DIFFRACTION WITH A LASER

OBJECT

Demonstrate diffraction using a laser and different slit configurations.

APPARATUS

Laser, optics bench, slit disks, screen, ruler

THEORY

Single slit diffraction pattern

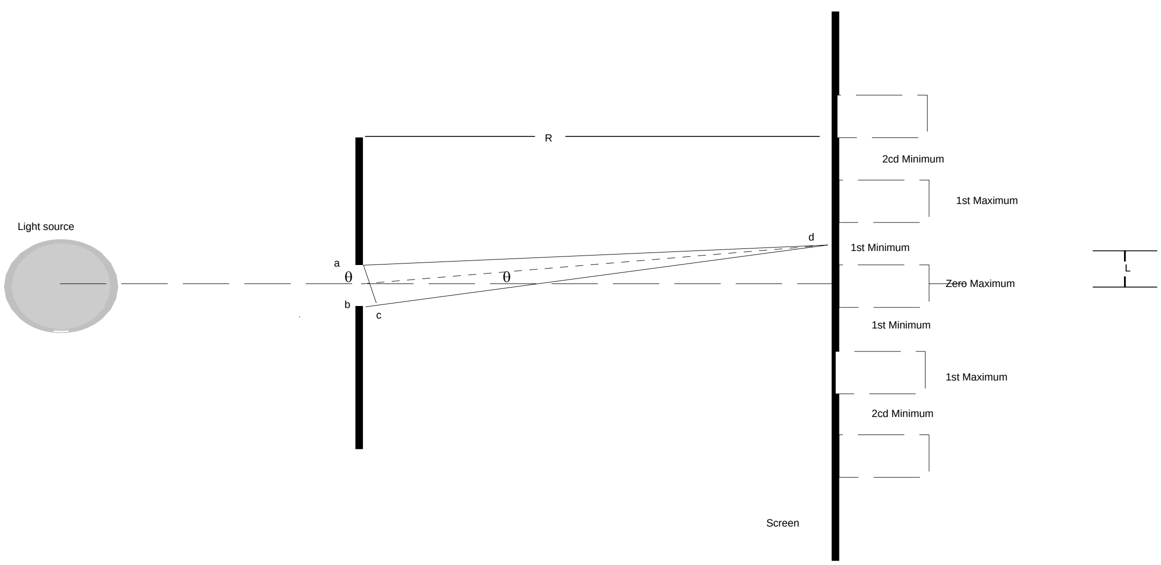

Figure 1. Illustration of single slit diffraction. W is the slit width.

The last several experiments have modeled light as a ray, or particle that can be reflected and refracted from a surface. In this experiment we will try to investigate the wave nature of light. We know that light is composed of electromagnetic radiation. The wave nature of light along with the Huygen's wavelet theory can explain interference patterns of light. When light from the light source strikes the slit, ab, each point on the slit acts as a wave source. The wave fronts from each point expand outward until they hit the screen. In the case of the illustration above light that left point b and reached point d has traveled farther than the light that has left point a and has traveled to point d. If the distance bd is greater then the distance ad by a full wavelength then the two waves are said to arrive at the point in-phase. We have seen in the wave on a string experiment, experiment 15, two or more transverse waves can be added together. In this case, the transverse electromagnetic waves will add-up constructively. The light that is in between points ab in the slit when they hit the screen at point d will vary in phase a full 360^{o}. This means that the waves can be paired so that each pair reaches d out of phase. When all the waves are added together a dark spot or minimum occurs. In the figure, point d makes an angle θ with respect to the slit and a perpendicular line drawn from the screen. By geometry the angle bca is also θ. The distance bc must be equal to a full wavelength, λ, for destructive interference. By trigonometry, the distance bc is,

$$bc = \lambda = ab\mathrm{Sin}(\theta) \qquad \text{Eq. 1.}$$

As illustrated in Figure 1 and as we will see in the experiment, there is more then one dark fringe or minimum and equation 1 must also describe the placement of the other minimum. For the second minimum to be reached, a path difference between the two points on the slit must be 2λ, for the third minimum to be reached a path difference of 3λ must exist, etc. With this in mind, we can rewrite equation 1 in a more general manner

$$n\lambda = w\mathrm{Sin}(\theta) \qquad \text{Eq. 2.}$$

Here w represents the slit width, λ the wavelength of light, θ the angle as illustrated in the figure, and n represents the order of the dark fringe, or minimum viewed. This equation gives the positions where **destructive** interference is expected.

