

PLASMA DYNAMICS

XIII. PLASMAS AND CONTROLLED NUCLEAR FUSION*

A. Waves and Radiation

Academic and Research Staff

Prof. G. Bekefi	Prof. S. C. Brown	Dr. P. A. Politzer
Prof. W. P. Allis	Prof. B. Coppi	J. J. McCarthy
Prof. A. Bers	Prof. E. V. George	W. J. Mulligan
	Prof. R. J. Taylor	

Graduate Students

F. W. Chambers	D. O. Overskei	M. L. Vianna
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RESEARCH OBJECTIVES

We continue our experimental and theoretical program designed to gain further understanding of the various types of waves and oscillations in ionized gases. We are particularly interested in processes that are relevant to controlled thermonuclear fusion and space research.

One of our major goals is the study of waves and radiation of large amplitude under conditions where nonlinear phenomena and plasma turbulence are prominent. In this connection we are studying such problems as the nonlinear coupling of two or more electromagnetic waves and anomalous absorption of intense microwave and laser radiation by the plasma. Studies of turbulence and fluctuations in plasma confined in two-dimensional magnetic field configurations are contemplated. For this purpose we shall use our steady-state linear quadrupole (SLIM-1) and our small toroidal facility (MINITOR). The construction of these two machines has been recently completed.

G. Bekefi

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B. Diffusion and Turbulence

Academic Research Staff

Prof. T. H. Dupree

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Graduate Students

A. R. Forbes

J. C. Hsia

P. M. Margosian

RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

1. Coherent Scattering at 10.6 μm

We have successfully observed coherent scattering of 10.6 μm radiation from moderate density steady-state plasmas. We have resolved the plasma frequency wings and are able to deduce information about the level of high-frequency fluctuations. We are now refining this experiment and plan to proceed to measurements and resolution of the "ion peak." The objective is to measure the spectrum of relatively low-frequency turbulence. This will allow important tests of nonlinear turbulence theory in the prediction of spectral shapes and saturation levels.

J. Hsia, L. M. Lidsky

2. Toroidal Electron Trap

Our original experiment for measuring the lifetime of electrons circulating in a toroidal magnetic trap has been completed. The technology needed to inject electrons and to measure their lifetimes has been perfected. A sweeping system to allow measurement of the angular distribution of the circulating electrons has been built and is being tested. This apparatus is being used for the study of waves propagating on electron beams.

P. M. Margosian, L. M. Lidsky

3. Runaway Electron Experiments

We are designing a small Tokamak (30 cm major radius, 4 cm minor radius, 5 kG toroidal field) suitable for studies of runaway electron behavior. The design under construction is unique in that it possesses complete toroidal symmetry and no ferromagnetic materials. The system is being designed with the constraint that it must be completely bakable to 300°C to avoid the vacuum problems that severely hurt devices of this sort. The final decision to construct the Tokamak and undertake this experiment will be made upon completion of the design study.

A. R. Forbes, L. M. Lidsky

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C. Plasma Diagnostics

Academic and Research Staff

Prof. G. Bekefi
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Graduate Students

R. J. Hawryluk

RESEARCH OBJECTIVES

The major goals of this program are to perfect known methods of measuring plasma properties and to devise new techniques. Our present interest concerns the use of optical spectroscopy in the diagnosis of dense, turbulent plasmas. The turbulent electric fields acting on excited atoms can cause a splitting of energy levels with the result that new spectral lines may become evident. These can then be used to determine the intensity and spectral distribution of the fluctuating fields. In the studies we use two types of plasma sources, plasmas produced by focusing intense laser radiation on gas or solid targets, and plasmas produced in a recently constructed coaxial plasma gun.

G. Bekefi

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D. Fusion-Related Studies

Academic Research Staff

Prof. L. M. Lidsky
Prof. R. A. Blanken

Graduate Students

R. L. McCrory
A. Pant
G. W. Braun

RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

1. Fusion Feasibility

We shall continue our work on the analysis of fusion power systems with particular emphasis on the possibilities inherent in fission-fusion symbiosis. The combination of a marginal D-T fusion reactor with a MSCR fission reactor operating on the thorium cycle will be analyzed in more detail. Another system to be studied during the next year is the D-D cycle mirror reactor with direct conversion. It appears that efficient use of the neutrons generated in the complete D-D cycle may suffice to make this concept economically viable also.

