Physical Optics: Polarization, Interference, and Diffraction
Lab Manual
Shialing Kwa 01 and Shane Smith 02

Purpose:
In this lab, you will develop your understanding of the phenomena of polarization, interference, and diffraction through hands on experimentation. In the process, you will also gain experience with geometrical optics and skills of optical alignment.

Vital Reading:
Because the topics covered in this lab are so broad, it is imperative that you read the following sections before beginning the lab; these topics simply cannot be sufficiently explained in the introduction: 8.1.0-8.1.4: Linear, Circular, and Elliptical Polarization and Natural Light, 8.7: Retarders. It would be impossible to explain the remaining topics in the necessary detail in the introduction to this lab, so you should familiarize yourself with the location of the details in the text. Important sections from Hecht, Third Edition include: 8.1 — 8.4, 8.6.0, 8.7.1, 8.8, 9.1 — 9.3.1, and 10.1-10.2.5. If for no other reason, your text will be priceless for its pictures and diagrams, so be sure to bring it to lab.

Introduction:
When you are working on this lab, be sure to take plenty of time to make certain that you understand the concepts behind what you observe. This will likely be your only chance to be able to play with these optical elements and gain a somewhat intuitive feel for what they do. Some of the principles mentioned or used here will likely turn up on tests, because the topics are so broad; since you may even use some of these elements on exams, you will want to use this time to find out exactly how they work!

What Do Polarizers and Wave Plates Do?
As you know, light is a transverse electromagnetic wave consisting of an E-field and B-field. Polarization refers to the direction of the E-field of a light wave. In natural, or unpolarized light, there are light waves of all orientations, so that there is no preferential direction of polarization; that is, for a given direction of propagation, there are waves with E-fields oscillating in many directions (all of which are perpendicular to the direction of propagation). Each one of these E-field vectors can be decomposed into horizontal and vertical components relative to the orientation of a polarizer that the wave will pass through. A linear polarizer will allow only one of these components to pass through it. So, when the light emerges from the opposite side of the polarizer, it is has only one component remaining.
This concept may be easier to visualize. Imagine that a wave is propagating out of the page and toward you, from the center of the axes in the left-most sketch in Figure 1. The axes correspond to the transmission and absorption axes of the polarizer. We are concerned about the $E$-field direction, represented as the solid line with arrow. As shown on the left-most drawing and center drawing, the $E$-field direction can be represented by two component vectors, one corresponding to each axis. When passing through the linear polarizer, one of these components is dissipated (the one in the direction of the polarizer’s absorption axis), while the other is transmitted. This means that the beam leaving the polarizer has an $E$-field component only in the direction of the polarizer’s transmission axis. Of course, the direction of this final polarization is dependent on the original orientation of the polarizer’s transmission axis whether it corresponded the x- or y-direction on the coordinate system in the first illustration. Also notice that the magnitude of the $E$-field vector is less than that of the unpolarized light; this will be a very important fact in the polarization and wave plates portion of the experimentation.

![Figure 1: Visualizing Linear Polarization](image)

What if instead of blocking one component of the light that enters it, the polarizing material simply treats the horizontal component differently from the vertical component? Materials that do so are called birefringent and tend to favor one $E$-field orientation over the other when propagating them through the material. The result is that one component is propagated through the polarizer faster than the other component. This, of course, means that the horizontal component is no longer in phase with the vertical component, so that when the two are viewed as one $E$-field, that field has a different direction of oscillation from the original input field. Materials that cause this phenomenon are called retarders; when the thickness of such a material is chosen so that the components have an intended change in relative phase, the retarder is called a wave plate. You will use wave plates extensively in this lab and you will need a solid understanding of exactly how they affect the behavior of light; for an excellent description, you should refer to section 8.7.1 of Hecht. Note that to understand this you will also need to understand circularly and elliptically polarized light, which is described in Hecht, section 8.1.

