PHYSICS

Double Slit Interference

Introduction

Is light a particle, or is it a wave? This is a question that has spurred scientific discussions and endeavors for quite some time. Sir Isaac Newton, for instance, saw light as particles that traveled in straight lines until they bounced off of matter. This viewpoint is supported by various observations, such as light reflecting from a mirror and light not bending around corners to illuminate rooms, much like sound waves do into an empty room.

Other scientists found a better description of light as a wave. Thomas Young proposed a double slit experiment soon after Newton to show that light was able to interfere with itself, something that a particle would never be able to do. Because of the power of his experimental observations, the viewpoint that light was a wave held sway throughout the 1800's, especially after James Maxwell finalized a set of 4 equations that explained how light travels and relates the electric and magnetic fields.

The beginning of the 1900's saw a change in this view with a landmark paper by Albert Einstein. He used a particle view of light to describe the photoelectric effect, something that had puzzled scientists for a while. He stated that light travels as tiny packets of energy called photons wherein the amount of energy in the photon was related to its color.

Today, we realize that the nature of light depends upon the experiment used to study it, i.e. if you go looking for a wave or particle nature, it will show you a wave or particle nature. The last two weeks have shown us some of the particle nature of light, as we have traced the path of light as rays. This week, we will go back to Young's double slit experiment to show that light also has a wave nature.

Theory

The light that we normally see consists of light waves of many frequencies moving in many directions with many different phases and polarizations, i.e. it is full spectrum, incoherent, and unpolarized. While this is great for doing our normal work, it can be problematic for use in studying the nature of light, as there are too many disparate factors that are not being controlled. Instead, we often need to use monochromatic, coherent light like that found in a laser in order to study its finer details.

One experiment which requires this type of light is Young's double slit experiment. It turns out that when monochromatic, coherent light is shown upon a double slit, it acts as two sources of light that are emitting waves at the same time with the same wavelength. This will produce a static pattern of constructive and destructive interference on a surface behind the slits. The positions of the maxima (constructive interference) are given by the equation

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

where λ is the wavelength of the light, d is the distance between the slits, θ is the angle between the central axis of the slit and maximum, and m is an integer = 0, 1, 2, 3, ...

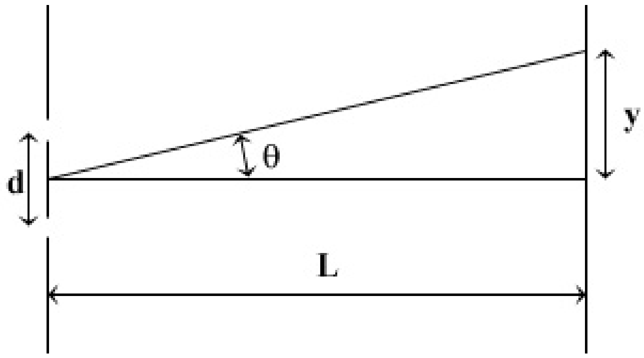

Fig. 1: Diagram of variables in double slit experiment

If we restrict ourselves to only consider those maxima that are close to the central maxima, then the angle θ will be small. If we also demand that the screen behind the slits be placed a far distance away L, we can approximate sin θ by y/L, where Y is the distance from the central maximum. Thus, our equation becomes

$$m \lambda = d\, y/L$$

Hence, by measuring the distance of the individual maxima from the central maximum, we should be able to determine the wavelength of the laser beam.

Fig. 2: Laser and slit accessory wheel

Procedure

In the lab this week, we are going to test this model using the equipment shown in Figure 2 and the Pasco optics bench. The slit accessory wheel allows us to try a variety of double slit widths and separations very quickly in this experiment

1. Set up the optical bench with the laser on one end of the optics table, the white screen on the other, and the slit accessory wheel between the two. The laser and the slit accessory wheel should be facing each other, and the wheel should be about .5 meters from the white screen.
2. Turn the laser on and position wheel such that the beam is striking the first set of double slits on the wheel ($a = 0.04$ mm, $d = 0.25$ mm).
3. Tape a blank sheet of paper to the white screen and mark the positions of the central maximum and the first three maxima to each side of it.
4. Remove the paper and measure the distances between the central maximum and the other maxima. Record the results on the activity sheet
5. Move the wheel to the next set of slits ($a = 0.04$ mm, $d = 0.50$ mm) and repeat steps 3 and 4.
6. Repeat step 5 for the other two sets of slits.
7. For each maxima, calculate the corresponding wavelength using the equation $\lambda = d\, y/(L\, m)$. Average the calculated wavelengths and compare to the stated value of 670 nm.
8. Answer the questions on the activity sheet.

Physics Activities	Activity Sheet Double Slit Interference

Name:

Distance from slits to white screen = L = _______

d = Slit Separation	3rd Max Left	2nd Max Left	1st Max Left	1st Max Right	2nd Max Right	3rd Max Right

Calculated Wavelengths

3rd Max Left	2nd Max Left	1st Max Left	1st Max Right	2nd Max Right	3rd Max Right	Average	% Difference

1. How close were your measured values for the laser wavelength to the stated value?

2. What systematic or random errors can account for any differences seen between measured and stated values?