Lab 2

Geometric Optics: Lenses

Please note that the manufacturer’s stated tolerance on the focal lengths for our lenses is ±1%.

1. We are going to study a convex lens. Please use the lens with the 100mm focal length. You will scan across the beam after the lens, as shown in the diagram below. Please do at least 6 scans.

   ![Diagram of laser beam scan](image)

   For each scan, find the full-width-at-half-max for the intensity distribution. Make a plot of the FWHM versus distance from the lens. From the data you obtain, calculate the focal length of the lens. Compare this to the nominal focal length written on the lens. Repeat the measurement using a ruler instead of the scanner. Which gives better results (be quantitative) and why?

2. Repeat the above exercise for a concave lens. You may use either the photodiode or a ruler, whichever you prefer. For this part, you only need 4 distances. Do not use the beam expander in this part. Use the lens with a focal length of 100 mm and compare its measured focal length with the nominal focal length written on the lens. Think about possible sources of systematic uncertainty before you start your measurement. For example, how will your measurement be biased if you do not scan through the center of the beam spot?

3. It can be shown (see P^3, chapter 18) that, for a system of 2 lenses, one with a focal length f followed by one with a focal length m*f, separated by a distance L, that rays that enter the system parallel to the lens system axis converge at a point a distance from the second lens of...
\[ d = \frac{mf}{\left(1 + \frac{m-L}{f}\right) \left(1 - \frac{L}{f}\right)} \]

Start with the 50 mm convex lens for the first lens and 100 mm convex lens for the second lens. Measure the distance \(d\) as a function of \(L\) for several different values of \(L\) (at least 6). Look carefully at the inside edge of the second lens. Is your beam too big for the size of the lens? Also, notice that the equation behaves in different ways when \(L\) is greater and less than \((1+m)f\). Think about this difference when deciding at which distances to scan. Think about what you would have to do to measure \(d\) in each case. Do not use the photodiode for this part. Use the paper to image the beam and find \(d\). Also, use the paper to look at the shape/size of the beam at different distances from the lens system. Describe qualitatively what you see in your lab report and compare, qualitatively, with what you expect. Do this kind of qualitative comparison for a case where \(L<(1+m)f\) as well.

For the measurements of \(d\), be sure to include the value of \(L\) for which \(d\) is as big as possible given the constraints of your table. Use the calibers plus the information in the drawings below to measure \(L\). Also note that the calibers have a part that sticks out their bottom that can be used to measure inside of cavities. Use the tape measure to measure \(d\). Compare your measurements to the theory.

What happens for the special case that \(L=f+mf\)? Using your knowledge of lenses and geometry to predict the ratio of the beam widths for this value of \(L\) (the diagram below may help). Take the value suggested from your data to be the best and set \(L\) to this value (you may need to do some fine adjustments to \(L\) by observing the beam as a function of distance from the second lens, to get \(L\) as close as possible to this special condition) and take at least 2 scans with the photodiode at different distances and measure the beam width. Comment on possible sources of any discrepancy between your prediction and the result.
(Hint: open the iris up all the way and look inside to see the location of the photodiode surface itself)