*What is interference?*

When two light waves arrive at the same point in space, the Principle of Superposition dictates that their $E$-fields add vectorially. The waves are said to interfere with each other,
with totally constructive interference (bright spots) occurring when the two waves are in phase with each other and totally destructive interference (dark spots) occurring when the two waves are 180 degrees out of phase. The consequences of this phenomenon are most easily seen in the results of Young's Experiment, which you will replicate in this lab. Young used a pinhole to create a spatially coherent beam of sunlight that then passed through two more, closely-spaced pinholes. As the light leaves these pinholes, it propagates in a spherical manner, as if each pinhole was a point source. Because the light is coherent, in the places where these spherical waves overlap the principle of superposition indicates that they will add constructively or destructively. This produces a system of alternating bright (constructive) and dark (destructive) bands known as interference fringes (see Figure 2 below).

In this lab, a laser will provide the incident coherent light wave and you will use two narrow slits instead of two pinholes. When the primary wavefront coming from the laser arrives at the two slits, its segments will be exactly in-phase. Thus, the two wavefronts that emerge from the slits can be considered two coherent secondary sources. Where these two waves overlap, interference will occur. At the points where the two waves are exactly in-phase, bright bands (maxima) are created. In contrast, at the points where the two waves are exactly out-of-phase, the dark bands (minima) arise. (See Figure 3, on the following page.)
By simple geometry and trigonometry, you will be able to derive an expression for the wavelength of the laser by calculating the spacing of these interference fringes. The figure below shows the important geometrical factors in this relationship: \( P \) represents the location of the \( m \)th maxima; \( y_m \) the distance between the central maxima and \( m \)th order one; \( a \), the slit spacing; \( r_1 \) and \( r_2 \) the distances from each slit to the point \( P \); \( s \), the slit to screen distance; and \( \theta_m \), the angle between the shortest path, \( s \), and the path from the slits to the point \( P \).

\[
\begin{align*}
\text{a sin}\theta_m &= m \lambda \\
y_m &= \left(\frac{s}{a}\right)m \lambda
\end{align*}
\]

In the pre-lab, you will use the geometry in Figure 4 and calculus to predict the change in the interference pattern of a green laser compared to that of a red laser, and in the lab you will use this geometry to measure the wavelength of the laser.

**What is diffraction?**

Diffraction and interference refer to the same physical phenomenon, but the distinction in terminology comes from the complexity of the situation. As Hecht states, it is customary, if not always appropriate, to speak of interference when considering the superposition of only a few waves and diffraction when treating large numbers of waves (433-34). For the purposes of this lab, when light is passed through an essentially one-dimensional opening (such as a slit), the
pattern of superposition is considered interference; on the other hand, a distinctly two-
dimensional opening (such as a square or circle) or obstacle produces a pattern that is referred to
as diffraction.

Imagine that you have a coherent light source, such as a laser beam, passing through a
small square hole. What would you expect to observe if you put a screen directly behind the
hole? You would probably predict that there would be a square of light projected onto the
screen, and this prediction is correct. If you now move the screen slightly away from the
aperture, an interference pattern will appear on the screen, reflecting near-field (or Fresnel)
diffraction. As you continue to move the screen away (just as moving the screen away from
slits), interference fringes will become noticeable around the edges of the square of light,
creating a more elaborate pattern due to the interference of the light passing through the opening.
When the screen is at this distance, you will be observing far-field (or Fraunhofer) diffraction.
According to Hecht, the switchover from near- to far-field diffraction for an aperture (or
obstacle) of greatest width \(a\) generally occurs at distances \(R > \frac{a^2}{\lambda}\). In this lab, you will
observe diffraction patterns in both the near and far field for a variety of apertures and obstacles.
Pre-Lab Problems:

