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R A STERN 30 MAY 85 153-3223-F AFOSR-TR-86-0423
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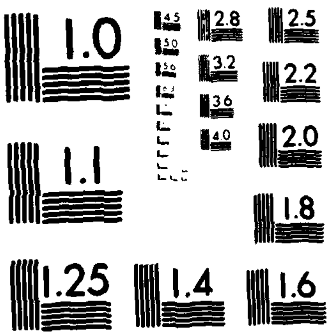
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Ion Beams, Beam-Plasma Interactions, Plasma Diagnostics, Laser Diagnostics

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

See Attached

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AFOSR-TR- 86-0423

GRANT No. AFOSR-B3-0325

Effective Date 30 September 1983

Duration 18 months

Research Title: "Ion Transport in Beam-Plasma Interactions"

FINAL REPORT
for 18-month period 30 September 1983-April 1, 1985

Principal Investigator: R.A. Stern
Professor
Astrophysical, Planetary and Atmospheric Sciences
and Physics Departments
University of Colorado
Campus Box 391
Boulder, Colorado 80309

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PROJECT OUTLINE

The project is concerned with the interaction of ion beams and plasmas, and their mutual destabilization. The goal is to characterize this interaction using novel diagnostic techniques. In the experiment, a gas-discharge plasma was to be constructed through which ions could be accelerated. A two-laser system would be assembled and variations of laser-induced flourescence (LIF) diagnostics used to measure the changes in ion properties of the beam and the plasma consequent on the instability.

The study, carried out by Lt. Col. (then Major) Howard E. Evans II, USAF, was planned to constitute his Ph.D. thesis project. Lt. Col. Evans was scheduled to teach Plasma Physics at AFIT, Wright-Patterson AFB, Ohio; with this in mind, and limitations on time available to him in Colorado, the experiment is specially designed to be modular and portable. That is, following design, construction and assembly of the basic instrumentation, the core experimental components could be dismantled and re-assembled at AFIT for the final stage: data taking and analysis.

The time-table allotted the project duration, 18 months, for the Colorado stages: duration of data and analysis is dependent on the amount of time allotted to, and by, Lt. Col. Evans at AFIT for work on the thesis. At Colorado, normal experimental thesis research in similar areas takes roughly three years of full-time work. A reasonable expectation is that the AFIT stage might span two years.

DESIGN AND PLANNING

The design criteria for this modular experiment are the following: first, that common non-specialized equipment such as an oscilloscope, a vacuum pump, and several power supplies will be available at AFIT. Consequently only the specialized instrumentation need be constructed and tested in Colorado. Secondly, to facilitate disassembly, shipping and re-assembly, and also to allow changes to be made at AFIT as needed by the experimenter, the plasma system was designed on an "erector-set" modular principle.

This structural plan was carried out. The lasers are flash-lamp pumped dye models; they are composed of interchangeable elements no larger than one ft. each. The basic design employs commonly available components at every stage, so that there is minimal dependence on a manufacturer or supplier. The plasma is designed around a Corning pyrex vacuum cross with four ports, maximum dimension two ft. and weighing roughly ten lbs. All plasma elements and probes are flange-mounted and assemble into the central cross. Standard feedthroughs, interchangeable elements, and simplicity of construction and assembly are the hallmarks of the design.

Lt. Col. Evans designed, constructed and assembled the equipment using elementary laboratory and machine shop facilities. This ensures that re-assembly and operation at AFIT can proceed in the absence of plasma or optics specialists, and without dependence on sophisticated research facilities.

The program stages were, in consequence:

A. Construction of a miniature, modular "DP" (double-plasma) device consisting of two adjoining plasma segments connected by a controllable grid interface, and fully instrumented for both conventional and optical diagnostics. One part of the plasma serves as the source of beam ions, which are injected into the second, "target" plasma.

B. Construction of a laser system capable of generating two pulses arbitrarily spaced in wavelength, time and position. These serve as "pump" and "search" pulse, which are used respectively to tag the beam ions within the source plasma before injection, and to follow their trajectory after scattering in the target plasma.

