secretary General Kyoto International Conference Hall Takara-ike, Sakyo-ku Kyoto 606
May 10-12	International Productive Symposium	Tokyo, Japan	Japan Productivity Center 3-1-1, Shibuya Shibuya-ku, Tokyo 150
May 15-19	7th International Conference on Liquefied Natural Gas	Jakarta, Indonesia	Institute of Gas Technology 3424 South State Street Chicago, IL 60616
May 16-20	1983 RCNP International Symposium on Light Ion Reaction Mechanism	Japan (undecided)	Professor Kondo Research Center for Nuclear Physics Osaka University Ibaraki, Osaka 567
May 16-20	The 5th National School and Conference on X-ray Analysis	Melbourne, Australia	Dr. R. A. Coyle X-ray Analytical Association New South Wales Institution of Technology P.O. Box 90 Parkville, Victoria 3052
May 16-20	Annual Scientific Meeting of the Australian Society for Microbiology	Brisbane, Australia	The National Secretary Australian Society for Microbiology Inc. 191 Royal Parade Parkville, Victoria 3052

Date	Title	Site	For information, contact
May 22-25	The 13th International Symposium on Multiple-Valued Logic	Kyoto, Japan	Professor Kitahashi Department of Information and Sciences Toyohashi University of Technology Hibarigaoka, Tempaku-cho Toyohashi, Aichi 440
May 29-June 3	International Conference on Fluidization	Mie, Japan	Professor D. Kunii Department of Chemical Engineering Faculty of Engineering University of Tokyo 7-3-1, Hongo Bunkyo-ku, Tokyo 113
May 30-June 3	International Conference on Chromatographic Detectors	Melbourne, Australia	Secretary, International Conference on Chromatographic Detectors University of Melbourne Parkville, Victoria 3052
May (tentative)	36th Annual Metals Congress	Pt. Kembla, Australia	Australian Institute of Metals P.O. Box 1144 Wollongong, N.S.W. 2500
June 27-30	4th International Conference on Integrated Optics and Optical Fiber Communication-IOOC'83	Tokyo, Japan	IOOC '83 Business Center for Academic Societies Japan 2-4-16, Yayoi, Bunkyo-ku Tokyo 113
June (tentative)	Biomedical Engineering Conference	Australia (undecided)	The Conference Manager The Institute of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
July 4-5	4th Topical Meeting on Gradient Index Optical Imaging Systems	Kobe, Japan	Nunoi Office Azabudai UNI-house 504 1-1-20, Azabudai Minato-ku, Tokyo 106
July (tentative)	Environmental Engineering Conference	Australia (undecided)	The Conference Manager The Institute of Engineers Australia 11 National Circuit Barton, A.C.T. 2600

1983, continued

Date	Title	Site	For information, contact
August 1-7	International Association for Dental Research	Sydney, Australia	Mr. Scott Gotjamanos Department of Pathology Perth Medical Center Verdon Street Nedlands, W.A. 6009
August 14-19	International Solar Energy Congress	Perth, Australia	Mr. P. Driver Honorary Secretary P.O. Box 123 Nedlands, W.A. 6009
August 14-19	Computers in Engineering	Australia (undecided)	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
August 17-24	The 4th International Congress of Plant Pathology	Melbourne, Australia	Mr. B. Price Victorian Plant Research Institute Department of Agriculture Victoria, Swan Street Burnley, Victoria 3121
August 21-25	Thermal Physiology Symposium	Sunshine Coast, Australia	Mr. J.R.S. Hales CSIRO Division of Animal Production P.O. Box 114 Eastwood, S.A. 5063
August 21-26	The Ninth International Congress of Heterocyclic Chemistry	Tokyo, Japan	Dr. T. Kametani Hoshi College of Pharmacy 2-4-41, Ebara Shinagawa-ku, Tokyo 142
August 21-27	The 5th International Congress of Immunology	Kyoto, Japan	The Japanese Society for Immunology Institute of Virus Research Kyoto University Kawaracho, Shogoin Sakyo-ku, Kyoto 606
August 22-26	The 10th International on Amorphous and Liquid Semiconductors	Tokyo, Japan	Dr. Kazuo Morigaki Institute for Solid State Physics Tokyo University 7-22-1, Roppongi Minato-ku, Tokyo 106

