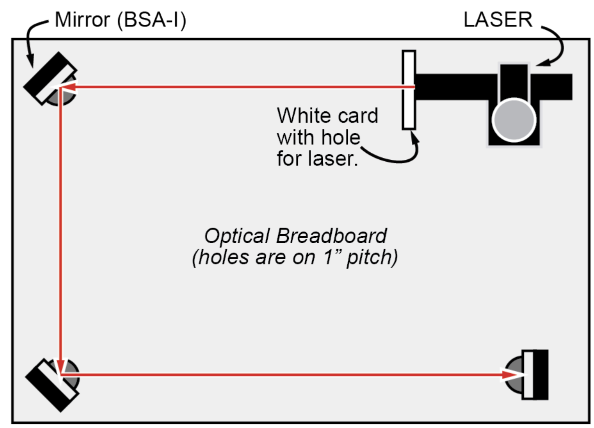
Week #1 – Basic Light Interactions

IF YOU DON'T FOLLOW PROCEDURES CAREFULLY AND TRY TO SKIP AHEAD, IT WILL OFTEN COST YOU MUCH EXTRA TIME IN THIS LAB! READ EVERYTHING CAREFULLY AND DO NOT SKIP ANY STEPS AT ALL!

Reminder! You have everything you need to complete these labs independently. Please see the parts listings and manuals in the 'Course Materials.zip' file found on blackboard. Also, note that you can use photos instead of diagrams/or drawings in your lab report where ever it is appropriate (but they must still be readily labeled/understood by the reader!).

Hint! Make sure you do your calculations BEFORE you tear down your experiments! Often it will tell you quickly if you did the experiment right or not!

1. Proper Optics Alignment - The first experiment is a very simple one, but practically will be the most important skill you use in building optical systems. Goal: learn proper optics alignment! Setup the simple system shown at right, keeping the laser at the same height above the table using the following procedure:



1) as you mount each mirror ensure the beam is centered on the mirror even as the mirror is rotated (if you can't achieve this, your mirror is assembled wrong!). You may need to adjust both the mirror and the laser to achieve this. Notice the tiny set-screw on the side of the BSA to secure the mirror. Remember, the front surface of the mirror MUST be over the axis of rotation!

2) then using the adjustment knobs (careful, don't break them) to refocus the beam path back onto the laser.

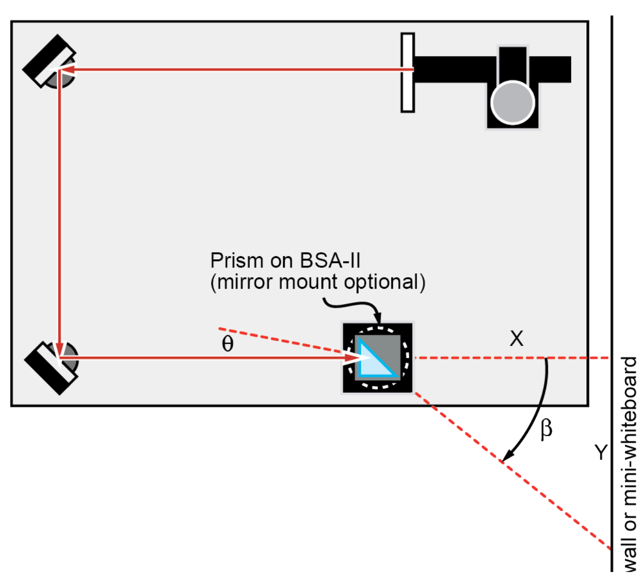
3) then place the large allen wrench (one with yellow handle) through the hole in the post and steer to the next direction. This works well because you don't have to touch the mirror!

4) repeat this process as you add the next component(s)… (*note: the last mirror can be mounted right onto the post, because you only have enough parts to make two assemblies where the mirror is centered on the axis of rotation*).

Generally, always project the laser along straight lines (follow the holes in the table), with the laser being steered at 90° angles. The procedure used above is used when you all sorts of components, including lenses. The point is, simple optical systems are mathematically reversible.

Reminder: be sure the laser hits the mirror above the center of the post, if it does not, then you have incorrectly assembled the mirror. Also, it helps visualization of laser position if you tape a white card to the laser with a hole where the laser can go through it.

2. Measure of Refractive Index Through Total Internal Reflection – Goal: detect the angular transition between refraction and total-internal reflection of a prism, and use this to accurately measure refractive index of the prism. Procedure:



1) setup the system shown in the diagram, with all parts but the prism, and precisely mark where the laser hits the wall with electrical tape.

