Interference of Light

Purpose: To study the interference of coherent, monochromatic laser light that passes through single slits, double slits and a diffraction grating. To determine the wavelength of the laser light from measurements of the interference pattern and experimental set-up.

Equipment: Optics bench, diode laser and power adapter, component holder, diffraction plate, diffraction grating, slit mask, 2 meter stick, viewing screen with white paper, screen holder, auxiliary light source.

Introduction: In 1801, Thomas Young demonstrated that light is a wave and he performed the first measurement of its wavelength. Today, you will study the patterns that develop when light passes through a variety of apertures, and you too will measure the wavelength of light.

Procedure:

1. Place the viewing screen near the end of the lab table *away from* the tables on the other side of the classroom.

2. Mount the diode laser, and the component holder on the optics bench. Place the slit mask on one side of the component holder and the diffraction plate on the other side. Which plate should go on which side of the component holder?

3. **ALTHOUGH WE ARE USING LOW POWER LASERS, DO NOT ALLOW THE LASER LIGHT TO SHINE INTO ANYONE'S EYES. NOR SHOULD YOU ALLOW REFLECTIONS OF THE LASER LIGHT TO SHINE INTO ANYONE'S EYES.** Plug the power adapter into the diode laser, and into the electrical outlet on your bench. Notice that the base of the laser is not as wide as the optics bench. Align the laser aperture with the slit mask/diffraction plate assembly, and the viewing screen. When you are certain that the laser's light will follow a safe path, switch the Laser on. Use the horizontal and vertical adjust knobs to center the beam in the middle of the slit mask. The distance between the laser and component holder should be about $\mathbf{40}\boldsymbol{cm}$, and the distance between the component holder and viewing screen should be about $\mathbf{1}\boldsymbol{m} - \mathbf{1.5}\boldsymbol{m}$.

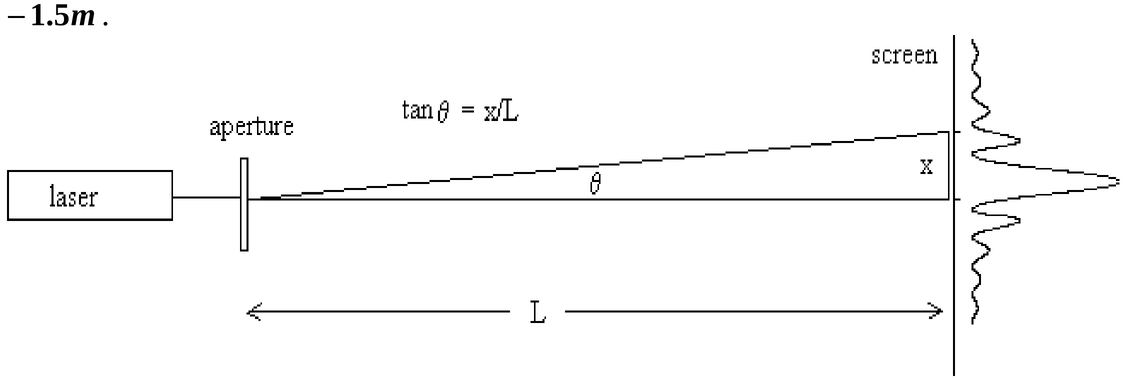


Figure 1 The experimental set-up and measurement variables.

4. Position the diffraction plate so that the single slit labeled $\boldsymbol{C}$ is illuminated, and make any necessary adjustments so that you can see a clear interference pattern on the viewing screen. With a sharp pencil, mark the center of the central maximum. Also mark the centers of the dark minima on either side until they become too indistinct to mark. Measure the distance between the component holder

and viewing screen to the nearest half mm. This is your measurement of L, as shown in Figure 1. Turn the viewing screen over and attach another piece of paper so that your lab partner can trace his/her own interference pattern. Everyone should have their own tracing to place in their lab journal. Your lab partner should measure L and record it also. Based on your observation of the interference pattern, is the slit vertical or horizontal?