Interference patterns from two or more slits.

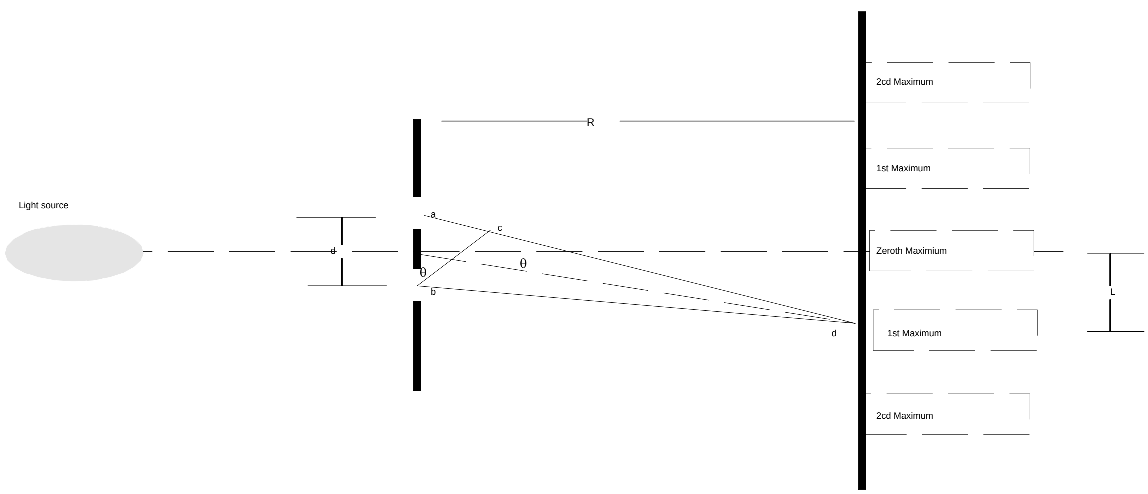

Figure 2. Illustration of double slit diffraction.

With two slits, waves coming from the slits will add up to give maximums and minimums. As illustrated in figure 2 the distance a wave travels along path ad is longer then the path a wave will travel along bd. if the path difference, ac is equal to one wavelength, λ, then the two waves will add up constructively. This **constructive** interference is given by the same equation

$$n\lambda = d\sin(\theta) \qquad \text{Eq. 4.}$$

Here n is the order of the maximum, λ the wavelength of light, d the separation distance between the slits, and θ the angle of incidence. θ is measured the same way it was in part 1. Please note that equation 4 is the same as equation 2 but we are measuring the placement of the maximums instead of the minimums. One should also note that the single slit diffraction pattern exists as an envelope over the double slit diffraction pattern. Do not confuse the two patterns. The pattern of fringes is so narrow for the multiple slit openings that it is advisable to use every third maximum in order to distinguish the spacing more accurately.

PROCEDURE:

1. Point the laser so that laser light is projected through the diffraction pattern wheel onto the screen beyond.

2. Measure the interference pattern spacing and the distance between the pattern and the slit wheel.

3. Do these measurements for the single slit, double slit and multiple slit openings on the slit wheel. Be careful to measure the dark fringes when doing the single slit experiment but measure the bright lines when doing the double or multiple slit experiment.

4. Calculate the slit spacing from the diffraction pattern and the wavelength of laser light given to you by your TA.

5. Compare the width calculated with the values given for the slit wheel.

Tip:

In order to get the laser to point easily through the slit opening, rotate the slit wheel **and the clamp ring of the slit wheel** so that the slit is at the bottom of the clamp circle. With this done you press the laser on the bottom of the other clamp tower circle and it shines directly through the bottom of the other circle, at the slit opening, without motion.