Physics 197 Lab 7: Interference

Equipment:

Item	Part #	Qty per Team	# of Teams	Total Qty Needed	Storage Location	Qty Set Out	Qty Put Back
Bottle of Bubble Solution with dipper		1	8	8			
Wine Glass		1	8	8			
Straw		1	8	8			
Optics Bench	PASCO OS-8518	1	8	8			
Red Diode Laser and Power Cord	PASCO OS-8525A	1	8	8			
Green Nd:YAG Laser and Power Cord	PASCO OS-8458	1	8	8			
Screen	PASCO OS-8480	1	8	8			
Multiple Slit Accessory	PASCO OS-8453	1	8	8			
Meter Stick		1	8	8			

Layouts:

Figure 1, Experiment A
Thin Film Interference in Bubbles

Figure 2, Experiment B
Two slit interference, red laser

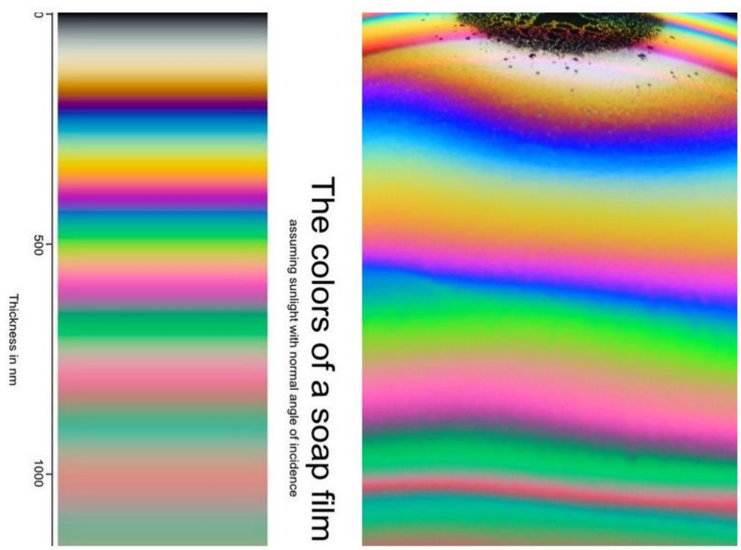
Figure 3, Experiment C
Two slit interference, green laser

Summary:

In this lab, students will investigate thin film interference using soap bubbles, along with Young's double slit experiment using red and green lasers. Bubbles will be formed in a wine glass and on a dipper and tilted at various angles so that the thickness of the bubble can vary in a uniform fashion. This should cause regular interference fringes of different colors to appear. Interference patterns from lasers going through double slits of different width and separation will be investigated at close range using a red diode laser. Then the interference patterns from a red laser and a green laser aimed through the same double slit and across the room will be compared.

PreLab:

As will be discussed in class, the colors in a soap bubble are caused by interference of light reflecting off of the front surface (with a 180 degree phase shift) interfering with light reflecting off of the back surface without a phase shift. For a soap bubble (water, index of refraction 1.33) with near zero thickness, there is no added phase shift from the round trip through the bubble, resulting in destructive interference and no reflection (black). As the thickness increases (see calculation of observed color vs. thickness and a photograph of these colors in a soap bubble from http://soapbubble.wikia.com/wiki/Color_and_Film_Thickness below), different wavelengths of light exhibit constructive and destructive interference, resulting in different observed colors. In your lab you will observe these colors with a soap film in different configurations.



At a thickness of 500 nm, the soap bubble appears green. Draw an appropriate diagram (showing front and back reflections) to calculate the wavelength which should have maximum constructive interference at this wavelength. From the picture above, it looks like this corresponds to 2.5 wavelengths round trip through the soap bubble (with index 1.33). Then calculate the wavelengths which will have maximum destructive interference (2 wavelengths or 3 wavelengths round trip). Based on these wavelengths, discuss why the soap bubble looks green at this thickness.

Experiment A: Thin Film Interference in Soap Bubbles.

Big Questions: *When white light passes through a thin film what kinds of visible patterns emerge? How can a colorless liquid appear to be colored?*

Select a wine glass and carefully fill it to about 2 cm depth with the bubble solution (1 part dish soap, 10 parts water). Be careful not to swirl the solution around to create a lot of bubbles! You will create a single, large bubble by doing the following (read ALL directions before attempting to follow them):

1. Gently tilt the glass and ***slowly*** swirl the solution around to coat the inside of the glass (at least halfway to the top).
2. Dip a beverage straw just into the surface of the solution in the bottle, tilt the glass slightly, take a deep breath, and blow ***gently*** into the straw. It may take a few tries to be successful, but you should be able to create a bubble that spans the diameter of the glass about ¼ to ½ way up the glass.
3. Carefully remove the straw and place a piece of paper over the glass.
4. ***Observe the film from several viewing angles over a period of 2-3 minutes. Record your observations in your laboratory notebook.(It helps to look for the reflection of the room lights in the bubble).***

Now have someone carefully tilt the glass and hold it at the tilted angle. You may rest the glass against something, but NEVER REMOVE YOUR HAND!!

Observe the film from several viewing angles over a period of 2-3 minutes. Record your observations in your laboratory notebook.

