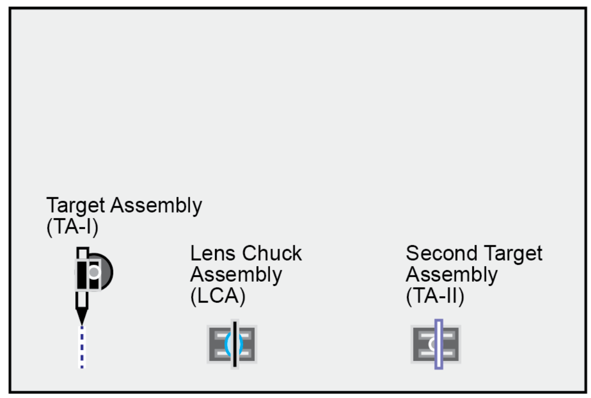
Week #2 – Lenses and Beam Expanders

Reminder! Use proper optics alignment just like last week. Even with the lenses, when using the laser you should be able to mathematically reverse your setups if everything is in alignment. Also, make sure the lenses are centered to the same optical axis (make sure the laser hits the lenses in the centers, if it does not, you will see poor results). This week will require darkness in the room to see the various images, so be extra careful with the lasers (keep them low, out of eye paths, your pupils expand in dark and let more laser light in!). You can use photos instead of diagrams/or drawings in your lab report where ever it is appropriate and where they can be properly labeled/understood.

I strongly recommend, this week and in all future weeks, that you carefully clean all lenses, mirrors, and other optics surfaces, BEFORE you start. Dirty optics cause misleading artifacts and fake beam spreading due to optical scattering! Use the special wipes sitting over by the storage bins please. 1 wipe per team is all you need for the week.

1. Focal Length of a Positive Lens - Goal: accurate determination of focal length of a positive lens.

You will need to create an object that is illuminated. There are two options: (a**)** Use the provided lamps as the high-intensity light source to illuminate a card with an x-y grid drawn with spacing of 5 mm for each line. That card will go into a target assembly (see at right). Front illumination tends to work better as it provides higher brightness and contrast. (b) you can draw the grid in powerpoint (full screen mode) and display it on your laptop (draw the rest of the screen black to keep the room as dark as possible). You could also try your cell phone screen, but sizing the grids might be more difficult. Add a few arrows to the grid so you can tell when the object/image inverts (as expected).



FOR LENSES ALWAYS USE SLIDABLE BASE PLATES with screws left a bit loose to the table, otherwise you cannot adjust lens distances! CAREFUL WITH THE LENSES, DROP THEM AND THEY BREAK EASILY! You may use the wipes provided in the lab to clean optics (only use those wipes).

Procedure:

(1) Mount the grid object you create in TA-1.

(2) Place a 100 mm focal length lens (KPX094) in the LCA (obviously a positive lens, else I would have said -100 mm).

(3) Place the lens 125 mm from the grid object (this is the object distance, z_1). Use rulers/tape measures found in the lab.

(4) Place a white card in TA-II to use to visualize the image. You may also use the larger white marker-boards. Move TA-II from the end of the breadboard slowly towards the LCA until an image is seen, then move it a bit back and forth to get the sharpest possible image (this is the image distance, z_2).

(5) Measure the distance between the grid lines in the image.

(6) Repeat steps 2-5 with the object distance z_1 changed from 125 mm to 200 mm, and to 400 mm.

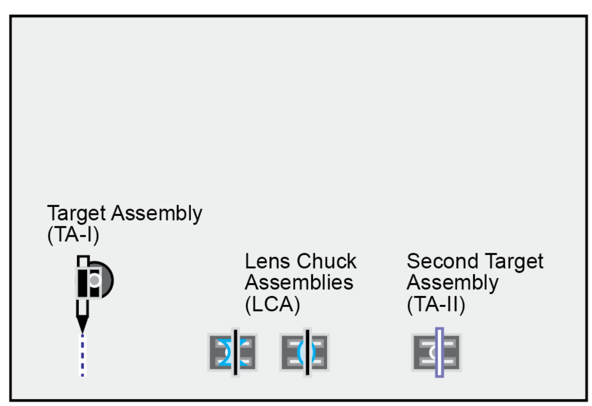
(7) Use the z_1 and z_2 data collected to calculate the focal length, and the object/image grid size measurements to calculate the magnification (don't forget, inverted image means the magnification is negative in value!). Average your results and compare these to the theoretically expected values for focal length and magnification.

2. Focal Length of a Negative Lens - Goal: accurate determination of focal length of a negative lens.

Procedure:

(1) Create a second LCA with a -25.4 mm focal length (KPC043) with the concave side facing the object. Measure the distance between this negative lens and the grid object.