Date	Title	Site	For information, contact
August 22-26	7th Australian Symposium on Analytical Chemistry	Adelaide, Australia	Mr. Don Patterson Honorary Secretary AMDEL, P.O.Box 114 Eastwood, S.A. 5063
August 25-September 1	Conference of the International Union of Forest Research Organization	Melbourne, Australia	Mr. B. Cumberland Forestry Branch Department of Primary Industry Canberra, A.C.T. 2600
August 27	Symposium Commemorating the 100th Anniversary of the Mount Krakatau Eruption	Jakarta, Indonesia	Dr. Didin Sastrapradja Indonesian Institute of Sciences LIPI, JL Teuku Chik Ditiro 43 Jakarta
August 27-31	The 25th International Geographical Congress	Sydney, Australia	Australian Academy of Science P.O. Box 783 Canberra A.C.T. 2601
August 26-September 2	The 18th International Ethological Conference	Brisbane, Australia	Professor E. McBride Department of Psychology University of Queensland St. Lucia, Queensland 4067
August 28-September 2	The 29th International Congress of Physiology	Sydney, Australia	Australian Academy of Science P.O.Box 783 Canberra, A.C.T. 2601
August 28-September 3	The 3rd International Mycological Congress (IMC 3)	Tokyo, Japan	Professor K. Tsubaki Institute of Biological Sciences The University of Tsukuba Sakura-mura, Ibaraki 305
August 29-September 3	Fourth International Symposium on Water-Rock Interaction	Tottori, Japan	Professor H. Sakai Institute of Thermal Spring Research Okayama University Misasa, Tottori 682-02
August 30-September 1	International symposium on Measurement and Processing for Indirect Imaging	Sydney, Australia	Dr. R.H. Frater, Chairman National Committee for Radio Science CSIRO Division of Radio Physics P.O.Box 76 Epping, N.S.W. 2121

Date	Title	Site	For information, contact
August (tentative)	Hydraulics and Fluid Mechanics Conference	Newcastle, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
September 5-7	International Symposium on Guanidino Compounds	Tokyo, Japan	Institute of Neurobiology Medical School Okayama University Okayama, Japan
September 5-10	IUTAM Symposium on Turbulence and Chaotic Phenomena in Fluids	Kyoto, Japan	Professor T. Tatsumi Department of Physics Faculty of Science Kyoto University Sakyo-ku, Kyoto 606
September 12-16	The International Ion Engineering Congress	Kyoto, Japan	Professor T. Takagi Ion Beam Engineering Experimental Laboratory Kyoto University Sakyo-ku, Kyoto 606
September 19-22	International Meeting on Chemical Sensors	Fukuoka, Japan	Professor T. Kiyoyama Interdisciplinary Graduate School of Engineering Sciences Kyushu University 33 Sakamoto, Kasuga Kasuga, Fukuoka 816
September 19-23	The 12th World Energy Conference	New Delhi, India	Dr. R.J. Ramdebough 1620 Eye Street Suite 808 Washington, D.C. 20008
September 22-26	The 4th Asian and Australian Conference ISRT (International Society of Radiologic Technologists)	Tokyo, Japan	Mr. Lucky Morimoto International Department The Japan Association of Radiologic Technologists 26-7, Shinkawa 1-chome Chuo-ku, Tokyo 104
October 2-5	The 3rd International Display Research Conference	Kobe, Japan	Japan Convention Services, Inc. Nippon Press Center, 8F 2-1, Uchisaiwai-cho 2-chome, Chiyoda-ku Tokyo 100

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Date	Title	Site	For information, contact
October 3-6	International Symposium on Interferons	Kyoto, Japan	Japan Convention Services Inc.. Osaka Branch Ikari Building 3-1-59, Fukushima Fukushima-ku, Osaka 553
October 16-24	The 8th International Conference on Calcium Regulating Hormones	Kobe, Japan (tentative)	Professor T. Fujita 3rd Division Department of Medicine School of Medicine Kobe University 7-13, Kusunoki-cho Ikuta-ku, Kobe 650
October 17-21	1983 (98th) IEC (International Electrotechnical Commission) General Meeting in Tokyo	Tokyo, Japan	Japan Standards Association 4-1-24, Akasaka Minato-ku, Tokyo 107
October 23-28	1983 Tokyo International Gas Turbine Congress	Tokyo, Japan	The Organizing Committee of 1983 Tokyo International Gas Turbine Congress Sansei International, Inc. Showa Building, 1-7-5 Akasaka, Minato-ku, Tokyo 107
October 24-28	28th Annual Scientific Meeting of the Royal College of Pathologists of Australia	Melbourne, Australia	The Secretariat, The Royal College of Pathologists of Australia 82 Windmill Street Sydney, N.S.W. 2000
November 7-11	Japanese National Committee of CIGRE Study Committee 34, 35	Tokyo, Japan	CIGRE The Institute of Electrical Engineers of Japan Shin Yurakucho Building 1-12-1, Yuraku-cho Chiyoda-ku, Tokyo 100
November 14-15	The 4th Mathematical Programming Symposium, Japan	Kobe, Japan	Professor R. Manabe Department of Management Science Kobe University of Commerce 4-3-3, Seiryodai Tarumi-ku, Kobe 655

