Daniel Broaddus
Summer Internship

Final Report

The purpose of this report is to outline the research I performed this summer. The two projects I worked on independently were the prototyping of a gas cell and the testing of a gas jet sent to us from Dr. James Dunn at Lawrence Livermore National Laboratory (LLNL). I also worked periodically under Dr. Ping and Weifeng Cheng on their Raman Backscattering Amplification (RBS) experiment, and attended a class on machining taught by Glenn Northey.

The Gas Cell

My primary project during the internship was the creation of two prototype gas cells. One was developed for a focusing scheme dependant on an axicon lens, and the other used a cylindrical focus scheme. The prototype cells are approximately 10 mm cubes of plexiglass with a hollowed center, windows glued to four of the faces, and 1/8" pipe for gas supply. A several hundred mJ pulse from a laser can then be fired into the cell through one of the windows to ionize the gas in the cell. FIGURE 1 shows a concept design of the plasma cells.

The purpose of these cells is to provide a new means for the creation of plasma for use in the RBS experiment. The idea is that the less dynamic gas of the cells(in comparison with that of the gas jet) would provide more uniform plasma for the RBS setup. This is desirable for reasons that will be detailed in the RBS section.

Machining The body of each gas cell was machined from a standard 1/2" plate of plexiglass. Plexiglass machines very well and leaves a semi-transparent finish, as long as it is well oiled during the milling and drilling process. After sawing a cube of plexiglass from the plate, each face is milled to ensure that all parallel faces of the cube are perpendicular to the other faces. After this is done, two holes (3mm dia.) are drilled across the cube from face to face for laser pathways. Outside these holes, bevels are cut to allow windows to be placed securely on the entrance of the laser pathway. For the cylindrical focus (CF) gas cell, I use a countersink to cut a taper instead of creating a bevel, in order to allow the beam to be focused on the center of the cell without clipping. Finally, another 3mm hole is drilled halfway through the cube from one of the two remaining faces so that gas can be supplied to the cell. The next task was to create a window into which the pump beam from the RBS experiment could enter. Since the beam was typically run at 60-120 mJ with a 10 ps pulse focused into a spot less than 100 microns in diameter, the intensities that any window for this beam would experience is in excess of 1 TW/cm^2. This is 3 orders of magnitude higher than that of the damage threshold of glass. Therefore, the only suitable window for such a beam is a hole through which it can pass. However, it is important that the hole is not a significant leak from the gas cell, and therefore must be very small. It was first decided to make a hole 100 microns in diameter. It was first attempted with a pin; however, this method made tears in the material and rarely created round

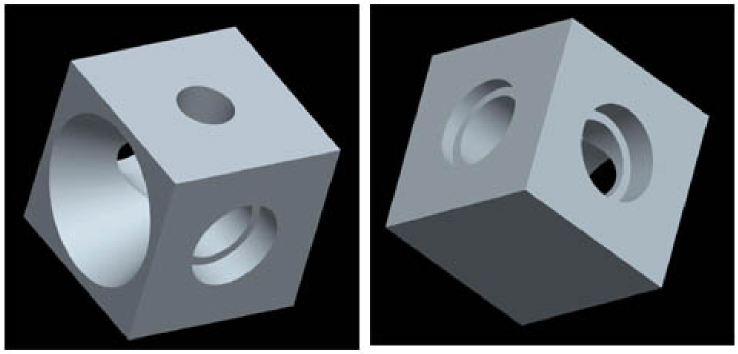

Figure 1: FIGURE 1 A concept design of a plasma cell's body

holes. We then attempted to drill such a hole, which was less successful in most cases, and general broke the drill. Eventually, a 100 micron hole was successfully drilled, but it was off center making it useless. At 200 microns, drilling yielded far more success and we were also able to create such a hole with the pump laser itself. With the 200 micron window a prototype CF gas cell was completed. After the completion of the cell, the next task was to test the level of vacuum one could achieve with a 200 micron hole in the cell. Unfortunately, the vacuum used in their experiment has leaks in its O-rings, and since my vacuum meter's resolution is 10 torr, it is impossible to discern the effect of the hole in the gas cell. In time, is likely that we will be able to procure a better vacuum meter, but for the time being it is apparent that the 200 micron hole is smaller than the other leaks present in the vacuum.

The next step after testing the vacuum was to see if plasma could be made in such a cell. Borrowing the Lumonics Nd:YLF laser from another project, we used a cylindrical lens to create a line focus inside the cell. The Lumonics has damage to its YLF crystal so the laser's warm up time is very long (4-5 hours), and the time it will fire at its maximum output is not long (1 hour). Though it is difficult to work with, it has very good power. When it is amplified fully, it can create a 400-500 mJ pulse 100 ps in duration. Inside the cell we focus this pulse into a .02mm $\times$ 3mm line which would cause breakdown in open air. However, it is difficult to determine whether there is breakdown in the cell because plasma is created on the wall of the cell itself. So far, I have made the first steps toward setting up diagnostics for the cell, a perpendicularly propagating beam for interferometry, and a CCD which I will continue to work with during the academic year.