(2) Place the LCA with the 100 mm lens more than 100 mm beyond the negative lens.



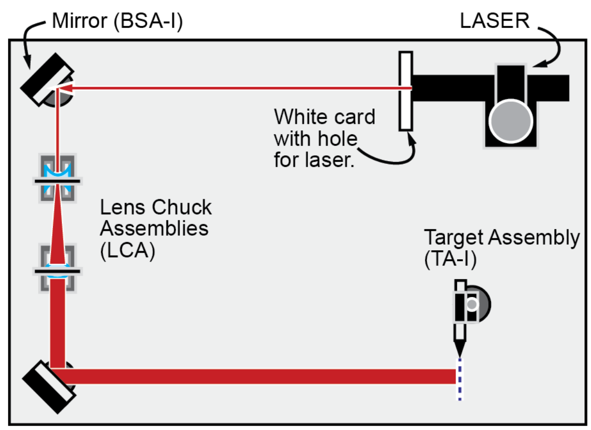
(3) Obtain a sharp image by moving/optimizing the location of TA-II. Then follow the procedure discussed in this weeks lecture to calculate f for the negative lens. Compare your result with the theoretical one.

Note, you may need to play around with the distances to get a good result. Also, the image on the card should typically be very small in size and quite clear. Ignore other 'false' images that might appear, else they will give you very strange results!

3. Beam Expanders and Divergence – Goal: build a Galilean beam-expander and measure its effect on beam divergence.

Make sure you route the beam back to the laser as you add each component! Also use a white card to inspect the laser beam at multiple locations to figure out if it is well centered/aligned or not, don't rely only on reflecting it back to the laser (see end of this doc).

When this experiment is completely setup and working, if he is available, please ask Prof. Heikenfeld to come see it, so he can check to see that you are using good alignment and other good practices in this lab.



1) Add the 1st BSA as shown in the diagram at right. Measure the beam width near the laser exit and at distances of 2 m, 4 m, and 8 m. You might need to use the BSA to steer the laser across the room and/or have a partner hold a mirror at wall. Use these measurements to calculate the divergence (θ). You don't have to use TA-1 as the measuring surface (use anything that works well for you).

2) Add the second BSA (see diagram) and ensure the beam is setup is well aligned optically by returning the beam back to the laser. Keep it this way as you add the LCA's in the next steps (keep the laser beam reflecting back to the laser).

3) Place the negative lens (-25.4 mm lens) and LCA in the beam path, about 5 inches past the 1st BSA, concave side facing the incoming beam. Adjust its position in the beam path and orientation such that the diverging beam is centered on the 2nd BSA. As usual, the system should be reversible back to the laser.

4) Create a 2nd LCA with a positive lens of 200 mm focal length (KPX106), and place it after the negative LCA at the separation required for a good beam expander (see lecture notes). Work on slightly adjusting the positive lens LCA such that the 2nd BSA returns the beam back to the laser with minimum distortion (it should return as a small dot again!).

6) Rotate the 2nd BSA and measure the beam width near the laser exit and at the same 2, 4, and 8 m distances. Use these measurements to calculate the divergence (θ). Note, it should be difficult to measure any divergence at all for the expanded beams. Rather emphasize proper setup of your beam-expanders and describe this in your report.

5% BONUS EXPERIMENT/QUESTION! If you take an expanded beam that is 1 cm wide, and then put a 1 mm wide small mirror in it, will the new beam have the same divergence? You could test this by putting a hole in black tape and placing it on a small mirror to make the new beam…

4. Setup Dismantle and Storage – Proper care of optical components is just as important to achieving reliable results as is careful experimental setup. Improper handling, setup, dismantling, and storage will detract from your final grade in this course. Unsure about any component? Just ask. The next group should find all parts neatly stored in the optics kit. There is a card with each kit that shows where each component goes.

5. Theoretical/Calculation Problem – (a) Use MATLAB and simple ray-transfer matrices to theoretically reproduce a positive lens experiment (you can choose distances, and angles, that make sense theoretically/experimentally, you are not limited to input variables like just z1, z2, like you were in the experiments). Place this in your lab report in the same section as the positive lens experiments and add to the discussion of results as well. (b) Use MATLAB to see if a negative focal length lens has the same ray transfer matrix as a positive lens, but with only the focal length changed to a negative value.

Lastly, while you are in MATLAB, please check out the ‘Ray Transfer Simulator’. There is a video presentation on how it was made and how to use it. And the code you can run in MATLAB and build up all sorts of experiments. It may be helpful throughout the semester.