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, Monday 3 Sept.

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

Worksheet: be sure to answer each question that is asked. Please type up your answers (it is easier for us to read).

1. Describe your alignment strategy for aligning a laser beam so that the beam is level to the optical table and straight along the holes. Include in your description answers to the following questions.
    a. How many mirrors do you need, and why?
    b. How do you ensure that the irises are at the same height?
    c. What is your procedure for optimizing the alignment of the mirrors?
2. Choose a pair of lenses to expand the laser beam by a factor of 2-3x.
    a. Make a sketch of the lenses, marking the lens focal lengths and the calculated optimum separation for the lenses?
    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 the 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. Beam size measurement: iris method
    a. 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. With the iris open, measure the total beam power, then slowly close the iris until the power drops to half its original value. 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: $w = 0.85 d_{1/2}$.
    b. Derive this relation.
4. 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 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. You can first move

the micrometer steadily and see the power meter plot. Do you recognize the 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 $w = x_{90-10}/1.28$. Compare the iris and knife edge scan measurements.

5. 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 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 ($w = d_{FWHM}/1.17$). 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.
   d. Derive the relation between the FWHM and the 1/e^2 radius.
6. 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, 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) for both focal lengths.
   b. Compare the ratio of focal spot sizes (w_0) to the ratio of the focal lengths.
   c. Measure 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.

Write down any observations or questions that came up while you did this lab.