Geometric Optics: Lenses

1 Introduction

In this experiment, we will continue to explore geometrical optics by studying the optics of simple curved mirrors and lenses.

2 Background - see Pedrotti[3], Sections 2-6 to 2-9

When studying the geometrical optics of mirrors or lenses one considers the following three quantities: object distance s_o, image distance s_i, and focal length f. These quantities are related by the equation

$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f} \tag{1}$$

There is a convention to be followed in the definition of these quantities. For lenses, a converging lens (convex) has $f > 0$ while a diverging lens (concave) has $f < 0$. For mirrors, $f > 0$ for concave mirrors, and $f < 0$ for convex mirrors. Also by convention, we place the object to the left of the lens, with $s_o > 0$. If $s_i > 0$, it is on the right of the lens and is a real image. If $s_i < 0$ it is to the left of the lens (same side as object) and is a virtual image. One can consider the mirror as a folded over version of the lens: s_o is positive and on the left, but now a $s_i > 0$ is on the left (the opposite of the lens) and $s_i < 0$ is on the right, behind the mirror, and a virtual image.

The focal length of a spherical mirror is simply $f = R/2$, where R is the radius of the mirror, and the focal length of a thin lens is given by

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right), \tag{2}$$

where n is the index of refraction, and R_i are the radii of curvature of the two surfaces.

3 Experiment

You are supplied with a concave mirror, and two lenses. Your first challenge is to find the focal lengths of the optics with the help of a partner. Use an object at infinity (or close to it) and bring it into focus with each of the three optical elements. The windows in the hallway are a good place to start.

Mount the motor so that the shaft is horizontal. Couple the motor shaft to the photodetector translation stage. From your previous knowledge of the lead screw pitch, <u>what distance does the translation stage move per motor step?</u>

Now align the laser into the detector. Close the aperture and/or adjust the amplifier gain until the voltage signal is within the measurement range.

With this scanning photodiode setup and your step-read MATLAB loop controlling the LabJack, do the following:

1. Without anything between the laser and detector, measure the beam profile at several distances from the laser aperture by scanning transverse to the beam propagation direction. Notice the effect of the aperture size on the shape of the beam cross-section. How would you measure the "true" beam shape? What is the beam width? What is the divergence angle?
2. Pass the beam through a convex lens from the ThorLabs box on your lab bench. Use multiple beam scans to measure the location of the focus. Compare this to the nominal focal length written on the lens. Repeat for a concave lens.
3. Using two lenses in series, construct a "beam expander" with a collimated output beam of larger diameter than the input beam. Measure the resulting beam width and determine the magnification. Compare to the prediction from lens geometry.

CAUTION: Make sure not to exceed the translation stage limits! Turn off the motor control **first** to rotate the motor shaft by hand.