Experiment 5

Diffraction and Interference of Light

WARNING: ***Laser light can damage the retina. Keep the laser level at all times to avoid shining the light into an eye either directly or off of a reflecting surface.***

In this experiment you observe the patterns formed by laser light after passing through different types of openings. The patterns, observed far behind the openings, consist of definite distinct areas of light and dark. The spatial variations in light energy arise from the constructive and destructive **interference** of light waves. The spatial distribution of energy in an interference pattern allows precise determination of the size and shape of the opening the light passes through, essentially allowing very precise distance measurements in terms of numbers of light wavelengths.

Preliminaries.

Light is an electromagnetic **wave**.

Note how multiple slits provide multiple waves that interfere.

You will use **diffraction gratings** to find the wavelength of light. Diffraction gratings consist of many narrow, evenly spaced slits. The many slits increase the amount of destructive interference, so that the constructive interference regions are very distinct and their positions easy to precisely measure. The change in the diffraction pattern as more slits are used is shown in Figure 1.

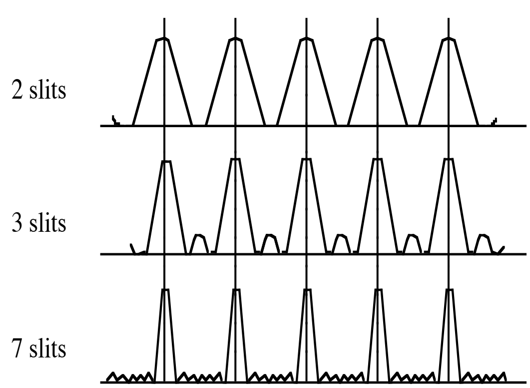

Figure 1. Diffraction patterns for different numbers of slits in the grating.

Can you explain with a diagram (with triangles) why adding more slits makes the resulting diffraction peaks sharper?

Usually the distance between the lines in a diffraction grating is specified by its reciprocal, the **line density** ρ. This value is usually expressed in units like 1/mm.

The use of diffraction patterns to determine wavelengths of light sources is known as **spectroscopy**. This is an extremely important diagnostic tool for identifying materials, as the distribution of wavelengths is distinctive and acts like a fingerprint.

The light sources used in this experiment are **lasers**. Lasers produce narrow beams of light at, essentially, a single wavelength. This simplifies the diffraction pattern analysis.

Can you use Fig. 2 to explain how diffraction works?

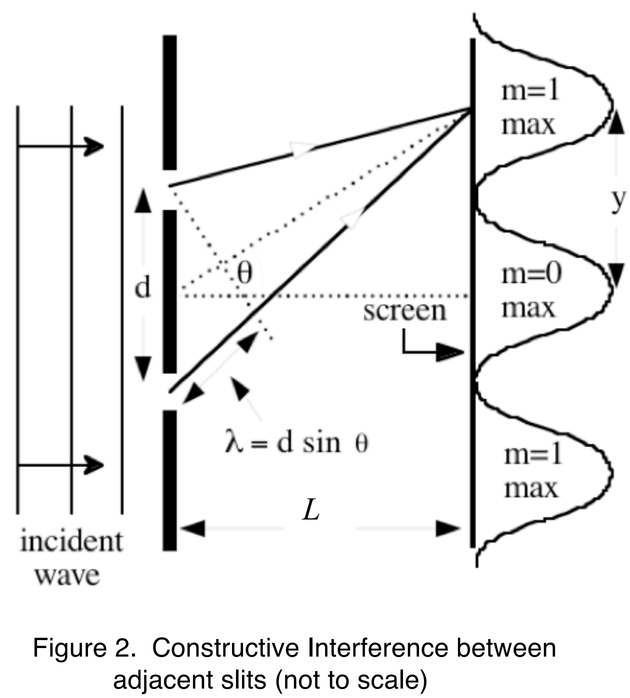

Figure 2. Constructive Interference between adjacent slits (not to scale)

Can you prove the equation defining when we have constructive interference?

$$d\sin(\theta_m) = m\lambda \qquad \text{(eq. 1)}$$

where $m = 0, 1, 2, 3$ is the **order** number.

In particular, you will need to know how to find θ from looking at where the peaks are and measuring the distances. Again, can you draw this triangle to define θ?

The discussion above is concerned with light waves originating from two or more identical slits. Light coming through a single slit can also show interference. This is because each point on the slit can be thought of as a wave source. What Principle is this? The light passing straight through the slit will produce a bright central maximum and the drawing of the triangles is the same for the double slit. However, instead of *maxima* we find *minima (no light)* at places where the distance in path length, $a \sin \theta$, from one edge of the slit versus the other is an integral number of wavelengths. Can you explain why this is the case? Can you also show, why the central max is twice as wide as the diffraction peaks and also much brighter? Can you see this?

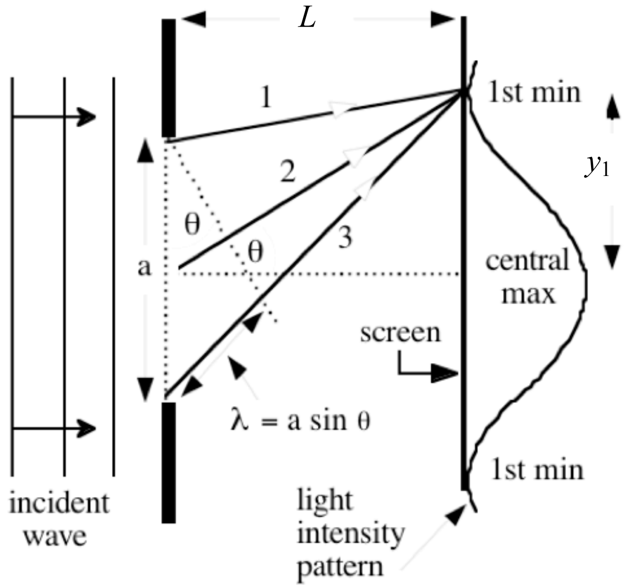

Figure 3. Diffraction through a single slit (not to scale)

In this experiment a spectroscopic analysis of laser light using a grating is performed to determine the wavelength of the laser. Subsequently, the known wavelength of the laser is used in a diffraction pattern analysis to determine slit widths and slit spacings.

Procedure.

Part A. Diffraction Grating

- Pass the laser beam through the diffraction grating. Move everything around and see if it makes any changes. Should the beam be perpendicular to the grating *and* to the viewing screen
- Find the manufacturer specified line density ρ of the grating. What is the distance between the slits?
- Using a good drawing, please find the wavelength of red light. Look up the helium neon laser wavelength to check your results, and % error. Is your % error within your expected uncertainty?

Part B. Single Slit

- Shine the laser through the single slit. Use these measurements to find the width of the single slit. Why is it better to measure from minimum to minimum rather than from the central max to the minimum?

Part C. Double Slit

- Shine the laser through the double slit with the smallest slit separation, and take the measurements necessary to calculate the slit spacing, *d,* using the known wavelength for your helium neon laser.
- Shine the laser through a double slit with different slit separation, *after you predict how the change in separation will change the diffraction pattern*. Note how the diffraction pattern changed. Did it change the way you thought it would?

Part D. Measure the width of your hair

- Put your hair across the laser. Note the diffraction pattern, and calculate the width of your hair.

Conclusions:

1) Make sure you can explain all your results using a good drawing and triangles.
2) Ideally, we might think that a double slit would produce diffraction peaks of equal intensity. Why is this not the case – Remember that each of the two slits is a single slit. Where should there be missing diffraction peaks? Is this where you see them missing?