Written report of Summer research for the PPST
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For the last two academic years I have been working part-time in Professor Suckewer's X-Ray Laser Group, assisting with research into a method for creating a laser-induced plasma channel to be used in Raman Backscattering Amplification

This summer I worked with graduate student Yushan Luo in Professor Suckewer's lab as part of the X-Ray Laser Group. The purpose of the research was to investigate a new plasma-formation technique to be in Raman Back-Scattering amplification. RBS amplification promises to be a superlative method of creating ultra short, ultra-high intensity laser pulses and Professor Suckewer's lab has been investigating and improving the technology for the last several years. Amplification of a seed pulse by a counter-propagating pump beam occurs inside a **plasma channel** which plays the role of the active medium. In the current experimental setup, the plasma channel is created by focusing an intense pulse onto a gas jet, however due to the chaotic nature of the gas jet the resulting plasma channel is plagued by uniformities in shape and density.

Yushan and I started our research by continuing on from research made the previous year, thus when the Summer commenced our experiment consisted of focusing a laser pulse into a gas cell via two pinholes, with vacuum outside the cell and around 80 torr of N_2 gas inside the cell. The laser system consisted of a Lumonics Ti:Sapphire front end laser amplified by a home-made Ti:Sapphire slab amplifier. The output pulse was measured to be ~100ps in duration, with maximum energy per pulse at around 500mJ.

The three main problems we aimed to overcome in this experiment were issues with shot-to-shot reproducibility of the plasma, making a plasma of sufficient length, and the axial uniformity of the plasma. Another major issue was the analysis of the interferogram to interpret the density profile of the plasma channel.

Irreproducibility came from two sources: shot-to-shot irregularity from the laser amplification system, and instabilities within the gas cell itself. A lot of time was spent tuning the Lumonics laser in order to improve shot reproducibility and increase the pulse energy (this was another important issue I will discuss in more detail later in this report). This included replacing a damaged glass rod inside the laser. Our efforts helped, but there was still a large amount of fluctuation in energy from shot to shot. We were able to take this into account by simultaneously measuring the energy of each shot along with the interferogram of the plasma.

With this taken into account, we were still seeing quite different interferograms from pulses with the same energy. To curb this irregularity we experimented with applying strong DC electric fields perpendicular to the pulse. To simplify this part of the experiment we removed the gas cell and filled the vacuum chamber entirely with N2 at low pressure, aligning the focus of the beam between two co-linear pins ~2mm apart at a potential difference of ~1KV. We experimented with different voltages and different arrangements of electrodes, with the hope that the electron cloud of a DC discharge would act as a source of seed electrons for the much higher density laser discharge. This, however, did not appear to improve reproducibility of the plasma, so we did not pursue the idea further.

The only clear limiting factor to the length of the plasma channel was the energy of the ionizing beam, which was limited by the performance of the Lumonics laser. Again, we attempted to increase the energy output of the laser, but were not able to increase the energy of one shot to produce the desired plasma length, which was 2-3mm. Our longest plasma channels from one amplified pulse were only 1mm.

A major breakthrough was made when we fired with two consecutive laser pulses (this was done after we removed the gas cell – we fired into the vacuum chamber with low pressure N2). This was easily arranged by changing the timing of the Q-switch inside the Lumonics laser to select two pulses (10ns apart) rather than only one. The effect of this was a much longer and thicker plasma. We believe the reason for this is that the first pulse preionizes the gas, and when the second pulse comes in there is an abundance of electrons which are accelerated by the E-field and start the avalanche which creates the plasma channel.

This regime did cause a complication in the acquisition of the interferogram though: the probe beam comes from a frequency-doubled portion of the ionizing beam, thus with two pulses there are also two interferogram pulses, and thus the interferogram appears as a superposition of two interferograms taken 10ns apart.

That was the extent of our progress by the end of my summer intership. Since then the experiment has been moved to a different part of the lab and makes use of three different lasers – two the two ionizing beams and a third for the interferogram, and this resulted in some promising plasma channels, however the data from those experiments has yet to be analyzed.