PHGN 480 Laser Physics

Lab 1: Basic alignment skills, working with laser beams, mirrors and lenses.
Two-week lab. Turn in the lab in class, Wednesday 9 Sept.

We share space with Advanced lab, which meets just after our class. You should start cleaning up your space at 11:30 or so.

Note that actual instructions on how to do the alignment are not written here. We will show you how, tell you how, or you can figure out your own methods.

We strongly recommend (but don't require) that you get a lab notebook. Any computer-generated plots or images you make can be taped into the pages.

Objectives:

1. learn how to clean and mount optics
2. align a laser beam to be level with the optical table and along its holes
3. construct a beam expanding telescope to collimate the beam
4. use and compare 3 different techniques for measuring a Gaussian beam size
5. measure and plot the beam size as a function of distance for a focused Gaussian beam

Directions for worksheet:

- get a TA or the prof to initial each numbered section before you move on to the next section.
- One lab report per team. Make sure all team members are listed, and that the name of the person writing the report is underlined. Take turns writing up.
- Be sure that your report answers each question that is asked in the different sections.
- You may use Mathematica to help with any of the plotting and calculations if you wish. Excel is ok only if you have to use it. Label your axes and use units.

1. *Alignment through irises.* Mount your HeNe laser on a post, and using mirrors to direct the beam, aligning a laser beam through two mounted irises so that the beam is level to the optical table and straight along the holes.
    a. **How do you ensure that the irises are at the same height?**

    b. **What is the minimum number of mirrors required to align the beam through the two irises, and why?**

    c. **What is your procedure for optimizing the alignment of the mirrors?**

2. *Beam expanding telescope.* Choose a pair of lenses to expand the laser beam by a factor of 2-3x.
    a. **Make a schematic showing the laser, mirrors and the pair of lenses, marking the lens focal lengths and the calculated optimum separation**

for the lenses. Explain how you arrive at the calculated lens separation.

b. **Describe your procedure for ensuring that each lens is placed so that the beam is centered on the lens, and that there is no twist on each lens.**

c. **How did you ensure that the beam is collimated at the output?**

d. **What was the measured lens separation? If there is a difference with part (a), why is there a difference?**

3. *Collimation check with shearing plate interferometer*
The shearing plate interferometer detects whether a beam is collimated, focusing, or diverging. If the interference fringes are aligned parallel to the reference line, it is collimated. Check your measurement in part 2 using this device. We have only one, so if the device is not ready when you are, you can skip this for now and come back to it. Information on the shearing interferometer can be found at http://www.thorlabs.us/newgrouppage9.cfm?objectgroup_id=2970

4. *Beam size measurement: iris method*
This is the easiest method to measure the beam size, but only works for fairly large beams. Mount an iris so that it is well-centered on the beam at the position you want to measure the spot size (somewhere after the beam expander.) With the iris open, measure the total beam power, then slowly close the iris until the power drops to half its original value. (For this either use the power meter or a photodiode and the oscilloscope, only relative power matters.) Use calipers to measure the diameter of the hole, $d_{1/2}$. For a Gaussian profile beam, the measured half-power diameter is related to the $1/e^2$ radius of the beam by the following relation: $w = 0.85 d_{1/2}$. **List the calculated beam size.** You will be deriving this relation for homework 1.

5. *Beam size measurement: knife edge scan method.*
This method works well for most size beams, even focused beams, since a translation stage can be moved precisely over small distances.
   a. Mount a razor blade or a sharp edged object on a post, and mount the post in a post holder and base on a translation stage. Make sure the power meter is zeroed (or record the power reading with the detector blocked). Scan the blade across the beam in the same *z* position as your iris measurement. Using the power meter, you can initiate a plot of the power and save the data for plotting. Move the sharp edge steadily across the beam and note the plot of power vs time. **Either take a picture of the curve, or save it and print it out for your report. Do you recognize the functional shape of the curve?**

   b. **Next record the distance between the positions that pass 10% and 90% of the beam power ($x_{90\text{-}10}$).** The relationship between the distance from the 10% and 90% transmission points and the 1/e^2 radius is $w = x_{90-10}/1.28$. (You will be deriving this relation in Homework 1.) **Cite your new beam diameter measurement. Compare the iris and knife edge scan measurements.** They should be close to each other.

6. *Beam size measurement: CCD camera method.* This is a method that works for any beam profile but can be tricky to get right. You will use the camera without a lens (you don't want to focus the beam onto the camera).
   a. The laser beam will be too bright for the camera, so you will need to take care to avoid saturating the camera. You can make use of a neutral density filter, but you may need to cut the signal down more. **Describe how you manage to check and ensure the camera is not saturated.**

   b. Instead of reading in actual distance, the camera reads out in pixels. To calibrate the lineout, you can take a couple (or more) measurements of the beam at different known sideways positions using the translation stage. Then look to see how many pixels the peak of the beam moves and calibrate the lineout that way. **How many microns per pixel are there for the camera?**

   c. Look at a lineout of the beam profile, and measure the full width at half maximum (FWHM) of the peak. Be sure to account for any baseline offset. **Convert the FWHM in pixels to a distance d_{FWHM}, then convert this to a 1/e^2 radius ($w = d_{FWHM}/1.18$).** You don't need to do this, but a more accurate measurement involves fitting the measured curve to a Gaussian, then extracting the beam size from the fit. To do this, use the FindFit[ ] function in Mathematica, fitting the line to the function $a\exp\left[-2(x-x_0)^2/w^2\right]+b$, with fitting parameters, *a*, *b*, x_0 and *w*.

   Again, compare this measurement with the other measurement.

7. *Measurement of w(z) for a focusing Gaussian beam.* A laser beam does not focus to a point, rather there is a limit to the focal spot size that depends on the wavelength (harder to focus long wavelength) and on how tightly the beam is focused (tighter focus = shorter focal length or larger input beam, leads to a smaller spot).
   a. For two choices of focal length (one if there isn't time), focus your collimated beam and measure the spot radius using the knife edge scan method at several z positions along the path through the focus. Be sure that you make measurements over a z distance sufficiently long for the beam size to increase by a factor of 4 or so from its smallest point. Plot w(z) as you record the data to be sure you have enough points. **Show a plot of w(z) for both focal lengths.** The functional form should follow $w(z) = w_0\sqrt{1+z^2/\left(\pi w_0^2/\lambda\right)}$

b. **Compare the ratio of focal spot sizes (w_0) to the ratio of the focal lengths.**

c. **Measure or estimate the distance between the z positions that correspond to where $w(z)=\sqrt{2}w_0$. This distance is called the confocal parameter, and is effectively the depth of focus. Compare the ratio of the confocal parameters to the ratio of the two focal lengths.**