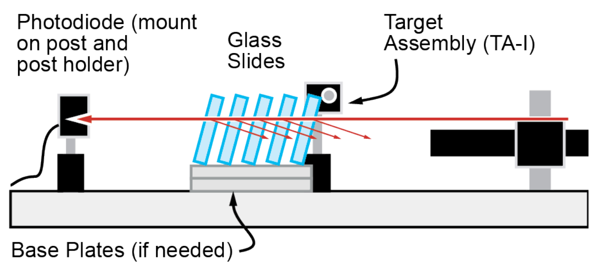
2) mount the prism such that the laser strikes the center of its hypotenuse even as you rotate the prism.

3) rotate the stage such that one of first flat faces of the prism Fresnel reflects part of the laser beam back into the laser. This is easier to do with the BSA-II because you can use the mirror mount under the prism to also get it perfectly level. When you are done you should also see no light hitting the wall behind the prism as the light is being totally-internally-reflected at the hypotenuse of the prism.

4) now, slowly rotate the stage clockwise (relative to the diagram) until the laser beam just starts to emerge tangential to hypotenuse. When this first happens, you will see the laser spread out a bit (streak) along the wall instead of being a tight dot. Using the tape measure, you can calculate the rotation angle θ according to: $\theta = \beta - 45°, \quad \tan(\beta) = Y / X$

5) you can then calculate the refractive index of the prism according to the following equation (it is not too difficult to derive it using Snell's law, we just give it to you here: $n^2 = \sin^2(\theta) + (\sqrt{2} + \sin\theta)^2$. You should be able to get within 0.1 of the refractive index which for most glasses is around n~1.5.

3. Measure of Refractive Index Using Fresnel Reflection – Obtain 5 glass slides. Goal: determine the refractive index using Fresnel Reflection and an optical power meter, with the setup shown in the diagram. Setup the slides such that they Fresnel reflect the light downward, but make sure the angle of the slides is ~10° or less so the Fresnel reflection will be independent of polarization (see the lecture notes for week 1). You can do this however you choose, and the diagram at right has one suggested approach. As you add each slide on-by-one, record the optical power loss, calculate refractive index, and then average the calculated refractive indices, to calculate a final averaged result for refractive index. Keep the slides slightly separated by a piece of paper or tape, or else optical interference might give you an error in your measurement (we will talk more about that in a later lab for this course). You should be able to get within 0.1 of the refractive index which for most glasses is around n~1.5.



Don't forget, there are two glass/air interfaces for each glass slide. Make sure you use the attenuator on the power detector that you zero the meter (will help reduce influence of light in the room). If you don't zero the meter, then you must at least mathematically take that into consideration in your measurement.

Obviously, for an optical system with many lenses and optics, this experiment will show you that the optical losses can be quite high. Therefore they coat the optics with anti-reflection coatings. For more information on how to reduce Fresnel Reflection, see: http://en.wikipedia.org/wiki/Anti-reflective_coating

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 – This problem deals with Snell's law, refraction, and total internal reflection. One of the biggest challenges for creating light emitting diodes (LEDs, solid-state lighting) is that the light generated internally emits in all directions, and much of this is therefore totally internally reflected (can't escape). In a later lecture we will review a simple 3D model that calculates the % of light that escapes (a.k.a outcoupled light).

Show that the critical angle and therefore the light outcoupling depends on only two things: (a) the refractive index of material where the light is emitted; (b) the refactive index outside the device, typically air. Your proof should show that any number of layers of materials with different refractive indices can be placed between the points of emission and the outside medium, and they will not effect the final critical angle calculation.

Do this two ways (do part 1 below, and then part 2 below, they will prove the same thing, but using different techniques):

(1) draw a simple/rough ray trace, and label the angles, for light starting at an angle of 30 degrees in glass and traveling through layers with these indices shown for stack (a) and stack (b) below, for both eventually reaching air (note, if you do this correctly, your result for (a) and (b) should be the same exit angle into the air):

(a) 1.5 / 1.3 / 1.8 / 1.0
(b) 1.5 / 1.0

(2) use Ray Transfer Matrices to provide a mathematical proof that incident and exit angles are the same if the indices of refraction at the input and the output are not changed, similar to what we have in the problem (1). Your proof should allow any refractive index, you may assume 4 layers.

Notice for quiz: *starting this week, you will have had used several of the equations we learned in lecture in the lab and lab homework, and therefore the quiz will start to incorporate calculation style problems as well. I don't expect you to memorize the equations, you will always be able to look them up anyway. Therefore each week you may bring to the quiz, 1/3rd of a sheet of paper with anything you want on it, anything! You can keep adding to it, for example, such that 3 weeks from now it is a full sheet, and then you start a 2nd sheet.*

IF THERE IS ANYTHING THAT WAS NOT CLEAR OR VERY DIFFICULT FOR THIS WEEKS LAB, PLEASE EMAIL DR. HEIKENFELD SO HE CAN IMPROVE THE PROCEDURES FOR NEXT YEAR!