Experiment Battle Plan for December 9-15, 2013 on Two-Color System

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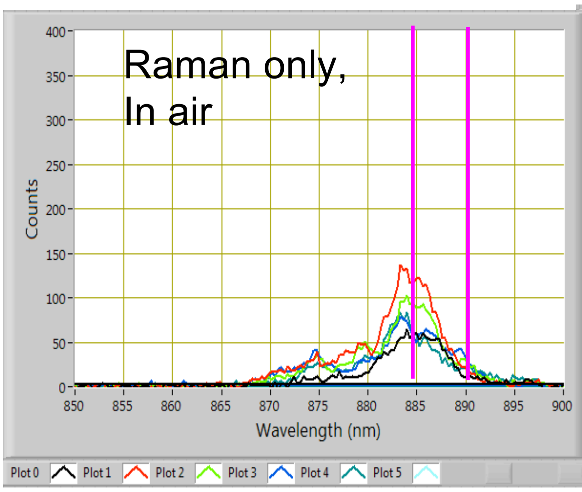
Scientific Goal(s)

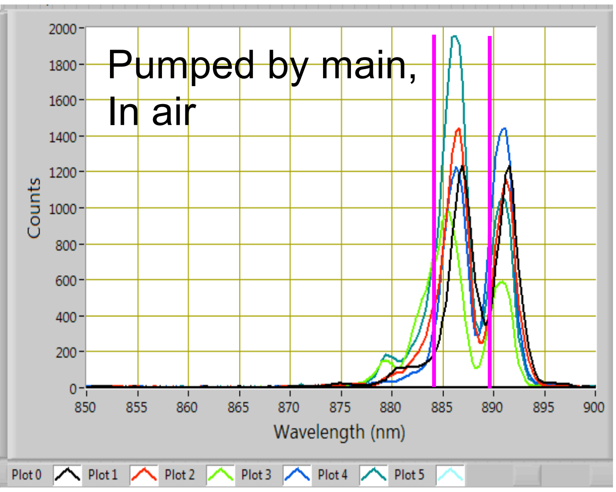
- Demonstrate proof-of-concept experiment showing that Raman beam reaches sufficient intensity for RSF suppression experiment; this corresponds to $a_0 \sim 0.15$--> I~4.1x10^{16} W/cm^2.
- This intensity is sufficient to ionize via barrier suppression: krypton (x8), argon (x8), nitrogen (x5), oxygen (x6) helium (x2), and neon (x5). Of these, neon's 5th ionization is at $a_0 \sim 0.157$--> I~4.04x10^{16} W/cm^2, and so by ionizing neon 5 times we would demonstrate that the intensity of the Raman beam is sufficient for RSF suppression. Or oxygen's 6th ionization is at $a_0 \sim 0.157$--> I~4.04x10^{16} W/cm^2.
- Alternatively, we can try to get at the Raman beam intensity by looking at ionization effects away from focus. This requires that we ahve a well-characterized beam in vacuum (energy and duration, plus mode as a function of longitudinal position).
- Additionally, we want to demonstrate spatial overlap and time synchronization between Raman and main beam. We have alread done this to within the precision of ionization effects (e.g. Ionization defocusing) in both air and helium gas: ~ps. Thus, it would be nice to demonstrate a more precise overlap, e.g. ~10 fs. This can e done with the RXPM experiment, using the main beam as pump nad the Raman beam as seed.

