

**Laboratory #1** Week of January 13

Read: Section 5.2 (pp.151-175) of "Optics" by Hecht  
Do:

1. Experiment I.1: Thin Lenses
2. Experiment I.2: Alignment Project
3. Experiment I.3: Expanding Laser Beams
4. Experiment I.4: Familiarization with Lab Equipment

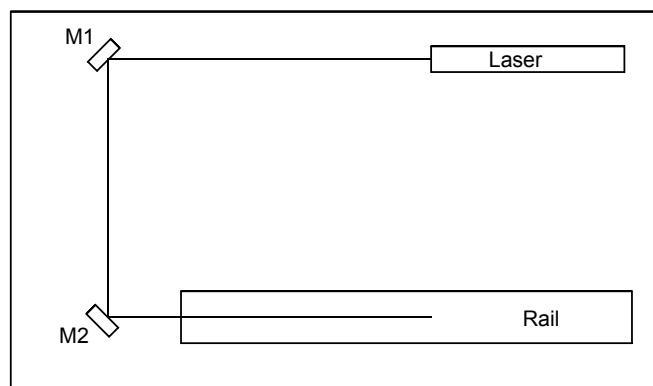
**Experiment I.1 Thin Lenses:**

In this experiment you will study imaging and verify the focal length of a positive (converging) lens. Use a 100-mm lens. A target on a photographic slide is provided for use as the object and white paper or card stock works as an imaging screen. Mount all components on the optical rail on your table. A piece of cardboard with a slide-sized hole cut in it helps to reduce stray light reaching the image plane. Use the desk lamp to illuminate the object, but do not put it so close that the object might melt.

Start with the object about 200 mm from the lens. Find the position of the screen where the image is the sharpest. Record the object and image distances (each measured from the lens). Also record the magnification of the image with respect to the object. Reduce the object distance 10 mm and repeat. Do this as many times as you can before the image is too far away to measure. Plot the image distance as a function of the object distance and fit the data to the expected dependence to determine the focal length of the lens. Also plot the magnification and compare to the expected function.

**Experiment I.2 Alignment project:**

For many situations, it is convenient if the laser beam is parallel to the top of the optical table and above a line of holes on the table. This will make insertion and adjustment of other components much easier. For convenience and safety our experiments use a "U" shape geometry with an optical rail in the last arm, as shown below. The rail is bolted to the table and has carriages that ride on the rail. Components can be mounted on the carriages so that they can be easily moved along the optical axis defined by the rail.



The U geometry is defined by the two mirrors labeled M1 and M2 in the diagram. The goal of this experiment is to ensure that the laser beam (i.e. the optical axis) is parallel to the table top and aligned above the center of the rail. Mount M2 on the optical table and position it close to the beginning of the optical rail such that the center of the mirror is above the center line

of the rail and is at a height greater than 14.5 cm above the table (**this height will ensure that the beam passes through the center of components like lenses mounted on the rail – check that it does!**). Set up two irises on the opposite ends of the optical rail. Adjust the iris heights (again  $> 14.5$  cm) to be as nearly equal as you can by using a ruler. You now want to direct the laser beam through these two holes, which define the optical axis.

Close the irises down. Use the knobs on the back of M1 to reflect the beam off M2 and through the first iris. Now adjust M2 so the beam passes through the second iris. This adjustment should do little to perturb your first adjustment because the first iris is so close to M2. That is the trick! You should repeat this procedure until you can open both irises to clip the outside of the beam and see a clean symmetric halo on each iris. You may have to open the irises some to start and iterate a few times to get it just right, but the procedure should converge very rapidly. Note how the beams move and play with this arrangement enough so that you can quickly and correctly determine which knob needs to be adjusted and which direction the knob must be turned to move the beam the correct direction (left, right, up, or down). Note the kinematic construction of the mirror mount; there are two orthogonal pivots about a single fixed point.

This procedure can be done with one iris as well – simply move the iris between the two positions on the optical rail.

