Department of Energy

Chicago Operations Office
9800 South Cass Avenue
Argonne, Illinois 60439

August 20, 2003

Michael Crisp
SC-55 GTN

SUBJECT: FINANCIAL ASSISTANCE TECHNICAL CLEARANCE, AWARD NO. DE-FG02-98ER54476

A copy of the final technical report is attached. The award cannot be officially closed out until we receive written assurance from you that the final technical report is considered satisfactory. Accordingly, it is requested that you complete and return the information requested below.

Tanisha Edwards
Tanisha R. Edwards, Procurement Technician
Operations Division
Office of Acquisition and Assistance

TO: Tanisha R. Edwards
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Chicago Operations Office
Office of Acquisition and Assistance
9800 S. Cass Avenue
Argonne, IL 60439

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The final technical report has been received and [X] is [ ] is not considered to be satisfactory. (If the report is not considered satisfactory, please indicate specific deficiencies below.)

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Michael D. Crisp — 9-5-03
DOE Project Officer — Date

DISCLAIMER

FINAL TECHNICAL REPORT

Project: DE-FG02-98ER54476

An investigation of the effects of a driven plasma rotation on fluctuation in a magnetized linear plasma source

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Project duration: 5/1/1998 – 3/31/2000

ABSTRACT:

The rotation of a plasma is one of the most fundamental global modes of plasma behavior. It is the zeroth order plasma response to a transverse electric field. In its simplest kinetic form, the so-called **E** x **B** drift (here, **E** is the electric field vector and **B** is the magnetic field vector), both the ions and the electrons will undergo a drift in the same direction. This motion is considered a universal mode of a plasma since the mechanism of the **E** x **B** drift is, to zero-order, independent of **both** the mass and the charge of the particles.

While the uniform **E** x **B** drift can be transformed away (in the usual slab geometry), important plasma effects arise when this drift is spatially inhomogeneous; i.e., the velocity profile is spatially sheared. The sheared velocity can significantly influence the plasma evolution and its eventual steady state conditions. For example, it is an important mechanism in many plasma systems ranging from ion acceleration in space plasmas to the high confinement mode (H-mode) of fusion energy experiments. Because of its broad applicability to the plasma behavior, theoretical and experimental investigations of plasma rotation are of great importance.

Project Report:

This project was awarded to the PI, Prof. Thomas, through US DOE Grant No. DE-FG02-98ER54476 at Fisk University in Nashville, TN on May 1, 1998. The focus of the project has been to characterize the effects of plasma rotation on self-generated and launched waves in a linear plasma experiment. The PI believes that the despite a number of challenges, the project has been successful.

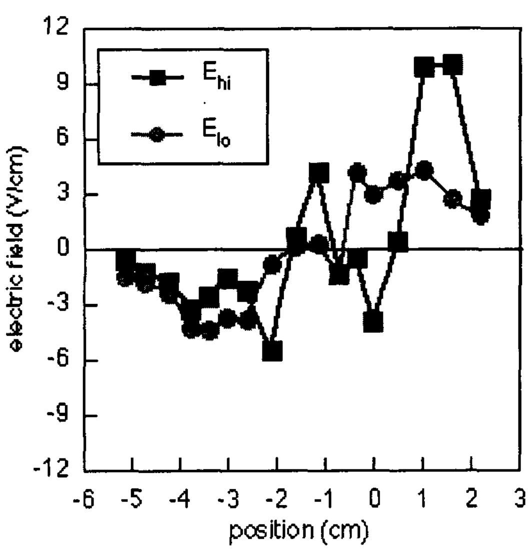
One of the major challenges to this project is the fact that the original grant of ~$75,000/year was approximately 40% below the original request. In response, proposed the experimental device was scaled down from a 150 cm long, 15 cm diameter device to a 60 cm long, 10 cm diameter device. Much of the manufacturing of the magnetic field coils was performed in-house at Fisk. Also, purchase of the primary data acquisition system had to be delayed to the second year of the project.

A second challenge arose when, during the second year of the project in August, 1999 the PI accepted a faculty position at Auburn University and moved there in January, 2000. Although the grant at Fisk was terminated, all of the equipment associated with the project moved to Auburn. By mid-February, 2000, experiments had restarted at Auburn. The third year of the grant was restarted at Auburn with a duration from July 1, 2000 through October 31, 2001 under US DOE Grant No. DE-FG02-00ER54476.

In spite of the disruption to the project, the move to Auburn University has been quite beneficial to this project. Through funds provided by Auburn, a major (~ $45,000) upgrade of the experimental device will begin in Spring, 2001. The upgrade will increase the length of the device to 180 cm, replace all of the existing electromagnets, improve the plasma generating capabilities, and overhaul the diagnostics.

