PHGN 480 Laser Physics
Lab 2: HeNe gain and lasing

Turn in your write-up in lab on Thursday, 24 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. measure the radius of curvature of the high reflector
3. set up a system to measure the double-pass gain at three different wavelengths.
4. install the output coupler and get the laser to lase. Use the power meter to optimize the output power.

Notes:

- Be careful: the HeNe tubes are fragile, and it is easy for the tube to slide out of the mounting cylinder.
- The anode is at high voltage, so it can give a spark, even after the power is turned off.
- The entrance window must be kept absolutely clean! Keep your fingers away from the window.
- There should be an identifying serial number on the laser tube. Make a note of it and include it in your report. Also, take a picture of the power supply you are using with the tube. Some tubes and power supplies perform better than others and this will help us keep track of which ones work. If your laser operates with low power, we can swap the tube out for another.

1. <u>Alignment of the HeNe laser tubes:</u>

a. If it is not already aligned this way, align the HeNe laser and the two fold mirrors so that the beam that is the same height as the mounted HeNe tube (nominally 6" above the table). The beam should be level to the table and straight along the table holes. A telescope should be used to collimate the beam. Make sure that you have a pair of irises after the mirrors that is well aligned to the beam. Later you will be sending laser light in from other lasers, so you will need to be able to use the fold mirrors to direct the new laser beam along the direction of your current alignment.

b. Coarse leveling the HeNe tube.

i. place the single-window HeNe laser tube on the table, and send your beam into the entrance window.

ii. If the height of the tube is not very close to the center of the window, use the three nylon screws to adjust the height of the tube.

iii. Turn the tube around, and adjust the other end to make sure it is also at the same height as input beam. Get the beam back through the entrance window, and iterate if necessary.

iv. Most tubes have a tilted Brewster window. If yours does, rotate the tube so that the reflection from the window stays level. That reflection should escape through the slot in the tube.

2. **Measurement of the HR radius of curvature**

   We will need to know the curvature of the high reflector mirror that is bonded to your HeNe tube. Use your collimated beam to reflect off the back of the HR mirror so that the reflection returns at small horizontal angle to the input. Then focus the beam with a lens of known focal length. If the HR mirror is curved, the reflection from the back of the mirror will diverge, and the focal point will be shifted to a position farther away from the lens. Use the knife edge test to measure the new focal position. Measure the distance from the HeNe HR to the lens, then use the lens equation to estimate the radius of curvature of the mirror. **Make a schematic of your setup, showing your measurements. Show your work for the calculation.**

   The shearing plate interferometer can also be used to measure the divergence. Direct the reflected beam into the interferometer and take a picture of the fringes. Make sure the reference line is visible in the image. Later in the course, we will learn how to calculate the divergence from the fringe rotation.

3. **Fine alignment through the HeNe tube.**
   a. Place a long focal length lens in the collimated beam so that the focus can be near the entrance window of the tube and the beam does not clip the inside walls of the tube. Orient the beam down the length of the tube so that it reflects back on itself. If the return beam is retro-reflected, it should travel all the way back to the alignment laser. If the vertical reflection is off, you can fine-tune using the screws holding the base to the tube. An alternative is to use the mirrors to get the input beam and reflected beam to be on top of each other. If you do this, remember to reset your irises to be along the input beam.
   b. 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.

4. Double-pass gain measurement:

The beamsplitter will allow you measure the power of the return beam with a power meter. The goal is to make a measurement of the double-pass gain, so you will measure the power with and without the tube on. Even without any gain, the tube will emit light witch can get into the power meter. The gain will not be more than 10%, so do your best to eliminate this stray light, and find a way to subtract the stray light from your measurement. Here is on approach: 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. Be careful not to let room light or glow from the HeNe tube affect your measurements. An iris that passes just the beam into the sensor might help. You should see roughly a 10% increase for the 632.8nm light, less if you are using a different HeNe wavelength.

Test gain at another wavelength: We have one or two HeNe lasers that operate in the yellow. Use your mirrors to align the other test laser beam through the irises. Measure and record the gain for the yellow wavelength.

5. <u>Alignment for lasing:</u>

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 be 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. Before using the output coupler, measure its transmission using an alignment laser running at 632.8nm and a power meter. Make this measurement carefully – it should be on the order of 1%.
b. Install the output coupler mirror (OC) a few cm from the end of the tube. If the OC is curved, 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 to achieve lasing:
c. If you slightly 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.
d. A second technique is to 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. You should see circular interference fringes; center these.
e. Turn on the laser tube, and look for lasing. If it does, go to step (f). 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.
f. 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.

<u>6. Power vs cavity length:</u>

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.

7. 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. It is hard to see this, but the 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.