PART 1

Experiment   : Diffraction from a Single Slit

EQUIPMENT REQUIRED

– track and screen from the Basic Optics System (OS-8515)
– Diode Laser (OS-8525)
– Single Slit Disk (OS-8523)
– white paper to cover screen
– metric rule

Purpose

The purpose of this experiment is to examine the diffraction pattern formed by laser light passing through a single slit and verify that the positions of the minima in the diffraction pattern match the positions predicted by theory.

Theory

When diffraction of light occurs as it passes through a slit, the angle to the minima in the diffraction pattern is given by

$$a \sin \theta = m\lambda \ \ (m = 1,2,3...)$$

where a is the slit width, θ is the angle from the center of the pattern to the mth minimum, λ is the wavelength of the light, and m is the order (1 for the first minimum, 2 for the second minimum, . . . counting from the center out). See Figure 1.1.

Since the angles are usually small, it can be assumed that

$$\sin \theta \approx \tan \theta$$

From trigonometry,

$$\tan \theta = \frac{Y}{D}$$

where y is the distance on the screen from the center of the pattern to the mth minimum and D is the distance from the slit to the screen as shown in Figure 1.1. The diffraction equation can thus be solved for the slit width:

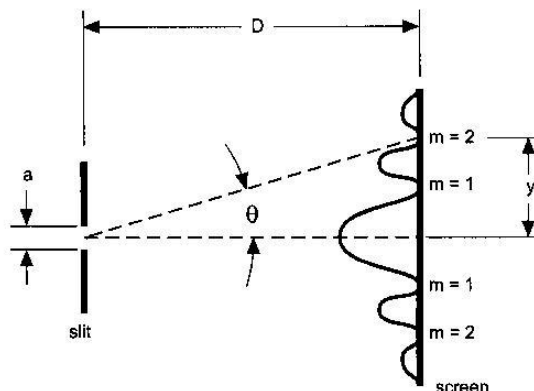$$a = \frac{m\lambda D}{y}\left(m = 1,2,3,\right)$$

Figure 1.1: Single Slit Diffraction Pattern

Setup

① Set up the laser at one end of the optics bench and place the Single Slit Disk in its holder about 3 cm in front of the laser. See Figure 1.2.

② Cover the screen with a sheet of paper and attach it to the other end of the bench so that the paper faces the laser.

③ Select the 0.04 mm slit by rotating the slit disk until the 0.04 mm slit is centered in the slit holder. Adjust the position of the laser beam from left-to-right and up-and-down until the beam is centered on the slit.
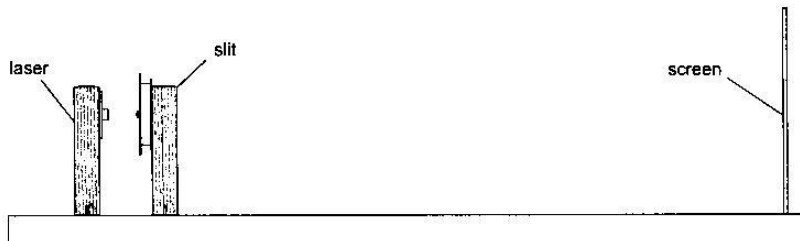

Figure 1.2: Optics Bench Setup

Procedure

① Determine the distance from the slit to the screen. Note that the slit is actually offset from the center line of the slit holder. Record the screen position, slit position, and the difference between these (the slit-to-screen distance) in Table 1.1.

② Turn off the room lights and mark the positions of the minima in the diffraction pattern on the screen.

③ Turn on the room lights and measure the distance between the first order (m = 1) marks and record this distance in Table 1.1. Also measure the distance between the second order (m = 2) marks and record in Table 1.1.

Table 1.1: Data and Results for the 0.04 mm Single Slit

Slit-to-screen distance (D) = _____

	First Order (m=1)	Second Order (m=2)
Distance between side orders		
Distance from center to side (y)		
Calculated slit width		
% difference		

④ Make a sketch of the diffraction pattern to scale.

⑤ Change the slit width to 0.02 mm and 0.08 mm and make sketches to scale of each of these diffraction patterns.

Analysis

① Divide the distances between side orders by two to get the distances from the center of the pattern to the first and second order minima. Record these values of y in Table 1.1.

② Using the average wavelength of the laser (670 nm for the Diode Laser), calculate the slit width twice, once using first order and once using second order. Record the results in Table 1.1.

③ Calculate the percent differences between the experimental slit widths and 0.04 mm. Record in Table 1.1.

Questions

① Does the distance between minima increase or decrease when the slit width is increased?

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Experiment   : Interference from a Double Slit

EQUIPMENT REQUIRED

– track and screen from the Basic Optics System (OS-8515)
– Diode Laser (OS-8525)
– Multiple Slit Disk (OS-8523)
– white paper to cover screen
– metric rule

Purpose

The purpose of this experiment is to examine the diffraction and interference patterns formed by laser light passing through two slits and verify that the positions of the maxima in the interference pattern match the positions predicted by theory.

