PHGN 480 Laser Physics
Lab 3: HeNe resonator mode properties

Due Wednesday, 17 Oct 2012
For this lab, you will explore the properties of the working HeNe laser.

1. **<u>Power vs cavity length:</u>**

Set up your output coupler so that it is easy to slide its mount along a range of distances from close to the Brewster window out to an additional 50cm. Using your alignment beam make sure that the mirror stays centered on the beam as it slides over that distance. You will be measuring the optimized output power vs cavity length to investigate the resonator properties.

a. Pick a cavity length near where you observed lasing previously and recover lasing. Use the power meter, optimize the OC angles and record the maximum output power. Check to make sure that the laser mode is approximately centered on the OC.

b. Place a lens at the output to expand the output beam on a screen. For some cavity lengths, and especially when the OC is misaligned, you should be able to see multimode (non-Gaussian) structure on the beam. Set up the CCD camera with a standard camera lens so that you can see the mode shape. Place an iris near the Brewster window. Gradually closing the iris, align its transverse position so that it is perfectly centered on the laser beam. You can use the partially-closed iris to discriminate against the higher-order spatial modes and force laser operation only on the Gaussian (TEM00) mode.

c. For several cavity lengths (10 or so), move the OC, re-optimize power, and record the cavity length and the power for multimode (iris open) and single mode (iris closed just enough to force TEM00 operation). Use the knife-edge scan to measure the output beam size just beyond the OC. When you move the OC along the rail, move slowly enough to keep the laser operating as you go to the new position. Watch to make sure that the beam doesn't walk towards the mirror edge. If it does, then re-center the mirror. You should reach a point for long cavity length where it becomes increasingly difficult to maintain lasing.

<u>2. Longitudinal mode measurements using scanning Fabry-Perot:</u>

For one of your cavity lengths (preferably on the long side of the range), collimate the output beam to approximately 4mm in diameter. Use a 250mm focal length lens and direct the output beam into the scanning Fabry-Perot interferometer. Align the beam and the interferometer according to the instructions for the device.

a. Using the sawtooth driving waveform for the Fabry-Perot and the lowest sweep speed, you should see a pattern of spikes that repeats itself. The period of this pattern in frequency space is called the free spectral range and is 1.5GHz for this device. Measure the corresponding time on the scope to calibrate sweep time to MHz/division. Zoom in on one of the lines and measure the FWHM of a single peak. You may need to optimize the alignment to make sure the line is as narrow as the specification (Finesse is approximately 200, so it should be about 7.5MHz wide).

b. Measure the cavity length and calculate a prediction for the mode spacing in MHz ($\Delta\nu = c/2L$). Record the longitudinal mode spectrum for your laser, using the internal iris to ensure the laser is operating in a single transverse mode. Compare the measured mode spacing for your laser to your prediction.

c. Open the internal iris to allow the laser to operate with multiple transverse modes. The higher transverse modes have a slightly longer round trip time and therefore a different mode spacing. See if you can observe new frequency components or at least a broadening in the longitudinal mode spectrum. Record an image of this lineshape.

d. Go back to TEM00 operation. Based on the envelope around the longitudinal modes, estimate the full width at half maximum for the gain of the lasing transition. The standard value given is 1.5GHz, which is the range of the scanning Fabry-Perot.

e. A window with parallel sides can be used to make a sub-cavity inside the laser that can be optimized to preferentially pass one of the longitudinal modes. The window acts like a Fabry-Perot interferometer of low finesse; used in this way the window is called an etalon. Mount an optical flat into a mirror mount and place it into the laser cavity near normal incidence. Restore lasing (this may require slight angle tuning of the window). Observe the longitudinal mode spectrum. angle-tune it to select one of the longitudinal modes. The mode spacing for the etalon is $\Delta\nu = c/2Ln\cos\theta$, where n is the refractive index of the window material (approximately 1.5), and θ is the internal angle of the ray inside the etalon. 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.

3. Intracavity beam profile for the laser:

When the laser is operating with a single transverse mode, the beam profile should be Gaussian in shape. The $1/e^2$ radius of a Gaussian beam propagates in a well defined manner: $w(z) = w_0\sqrt{1+z^2/z_R^2}$, where w_0 is the minimum beam size (at the beam "waist") and $z_R = \pi w_0^2/\lambda$. called the Rayleigh range, is a measure of the length of the beam waist.

This section of the lab has two goals: to make measurements of how the beam propagates inside the laser cavity and to find out the waist radius, the position of the waist, and the radius of curvature of the cavity end mirrors.

a. *Measure the beam size inside the cavity.* Either by using the reflection from the Brewster window or by placing a thin microscope slide in the laser cavity near the Brewster angle, perform a knife-edge scan at several locations away from the window to track the beam size vs. distance. This measurement must be performed carefully, with known distances from the sampling surface.

b. *Determine the beam parameters of the intracavity mode.* Make a plot of $w(z)$ in Mathematica and fit the expression for the Gaussian beam radius above to your measured curve: $w(z) = w_0\sqrt{1+(z-z_0)^2 / z_R^2}$. In this version, the two unknown parameters for the fit are w_0 and the position of the waist z_0 . You can either use a fitting routine (e.g. FindFit[ ]) or make a plot of the measured points and superpose a plot of the calculated waist size and manually vary the parameters to get a good fit. Include a plot of your fitted curve along with the data points. It is best to do this fitting while you are in the lab in case the measurements need to be repeated.

c. *Determine the radius of curvature of the end mirrors.* A stable mode in a laser resonator is one where the beam wavefront matches the shape of the end mirrors. The radius of curvature of a Gaussian beam follows the expression: $R(z) = z(1+z_R^2 / z^2)$. Since you have measured the beam waist position and the minimum spot size, calculate the radius of curvature of the high reflector and the output coupler.

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