1. ***The bubble solution is colorless, and the incident light from the ceiling is white. What (<u>in general</u>) must be happening to produce the colors you see?***
2. ***If the bubble was illuminated with monochromatic red light instead of white light…***
   a. ***Formerly red areas would look ____________***
   b. ***Formerly blue areas would look ____________***
3. ***Is the liquid static? What observations did you make to support your answer?***
4. ***When you tilted the glass, the force of gravity produced effects on the liquid.***
   a. ***Where does the film become the thickest over time?***
   b. ***Where does the film become the thinnest over time?***
   c. ***What effect does the thickness seem to have on the color pattern?***
   d. ***Where does the clear/colorless or dark/black region form over time? Does the area seem to grow or shrink?***

Obtain a bottle of bubbles and pull the stick out of the bubble solution, holding it vertically.

Observe the film from several viewing angles until the film pops. Record your observations in your notebook, and discuss how they compare to your observations of the tilted bubble in the wine glass.

Experiment B: Interference from a Double Slit.

(The following write-up is partially taken from the manual for the PASCO OS-8523 Slit Accessory.)

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 m^{th} 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.

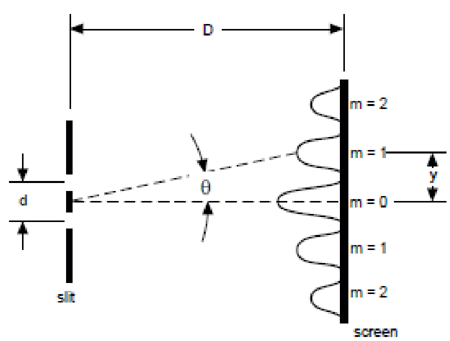


Figure 2.1: Interference Fringes

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 m^{th} 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:

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

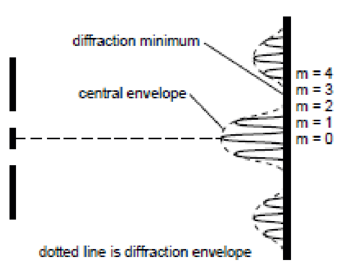


Figure 2.2: Single Slit Diffraction Envelope

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.

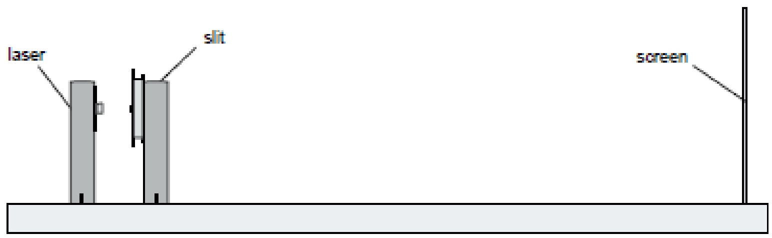


Figure 2.3: Optics Bench Setup

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 (Follow this procedure using the red diode laser)

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).

② Turn off the room lights and mark the positions of the maxima in the interference 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. Also measure the distance between the second order (m = +/- 2) marks and record.

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*.

② Using the average wavelength of the laser (650 nm for the Diode Laser), calculate the slit 1 separation twice, once using first order and once using second order. Record the results.

③ Calculate the percent differences between the experimental slit separation and 0.25 mm.

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?

Experiment C: Interference from a Double Slit comparing red and green lasers.

Shine the red diode laser through the 0.04 mm slits separated by 0.25mm and propagate it to a wall across the room. Measure the distance to the wall, sketch the pattern on the wall, and carefully measure the distance between interference maxima.

Now shine the green Nd:YAG laser with a wavelength of 532 nm through the same slit and across the room to the wall. Sketch the pattern on the wall, and carefully measure the distance between interference maxima.

How are the distances between maxima related to the laser wavelength? Assuming the green laser is known to be 532 nm, calculate the red diode laser wavelength and compare that to its nominal wavelength of 650 nm.

Given the slit separation, the green laser wavelength of 532 nm, and the measured distance between interference maxima, calculate the distance from the slit to the wall. Compare this to the measured distance, and discuss what you think might be the largest source of any discrepancies.

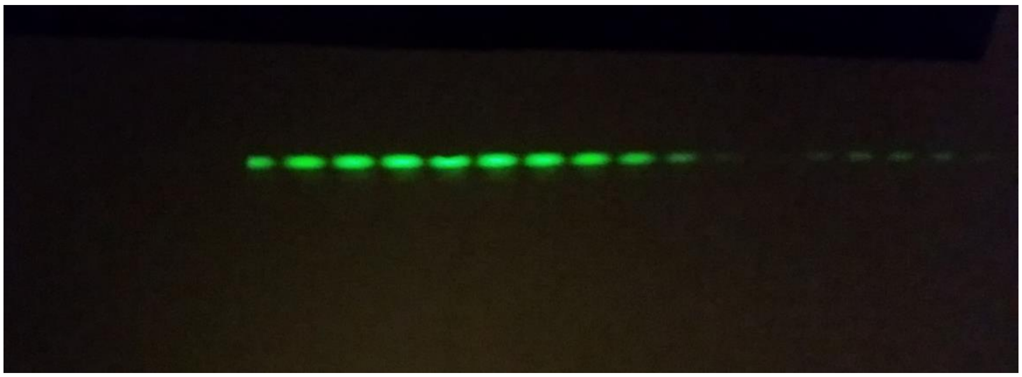


Figure 4. Green Laser interference pattern across room.