The Gas Jet

Prior to my work on the gas cell, I was charged with testing a new gas jet send to us from LLNL. In open air, the valve on the jet opened easily when 120 psi was placed on it. For safety, I paused my testing until I had setup a vacuum chamber in which I could test the jet. Its performance exceeded expectations of 160-180 psi, with the valve opening at 210-220 psi. I continued testing it, and verified that it would open at 210-220 psi in a reproducible fashion.

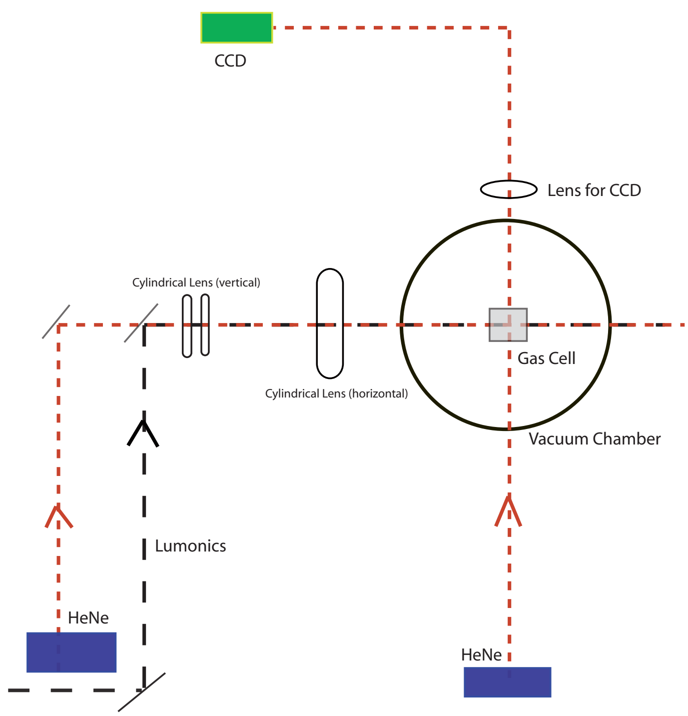

Figure 2: FIGURE 2 The lasing setup of the CF gas cell.

It preformed in a stable fashion; however, my tests were rarely longer that 10-15 shots. After these tests, I then attempted to create plasma with the jet and the Lumonics laser. Using a line focus from the same cylindrical lens I went on to use in the gas cell project, I attempted to focus the beam to achieve breakdown. These efforts ultimately ended with no success, as I was never able to time the gas jet with the laser before the Lumonics stopped lasing correctly. Also, by this time it was necessary to incorporate the gas jet into the primary RBS experiment. This entailed testing a different nozzle on the gas jet, machining a new plate for their vacuum, and helping Dr. Ping and Weifeng install the jet. Changing from the 8mm nozzle with which I had previously tested the gas jet to the 2mm nozzle that the RBS experiment called for led to a discovery that the valve was still opening at more than 450 psi and I simply had to stop my test, because my setup was not rated for that high a pressure. We then realized that the new gas jet was designed in such a fashion that the pressure at which is could open was dependant on the area of the nozzle opening, and theoretically the valve could open at 880 psi with a 2mm nozzle. However, such pressures were never tested. I machined two plates to hold the gas jet in the vacuum. One was 3/16" aluminum, which was too thin and bowed when placed under vacuum. I designed the second plate in PRO/E and machined it entirely in the CNC mill. It was 3/4" thick.

Raman Backscattering Experiment

While working on the Raman backscattering experiment, I was given the opportunity to help and closely observe Weifeng's and Dr. Ping's work on their experiment. As I worked along with them, they explained how the equipment we used took advantage of certain phenomena to provide diagnostics on their beam. Specifically, they instructed me on how to use second harmonic generation in a crystal to measure pulse duration, and how density is determined through interferometry. Generally, I assisted them in data collection because the apparatus for the experiment took two people to operate. I also helped in the alignment of the laser, which was helpful for me because I was able to apply the techniques I learned from working with them to my own experiments with the gas cell and gas jet. The RBS experiment also required the creation of uniform plasma. We pumped this plasma with the terawatt positive light laser to create a population inversion, and then fired a short seed pulse (500 femtoseconds). This seed pulse then stimulated Raman backscattering in the plasma. If this plasma is uniform the quality and intensity of the output RBS is much better, and if the plasma is dense there will be more molecules for the seed and pump lasers to interact with. Therefore, improved plasma can lead to improved yields in amplification, and is desirable.

Acknowledgements

I found the internship to be a very positive experience and a unique opportunity for me to gain some laboratory experience. Working with such a world class team under the guidance of Prof. Suckewer was an experience that has excited me about my own career opportunities in beam physics. I would also like to thank the Plasma Physics Program and Prof. Sam Cohen for sponsoring me this summer.