L. M. Lidsky

2. Divertor Design for Toroidal Reactors

Engineering studies of divertors for axisymmetric toroidal reactors are under way. We have completed magnetic designs for reactors with circular cross section and we are working on the magnetic design for reactors with noncircular cross section. We are now considering questions of engineering feasibility, including the use of superconducting coils instead of normally conducting coils, as well as radiation and particle damage, heat transfer, and cooling of the coils.

R. A. Blanken

3. Shock Coil Design

We have started a study of the engineering design of the shock coil structure of a staged theta-pinch reactor. We plan to make accurate predictions of the thermal and mechanical stresses and then to model these stresses in scaled experiments. We shall concentrate on the problems of coil fatigue effects under the combined stress fields. The magnetic fields required to simulate the mechanical stresses are available at the Francis Bitter National Magnet Laboratory, M. I. T.

A. Pant, L. M. Lidsky

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E. Feedback Stabilization

Academic Research Staff

Prof. R. R. Parker
Prof. K. I. Thomassen

RESEARCH OBJECTIVES

The objectives of this research are to use feedback control techniques for the diagnostic study and suppression of instabilities in plasmas. Under investigation are ways to couple the feedback system to the plasma, the applicability of this method to fusion devices, and the study of continuum feedback methods in general.

At present, we are considering the design of either a screw-pinch or a small Tokamak experiment. The purpose of this experiment is to investigate the nature of the MHD instabilities which occur in Tokamaks near rational values of q , and to correlate the onset of instability with the shape of the current distribution. We also plan to study the feasibility of feedback control of these modes, as predicted by our previous theoretical models.

Work Completed

During the past quarter a Ph.D. thesis entitled "MHD Kink Mode Interaction with External Boundaries and Requirements for Feedback Stabilization" was submitted by R. S. Lowder, completing one of the theoretical areas of research described in our statement of objectives. The contents of this thesis has been covered in the Quarterly Progress Reports of the Research Laboratory of Electronics during the past two years.

R. R. Parker, K. I. Thomassen

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F. High-Temperature Plasma Physics

Academic and Research Staff

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Dr. D. B. Montgomery†	Prof. R. R. Parker	Dr. R. Pozzoli
Prof. G. Bekefi	Prof. R. J. Taylor	Dr. G. Righetti
Prof. A. Bers	Prof. K. I. Thomassen	Dr. F. C. Schüller
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Graduate Students

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D. P. Hutchinson		S. M. Wolfe

RESEARCH OBJECTIVES

The understanding of the physics of high-temperature plasmas is of primary importance to the solution of the problem of controlled thermonuclear fusion. One of the aims of this field of research is the magnetic confinement and heating of plasmas with densities of the order of 10^{14} particles/cm³ and thermal energies of the order of 10 keV. The macroscopic transport properties (e.g., particle diffusion, thermal conductivity, and electrical resistivity) of plasmas in these regimes are weakly affected by two-body collisions between particles. They are significantly influenced by the types of collective modes (such as density fluctuations caused by microinstabilities) that can be excited in them.

A theoretical and experimental program is being carried on in this general area, focused on the toroidal confinement device Alcator. The purpose of this program is to realize plasmas capable of sustaining very high current densities (up to 1400 A/cm²) without becoming macroscopically unstable, in order to achieve the highest possible rate of resistive heating of the plasma itself. The construction of Alcator has been carried out at the Francis Bitter National Magnet Laboratory, and the first plasma operation was achieved in November 1972. The first significant plasma experiments are expected to start in January 1973.

Another experimental apparatus, SLIM-1, has become operational in 1972 and has already yielded significant results. This device is a linear quadrupole designed to study the dynamics of magnetically trapped particles and the microinstabilities which are set up by them.

B. Coppi

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†Dr. D. Bruce Montgomery is at the Francis Bitter National Magnet Laboratory.