1. Geometrical Optics. For the diffraction part of this lab, you will need an expanded, collimated laser beam that is larger than the apertures. This can be achieved using two lenses; see Figure 5. Expanded simply means that the diameter of the beam has been made larger than the aperture; in the diagram, this is achieved by passing the beam through a lens that focuses it to a point, but then causes it to diverge after that point. Collimated means that the light will be propagating perpendicular to the aperture, instead of diverging through the aperture (as would be the case if the lens on the right were not present). In the lab, you will have available to you plano-convex lenses (as in Figure 5) of focal length 25.0, 75.0, 100.0, 150.0, 200.0, and 400.0 mm; the lenses have a diameter of 25.0 mm, and you will want to make sure that all of the diverging light goes through the second lens. Plan a setup using two of these lenses to expand and collimate the beam. Remember not only to choose lens focal lengths, but also to calculate the space between the lenses. Though you should be able to choose the lenses by estimating the size of the laser beam, you may choose to leave the expression for focal length in variables until you begin the lab, at which point you can measure the diameter of the beam and determine which lenses to use.

![Figure 5: Beam Expansion Using 2 Plano-Convex Lenses](image)

2. Interference. In the lab, you will choose a two-slit array to measure and observe the difference in the interference fringe pattern made by changing the wavelength of the light source. The green laser should have a wavelength of 543.5 nm, while the red should have a wavelength of 632.8 nm. Referring to Figure 4, derive an expression for $dy$, the change in the distance between the central maximum and $m$th order maximum when you change the wavelength from green to red. Your expression should be in terms of geometrical variables that remain as variables until you setup in the lab and choose the slit array; then, you should be able to plug in the geometrical factors and get a numerical value for $dy$.

3. Diffraction. Your text has a mathematical description of the specific cases for diffraction of a rectangular and circular aperture. You should go through these carefully and work
with the equations until you can draw a prediction of what you expect the diffraction patterns from a square aperture of sides of 0.935 mm and a circle of radius 3.25 mm to look like. Note that you will have to assume a distance from the aperture to the screen that you will be holding; 3 meters is probably a good estimate. Your final drawing should be made to scale using a ruler and should be a series of marks (for the square) or circles indicating lines of maximum intensity. For the square, concern yourself with only the patterns that result along the Y- and Z-axes (as labeled in Hecht). In the lab, you will make your setup, then take your drawing to the specified distance from the aperture, and see if it matches with the pattern that is actually created.
**Apparatus:**
1 overhead projector
1 screen for the projector (if room permits its use)
2 large sheets of linear polarizer
1 polarizer / wave plate kit (including minimally 1 _ wave plate and 1 _ wave plate)
1 mystery polarizer and/or waveplate combination
1 low power red He-Ne laser w/ mount
1 low power green He-Ne laser w/ Newport mount
1 breadboard
5 bases
5 post holders
5 posts
5 spring-loaded screws
3 lens holders
1 iris
1 Edmund s Scientific lens kit
Various screws and washers for making assemblies and attaching them to the breadboard
1 3/16 ball driver
1 slit plate
1 physical optics kit slide selection
sticky wax to attach slides to posts
1 piece of white foam-core board with stand
1 index card
2 flashlights
1 opaque disc with wire

This optical equipment is virtually identical to that used in the Building a He-Ne lab, so it will not be described again here. The only main piece of equipment that is different is the lens mounts; however, your TA will mount the lenses that you choose in the mounts, so it is not important that you know how to use them.

**Procedure:**
*Part I: Polarizers and Wave-Plates*
First, you will complete experimentation with the polarizers and wave plates using an overhead projector. It will probably be easiest to project the image onto a screen to view it, but if there is no room for this, then you can observe the polarizers directly on the surface of the overhead.

1. Plug in the overhead and aim it at a convenient blank spot on the wall or a screen. Turn it on and place one of the large linear polarizing sheets on top. Record in your lab notebook what you observe and explain what the polarizer is doing to the light from the overhead. Try rotating the polarizer on the overhead, and record your observations. Physically, what is happening that caused what you observed?

