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Re: Final Report for DOE EPSCoR Laboratory Partnership Program Project ER45849:
Development of a Tunable Diode Laser Induced Fluorescence Diagnostic for the Princeton Magnetic Nozzle Experiment: West Virginia University and Princeton Plasma Physics Laboratory

Principal Investigator: Earl E. Scime

Reporting Period: August 2000 – August 2003

Project Summary: This project involves the construction of a compact, portable, laser induced fluorescence (LIF) diagnostic for measurements of neutral helium, neutral argon, and argon ion velocity space distributions in a high density, steady state, helicon source. The project is collaborative effort between the Princeton Plasma Physics Laboratory (PPPL) and the West Virginia University (WVU) helicon source group. A key feature of the diagnostic system will be the use of tunable diode lasers instead of the tunable dye lasers typically used in LIF experiments. This project began in August of 2000

Accomplishments: Using a single, low power, tunable diode laser at 668 nm, we have successfully completed laser induced fluorescence experiments on all three ion and neutral species (argon ion, helium neutral, and argon neutral) that we described in our original proposal. The last species, argon neutral atoms, was particularly challenging and our successful demonstration of LIF in that species has opened up an entire regime of applications for diode laser based LIF. Our collaboration with Princeton Plasma Physics Laboratory (PPPL) has led to the discovery of an electric double layer at the end of their high power helicon source. This double layer spontaneously accelerates ions to supersonic velocities and was a completely unexpected process with significant implications for both plasma thruster physics and plasma processing applications.

We are in the process of testing our proposed LIF scheme for helium neutrals – the highest risk portion of the original proposal. Having accomplished the key elements of our proposal, we plan to spend the next few months trying different plasma source conditions and optical configurations as we search for helium ion LIF signal. The 668 nm diode laser will return to PPPL this summer for additional experiments on their facility.

Graduate Students: The project includes only partial funding for one graduate student at WVU. Mr. Xuan Sun, a third year graduate student, spent the summer of 2003 at PPPL operating the diode laser system on the MNX experiment.

Postdocs: Dr. Costel Biloiu, a new postdoc who joined the group in September of 2002 was actively involved in this project. The former postdoc, Dr. Robert Boivin, joined the physics faculty at Auburn University. His expertise with diode laser based LIF (obtained on this project) was the key reason for his hire.

Publications Directly Resulting from this Project:

- Cohen, S., X. Sun, and E. E. Scime, 'On Collisionless Ion and Electron Populations in the Magnetic Nozzle Experiment (MNX),' *IEEE Trans. Plasma Sci.* **34**, 792 (2006).
- Sun, X., S. Cohen, and E. E. Scime, 'On-axis parallel ion speeds near mechanical and magnetic apertures in a helicon plasma device,' *Phys. Plasmas* **12**, 103509 (2005).
- Keesee, A., E. E. Scime, C. Charles, A. Meige, and R. W. Boswell, "The ion velocity distribution function in a current-free double layer," *Phys. Plasmas* **12**, 093502 (2005).
- Scime, E., C. Biloiu, C. Compton, F. Doss, J. Heard, E. Choueri, S. Spektor, 'Laser Induced Fluorescence in Pulsed Ar Plasmas,' *Rev. Sci. Instrum.* **76**, 026107 (2005).
- Sun, X., S. Cohen, and E. Scime, 'Determination of Ion Collisionality by Measurement of Asymmetric Optical Pumping of Ions Accelerating in a Magnetic Field Gradient,' *Phys. Rev. Lett.* **23**, 235002 (2004).
- Keesee, A. M., R. Boivin, and E. Scime, 'LIF measurements of three plasma species with a tunable diode laser,' *Rev. Sci. Instrum.* **75**, 4091 (2004).
- Sun, X., C. Biloiu, R. Hardin, and E. Scime, 'Parallel velocity and temperature of argon ions in an expanding, helicon source driven, plasma,' *Plasma Sources Sci. and Tech.* **13**, 359 (2004).
- Boivin, R.F. and E. E. Scime, 'Laser Induced Fluorescence in Ar and He Plasmas by Tunable Diode Laser,' *Rev. Sci. Instrum.* **74**, 4352 (2003).
- Cohen, S.A., N.S. Siefert, S. Stange, E.E. Scime, R. F. Boivin, and F. Levinton, 'Ion acceleration in plasmas emerging from a helicon-heated magnetic-mirror device,' *Phys. Plasmas* **10**, 2593 (2003).