Theory

When light passes through two slits, the two light rays emerging from the slits interfere with each other and produce interference fringes. The angle to the maxima (bright fringes) in the interference pattern is given by

$$d \sin\theta = m\lambda \quad (m = 0, 1, 2, 3, \ldots)$$

where d is the slit separation, θ is the angle from the center of the pattern to the mth maximum, λ is the wavelength of the light, and m is the order (0 for the central maximum, 1 for the first side maximum, 2 for the second side maximum, . . . counting from the center out). See Figure 2.1.

Since the angles are usually small, it can be assumed that

$$\sin \theta \approx \tan \theta$$

From trigonometry,

$$\tan \theta = \frac{y}{D}$$

where y is the distance on the screen from the center of the pattern to the mth maximum and D is the distance from the slits to the screen as shown in Figure 2.1. The interference equation can thus be solved for the slit separation:

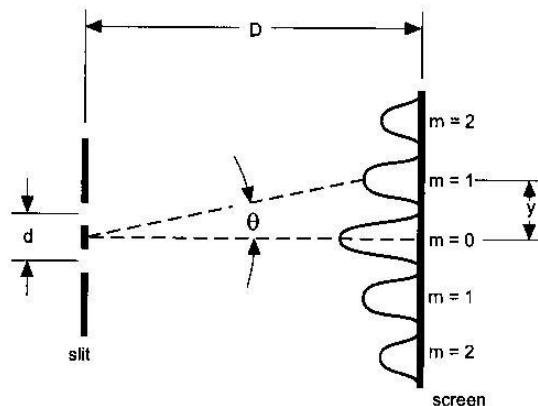$$d = \frac{m\lambda D}{y} \quad (m = 0, 1, 2, 3,\ldots)$$

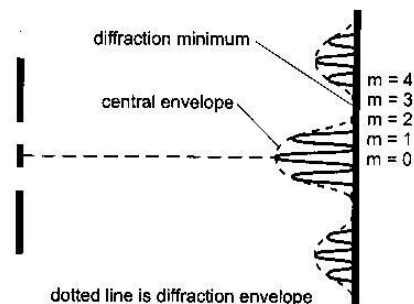**Figure 2.1: Interference Fringes**

Figure 2.2: Single Slit Diffraction Envelope

While the interference fringes are created by the interference of the light coming from the two slits, there is also a diffraction effect occurring at each slit due to Single Slit diffraction. This causes the envelope as seen in Figure 2.2.

Setup

① Set up the laser at one end of the optics bench and place the Multiple Slit Disk in its holder about 3 cm in front of the laser. See Figure 2.3.
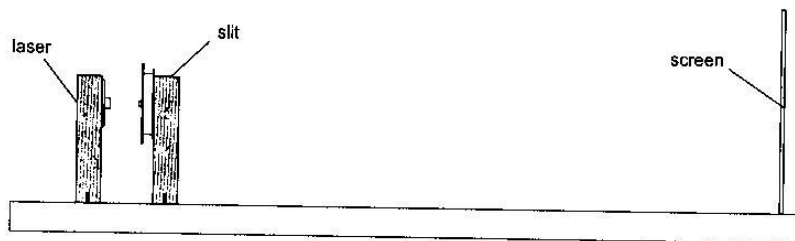

Figure 2.3: Optics Bench Setup

② Cover the screen with a sheet of paper and attach it to the other end of the bench so that the paper faces the laser.

③ Select the double slit with 0.04 mm slit width and 0.25 mm slit separation by rotating the slit disk until the desired double slit is centered in the slit holder. Adjust the position of the laser beam from left-to-right and up-and-down until the beam is centered on the double slit.

Procedure

① Determine the distance from the slits to the screen.

Note that the slits are actually offset from the center line of the slit holder. Record the screen position, slit position, and the difference between these (the slit-to-screen distance) in Table 2.1.

② Turn off the room lights and mark the positions of the maxima in the interference pattern on the screen.

Table 2.1: Data and Results for the 0.04 mm/0.25 mm Double Slit

Slit-to-screen distance (D) = _____

	First Order (m=1)	Second Order (m=2)
Distance between side orders		
Distance from center to side (y)		
Calculated slit separation		
% difference		

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③ Turn on the room lights and measure the distance between the first order (m = 1) marks and record this distance in Table 2.1. Also measure the distance between the second order (m = 2) marks and record in Table 2.1.

④ Make a sketch of the interference pattern to scale.

⑤ Change to a new double slit with the same slit width (0.04 mm) but different slit separation (0.50 mm) and make a sketch to scale of this new interference pattern.

⑥ Change to another double slit with a slit width of 0.08 mm and the original slit separation (0.25 mm) and make a sketch to scale of this new interference pattern.

Analysis

① Divide the distances between side orders by two to get the distances from the center of the pattern to the first and second order maxima. Record these values of *y* in Table 2.1.

② Using the average wavelength of the laser (670 nm for the Diode Laser), calculate the slit 1separation twice, once using first order and once using second order. Record the results in Table 2.1.

③ Calculate the percent differences between the experimental slit separation and 0.25 mm. Record in Table 2.1.

Questions

① Does the distance between maxima increase, decrease, or stay the same when the slit separation is increased?

② Does the distance between maxima increase, decrease, or stay the same when the slit width is increased?

③ Does the distance to the first minima in the diffraction envelope increase, decrease, or stay the same when the slit separation is increased?

④ Does the distance to the first minima in the diffraction envelope increase, decrease, or stay the same when the slit width is increased?

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