Experiment 11

Diffraction of Light

Preparation

Prepare for this experiment by looking up coherent light, diffraction by slits and gratings, and interference.

Principles

Light can be represented as a wave with a **period** and an **amplitude**. When two waves of the same frequency are made to overlap they are **superimposed**. If the superimposed waves have the same phase relative to each other they will **constructively interfere**. The resultant wave will have the same frequency, but the amplitude will be equal to the sum of the amplitudes of the two waves. If the superimposed waves are 180° out of phase with each other the amplitude of the resultant wave will be the **difference** between the two amplitudes. This is **destructive interference**. If the two original waves had the same amplitude the waves will cancel each other completely and no light will be seen.

When light passes through a slit that is small relative to the wavelength of the light, each point on the slit acts as a point source. Rays from each point spread out in all directions. When these rays then are allowed to fall onto a screen a pattern of light and dark patches will emerge as a result of the constructive and destructive interference of the rays that have passed through the slit. This is because some of the rays have traveled farther than others in order to reach the screen. For a single slit the dark spots will occur when rays from the edge of the slit and the center of the slit are 180° out of phase. This occurs when the path difference is $\lambda/2$, $3\lambda/2$, $5\lambda/2$, etc.

The distance from the slit to the screen is called L. The rays that go straight through the slit will form a bright spot. The diffracted rays that have a path difference of $\lambda/2$ will form a dark spot a distance, y, away from the central maximum. They will make an angle, Θ, with the undiffracted rays. The condition for the first minimum is that:

$$\sin \Theta = \frac{\frac{\lambda}{2}}{\frac{b}{2}} = \frac{\lambda}{b}$$

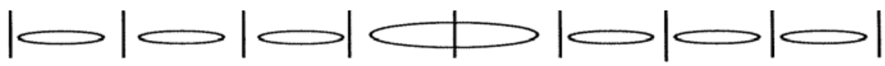
where b is the width of the slit.

Sin Θ can be found using the Pythagorean Theorem:

$$\sin \Theta = \frac{y}{\sqrt{L^2 + y^2}}$$

Θ is usually very small. You can then use the approximation sin Θ = tan Θ that applies to small angles. This simplifies the calculations since:

$$\tan \Theta = \frac{y}{L}$$



The single slit pattern will look something like this when you project it onto the wall. Note that the central maximum is two *y* wide.

If λ and L are known and the average distance, y, between successive minima is measured, the width of the slit can be calculated by combining the equations:

$$b = \frac{\lambda L}{y}$$

For double and multiple slits the quantity of interest is d, the spacing between the slits. A diffraction grating is a piece of glass or plastic with a large number of very fine slits ruled on it. The first maximum will occur when:

$$\sin \Theta = \frac{\lambda}{d}.$$

The multiple slit equation is the same as the single slit equation:

$$d = \frac{\lambda L}{y}$$

where again, y is the distance between successive minima.

The double slit pattern will look like this.

<u>Equipment</u>

1 laser
1 element holder
1 optical bench stand
1 support rod
1 short rod
1 table clamp
1 large clamp
1 small clamp
1 slide and grating holder
1 slit slide
1 diffraction grating
1 piece of paper
masking tape
meter stick
desk lamp

Procedure

For this experiment you will use a diode laser as your light source. The beam of light is very narrow and intense and all the waves are in phase, so there is no need for any focusing or collimating. **Do not look into the laser or at its reflection off a mirror. Do not point the laser at other people's faces.** The wavelength of the laser is around 640 nm, or 6.4×10^{-7} m. Use SI units for all measurements. The room must be dark for this experiment.

Single and Double Slits

1. Mount the slit slide in the holder. Your instructor will show you how to attach the holder to the table rod. Mount the table rod so that the slit is at least two meters from a flat section of wall. Measure *L*, the distance from the slit slide to the wall.

2. Turn the laser in the holder so that the clamp pushes against the button. Put the clamp in the stand and position it so that it illuminates the narrower of the single slits. It is very important that the slit slide be parallel to the wall and that the laser be perpendicular to the slide.

3. Move the laser back and forth until you get the brightest diffraction pattern. Use masking tape to tape a long piece of paper to the wall. Mark the positions of the minima of the pattern.

4. Repeat the procedures using the narrower set of double slits.

The Diffraction Grating

5. Replace the slit slide with the diffraction grating. The diffraction pattern will probable be too wide to project onto a single piece of paper. Measure the distance from the central bright spot to the first maximum on either side.

6. Turn the laser off, dismantle the apparatus and put it away.

Analysis

1. For the single slit pattern measure the distances between as many successive minima as you can. Find the average distance between them by dividing by the number of bright spots. Count the central maximum twice. The average distance is *y*. Calculate *b*, the width of the slit. It should be about 1×10^{-4} m. Find the percent error.

2. Find the average distance between minima for the double slit pattern. Calculate d, the separation between slits. It should be about 2×10^{-4} m. Find the percent error.

3. Average the two distances from the central bright spot to the first maxima for the diffraction grating. The angle between the center and the first maximum is too large to use the sin Θ = tan Θ approximation so you will have to use $\sin \Theta = \frac{y}{\sqrt{L^2 + y^2}}$ to calculate *d*. The slit density (number of lines per unit length) will be marked on the grating. The inverse of the slit density is the slit separation. Find the percent error of your value.