2. You will now determine the axis of transmission of both polarizers. As you have probably learned in class, light that is reflected off a surface is preferentially polarized in a direction that is perpendicular to the plane of incidence. You also know that linear polarizers transmit only one orientation of light. Thus, by looking through a linear polarizer at a reflection and
rotating it until the reflection is the brightest, you can determine the axis of transmission of the polarizer. Using this method, you should now determine the transmission axis of both of the linear polarizing sheets. (The reflection you use should be a sort of glare like that occurring from the reflection of an overhead light on the floor or off a book cover, both at a glancing angle.) Record the code on the polarizers and the label of the axis that you think is the polarizer’s transmission axis.

3. Take the second large linear polarizer and hold it above the first one, which is still resting on the overhead. Slowly rotate the top polarizer. Record your observations and give an explanation of what is happening. Arrange the polarizers so that the overlapping area is at its darkest. Note the relative orientation of the axes of transmission, and explain why this area is completely dark. From here forward the polarizer that rests on the overhead will be referred to as simply the linear polarizer whereas the other one that is held above will be called the analyzer, which makes apparent the optical effects of the wave plates and polarizers.

4. Set the analyzer aside, place your half-wave plate on the linear polarizer, and rotate it. Note your observations. Now place the analyzer over the polarizer / wave plate combination, such that the axes of transmission of the analyzer and polarizer are perpendicular to each other. Slowly rotate the half wave plate 360 degrees, and note results. Explain, in general, what is happening. Also explain why this result was nearly undetectable without the analyzer. Rotate the wave plate so that the light coming through the entire system is maximized. Note the angle that the wave plate makes with the axis of transmission with the polarizer and with the analyzer. Explain why the maximum amount of light passes through the system at this angle. (Hint: think about the components of the E-field entering the wave plate at this angle.)

5. Remove the half wave plate and replace it with the quarter wave plate. Rotate the quarter wave plate (with the analyzer above) and note your observations. Is this behavior similar to that from the half wave plate? Do you notice a difference in intensity? As with the half wave plate, rotate the quarter wave plate until the maximum amount of light is being transmitted through the system. What is this angle? Explain why this is the angle of maximum transmission. From this explanation, would you expect the intensity of the transmitted light to be brighter or dimmer than that of the half wave plate at the same angle? By what factor would the two differ? Place the quarter wave plate and the half wave plate on the polarizer, so that they are touching along one edge. Rotate the two until the maximum light is transmitted through each. Note the relative intensities of the light passing through each. Does it correspond to your prediction? If not, why? Explain what is happening in the system.

6. Locate your mystery device and record the code on it. It is a combination of one or more linear or circular polarizers and/or wave plates. Believe it or not, you should be able to come to a logical, sound conclusion about exactly what your mystery device is made of. You can use any of your other polarizers or wave plates if you need them to determine what it is. Experiment with it until you are convinced of what elements are. Record what these elements are, if they are necessarily connected at a specific angle and what that angle is, and your reasoning for your conclusion about it’s make up.
Part II: Interference

This portion of the procedure will be carried out atop the optical breadboard like the ones that you have used or will be using in the other labs for this course. It is your opportunity to experiment with different sizes and spacing of slits and apertures, distances from the slit plate or aperture slide, and wavelengths. The procedure written here is minimal, but you are greatly encouraged to experiment on your own until you have a good understanding of how changing the parameters in the experiment affect the results. Though the slit plates that you are using may have a wide variety of numbers of slits, for this procedure you should always use two slit configurations. You are welcome to experiment with arrays of more than two slits, but for the measurements that you will be doing, 2 slits will be simplest. Though the setup for this procedure is very simple, Figure 6 (the diffraction setup) may be helpful; in this part of the procedure, the lenses will not be there, but in the place of lens 1 will be the slit plate.