Date	Title	Site	For information, contact
November 14-20	The 71st FDI Annual World Dental Congress (Federation Dentaire Internationale)	Tokyo, Japan	Japan Dental Association (Japanese Association for Dental Science) 4-1-20, Kudan-kita Chiyoda-ku, Tokyo 102
November (tentative)	Conference on Microprocessors	Australia (undecided)	The Conference Manager The Institute of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
November (tentative)	Metal Structures Conference	Brisbane, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
December (tentative)	The 12th International Laser Radar Conference	Melbourne, Australia	Dr. C. Platt, CSIRO Division of Atmospheric Physics P.O. Box 77 Mordiattoc, Victoria 3195
December (tentative)	Applied Mechanics Conference	Australia (undecided)	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
December (tentative)	Annual Meeting of the Australian Society for Immunology	Perth, Australia	Executive Officer Australian Society for Immunology P.O. Box 206 Nedlands, W.A. 6009
Undecided	The 13th International Congress of Chemotherapy	Melbourne, Australia	Dr. B. Stratford St. Vincent's Hospital 59 Victoria Parade Fitzroy, Victoria 3065

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Date	Title	Site	For information, contact
April 3-5	Tele Conference (tentative name)	Tokyo, Japan	Data Communications Department Kokusai Denshin Denwa Company, Ltd. 2-3-2, Nishi-Shinjuku Shinjuku-ku, Tokyo 160
February 12-16	14th Australian Polymer Symposium	Ballarat, Australia	Dr. G.B. Guise P.O. Box 224 Belmont, Victoria 3216
February (tentative)	International Conference on Mesoscale Meteorology	Australia, (undecided)	Royal Meteorological Society Australian Branch P.O. Box 654 Melbourne, Victoria 3001
May (tentative)	5th International Soils Expansion Conference	Adelaide, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
June (tentative)	World Computing Services Industry, Congress 4	Tokyo, Japan	Japan Software Industry Association Kikai Shinko Kaikan 3-5-8, Shiba-koen Minato-ku, Tokyo 105
August 24-30	5th International Congress on Mathematical Education	Adelaide, Australia	Dr. John Mack Department of Mathematics University of Sydney N.S.W. 2006
August 26-31	The 3rd International Congress on Cell Biology	Kyoto or Kobe, Japan	Japan Society for Cell Biology Shigei Medical Research Institute 2117 Yamada Okayama 701-02
August 26-September 1	International Conference on the Photochemical Combustion and Storage of Solar Energy	Osaka, Japan	The Society of Kinki Chemical Industry 1-8-4, Utsubo-hommachi Nishi-ku, Osaka 550

Date	Title	Site	For information, contact
August 27- Seotember 1	The 9th International Conference on Raman Spectroscopy	Tokyo, Japan	Professor M. Tasumi Department of Chemistry Faculty of Science University of Tokyo 7-3-1, Hongo Bunkyo-ku, Tokyo 113
September 1-7	The 6th International Congress of Virology	Sendai, Japan	Professor T. Ebina Department of Bacteriology, Medical School Tohoku University 2-1, Seiryo-cho Sendai, Miyagi 980
September 2-7	International Symposium on Snow and Ice Processes at the Earth's Surface	Sapporo, Japan	The Institute of Low Temperature Science Hokkaido University 8-chome, Kita 19-Jyo Kita-ku, Sapporo 060
September 2-8	The XIIth International Biometric Conference	Tokyo, Japan	Dr. T. Okuno Department of Mathematical Engineering and Instrumentation Physics Faculty of Engineering Tokyo University 7-3-1, Hongo Bunkyo-ku, Tokyo 113
September 3-7	1st International Conference on Technology of Plasticity	Tokyo, Japan	Japan Society for Technology Plasticity Torikatsu Building 3F 5-2-5, Roppongi Minato-ku, Tokyo 106
September 11-14	10th International Conference of IMEKO TC-3 (International Measurement Confederation)	Kobe, Japan	Professor T. Ono Department of Mechanical Engineering College of Technology University of Osaka 4-804, Ume-machi, Mozu Sakai, Osaka 591
September (tentative)	Shiga Conference '84 on Conservation Management of World Lake Environment	Shiga, Japan	Department of Civil Life and Environment Shiga Prefectural Government 4-1-1, Kyo-machi Otsu, Shiga 520

