Laboratory study of magnetic reconnection generated Alfvén waves

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Summary

The above grant was funded through the Department of Energy, Office of Fusion Energy *Junior Faculty Development Program*. The grant funded the construction and start-up of the Articulated Large-area Plasma Helicon Array (*alpha*) experiment, and initial studies of Alfvén wave propagation in helicon generated plasmas. The three year grant contract with Auburn University was terminated early (after two years) due to PI's acceptance of a faculty position at New Mexico Tech. The project continues at New Mexico Tech under a different grant contract.

The project met all of the second-year goals outlined in the proposal, and made progress toward meeting some of the third-year goals. The α/pha facility was completed and multi-helicon operation was demonstrated. We have made initial measurements of Alfvén waves in a helicon plasma source.

The α Facility

α is a 4 m long, 50 cm diameter facility containing numerous ports for excellent diagnostic access. Design parameters for the planned experiments in the device demanded 1) low magnetic field ripple, 2) modest machine length and large diameter, 3) steady-state, high-density plasma. The final two criteria are mandated by the plan to study of Alfvén waves.

The first year of the project saw the construction of the facility. The stainless steel vacuum chamber was manufactured by K.J. Lesker. The aluminum support structure was manufactured by Davis Machine Works. Magnets were constructed in-house using hollow copper tubing embedded in a fiberglass matrix. Dave Anderson of the HSX group provided invaluable assistance in this. A closed loop chilled water system cools the magnets during operation. A 1000 l/s turbo pump achieves a base pressure of a few 10^{-7} torr, while a computer controlled valve maintains constant a pressure of a few mtorr during plasma operation. Measurements of the vacuum magnetic field indicate a field ripple exactly to design specifications, with less than 1% ripple on axis, and better than 0.5% uniformity over any cross-section.

Helicon Plasma Operation

The plasma is produced by a set of seven helicon sources. Helicons have been shown in the past to be very efficient at producing high density, highly-ionized plasma. However, the large area of α requires multiple sources, since the efficiency of plasma production drops with increasing source diameter. Work by

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other groups indicated that a single RF amplifier system could be used to drive the helicon sources. But, tests with the larger magnetic field of *alpha*, along with the additional power requirements, demonstrated that multiple RF amplifiers were preferable to a single amp. Thus, *alpha* uses seven Henry Radio amplifiers capable of 5kW each continuous. During the two-year period of this grant two sources simultaneous were tested in this fashion. Measurements of the plasma parameters in argon indicate a chord-averaged density of $\sim 10^{19} \text{ m}^{-3}$, with a peak density of $2.5 \times 10^{19} \text{ m}^{-3}$, and temperatures of order 3 eV. These are the expected parameter ranges from the system design. Since moving to New Mexico Tech the complete 7 amplifier RF system has been installed, though all seven source have not yet operated simultaneously.

Alfvén Wave Studies on ALESPI

Alfvén wave measurements were undertaken on a prototype of *alpha*, the Auburn Linear Experiment for Space Plasma Investigations (ALESPI) to develop diagnostic techniques. Because the high density of the plasma translates into an unacceptable heat load to standard probes, water cooled probes were tested and found to work satisfactorily. We looked at propagation characteristics for Alfvén waves over a frequency range encompassing the non-linear regime near the ion cyclotron frequency. Our measurements agreed well with theoretical predictions, and we published these results in *Physics of Plasmas*. Additional studies in a plasma regime with a high neutral fraction have been carried out. Again, these measurements show excellent agreement with theoretical predictions, and are the subject of a paper in press.

We note that the water cooled probes may prove cumbersome in the long run, and we are testing pulsed plasma operation as a possible remedy.

Publications Related to the Project

Construction and initial operation of the *alpha* facility has been reported at numerous national and international meetings throughout the past two years (American Physics Society Division of Plasma Physics, American Geophysical Union, APS Southeast Conference, APS Undergraduate Research

Conference, IPELS). Alfvén wave studies were published in Physics of Plasmas [PoP B, 4251 (2001)]. Details of the *alpha* facility will be published shortly in Review of Scientific Instruments and Plasma Sources, Science and Technology.

Continuation at New Mexico Tech

A new grant for continuation of the research through the original contract length (one additional year) was provided for at New Mexico Tech. It is anticipated that all the goals of the original grant proposal will be met. Full operation with all seven helicon source is imminent. Alfvén wave studies have already begun, and will continue until the contract's end.