7. First you simply need to setup the equipment. Assemble five post holders to five bases using short screws. This entire procedure should be completed while facing one of the long edges of the table: the interference fringes will spread out more and be more easily observable if slit-to-screen distance is maximized. With washers on the screws, screw one base and post holder to the far right side of the breadboard, so that the post holder is aligned with a row of screw holes. Place one of the longer screws in the laser mount, and drop it through the center of the three holes, so that the bottom barely reaches through the bottom of the mount. You can now turn a post upside down (where there will be a larger screw hole) and attach it to the screw you have inserted through the laser mount. Tighten this assembly and place the post in the post holder that you have fastened to the breadboard. Attach the other base and post holder assembly to the board so that there are 5 holes open between it and the base of the laser mount’s base. You can screw this base down loosely, as you will be moving it frequently. Place the slit plate that has been mounted onto a post into this post holder. Insert the 1mW green laser into the mount so that there is a small mount of space (about 1 cm.) between the tip of the laser head and the slit plate. The laser will not be centered in the mount, but it will be far enough in so that the mount maintains a good grip on the laser. Dim the lights or turn them off for the reminder of the lab. Use your flashlight if necessary to read the procedure. Plug the laser into its power supply, plug the power supply in, and turn the laser on. **DO NOT stare directly into the laser beam.** Prop up a piece of foam core board on the end of the breadboard opposite the laser, and arrange the slit plate so that the beam passes through slits and forms interference fringes on the foam core board.

8. First, you’re going to characterize the behavior of interference fringes as you change the slit spacing. What do you expect to happen to the pattern as you increase the spacing of the slits? Try it by moving the slit plate so that the laser passes through different slit spacings, keeping the plate in the same location and keeping the slit width constant. Record the specific widths and spacing of the slits that you use. What do you observe? If you notice a change, is it what you had predicted? If you don’t notice one, or if it’s too slight to pinpoint what has changed, explain why (keep in mind the geometry of the situation and recall the equations which describe this scenario).

9. You’re now going to measure the wavelength of this green laser just as with the red laser that you have built or will build. Move the slit plate so that the beam is passing through a pair of slits that cause interference fringes on the foam core board that are separated enough to measure. Make appropriate distance measurements of your setup and the fringe pattern so
that you can use one of the equations in the introduction. (Look at diagram from introduction). Use the equation to calculate the wavelength of this laser. Make sure to record the slit width, spacing, measurements you take, your calculation, and the result. The wavelength of the green laser is 543.5 nm. How close is your measurement?

10. Next, you will observe the effects of changing the wavelength of the light passing through the slits on the slit pattern. Qualitatively, what do you expect to happen to the pattern of interference fringes if you simply remove the green laser and replace it by a red one (632.8 nm wavelength)? From your pre-lab problem, how much do you expect the distance between the central maximum and the first order maximums to change? (plug in measurements from geometry of your setup to make this prediction) How much should the difference in power affect your results?

11. Choose a two-slit pattern that has interference fringes that are large enough to easily observe. Record the distance from the slits to your foam core board and the specifics about the slits you will be using. On the foam core board, use a pencil or pen to carefully mark the edges of the interference fringes produced by the green laser, at least through the second maximum on each side of the central maximum; also mark on the board the approximate centers of the fringes and note the position of the central maximum. Be sure you can remember what all your marks mean and that you have recorded the dimensions of the slits you have chosen to use! Do not move the foam core board. Shut the green laser off, and remove it from the setup by taking the mount and post out and setting it aside the red laser should also be mounted on a post. In the same post holder put one of the red Metrologic lasers. If the laser position cannot be adjusted to make the beam pass through the same slits as the green laser, then reposition the slit plate so that the beam is passing through those slits; of course, you will only want to change the base position perpendicular to the beam path, because moving it parallel to the beam (toward or away from the laser) would alter the slit-to-screen distance which is vital in the calculations. Position the foam core board so that the fringe pattern falls on it, and mark the same dimensions as you did for the green laser (if this position would mean marking over your previous marks, then reorient the board so that this will not be a problem). By looking at the two patterns, does there appear to be a difference? If so, what is it? Use the ruler to measure the distance from the central maximum and each of the other maxima you marked, and record those distances on a diagram in your lab notebook. Compare the distances you have measured for the red and green lasers. Are the results as you predicted? If not, why do you think this is the case? Turn the laser off.

