Experiment
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Interference

INTRODUCTION

As long ago as the 17^{th} century, there were two competing models to describe the nature of light. Isaac Newton believed that light was composed of particles, whereas Christopher Huygens viewed light as a series of waves. Both models could explain reflection and refraction, but the phenomena of diffraction and interference could be more easily explained by Huygens' wave model. In the early 19^{th} century, Thomas Young's double-slit experiment provided evidence that supported the wave nature of light. This is the first of two experiments that examine the related phenomena of diffraction and interference. You will first compare the patterns that are produced when laser light passes through one or two slits and then strikes a screen. You will then focus your attention on the analysis of the double-slit interference pattern.

OBJECTIVES

In this experiment, you will

- Compare and contrast features of the patterns produced on a screen when light from a laser passes through either one or two slits.
- Discern which features of the pattern arise from the interaction of the light with the single slit and which arise from the double slits.
- Use the principle of superposition to explain how waves from two sources could interfere constructively or destructively.
- Use a diagrammatic explanation of how path length differences for light passing through the two slits give rise to bright and dark fringes in the pattern.
- From experimental parameters, predict the spacing between bright (or dark) fringes in the pattern.
- Collect intensity *vs.* position data to test your predictions.

MATERIALS

Vernier data-collection interface
Logger *Pro* or LabQuest App
Diffraction Apparatus
ruler
Vernier Optics Expansion Kit
Vernier Dynamics Track
Green Diffraction Laser (optional)

PRE-LAB INVESTIGATION

Direct exposure on the eye by a beam of laser light should always be avoided with any laser, no matter how low the power.

1. Attach the laser at one end of the track so that it faces down the length of the track. Connect the power supply. Leave the laser off until all parts are in place to avoid accidental reflections.

2. Set the diffraction slit assembly to a single slit of width, *a* = 0.08 mm. Attach the assembly to the track, with the silver reflective side of the glass plates facing the laser. Position it about 10 cm from the laser assembly.

3. Attach the High Sensitivity Light Sensor and the Linear Position Sensor to the other end of the track, with the light sensor facing the slits.

4. Turn on the laser. Adjust the horizontal laser position to achieve maximum brightness of the pattern. Adjust the vertical laser position to center the pattern vertically on the entrance aperture of the light sensor. Use this procedure every time you change the slits.

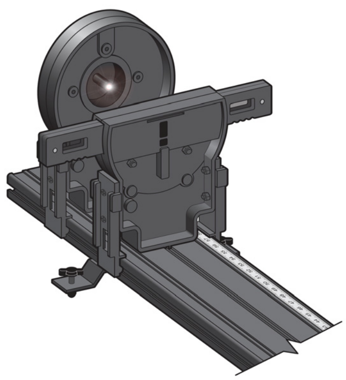

Figure 1 Laser and slit assembly

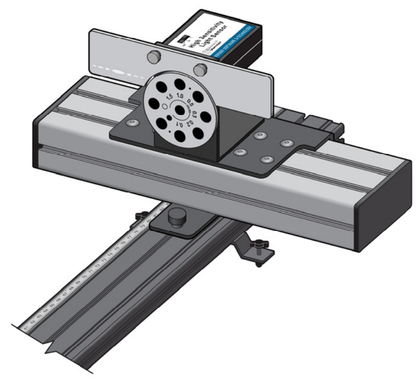

Figure 2 Light sensor assembly

5. Slide the light sensor assembly so that the pattern from the beam falls on the screen to one side or the other of the aperture disk (see Figure 2). Observe features of the pattern and record your observations in your lab notebook.

6. Now, set the slit assembly to a double slit where the slit width, *a*, is 0.08 mm, and the slit separation, *d*, is 0.25 mm. Align the laser as you did in Step 4.

7. View the pattern that forms as the laser beam passes through the double slit. Record your observations in your lab notebook, then turn off the laser.

Discuss what features the patterns have in common and the ways they appear to differ. You may find it helpful to repeat your observations of the single slit and double slit patterns.

Study the similar behavior of water waves using a simulation that can be found at the PhET web site: http://phet.colorado.edu/en/simulation/wave-interference. The simulation allows you to examine the patterns resulting when water waves from a dripping faucet pass through one or two slits in a barrier.

