LABORATORY 12
PHYSICAL OPTICS I: INTERFERENCE AND DIFFRACTION

Objectives

- To be able to explain demonstrate understanding of the dependence of a double slit interference pattern on slit width, slit separation and wavelength

- To be able to demonstrate understanding of the dependence of a single slit diffraction pattern on slit width and wavelength

CAUTION: NEVER LOOK DIRECTLY INTO THE LASER BEAM.

Overview: We will examine double slit and single slit interference patterns. In particular, we will examine the dependence of a double slit interference pattern on slit width, slit separation and wavelength and the dependence of a single slit diffraction pattern on slit width and wavelength.

Equipment:

1 optical bench
1 Multiple Slit wheel
1 screen
1 red laser
1 green laser

Exploration 1: Double slit interference

Exploration 1.1 Take the pre-test for this lab.

Exploration 1.2 Double slit interference pattern

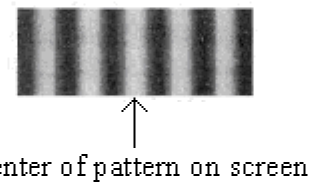
a. On the optical bench is a Multiple Slit wheel. Place it about 10cm in front of the laser, **BUT DO NOT TURN THE LASER ON YET.** The Multiple Slit wheel contains a number of different slit combinations, including various slit widths and slit separations. Suppose you were to set the Multiple Slit wheel so that the laser strikes two 0.04 mm slits separated by 0.25 mm. DO NOT DO IT YET. THIS IS A PREDICTION.

Predict the pattern that would appear on the screen. Make a sketch of the pattern, if you think it is relevant.

b. With the Multiple Slit wheel about 10 cm in front of the laser, move the Rotary Motion Sensor to one side so that it does not intercept the laser. Adjust the wheel on the Multiple Slit disk so that the laser strikes two 0.04 mm slits separated by 0.25 mm. Turn the laser on. Place a screen at the end of the optical bench to look at the pattern of laser light after it passes through the slits or look at the pattern on a nearby wall.

Describe the pattern you see. Does it match your prediction?

The pattern of dark and light bands in the center of the screen should look similar to that in the Figure below.



For right now, we will focus only on the central part of the pattern.

b. Suppose that *one* of the two slits in part **a.** were covered. Sketch the pattern that would appear on the screen in the space below. **THIS IS A PREDICTION.**

c. Instead of covering one of the slits, replace the Multiple Slit disk with the Single slit disk. Rotate the disk so that the laser strikes a single 0.04 mm slit.

Describe the pattern. Does it match your prediction?

d. Why is the pattern with both slits open not simply twice the intensity of the single slit pattern? What does the double slit pattern tell you about the nature of light? Explain.

Exploration 1.3

When the screen or wall is very far away from the slits, the difference in the distance from each source, ΔD, is equal to the distance between the slits times the sin of an angle between a line drawn from the center of the slits to the wall and a line drawn from the center of the slits to a point of constructive interference or a point of destructive interference, as shown in the diagram below. If point P is a point of constructive interference,