Part III: Diffraction

For the second part of this procedure, you are going to explore some of the properties of diffraction; specifically, you will pass coherent light through openings, or apertures, of different sizes and shapes. Just like the (essentially) one-dimensional slit caused an interference pattern that varied in one dimension in the above part of the procedure, these two-dimensional openings will cause a two-dimensional diffraction pattern. However, as you might imagine, most apertures of a size that you could position easily would be big enough that the tiny laser beam would pass straight through the opening without being affected. To cause a diffraction pattern, the opening would have to be very, very small or the beam would have to be large compared with its natural size. The larger beam will be much more practical to work with, so first you will establish a system to expand and collimate the beam using lenses, as you have made plans for in the pre-lab. Below is the diagram for the setup that you will be using for this part of the lab.
12. Remove the red laser and replace it with the mounted green one. Make sure that both lenses are mounted in lens mounts, which are screwed onto posts. Remove the slit plate and replace it with the lens that has the shorter focal length; slide the post all the way into the post holder and loosen the screws on the base so that you will be able to slide the lens in the direction perpendicular to the beam path. Place the post of the other lens in a post holder. Turn the laser on and adjust the height of the first lens so that the beam passes over top of the lens mount and strikes the foam core board at the opposite end of the breadboard. Note the approximate position of the beam, and then raise the first lens so that the beam passes through it. Adjust the height of the lens and the position of the base so that the diverging beam is centered at the same place as the original beam was on the foam core board. Tighten the thumbscrew and the screws on the base.

13. Move the second lens (in its base) into the beam path, but turn the base so that it is parallel with the beam path. Adjust the height so that the beam passes through this lens and, as before, is at the same vertical height as the original beam. You should now work with the beam until it is collimated. To check for collimation, place your foam core board close to the surface of the second lens. Move the board back and forth for several meters, keeping it in the path of the beam. In the beginning and likely until a couple of other tries, this motion of the board will cause the spot to become larger or smaller, depending on the direction of motion. This means that the beam is not collimated (see introduction) and you should readjust the positioning of the second lens until the beam is successfully collimated. If you have difficulty telling if the beam is, in fact, changing size significantly as you move the card, then mark the size of the spot on the card when it is close to the lens and then compare it with the size of the spot a distance away. Once the beam is collimated, you should be able to attach a screw and washer through the base so that the lens can't move one screw is enough. If for some reason this is not possible, then don’t worry; you’ll just need to be careful that you don’t accidentally change the lens’s position.

14. You will be passing this wider beam through three different sizes of square holes. The beam should be slightly or significantly larger than two of them. For all three, draw what you
expect the basic form of the diffraction pattern for each will look like. Do not be concerned if you are unsure, but use your knowledge of how light passes through slits to predict what might happen. Also, draw what you predict the resulting pattern will be if you observe the pattern in the near field (very close to the aperture).

15. Somewhere in front of but close to the second lens, attach another post holder and base to the breadboard using only one screw and washer. Put this one in the regular alignment with the base perpendicular to the path of the laser beam. Find slide A (the one that has 3 holes shaped as squares), attach it to a post, and place the post in this last post holder. Adjust the position of the base and the height of the post so that the beam passes through the smallest square aperture. Use the foam core board to observe the pattern in both the near (less than 1-2 inches) and far fields. If you have difficulty deciphering the pattern in the far field, sometimes it helps to rotate the board some about the vertical or horizontal axis, causing the pattern to spread out over more of the board. If space is limited so that far away from the aperture you still cannot resolve the basic pattern, try putting a diverging lens (such as the Plano-Concave f=50.0mm) into an extra post holder and base, and put the assembly in the beam path, between the aperture and a foam core board setup at the end of the breadboard. You can try different positions to see what projects the image the best for your purposes. This should make the far field pattern visible at the end of the breadboard. Draw your observations in your lab notebook. Is the pattern what you expected? Does the general form match your prediction from the pre-lab? What relation does the pattern that you observe in the far field seem to have with that of the interference pattern caused by a single slit? Remove the diverging lens if you had to add it to the setup.

