# PHGN 480 Laser Physics
# Lab 4: HeNe resonator mode properties

Due Wednesday, 20 Nov 2013

For this lab, you will further explore the properties of the working HeNe laser. You should also complete any work with the Fabry-Perot (scanning or passive) that you did not get to earlier.

## 1. Single longitudinal mode operation with intracavity etalon:

As you saw in the previous lab, the gain bandwidth of the HeNe laser is large enough to support lasing on a few longidudinal modes. By adding a window to the cavity, it is possible to introduce loss to all but one of those modes and force oscillation on a single longitudinal mode. The window acts as a low-reflectivity passive Fabry-Perot cavity, with a frequency spacing that is larger than that of the laser cavity. We have windows of 3 different thicknesses. The thinner ones should be easier to insert while maintaining lasing, but the thicker ones will likely give better discrimination against the other modes.

a. Supporting calculations:
   - calculate the longitudinal mode spacing for your laser cavity and for the etalons available
   - The angle of the etalon will need to be adjusted so that a transmission peak can be centered on one of the laser modes. With the passive Fabry-Perot you found that the transmission varied with angle. The round trip phase of the etalon will be $\phi(L,\theta_2)=\frac{2\pi n}{\lambda}2L\cos\theta_2$ , where $\theta_2$ is the internal refracted angle. Plot $\phi(L,\theta)/2\pi$ vs. *incident* angle near normal incidence to determine the range of angles you will need to sweep through to get a full wave of phase shift.
   - The angular change will introduce a shift in the beam as it zig-zags between the interfaces. As you saw before, if that shift is large, there is no interference between the beams and therefore no etalon effect. Calculate the maximum shift for the $2\pi$ phase change, and compare it to the laser cavity beam size near the output coupler. (If the OC is flat, this shift should not dramatically change the alignment of the end mirrors.)

b. Check the alignment of your HeNe laser for lasing, and mark the output beam with external irises. Make sure there is sufficient room between the OC and the tube to insert a mirror mount to hold the window. Align the reference laser beam to those irises. Mount the window or slide and insert it into the cavity near the output coupler. Use the alignment laser to make sure that you are starting with the window at normal incidence to the cavity axis. Try to get the laser operating again by sweeping through the range of angles you calculated above. An alternative approach with the thinnest window would be to insert the window near the Brewster angle (near zero reflectivity), then to try to place the window at the same angle of incidence but reflecting out of plane. This will require some creative mounting, but effectively allows tuning of the reflectivity as the incidence varies from P to S.

c. See if you can angle tune the etalon across two neighboring longitudinal modes. Estimate the angle over which you adjust the etalon and compare to what you would predict from the mode spacing calculation.

d. Assuming you are able to get the laser operating again, verify single mode operation either with the scanning Fabry-Perot, or to put a photodiode on the output beam (50Ohm termination) and look on a fast timescale for the absence of mode beating.

**2. Cavity mode measurement:**

With a flat OC, there should be a beam waist at the laser output.

a. Using either the camera or the knife edge scanning technique, measure the output beam 1/e2 radius. Calculate the Rayleigh length zR for that beam size and compare it to the distance between your measurement position and the reflecting side of the OC. If the distance is small compared to zR, you can assume you have measured the actual waist size. Otherwise you will need to correct for that distance.
b. Measure the cavity length, and calculate the radius of curvature of the beam at the HR. Compare this to your previously measured radius of curvature of that end mirror. Before moving on to your next section of the lab, make sure that the results are reasonably consistent.

**3. Extended double curved mirror cavity:**

Instead of using a flat OC, the laser should also work with a curved OC. The alignment will be challenging.

a. With the laser operating with the flat OC, set two irises to mark the output beam direction, making sure that they are not in the way of where the new OC will go (maximum room to allow will be R2=43cm). Align your reference laser to this direction, which locates the laser cavity axis.
b. The laser resonator will have two zones of stability when there is a mismatch in the curved mirror radii. Check the stability calculation for the resonator and place the new OC in the middle of the outer zone. Align the back reflection off the OC to retroreflect and try to get the cavity to lase.
c. Depending on the cavity length (and the mode size back at the HR), the laser may run multimode. You can put an iris at the beam waist position to force single mode operation. Measure the output power of your cavity.
d. If you have time, try to move the OC to shorten the cavity length to find the inner edge of the stability region. Compare this with the calculation.
e.

**4. Variable output coupling:**

The output power is a function of the amount of power coupled out of the cavity. For zero output coupling, there is zero output. For too much output coupling, the threshold for lasing is high, and there is low output. There is a maximum in the middle.

a. Using your alignment irises and reference laser, swap out the output coupler for a flat HR and get the laser to lase. There will be very low output, but you should be able to see the internal beam. Measure any output power through that mirror, off the Brewster window, and out the back HR.

b. Mount the thinnest window (the cover slip) on a rotation stage and insert it into the cavity at the Brewster angle. Adjust the angle for minimum reflection from the window. You may need to tweak the end mirror to optimize power. Note the angle on the rotation stage – this is the Brewster angle, giving you minimum output coupling. Measure the output power, if any.
c. At various window angles, measure the output power. Always make sure the power is peaked up. Make a plot of output power vs angle, then use the Fresnel equations for the reflectivity of the glass vs incident angle to make a plot of output power vs output coupling percentage. Determine the optimum degree of output coupling. Remember that there are two interfaces that reflect and that the internal beam passes through it twice. If the beam offset is small, the two reflections may be superposed and the actual reflectivity will be affected by etalon effects. Using a thicker slide should avoid this issue.

Resources:

There is a huge amount of practical information on the website Sam's Laser FAQ: http://www.repairfaq.org/sam/laserhen.htm#hentoo1