5. For the single slit interference pattern, the interference minima satisfy the following equation: $\sin\theta_m = \frac{m\lambda}{W}, m = \pm1, \pm2, \pm3, \ldots \quad Eq.1$, where W is the width of the slit, λ is the wavelength of light, m is an integer that identifies the *order* of the interference minima and θ_m is the angle to the m^{th} order minimum, measured from the perpendicular between screen and diffraction plate. On your interference tracing, label the m values for each of the minima. You can follow the convention that the minima to the right of center have $m > 1$, while those to the left have $m < 1$. Does the geometry of your experimental set-up allow you to use the small angle approximation? If so, then $\sin\theta_m \approx \tan\theta_m = \frac{x_m}{L}$, and $Eq.1$ becomes: $\frac{x_m}{L} = \frac{m\lambda}{W}, m = \pm1, \pm2, \pm3, \ldots \quad Eq.2$, where x_m is the distance on the screen between the center of the interference pattern and the center of the m^{th} minimum. Carefully measure these distances on your tracing and make a table in your lab journal like the following:

Slit id	m	$x_m[mm]$

Include enough rows to accommodate all the minima you were able to measure.

6. Next, open the application Graphical Analysis on the computer. In the data table window enter your m values in the column for the independent variable. Enter your x_m values in the column for the dependent variable. You should see a linear graph in the graph window. Fit the graph to a straight line. Looking at $Eq.2$, see if you can determine the wavelength of the laser light from the slope of your graph. The width of the slit can be found from Figure 2. As usual, turn off connecting lines, label the axes and put a title on the graph. Compare your experimental value of the light's wavelength with the known value $\lambda = 650nm$, and calculate the percent difference.

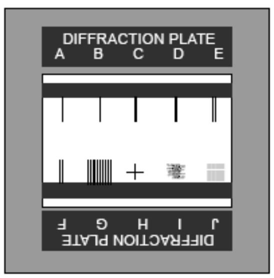
7. Repeat steps 4 through 6 for slits A and B. What trend do you see in the interference pattern as the slits become narrower?

8. Next, look at the interference pattern resulting from the illumination of double slits. Allow the beam to pass through the slits at D. Can you see the single slit interference pattern modulating the closely spaced bright and dark fringes that result from double slit interference? Observe the patterns that result from shining the beam through the diffraction plate at E and at F. What trend do you see in the interference pattern as the slits become farther apart? What trend do you see in the interference pattern as the slits become narrower?

9. Remove the diffraction plate and slit mask from the component holder. Replace with the diffraction grating. The diffraction grating has many, many identical slits that are equally spaced. Pass the beam through the diffraction grating. How does the resulting interference pattern on the viewing screen look different from the single and double slit patterns? The interference maxima you see

satisfy the equation: $\sin\theta_m = \dfrac{m\lambda}{d}, m = \pm 1, \pm 2, \pm 3, \ldots$ ***Eq*.3**, where d is the distance between neighboring slits, λ is the wavelength of light, m is an integer that identifies the *order* of the interference maxima and θ_m is the angle to the m^{th} order maximum, measured from the perpendicular between screen and diffraction plate. In a manner similar to steps 4 through 6, trace, measure and plot the positions of the intensity maxima as a function of m. Will you be able to use the small angle approximation to write an equation similar to ***Eq*.2**? Given that there are **600** $\dfrac{slits}{mm}$ on the diffraction grating, calculate the distance between the slits. From the slope of your graph, calculate the wavelength of the laser light and compare to the known value. Determine the percent difference.

10. If time permits, take a look at the interference patterns that result from the other apertures on the Diffraction Plate, and see if you can determine what the pattern of apertures must look like to generate the interference pattern seen.



Pattern	No. Slits	Slit Width (mm)	Slit Spacing center-to-center (mm)
A	1	0.04	
B	1	0.08	
C	1	0.16	
D	2	0.04	0.125
E	2	0.04	0.250
F	2	0.08	0.250
G	10	0.06	0.250
H	2 (crossed)	0.04	
I	225 Random Circular Apertures (.06 mm dia.)		
J	15 x 15 Array of Circular Apertures (.06 mm dia.)		

Figure 2 Description of the Diffraction Plate apertures.