C. Assembly of a detection system consisting of light transport, wavelength discrimination, and photon-detection elements.

These have been completed by April 1985; the final stage, test and measurement of the beam-plasma interaction physics is to be carried out in completion of Lt. Col. Evans' thesis.

CURRENT STATUS AND ACHIEVEMENTS

At the end of the final period after start of the project, tasks A, B and C are completed. The details are given below.

Plasma Device

i. a vacuum and gas-control system has been assembled.

ii. a test chamber with multi-axial ports for probe and optical access has been constructed.

iii. a plasma source, including filaments, electrodes, power supplies and control, as well as an electron-confining magnetic field, have been put together. The entire system (i, ii, iii) has been assembled, tested and successfully operated.

iv. Langmuir probes have been constructed, instrumented, and used to characterize the plasma generated by the source in the test chamber. The plasma properties are satisfactory. To date, an unexplained high-energy electron component is detected in the plasma under a variety of conditions. We note that this component is not expected to have any influence on the processes we propose to study.

In summary, plasma device construction and testing are finished.

Laser System

All components for the laser system have been acquired or constructed, and their assembly and test carried out. Specifically:

i. two independent power systems: high-voltage supplies, energy capacitors, spark gaps and trigger circuits have been put together.

ii. cavities, flash lamps, dye flow tubes and pumps, mounts, mirrors and gratings for two independent pulsed lasers have been assembled and tested successfully.

Detection System

All elements of the detection system have been acquired, assembled and tested. They consist of:

i. stand, mounts, lenses and positioning gear for detection optics and associated electronics.

ii. ½-meter monochromator and Fabry-Perot interferometer for wavelength discrimination.

iii. photomultipliers, power supply, amplifier and pulse detector (boxcar integrator).

In conclusion, stages A-C of the project; design, construction, assembly and test of a modular laser/plasma experiment, were successfully carried out within the planned period.

The appended photograph is an overview of the entire research facility. In the foreground can be seen the detection system, with the monochromator and photomultiplier in the center, monitoring the optical emission from an Argon ion line from the plasma. The oscilloscope at the right displays on the top trace the PMT intensity as a function of time (more signal down), while the lower trace monitors the plasma current. The scale is about one msec/cm, and here the current density is 10 amps/cms, with Argon at 3×10^{-4} Torr, and a charge density of 10^{12} cm^{-3} at a magnetic field of 1 KGauss. The x-y plotter at the left is a boxcar trace of the emission, obtained by scanning a gate across the PMT output. It reproduces with much more detail the time-dependent Argon ion emission.

The middle ground is taken up by the plasma, pumping station, gas control and power supplies for discharge and magnetic field. The discharge pulser is partially shown in the electronics rack at the extreme right.

The background optical table supports the two lasers; the power supplies, triggers and dye pumps are under the structure. The lasers typically fire at 10 Hz, with 1 KW pulse power typical near the peak of Rhodamine G. The triggers and power supplies are independent, so that each laser can be fired at will.

PERSONNEL & CURRENT STATUS

Initial work was carried out by Lt. Col. Evans with assistance from two undergraduates, under the direction of Prof. R.A. Stern. The following changes in personnel took place:

1. Lt. Col. Evans returned to active duty in August 1984, roughly 2/3 through the project period, and is presently on the staff of AFIT, Wright Patterson AFB, charged in part with responsibility for Plasma Physics. A number of components of the plasma device were loaned to AFIT, and were hand-carried there by Lt. Col. Evans. All these components were replaced by newly-made or acquired parts so that the entire system is complete and operational in Colorado.

2. From September 1984, continuing work on the project was carried on by Paul Arndt, University of Colorado student, under the direction of Prof. R.A. Stern.

3. Lt. Col. Evans is proceeding to assemble at AFIT an experiment which shares with the present project the fundamental diagnostic technique, LIF.

As mentioned in the proposal letter to AFOSR, Lt. Col. Evans needs, in order to obtain his Ph.D., to complete thesis research within timetables and rules of the University of Colorado. All the instrumentation and equipment needed for this purpose have been put together and tested, within the grant period. At the present stage therefore, Lt. Col. Evans could proceed to assemble at AFIT the ion-plasma interaction experiment and complete data taking and analysis there. Alternatively, he may choose to use the Colorado system, which is complete, operational, and available for use.