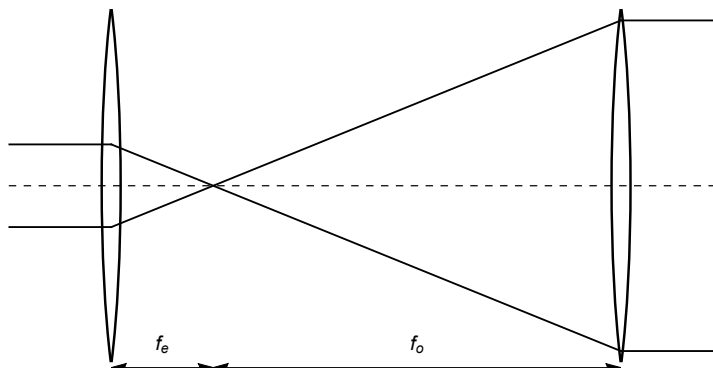
Leave the laser beam aligned so that you can use it in Part 3.

Do not unscrew the irises from their posts; they can easily be damaged. If you need another post to mount something else, ask and you shall receive.

### **Experiment I.3: Expanding Laser Beams:**

In this experiment, you will build a Keplerian telescope to expand the size of the laser beam. The Keplerian telescope has two positive lenses as shown below. The objective has a focal length  $f_o$  and the eyepiece has a shorter focal length  $f_e$ . The lenses are separated by the sum of the two focal lengths. In astronomy, the starlight enters the objective and ultimately forms an image at the back of your retina. In this lab, the laser enters the eyepiece and exits the objective. The magnification of the diameter of the laser beam is  $M = f_o / f_e$ .

Build a telescope on your optical rail. Adjust the separation of the two lenses so that the beam exiting the objective is as collimated as you can make it. Then compare the measured separation to the theory. Measure the beam magnification by estimating the beam size on a card, and compare with the expected value.



## **Experiment I.4: Familiarization with Lab Equipment:**

For this section you will need to go to the back room in the lab and collect the following items:

### **USB Camera – Camera and USB Cable**

Connect the camera to the computer through a USB port. On your desktop you will find the camera's program IC Capture. The program should automatically recognize the camera when you open the program. *Do not take pictures of the laser unless you have decreased the laser intensity.* With the lens you measured earlier in front of the camera take a picture of an illuminated ruler in focus. Measure the object and image distances to acquire the magnification. Now open your image in the program ImageJ. Using the rectangular highlighter tool, highlight a portion of the image and look at its profile by clicking “Analyze → Plot Profile”. Explain what this function does. Now use the measure function to determine the size of one pixel. *Save this value somewhere special, you will need it for future labs!*

### **USB Stages – Translational stage, Rotational Stage, Control Box, Power Cable, USB Cable**

Connect the translational stage to the control box and the control box to the computer using the USB cable. Open the program APT User on the desktop. The program should automatically recognize the stage when you open the program. Play around with the stage.

What is the minimum speed at which the will travel? What is the range of the stage?

Repeat for the rotational stage.

### **Photodiodes – Photodiode, BNC Cable, T-Connector, Resistor Clip, Resistors**

Connect a photodiode to the oscilloscope with a coaxial cable. Make sure to turn off the photodiode when not in use. Measure the intensity of the room lights when pointing the detector at the lights and at the floor. What is the maximum voltage output of the photodiode? Try this with different resistors attached to the clip. What happens?

Equipment needed:

Item	Qty	Source (part #)
Helium-Neon Laser	1	Melles Griot 05 LHP 121
Optical Rail	1	Newport PRL-36
Rail carriage	3	Newport PRC-1
Lamp	1	
Target slide	1	OSU
100 mm lens	1	Newport KPX094
200 mm lens	1	Newport KPX106
25 mm lens	1	Newport KPX076
-25 mm lens	1	Newport KPX043
Index card	2	
Filter holder	2	Thor Labs FH2
Al mirror	3	Newport 10D10ER.1
Iris (adjustable)	2	Thor Labs ID12
Meter stick	1	