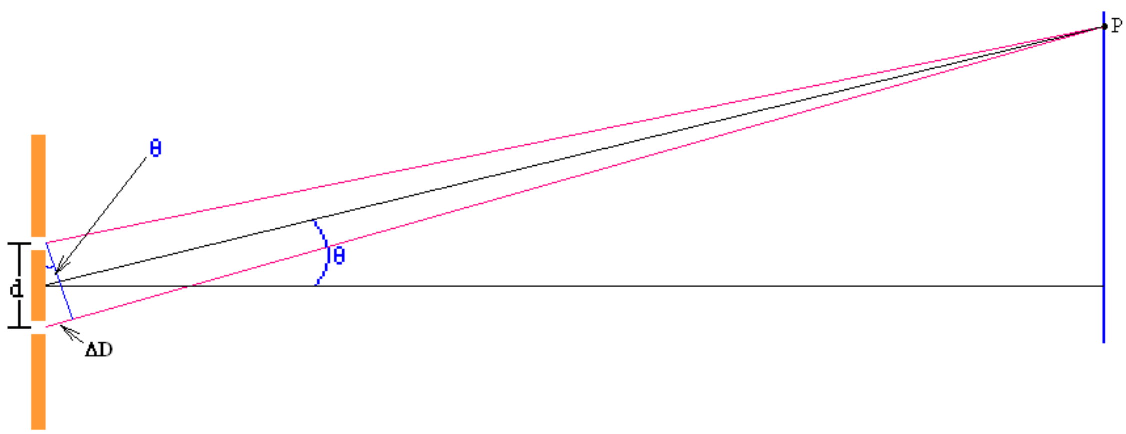
$$\Delta D = d\sin\theta = m\lambda$$

where m is an integer and m = 1 if point P is the first point of constructive interference from the central maximum, m = 2 if point P is the second point of constructive interference from the central maximum, etc.

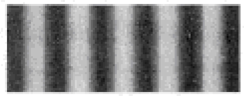
If point P is a point of destructive interference,

$$\Delta D = d\sin\theta = \left(m + \frac{1}{2}\right)\lambda$$

where m is an integer and m = 0 if point P is the first point of destructive interference from the central maximum, m = 1 if point P is the second point of destructive interference from the central maximum, etc.



If red light from a distant point source is incident on a mask with two identical, narrow vertical slits, the pattern illustrated below appears at the center of a distant screen.



a. In each part below, suppose a *single* change is made to the original apparatus. Describe how the interference pattern on the screen would change. Do not carry this out. It is a prediction. Record your predictions below.

(i) The distance between the slits is increased. Explain your reasoning.

(ii) The screen is moved closer to the mask containing the slits. Explain your reasoning.

(iii) The wavelength of the light is increased. Explain your reasoning.

(iv) The width of each slit is increased. Explain your reasoning.

b. Use the Multiple Slit wheel and the red and green lasers to test your predictions. Record how the pattern changed for each case below.

(i) The distance between the slits is increased. Explain your reasoning.

(ii) The screen is moved closer to the mask containing the slits. Explain your reasoning.

(iii) The wavelength of the light is increased. Explain your reasoning.

(iv) The width of each slit is increased. Explain your reasoning.

Equipment:

1 optical bench
1 Single Slit wheel
1 screen
1 red laser
1 green laser

Exploration 2 Diffraction

Exploration 2.1 Single Slit diffraction Pattern

a. On the optical bench is a Single Slit wheel. Place it about 10cm in front of the laser, **WITH THE LASER TURNED OFF.** The Single Slit wheel contains a number of different slits and apertures of various widths. Suppose you were to set the wheel so that the laser strikes the 0.08 mm aperture in the section entitled Single Slits. DO NOT DO IT YET. THIS IS A PREDICTION.

Predict the pattern that would appear on the screen. Make a sketch of the pattern, if you think it is relevant.

b. With the Single Slit wheel about 10 cm in front of the laser, and the Rotary Motion Sensor to one side so that it does not intercept the laser. Adjust the wheel on the Single Slit disk so that the laser strikes the 0.08 mm aperture. Use the red laser. Turn the laser on. Place a screen at the end of the optical bench to look at the pattern of laser light after it passes through the slits or look at the pattern on a nearby wall.

Describe the pattern you see. Sketch it. Does it match your prediction?

c. How can a single slit produce an interference pattern? Explain.

Exploration 2.2 Diffraction pattern dependence on single slit width

a. Adjust the wheel on the Single Slit disk so that the laser strikes a different slit aperture. Try the 0.04mm aperture. Observe the pattern that appears on the screen. How does it compare to the pattern of the 0.08mm aperture?

b. PREDICT how the pattern of an 0.02mm aperture would compare the that of the 0.04mm and 0.08mm apertures. Explain why you chose the prediction you did.

c. Test your prediction you made in part **b.**

d. PREDICT how would the pattern of a 0.16mm aperture compare to that of the0.08mm aperture. Explain why you chose the prediction you did.

e. Test your prediction you made in part **d.**

f. Find the variable slit on the Single Slit wheel. Adjust it so that the laser is at the narrowest part of the slit. Slowly turn the wheel to change the diffraction pattern from one produced by a narrow slit to one produced by a wide slit.