Experimental results

Assembly of the experiment was completed by late August, 1998 and first plasma was achieved on September 15, 1998. Much of the initial experimental work of the first year focused on measurements of the magnetic structure of the device and the initial characterization of the magnetic fields. By the end of the first funding period, experiments had characterized the radial potential structure of the plasma and the fluctuations that were present in the plasma.

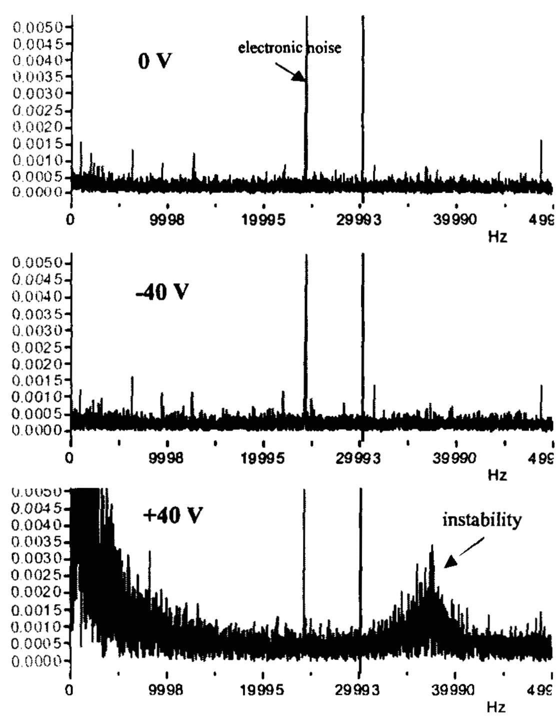


By the beginning of the second year of funding, in May, 1999, the first plasma rotation experiments had begun. In these experiments, a 7 cm long, 4 cm diameter cylindrical electrode that was concentric with the plasma was used to modify the radial potential structure of the plasma. With the addition of a 16 channel data acquisition system, measurements could be performed simultaneously at several points along the plasma column. The goal of the first series of experiments was to verify that this biased electrode technique could modify the radial electric field of the plasma. The figure on the previous page shows the modification of the radial electric field structure before ($V_{re} = 0$ V; E_{hi}) and during ($V_{re} =$ 50 V; E_{lo}) the application of a bias voltage to the cylindrical electrode. Note that in this experiment, the plasma axis was centered at R -1 cm.

After showing that the radial electric field (and correspondingly the $\mathbf{E} \times \mathbf{B}$ drift velocity) was modified, experiments then moved into two areas. One series of experiments focused on the temporal response of the plasma as the rotation of the plasma was altered. Here, it was observed that with the application and/or removal of the bias voltage to the cylindrical electrode, the floating potential of the plasma responded within 5 to 10 μsec. However, the plasma density (as measured via the ion saturation current) had a much longer time response (~ 5 to 10 msec).

A second series of experiments characterized the impact of the change in the rotation of the plasma on the propagation of waves. In these experiments, an ion acoustic wave is launched into the plasma column at one end. The cylindrical electrode is then biased, either positively or negatively, and the effects on the wave are characterized. Generally, it is observed that for positive bias voltages (when there was a reduction of the radial electric field), the wave appeared to propagate more efficiently through the plasma, as compared to the unbiased case. For negative bias voltages, the wave did not propagate as efficiently as compared to the unbiased case. However, these experiments are ongoing.

Another area that have been explored in this project has been the appearance of a large amplitude, low frequency ($f \sim 0.5 - 4\ f_{ci}$ - the ion cyclotron frequency) wave, under certain operating conditions of the device. It is also important to note that the appearance of this wave is asymmetric; i.e., it is dependent upon the sign of the applied voltage on the cylindrical rotation electrode. This wave has a large perpendicular wave number ($k_\perp$ $k_\parallel$) and has characteristics of either a velocity shear driven instability or a type of current driven instability. This is shown in the figure below.



In other experiments (November to December, 2000), a second electrode, a 2 cm diameter circular disk (paddle) probe is placed in the center of the plasma. A bias voltage is applied to the paddle probe to draw an axial current. Once again, the instability appears in the plasma. Now, by adjusting the bias voltages on the cylindrical (rotation) electrode and the disk (paddle) electrode, it is possible to maintain control over the growth and formation of this instability.

Student training

In spite of the many challenges that have faced this project, it has maintained a commitment to student training. Two graduate students have worked on this project. One of the graduate students, Mr. Cleon Barnett, is in the final stages of completing his M.S. degree (by February, 2001) at Fisk University and is currently applying to PhD programs. The second graduate student, Mr. Gregory Lampkin, is continuing work on his M.S. degree at Fisk University and should be completed with his work by Spring, 2001. Additionally, five undergraduate students (two at Fisk, three at Auburn) have contributed to this project. In total, the students have made four presentations at American Physical Society – Division of Plasma Physics conference in 1999 and 2000 and two presentations at student conferences.