DOE Plasma Science Center

Visiting Graduate Student/Post-Doctoral Researcher Fellowship Report

Title of Project:	**Development and Implementation of Electric Field Measurements in Pulsed Discharges Using Four Wave Mixing**	
Name:	Benjamin M. Goldberg	
Institution:	The Ohio State University	
Email:	Goldberg.156@osu.edu	
Advisor:	Igor Adamovich	
Advisor email:	Adamovich.1@osu.edu	
Institution Visited:	Princeton Plasma Physics Laboratory	
Host:	Yevgeny Raitses	
Host email:	yraitses@pppl.gov	
Dates of Visit:	Start: July 16, 2015	End: July 17, 2015

I. Description and Importance of Research Issues Investigated During Visit

Researchers at the Non-Equilibrium Thermodynamics Laboratory (NETL) have shown an extensive knowledge of many laser spectroscopic techniques which are of particular use in plasma discharges where conditions may not always be perfect. These include well known techniques such as CARS, TALIF, LIF, CRDS, Thomson Scattering, and Raman Scattering as well as techniques currently being developed at NETL such as the electric field four wave mixing project. Current work being done by Dr. Yevgeny Raitses at the Princeton Plasma Physics Laboratory (PPPL) involves measurements and characterization of arc discharges with the purpose of generating nanoparticles as well as the characterization of a Penning Discharge. For all of these measurements, traditional probe techniques are difficult to perform and accurately interpret due to the high current within the discharge, generation of nanostructures physically changing the probe tip geometry, and the presence of magnetic fields leading to the possibility of misinterpreting results. The knowledge and expertise in advanced laser diagnostics utilized in the NET Lab could possibly be applied to these systems in order to help gain better insight into the plasma properties and species generation within the discharge.

A visit was made to the PPPL in order to give advice and expertise with the following issues:

- Feasibility of electric field four wave mixing measurements within the high current arc discharges
- Important experimental considerations for additional four wave mixing measurements for temperature and molecular species concentrations
- The possibility of additional spectroscopic techniques such as LIF, TALIF, and Thomson scattering for radical species concentrations and electron number density measurements

II. Discussion of Research Outcomes and Findings Resulting from Visit

This trip led to a significantly improved understanding of the difficulties and experimental considerations of carrying out optical diagnostic measurements as well as the possibility for increased collaboration between the PPPL and the NET Lab.

One topic which was covered at length was the opportunity to take electric field measurements within the arc discharges being used for nanoparticle generation. Electric field measurements are of extreme importance for improved understanding of plasma properties as well as predictive control over how the plasma discharges can be used. The main technique which was discussed was the possible use of the electric field four wave mixing technique which is being developed in the NET Lab. Compared with the probe measurements currently being employed at the PPPL, there are several key benefits to the optical technique. The most important benefit of the laser diagnostic measurement of the field is the use of a laser beam rather than a physical probe placed within the discharge. This allows for non-invasive measurements whereas the probe tip is currently becoming physically altered due to the large current and carbon sublimation occurring in the arc discharge experiment. Additionally, the presence of a magnetic field within the penning discharge greatly complicates the theory behind probe measurements. This magnetic field would not have a large effect upon the four wave mixing results.

Additional discussions were had about other four wave mixing techniques such as CARS, which is heavily used in the NET Lab, and CRBS which is currently being setup at the PPPL. The two techniques are similar in that they require three separate laser beams focused together, and a fourth signal beam is emitted and can be analyzed. Due to their similarities in experimental design, extensive discussions were had on possible ways that either technique could be utilized in the other laboratory. For example, the possibility of changing the optical alignment of the CRBS experiment was discussed with the hope of increasing the spatial resolution of the technique, allowing for more accurate measurements of macroscopic properties of the discharge such as translational temperature, sound velocity, and bulk viscosity of the flow. Additionally, the conversation about the Brillouin beam has led to new ideas about how this beam might be utilized at the NET Lab. The four wave electric field measurements rely upon using a picosecond laser beam and a stimulated Raman cell to generate collinear pump/Stokes beams with a high enough intensity for signal generation. However, after discussions with the researchers at PPPL, it may be possible to instead use a more common nanosecond laser system in combination with Brillouin back scattering to generate the required beams for electric field measurements. If this were possible, it would greatly decrease the cost of the experiment as well as leading to an increase in the timing accuracy of the data.

Finally, discussions were had about the challenges of setting up Thomson and LIF experiments for electron number density and radical species concentrations. The current experimental setup being used at PPPL is designed around the use of a probe to measure the field as well as the electron number density. Thus, optical access is currently limited, and new windows and flanges will be necessary to perform the desired experiments. One thing that had not been considered however is the possibility of scatter off the windows to influence the measurements. Thus, it was suggested that Brewster angle windows could be employed to decrease the scatter and increase the sensitivity of the measurements.

III. Follow-up to Visit

After this trip, the researchers at the PPPL now have a better understanding of the challenges present in the setup and execution of many optical diagnostis. This knowledge will lead to the opportunity to employee several of the advanced optical diagnostics currently in use in the NET Lab for discharge configurations not being employed here. Additionally, the discussion of CRBS has led to new thoughts on how the Brillouin backscatter currently present in our experimental setup can be utilized in order to gain additional information about the nanosecond pulsed discharges being studied here.