The minima of a single slit diffraction pattern are found at

$$a\sin\theta = m\lambda$$

where a is the slit width, λ is the wavelength, θ is the angle between a line (from the slit) to the center of the pattern and a line to the first minimum, as in the picture below, and m is an integer that describes the order (m = 1 is the first minimum, m = 2 is the second minimum, etc.).

Exploration 2.3 Diffraction dependence on the wavelength

a. If you were to keep the 0.08mm aperture and change from the red to the green laser, how would the pattern change? Would the first minima be in the same place, closer together or further apart? Explain your reasoning.

b. Switch from the red to the green laser and test your prediction in part **a.** Are the minima in the same place, closer together or further apart?

Equipment:

1 optical bench
1 Single Slit wheel
1 screen
1 red laser
1 green laser

Investigation 1 Diffraction

Investigation 1.1 Diffraction dependence on slit width

In Explorations 1 and 2, you examined the pattern of light intensity on a screen placed much further from single or the double slits than the width of the slits and distance between slits. It is possible to use a light sensor to record the light intensity that appears on a distant screen.

a. Set up the Single Slit wheel about 10 cm in front of the laser. Adjust the wheel on the Single Slit disk so that the laser strikes the 0.04mm aperture. You will collect data by using a Linear Translator to move the Light Sensor across the screen. The Light Sensor will record the intensity of light and send that information through the computer interface to the computer. The computer software will plot the intensity of the light as a function of distance, as you move the Light sensor across the interference pattern.

Bring up Data Studio and click on Create and Experiment. Click on one of the digital input channels on the left. Select Rotary Motion Sensor. Click on the second "Measurement" tab. Choose Position. Click on Analog Channel A. Choose Light Sensor.

You will need to dim the lights, in order to collect data. Depending on which side of the pattern you start the Linear Translator, your distance will either be plotted positive or negative. Move the Light Sensor SLOWLY across the pattern, using the Linear Translator. A good rule of thumb will be to take a minimum of about 30 seconds to move the Translater across the pattern. After you have taken the data, save it on the screen.

You can take multiple data runs and display them at the same time. Leave the first data up and record data for the 0.08mm aperture on the same graph.

b. Calculate θ for the first minima for each slit. Show your work below.

c. Did the angle to the first minima double, halve, or change by some other amount when the slit width was halved? Explain your reasoning.

Investigation 1.2 Diffraction dependence on wavelength

a. If you were to graph the diffracton pattern for both the red and green lasers on the same plot, would any of the diffraction minima overlap? Predict if there would be an overlap. What would be the condition for overlap? Explain your prediction.

b. Graph the interference pattern for both the red and green lasers on the same plot for the same slit width. Use an 0.08mm aperture. Do any of the minima overlap?

Equipment:

1 optical bench
1 Multiple Slit wheel
1 screen
1 red laser
1 green laser

Investigation 2 Double Slit Interference

Investigation 2.1 Dependence of interference pattern on slit separation distance

a. Set up the Multiple Slit wheel about 10 cm in front of the laser. Adjust the wheel on the Multiple Slit disk so that the laser strikes two 0.08mm slits separated by 0.25 mm. You will collect data by using a Linear Translator to move the Light Sensor across the screen. The Light Sensor will record the intensity of light and send that information through the computer interface to the computer. The computer software will plot the intensity of the light as a function of distance, as you move the Light sensor across the interference pattern.

You will need to dim the lights, in order to collect data. Depending on which side of the pattern you start the Linear Translator, your distance will either be plotted positive or negative. Move the Light Sensor SLOWLY across the pattern, using the Linear

Translator. A good rule of thumb will be to take a minimum of about 30 seconds to move the Translater across the pattern. After you have taken the data, save it on the screen.