PART 1 SINGLE AND DOUBLE SLIT PATTERNS–A CLOSER LOOK

PROCEDURE

1. Return to the diffraction apparatus. Examine the pattern obtained when the laser shines through the single slit with *a* = 0.08 mm. Using a ruler, measure the distance between the midpoint of the central bright region and the midpoint of the first dark fringe. Repeat this

measurement for the second dark fringe. Then, measure the width of the central bright region from dark fringe center to dark fringe center.

2. Now, take a closer look at the pattern obtained when the laser shines on the double slit used in the Pre-Lab Investigation (a = 0.08 mm, d = 0.25 mm). Using a ruler, measure the distance between the middle of the central bright region and the location where the alternating bright and dark fringes seem to disappear. Then, measure the width of the central bright region.

EVALUATION OF DATA

1. Compare your measurements for the single- and double-slit patterns. What feature of the pattern appears to arise from the single slit? What feature appears to arise from the double slit? Compare your findings with those of other groups.
2. Consider what feature of the single-slit pattern would change if you changed the slit width. Test your prediction.
3. Consider what feature of the double-slit pattern would change if you used the same slit width but changed the separation between the slits. Test your prediction.

PART 2 INTERFERENCE AND THE DOUBLE-SLIT PATTERN

Refer to your text or a web resource to compare its explanation of the double-slit interference in to your observations. Determine how the superposition of waves can give rise to either constructive or destructive interference. Show that the small angle approximation allows you to substitute y/D for $\sin\theta$ in your calculation of fringe spacing. What variables affect the spacing of the bright fringes in the double-slit pattern?

PROCEDURE

1. Connect the High Sensitivity Light Sensor and the Linear Position Sensor to the interface and start the data-collection program.
2. Record the distance, D, from the slit assembly to the light sensor. Record the slit width, a, and the slit separation, d, for the double-slit configuration you used in Part 1, as well as the wavelength, λ, of the laser.

4. The optimal combination of light sensor sensitivity and sensor aperture depends on the type of laser and the slit configuration. It allows an intensity reading that reveals the detail necessary for you to make your measurements. For the red laser and the double-slit configuration you used in Part 1, we suggest setting the sensitivity to 10 μW and using an aperture of 0.5 mm.
5. Move the sensor assembly all the way to the right as viewed from the laser. Zero both sensors.
6. Start data collection, and then move the sensor assembly stage toward the other side of the rail on which it is mounted. Take at least 20 seconds to execute the motion, slowing when the sensor is traversing the brightest portions of the pattern. Stop collecting data when the stage reaches the end stop. Test that you moved the stage sufficiently smoothly by storing the run

and collecting another run, moving the stage in the opposite direction.[1] The trace of the second run should overlay that of the first.

7. Choose a double-slit configuration in which you change either the slit width or the slit separation, then repeat the previous step. You may find it necessary to change the aperture on the light sensor to obtain sufficient detail to complete your evaluation of data. When you are finished collecting data, save your experiment file and turn off the laser.

EVALUATION OF DATA

1. From the values of D, d and λ, calculate the theoretical distance y_n, for the first three maxima to either side of the central maximum for your first trial.

2. View the intensity *vs.* position graph for your first trial. Zoom in on the portion of the graph that shows the most useful information. Choose the Examine tool from the Analysis menu and position the cursor on the peak corresponding to the central maximum. Record the position in your lab notebook. Find the positions of the first two bright fringes on either side. Explain why you have difficulty finding the n = 3 bright fringe.

3. Determine the distance, y_n, from the central maximum to the first two bright fringes on either side. If the distances are not the same on either side, decide how to best report them.

4. Determine the percent difference between the theoretical and experimental values of the fringe spacing for this double-slit configuration.

5. Repeat Steps 1–4 for trials you have performed with other double-slit configurations. If more than two bright fringes are detectable, measure the positions at least three of them.

6. Compare your findings with those of other groups. On which parameter, slit width or slit separation, does the spacing of the fringes depend?

EXTENSIONS

1. Predict how your findings would differ if you were to use one of the double-slit configurations you did not test in Part 2. Test your prediction.

2. Predict how your findings would differ if you were to replace the red laser with a green diode laser. Test your prediction.

[1] If you are using LabPro, do not move the stage between runs or the second run will be shifted horizontally.