Summary of Last Time

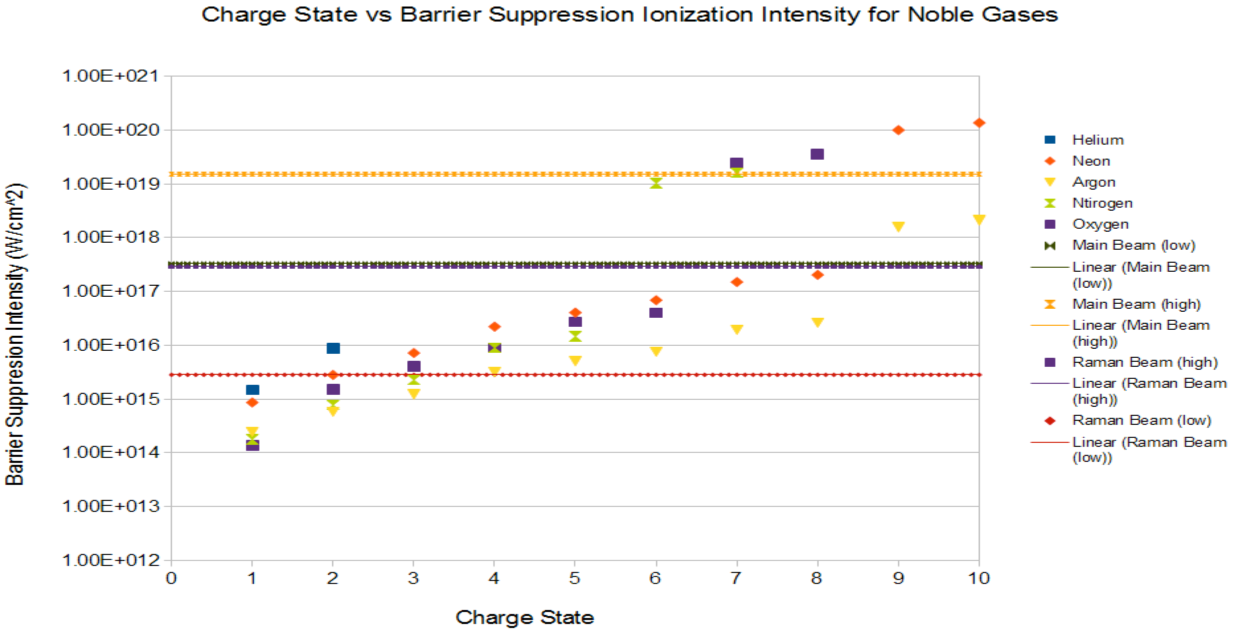
Last time, we attempted to view spectral variations due to RXPM and RSPM in the two beams. We were still operating with the damaged power amp crystal, and of course the crystal in the Raman line's 6-pass is badly damaged. Here is what we saw:

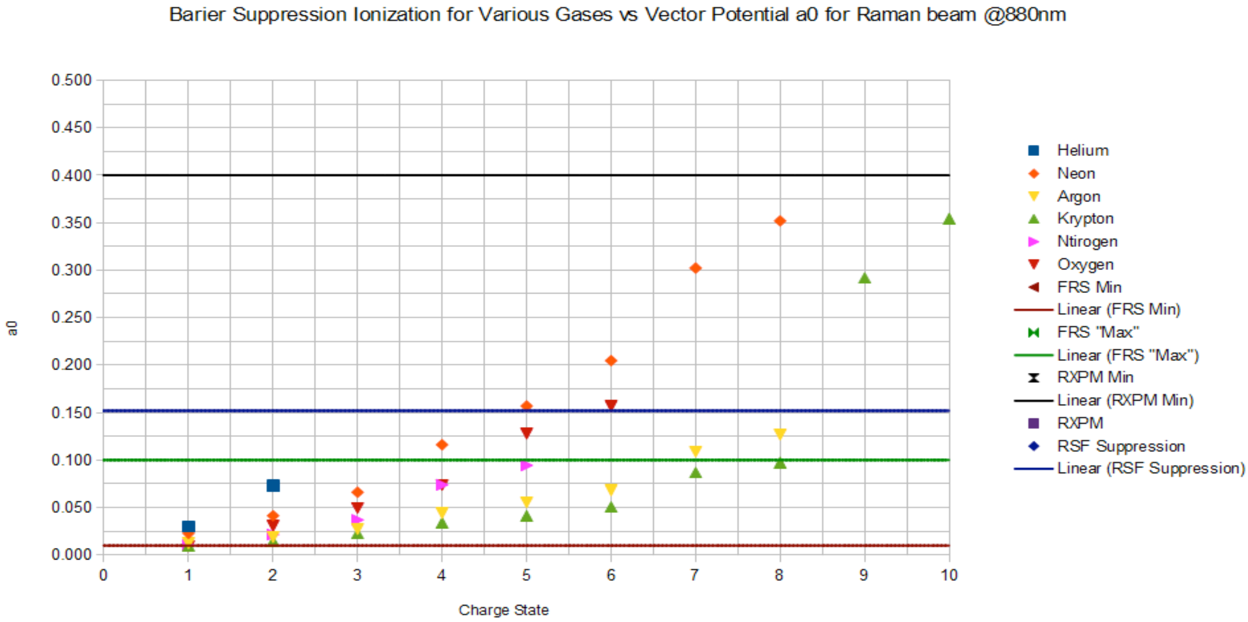
- First, the laser system's specs. Before pumping down and sealing off, we had to make minor day-to-day adjustments, but the typical performance was 380 mW mode-locked from oscillator, ~140mW after stretchers but before the 9-pass, 300-310 mW from the 9-pass (35.5 A Jade current), 12-15 mW from XPW, 120-130 mW @1kHz from Booster with ~40 nm FWHM bandwidth, 35-40 mJ from pre-Amp, and ~1 J after Power Amplifier/pre-compression (~900 mJ into Main line) compressible to ~40 fs (bandwidth indicated better compression obtainable, but I only observed to 40 fs). For the Raman line, I had ~75-80 mJ after the 6-pass pre-compression, compressible to ~125-130 fs.
- Raman and main transverse modes at focus were approximately the same size.
- In air, I am limited to only 30 mJ on the gratings in main line. I was able to observe ionization blue-shifts and probably SPM with the main beam, but not the Raman beam. I could also see ionization defocusing, and the main beam's ionization would defocuse the Raman beam.
- By using an iris before the compressor, I could change the Main beam's mode profile in such a way to also get ionization focusing/channel guiding (I think) of the Raman beam by the Main beam.
- During ionization defocusing, I used an iris to make the Raman beam big at focus, and observed only the center part getting defocused—this indicates that the two beams are well-aligned; additionally, the ccds monitoring this system are using a relay-image of the the two beams in the focal plane of the Main beam (the Rmaan beam's focal plane is adjusted to overlap the main beam's focal plane). I can switch which beam each ccd views using interference filters to block the main beam or the Raman beam. Therefore, I can overlap both beams on the same point on a given ccd, indicated further that the two beams are overlapped.
- I observed what appears to be modulation of the Raman beam's spectrum in air using the main beam as pump. This is observed by comparison of spectra when the main beam is present and when it is absent—I was unable to obtain both input and output spectrum simultaneously on this run.





- Once the system is placed under vacuum, it is inadvisable to make drastic changes to beam allignment because the Raman beam has a tendency of getting walked off from the main beam. Unfortunately, some such adjustemnets were made, but overlap was re-obtained. Now the main beam power is down to only ~700 mJ pre-compression, which with a duration of 150 fs gives a normalized vector potential of a_0=0.59 (I ~ 7.56 x 10^{17} W/cm^2) using our spot size (~14 μm FWHM) and Strehl ratio (~0.6). The Raman beam's energy was only ~55mJ after the 6-pass (pre-compression).
- Under these conditions, I could observe ionization defocusing of the Raman beam (ionization caused by Main beam) in helium, and some SPM of the main beam. However, I never observed any discernible phase-modulation effects in the Rmaan beam. I even did a fine-scan of Raman beam delay timing. I never observed any phase modualtion effects.
- Additionally, a simple calculation shows that even under our best observed operating conditions (~200 mJ pre-compression and ~100 fs in the Raman line), the intensity is not sufficient to pump RXPM. Ideally need a_0~1 (I ~ 1.78 x 10^{18} W/cm^2-->~1 J before compression), could probably see some small (and thus difficult to decisely discern) effects around a_0~0.4 (I ~ 2.81 x 10^{17} W/cm^2-->154 mJ before compression). Our beam can achieve up to 200 mJ pre-compression when using an undamaged 6-pass crystal (a_0~0.45 -->I ~ 3.60 x 10^{17} W/cm^2 if compressed to 100 fs duration, or a_0~0.37 I ~ 2.40 x 10^{17} W/cm^2 if compressed to a more realistic 150 fs duration, or a_0~0.31 I ~ 1.72 x 10^{17} W/cm^2 for the best-case for RSF 210 fs), and perhaps 140 mJ pre-compression on a good day with the crysal we have (a_0~0.38-->I ~ 2.52 x 10^{17} W/cm^2 or a_0~0.31 I ~ 1.68 x 10^{17} W/cm^2 for 150 fs, or a_0~0.26-->I ~ 1.20 x 10^{17} W/cm^2 for 210 fs).