4. The technical and professional activities of the Principal Investigator during the 18-month contract period are detailed on the enclosed pages.

Principal Investigator, Scientific Activities, September 30, 1983 - April 1, 1985

R. Stern, Professor, APAS and Physics Departments

Research Projects: 6

sponsored by NSF, AFOSR, Los Alamos National Laboratory, and EURATOM

On-going national & international research collaborations: 1) Los Alamos, 2) Center for Research in Plasma Physics (Lausanne, Switzerland), 3) California Institute of Technology, and 4) University of California, Irvine. Visiting Professor, CRPP Lausanne, May-August 1984; Visiting Research Physicist, UC Irvine, Dec.-Jan. 1983-84, and 1984-85.

Invited Papers:

Annual Meeting, Division of Plasma Physics, Nov. 1983.

Gordon Conference on Plasma Chemistry, August 1984.

APS Conference on High-Temperature Plasma Diagnostics, Sept. 1984.

US-Japan Workshop on Field Measurements in Plasmas, Sept. 1984.

Invited and review articles:

"Tracking Particles by Lasers," Europhysics News 15, 2 (1984)

"Laser-Ion Beam Diagnostics for Potential and Magnetic Field Measurements in Plasmas," in press, Review of Scientific Instruments

Contributed papers:

"Laser Fluorescence Measurements in a Neon Plasma with High Temporal Resolution," P. Kohler, R.A. Stern, B. Hammel, M.Q. Tran, B.M. Lamb, P.J. Paris and M.L. Sawley, Proc. 1984 Int'l Conf. on Plasma Physics, II, 317 (1984)

Invited seminars or colloquia:

Ecole Polytechnique, Paris, March 84

Bell Telephone Laboratory, Murry Hill, NJ, April 84

Lawrence Berkeley Laboratory, May 84

Vaud Physics Society, Lausanne, July 84

Perkin Elmer Corporation, October 84

New York University, October 84

Cornell University, March 85

Conference and organization chairs:

Basic Plasma Session, Int'l Conf. on Plasma Physics, Lausanne, June 1984

Program Committee, Division of Plasma Physics, 84

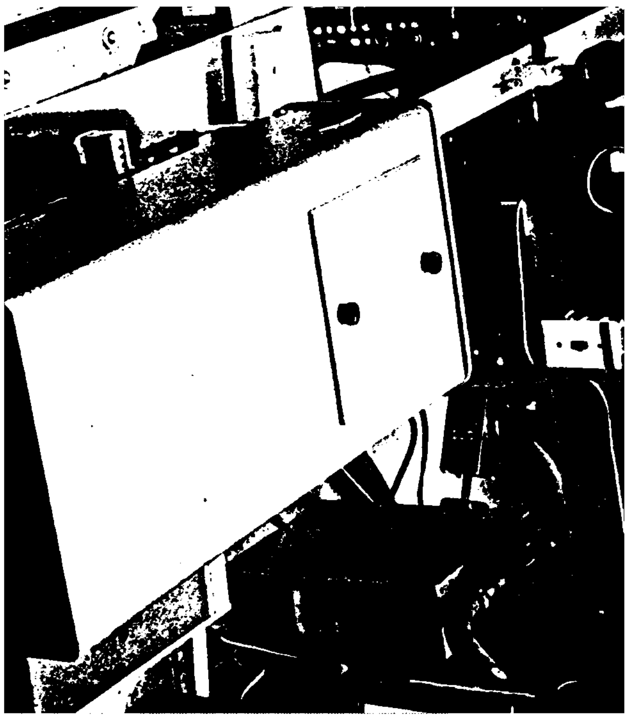
General Plasma Science Session, IEEE Int's Conf. on Plasma, organizer and chair, Suene, June 85

Professional activities:

Associate Editor, The Physics of Fluids

Honours:

elected Sherman Fairchild Distinguished Scholar, California Institute of Technology (effective Jan. 1986)



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