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Date	Title	Site	For information, contact
October 7-12	XVIIth International Congress of Internal Medicine	Kyoto, Japan	The Japan Society of Internal Medicine Hongo Daiichi Building 8F 3-34-3, Hongo Bunkyo-ku, Tokyo 113
October 16-18	1984 International Symposium on Electromagnetic Compatibility (EMC)	Tokyo, Japan	Professor T. Takagi Department of Electrical Communications Faculty of Engineering Tohoku University Sendai, Miyagi 980
October (tentative)	3rd Asian Pacific Regional Astronomy Meeting of IAU	Tokyo, Japan	Professor T. Kogure Department of Astronomy, Faculty of Science University of Kyoto Sakyo-ku, Kyoto 606
November 22-23	Technology Past, Present, and Future	Melbourne, Australia	Executive Officer Australian Academy of Technological Sciences Clunies Ross House 191 Royal Parade Parkville, Victoria 3052

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Date	Title	Site	For information, contact
February 11-14	International Symposium on Characterization and Analysis of Polymers	Melbourne, Australia	Polymer 85 Royal Australian Chemical Institute 191 Royal Parade Parkville, Victoria 3052
March (tentative)	Annual National Conference of the Institution of Engineers, Australia	Melbourne, Australia	LtCol. J.A. McDonald Secretary, Victoria Division Institute of Engineers Australia National Science Center 191 Royal Parade Parkville, Victoria 3052

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Date	Title	Site	For information, contact
May 20-24	3rd Conference on Steel Development	Melbourne, Australia	Australian Institute of Steel Construction P.O. Box 434 Milsons Point, N.S.W. 2061
August (tentative)	Coastal Engineering Conference	Melbourne, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
August (tentative)	International Association Hydraulic Resources Conference	Melbourne, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
September (tentative)	11th International Teletraffic Congress ITC-11	Kyoto, Japan	ITC-11 Committee Musashino Electrical Communication Laboratory 3-9-11, Midorimachi Musashino, Tokyo 180
October 15-18	International Rubber Conference	Kyoto, Japan (tentative)	The Society of Rubber Industry, Japan Tobu Building 1-5-26, Motoakasaka Minato-ku, Tokyo 107

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Date	Title	Site	For information, contact
May 11-17	Congress of the International Society of Haematology and the International Society of Blood Transfusions	Sydney, Australia	Dr. I. Cooper, President Haematology Society of Australia Cancer Institute 481 Little Londsdale Street Melbourne, Victoria 3001
September 21-25	The World Congress of Chemical Engineering	Tokyo, Japan	Society of Chemical Engineers Japan Kyoritsu Kaikan 4-6-19, Honhinata Bunkyo-ku, Tokyo 112

1986, continued

Date	Title	Site	For information, contact
Undecided	International Microbiological Congress	Perth, Australia	Australian Academy of Science P.O. Box 783 Canberra, A.C.T. 2601
Undecided	International Institute of Welding Annual Assembly 1986	Tokyo, Japan	Japan Welding Society 1-11, Sakuma-cho, Kanda Chiyoda-ku, Tokyo 101

★ U.S. GOVERNMENT PRINTING OFFICE: 1983—401-394

NOTICE

The Office of Naval Research Scientific Liaison Group, Tokyo was disestablished on 30 September 1981. Effective 1 October 1981, the Office of Naval Research, Liaison Office, Far East (ONRFE) has been established as a tenant of the Akasaka Press Center, Tokyo. The ONRFE office is located on the second floor of Bldg #1, Akasaka Press Center and it bears the following mail identification:

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