16. Move the foam core board to the distance that you specified for your solution to pre-lab problem 3. Hold or tape each partner's solution to the pre-lab onto the foam core board. Align the center of the prediction with the center of the pattern, at the specified distance. Does the pattern and prediction match? If not, how close is it? Mark the maxima of the pattern that are located in the same area as the parts of the prediction, and submit this with your lab notebook.

17. Adjust the post holder base position and post height to have the beam pass through the medium-size square openings. Note that the diverging lens cannot successfully be used in this setup. Record what you observe as the result in both the near and far field and note if these patterns matched your prediction. Repeat for the large square aperture.

18. Next, you will repeat the same thing with circular apertures. Again, there will be a slide with three circular openings. Again using your knowledge of slit interference and diffraction, and with your new experimentation with square apertures, predict the patterns that you expect of the circular apertures in the near and far fields.

19. Remove the square apertures from the beam path, and replace them with the slide of circular apertures (labeled B). Follow the same procedure as with the square apertures to observe the patterns in both the near and far fields (note that if the diverging beam is necessary in this setup, it should work for both the medium and small size circular apertures). Again, without the diverging lens, setup as in step 10 to test your prediction for the circular aperture. As with the squares, record your observations for both near and far field for each of the 3 sizes of circular apertures. Compare these with your predictions.

20. Now that you know what a circular aperture will do, predict what changing the size of that aperture will do. That is, what if you could vary the radius of the circle. Draw three different
size circles to represent three different size circular apertures. Then, draw what you think their diffraction patterns will look like relative to the other sizes.

21. Prop your foam core board for observation at the far end of the breadboard. Remove the slide containing the circular apertures and replace it with an iris that is open. Adjust the base position and height so that as much of the beam is passing through the iris as possible and the beam is centered on the iris. Opening and closing the iris may help with centering, but be sure to leave it opened when finished. If you haven't used it for other parts, you will now want to put the diverging lens into the setup to expand the pattern so that it can be observed at the end of the breadboard. Simply place the post of the lens mount into a post holder with base, and slide the lens into the beam path. Any position will work, and you may change the position if you feel you cannot see the diffraction pattern well. When close to the foam core board (less than 6 inches is good), the image is slightly expanded and very sharp, whereas halfway in between the board and apertures the image is larger but somewhat blurry. When you have chosen a position to begin with, adjust the height and base position so that the beam falls on the same place on the foam core board before and after adding the lens to the setup. This lens dramatically expands the beam, making the patterns much more easily observed.

22. Slowly close the iris and record what happens to the diffraction pattern. Make sure to pay attention to and record what happens to the very center of the pattern (this may be a good opportunity to move the diverging lens close to the board if it is not already there). Also, note how the pattern is different from a regular circular aperture. When you are finished, remove the iris, carefully examine it, and explain why the pattern differs from that of a circle.

23. What do you expect the diffraction pattern of a piece of wire to look like in the far field? Draw your prediction. (Hint: use what you know about the interference pattern that a slit produces)

24. Find the post that has a wire with a metal circle on the top taped to it. Put this post in the post holder where the iris was, so that only the wire is in the laser beam spot. Place the diverging lens in the beam path, about halfway between the foam core board and the wire. Observe the diffraction pattern of the wire and record it. Was it as you had predicted? If not, what does it remind you of?

25. From the information found in the introduction and your observations made earlier, what do you expect the diffraction pattern around the metal circle to look like in the far field? Draw your prediction.

26. Adjust the post so that the metal disc is in the approximate center of the beam. Adjust the position of the diverging lens so that you can clearly see what the diffraction pattern looks like; record it. Is it as you had expected? If not, does it remind you of any other diffraction patterns that you have observed? In the process of searching for the diffraction pattern around the outside of the metal disc, did you notice anything unexpected in the center of the shadow? If so, be sure to note it also; you will study this later in the course.

27. Turn off the laser. Take the equipment apart, reorganize it, and return it to where you found it.