Does it agree with the pattern of light intensity you saw on the screen? Explain.

b. With the pattern from part **a.** still on the screen, rotate the Multiple Slit wheel so that the laser strikes the 0.08mm slits separated by 0.50 mm. Move the light Sensor SLOWLY across the pattern to record the new intensity plot on top of the first. Save the plot.

Investigation 2.2 Dependence of interference pattern on slit width

a. Use the Light sensor to create two plots, with the same slit separation, but different slit widths. Use both the 0.04mm slit width and the 0.08mm slit width, each separated by 0.25 mm. Save both plots on the same screen.

Do the plots agree with Exploration 1? Explain.

Investigation 2.3 Dependence of Interference Pattern on Wavelength

a. For the 0.08mm slit width and the 0.25mm slit separation, use the Light Sensor to create two plots, one for the green laser and one for the red laser. Save both plots on the same screen.

Do the results agree with Exploration 1? Explain.

Investigation 2.4 Determination of the laser wavelength

a. Use data from one of the three previous Investigations, Investigation 1.1, 1.2 or 1.3 to determine the wavelength of the laser. Clearly show and explain your process for determining the wavelength. Clearly indicate all of the measurements you made. Clearly show all calculations.

Equipment:

- 1 optical bench
- 1 Single Slit wheel
- 1 screen
- 1 red laser
- 1 green laser

Investigation 3 Comparison of Single Slit and Double Slit Patterns

Investigation 3.1

Compare the diffraction pattern for a single slit to an interference pattern for a double slit, with the same slit width. You can use your previous data or the horizontal comparison slits on the Single Slit wheel.

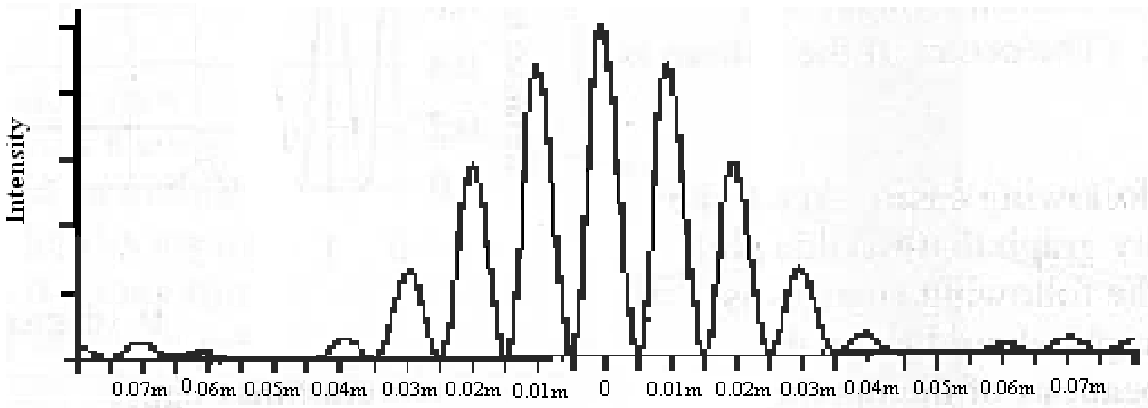
a. How do the patterns compare?

b. How do the intensities compare? Is one maximum intensity greater than the other? Why or why not? If there is a difference in maximum, how do the intensities compare? Explain.

Summary. Summarize the dependence of a double slit interference pattern on the slit width, slit separation and wavelength and the dependence of a single slit diffraction pattern on slit width and wavelength.

Laboratory 12 Homework
Interference and diffraction

1) Red laser light of wavelength 633nm is shone through two identical narrow slits to a screen 10m away. The intensity of the light as a function of position on the screen is shown in the picture below. The spacing between the bright fringes of the interference pattern is 0.01m, as in the picture.



a) Determine the distance between the slits. Show your work.

b) Determine the width of each of the slits. Show your work.

1)