Actions and Experiments

Preliminary:

1. Overlap Raman and Main beam in 4D (transverse; longitudinal focus; time overlap via ionization defocusing).
2. Test energy loss for Raman beam from compressor to on-target: assumes that we have a working poer meter back
3. Set-up ccd after diagnostics window into chamber for Raman compressor pointing allignment. I would prefer to have a dedicated ccd for this, meaning for my purposes a ccd which can be placed there at the beginning of my run and then not moved until after my run.
4. Install Zaber motors as necessary; turn on and "zero" all motors as a part of basic early allignment, since they have a tendence to fail to communicate when first turned on/under vacuum.
5. Transverse (shadogram/interferometer) probe overlapped in space and time with focus of Main and Raman beams. Simple test: can we detect the effect of the Main beam in single-shot mode on a glass test-slide?

In vacuum with gas jet:

1. Power scan of Raman beam in neon; what kind of blue-shifts do we get in spectrum, and what kinds of fringe shifts in interferogram? This would be for ionization in neon—can we observe the 5th ionization?
2. Can also try (with well-calibrated mode, energy, and duration) doing a scan of of position for focal plane—place focal plane before the gas (thus, defocusing-->larger spot size-->lower intensity at gas jet entrance), and no/fewer ionizations occur than if plane is at gas jet entrance. This can be done in helium:
   - First, do scan of beam profile from focus to several Raleigh ranges later (z= 0 up to z ~$5Z_R$) in vacuum.
   - No, repeat with helium gas jet. At what position do we observe the onset of ionization? This tells us the position (and hence when compared to the vacuum images, the spot size) where the intensity is sufficient to ionize helium (for first ionization, (I~1.46×10^{15} W/cm^2 and for second, I~8.77×10^{15} W/cm^2).
   - Intensity at focus is the ionization intensity for helium multiplied by the square of the ratio of the spot size at ionization threshold position to the spot size at focus.
3. May do a gas density scan from ~20 psi to 200 psi, again using neon or possibly nitrogen or helium in the gas line.
4. Get fine-overlap of Main and Raman beams in time with gas jet present—hopefully very minor tweaks in light of the in-air experiments. Should be able to observe ionization defocusing of main beam by Raman beam.
5. Now switch roles, with Raman beam acting as the probe, but the desired effect is RXPM. The main beam will be the pumping beam, need a_0>0.4 (I ~ 3.36 x 10^{17} W/cm^2) and a_0 >1 (I ~ 2.13 x 10^{18} W/cm^2) is prefereable.

Specific Diagnostics:

1. Spectrum—we will look at the spectrum for both beam both before and after the gas jet using the existing fiber spectrometer and the spectrometer which is in the FDH area; beam is transported to this spectrometer via fiber. This is our primary diagnostic—if other diagnostics fail, we can press ahead without them, but this one has to work.
2. Interferogram: we can use fringe shifts to detect ionization, and compare the onset of these shifts to the corresponding blue-shift in spectrum. We can also us this to determine plasma density, which can be checked against spectral shifts.
3. Modes: we can look at the mode at the focal plane and at later positions with our CCD cameras. One camera monitors Rmaan mode, one monitors main mode.
4. All of this is triggerable in single-shot mode, which we will use.

Laser Requirements:

1. Full system experiment: need ~0.5-1 J pre-compression in Main beam, 100 mJ into Raman and Probe line (70 to Raman, 30 to Probe)
2. Will compress to ~150-200 fs for Raman beam (this is the approximate duaration needed for RSF experiments). The main beam can be compressed to 30 fs for maximum intnsity in RXPM experiment.