PHGN 480 Laser Physics
Lab 2: HeNe gain and lasing

Do this by the end of the day Monday, 26 September. Turn in your write-up in class on Tuesday, 27 Sept.

For this lab, you work on testing the gain of the HeNe tubes and to align the lasers.

The goals of this lab are to:
1. align the laser tube so that it is level to the table
2. set up a system to measure the double-pass gain at three different wavelengths.

The first step can be done in parallel with multiple groups working at the same time. The second step requires the use of a couple of HeNe laser that we have that run on different wavelengths, and we only have one of each of those.
1. align the laser tube so that it is level to the table
2. install the output coupler and get the laser to lase. Use the power meter to optimize the output power.
3. Vary the current on the laser power supply and obtain a curve for output power vs. input current.

1. **<u>Alignment of the HeNe laser tubes:</u>**
   a. The laser tube is to be aligned on your breadboard (under the optical bench). Pick a beam line along the holes of the breadboard for the laser and set up a pair of irises along this line. Be sure to pick a beam height that is compatible with the posts that we have. Use a pair of mirrors to align your HeNe reference laser along this line.
   b. It will be useful to know if the high reflector mirror bonded to your HeNe tube is flat or curved. To test, reflect the laser beam off the back of the mirror and look at the reflected beam. If the divergence changes, it is curved. Is your mirror curved? Which way is it curved, if it is. Try to use a measuring tape to estimate the beam size at a couple of distances from the mirror. How can you estimate the mirror radius of curvature from these measurements?
   c. We want our alignment beam to pass through the tube and back without touching the walls of the tube. Use a lens to focus the beam into the laser tube, choosing a moderate focal length ~500mm. Use the knife-edge technique to find the focal point of the lens. Since the beam diverges out of the laser, the focal point may be farther from the lens than the focal length.
   d. Align the tube to the laser beam:
      i. Use the 6 screws on the polycarbonate tube to get the laser tube visually centered on the polycarbonate tube.
      ii. Position the z-position of the tube so that the alignment beam waist is either at the HR mirror (if the HR is flat) or somewhere near the focal point of the HR (if it's curved).
      iii. Adjust the entrance face of the tube so that the beam seems centered on the input window.
      iv. If your tube has a tilted Brewster window, rotate the tube (without power!) so that the reflection is level to the table. Now align the back of the tube so that the

beam can go through to the end mirror and back. Try to point the beam back through one of your alignment irises.

v. Install a beamsplitter into the beam path before the laser tube. You should be able to do this without introducing clipping on the laser tube. The beam should go through the tube without any clipping, looking like a smooth Gaussian beam.

2. Double-pass gain measurement:

The beamsplitter will allow you detect the return beam with a power meter. Set up a power meter head on a post, and center the return beam on the sensor. Note that there is no zeroing feature on the power meters. Get the background signal by blocking the beam near the laser output. Measure and record the initial power, then power on the test laser tube and measure the output power. Subtract the background, and calculate the ratio of the signal with to without power to the tube. You should see roughly a 10% increase for the 632.8nm light.

Test gain for other wavelengths: We have at least two different color HeNe lasers, red and yellow. (There may be a third available that lases in the orange.) Use your mirrors to align the other test laser beam through the irises. Measure and record the gain for those wavelengths.

3. Alignment for lasing:

In principle, the degrees of freedom for lasing are the two mirror angles and the cavity length. The transverse position of the mirror just needs to centered enough to avoid any clipping of the beam on the mirror. As we will learn soon when we discuss resonators, there is a range for the separation between the two cavity mirrors that allows the light to stay trapped in the resonator in a stable way.

a. Install the output coupler mirror (OC) a few cm from the end of the tube. Be sure the curved surface is on the side of the laser tube. Center the mirror on the beam by looking at the spot on the mirror. Adjust the angle of the OC so that the back reflection is directed back through one of your alignment irises. You should also see a bright back reflection from the beamsplitter. Try one of the two following methods to align the OC angles:
b. If you detune the OC reflected beam, you should be able to see a faint return beam from the HR. Inserting the OC may have deviated the beam to the HR, so you may need to adjust the transverse position of the OC to get a clean return from the HR. Then align the OC so that its reflection is directly on top of it.
c. In the other technique, put a CCD camera right near the outside of the HR mirror. You should be able to see a beam leaking through the HR. With the OC installed, you may also see a second beam that makes one extra round trip through the cavity. Alignment of these on top of each other will make sure the cavity is aligned.
d. Turn on the laser tube, and look for lasing. If it does, go to step (e). If it doesn't, try a small tweak back and forth on the OC angles, to see if you can see the laser flash. If that doesn't work, you can try walking the cavity: detune the OC in one direction, then moving the other adjuster back and forth (around +/- one turn).

Then increment the first adjuster by a bit (about 1/10th of a turn) and repeat, looking for the lasing flash.

e. After you get it to lase, then put the power meter on the output beam (no beamsplitter), and optimize the output power with the OC angles. Note the sensitivity range of those adjustments.

4. Power vs cavity length:

Once you have the laser running, it is possible to gradually move the end mirror to different separations and maintain lasing. Try different cavity lengths, in increments of about 2", record and plot the optimized output power vs cavity length. It will help to clamp a straight edge (e.g. meter stick) to the table and slide the base of the OC mount along it. As you move the mirror, make fine adjustments to the OC angles to keep the laser lasing. Also check to make sure the beam location on the OC doesn't drift to the side. Make measurements over as large a range as possible, trying to find the limits of the cavity stability. Also note observations about the beam profile at these different positions.

5. HeNe tube spectral measurements:

We have one fiber-coupled spectrometer which can be used to measure the emission spectrum of the discharge. Placing the fiber tip in a mount so that the spectrometer can pick up the glow of the discharge, record the emission spectrum under the following conditions:

a. when your tube is not lasing, and when your tube is lasing
b. place a mirror that takes the output of your laser and directs it right back into the laser. This is normally "bad" for the laser: for higher power lasers and diode lasers this feedback can lead to optical damage. But it's ok for a HeNe. This feedback can allow other HeNe gain lines to lase simultaneously. Use the fiber spectrometer to look at scatter from the OC and see if you can see other laser lines as you align the feedback mirror. If you optimize one of those lines, re-check the spectrum of the HeNe tube with and without lasing.
c. Using the spectrometer software, compute the difference spectrum for cases (a) and (b) and discuss the differences.
d. For reference, record the spectrum of a neon discharge tube. This tube does not have the helium which helps to preferentially pump the lasing levels of neon.