

## Light Wave Interference



**Objective:** To see how light waves interfere constructively and destructively. To observe interference and diffraction. To measure small apertures or objects from their diffraction patterns.

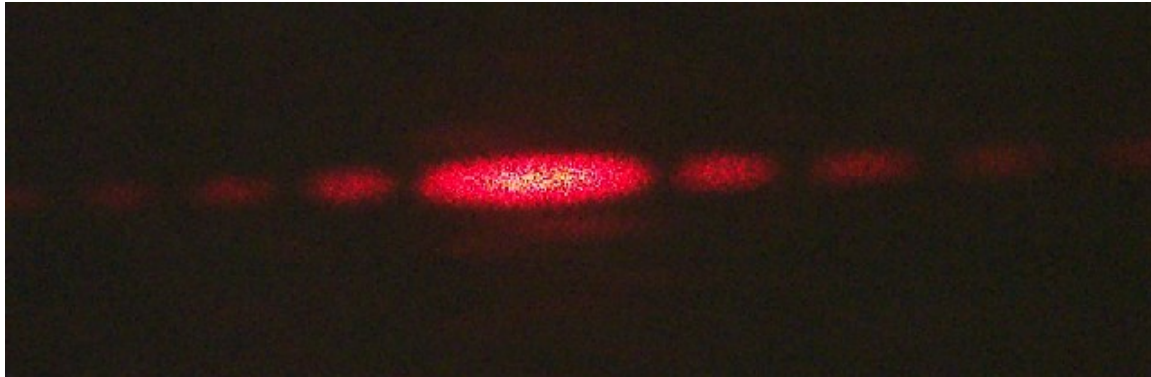
**Apparatus:** Laser, slides (single-slit, double-slit, diffraction grating), slide holder clip and stand assembly, small projection screen with white paper, meter stick

### Introduction

You may have learned from lecture that light has wave properties, and that two light waves of the same frequency can add up constructively (bright areas) or destructively (dark areas) depending on the path difference (the difference in distance from each light wave to the point where they meet) or their phase (the point in the wave cycle at a particular point in time – for instance, a wave described by the sine function leads a wave by the cosine by 90 degrees).

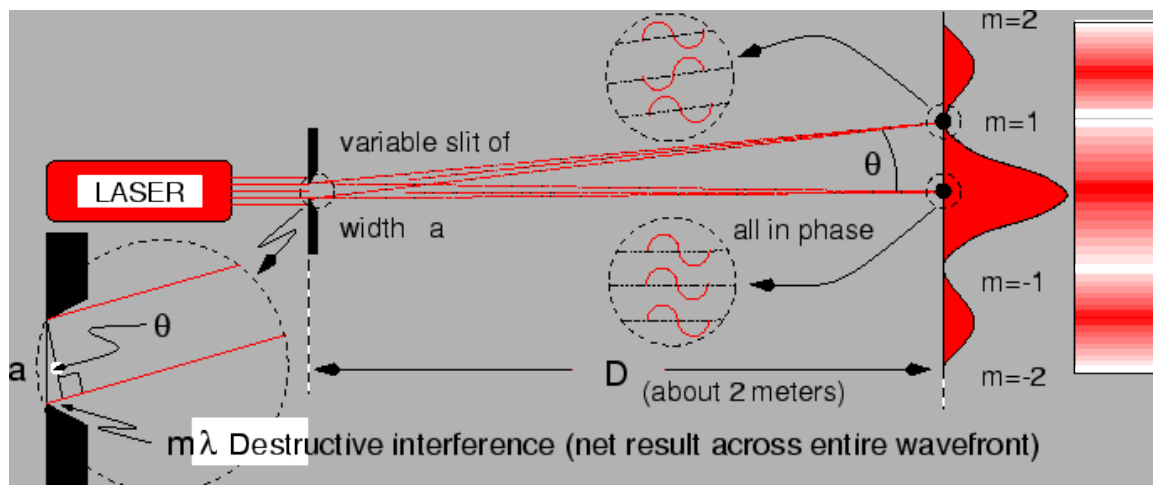
Waves add up either when the original light wave is split up into two constituent waves (double slit interference) or when the same portions of the original light wave interfere with themselves (single slit or grating diffraction). The equations describing the position of the bright spots (maxima) or dark spots (minima) of light coming out of a slit or grating projected upon a screen far away are summarized as follows:

## Single Slit



$$b \sin \theta = m \lambda \quad ; m = 1, 2, 3, \dots$$

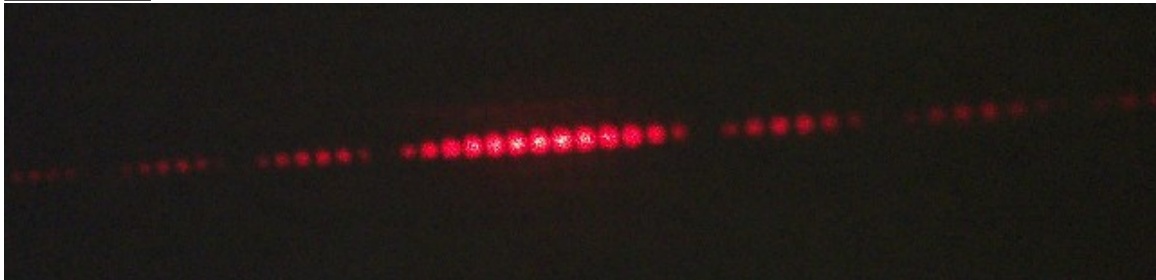
Here  $b$  is the width of the single slit,  $\theta$  is the angular deflection (as measured from the middle of the central maxima, at which the path difference is zero and there is maximum addition of the two waves) of the dark areas (minima) on a screen far away.  $\lambda$  is the wavelength of the incoming light and  $m$  is the *order* of the minima – the higher order minima are farther from the central maxima; positive minima are to the right of the central maxima, while negative minima are to the left of the central maxima. See the diagram below:



Note that in this lab (and the Bragg Diffraction lab later in the semester), you will find single-slit diffraction to be useful in determining the sizes of very small things. For small apertures, you can determine the size from the equation above. For small obstructions, you can use the same equation if you employ what is called Babinet's Principle - the diffraction pattern for an aperture is the same as the pattern for an opaque object of the

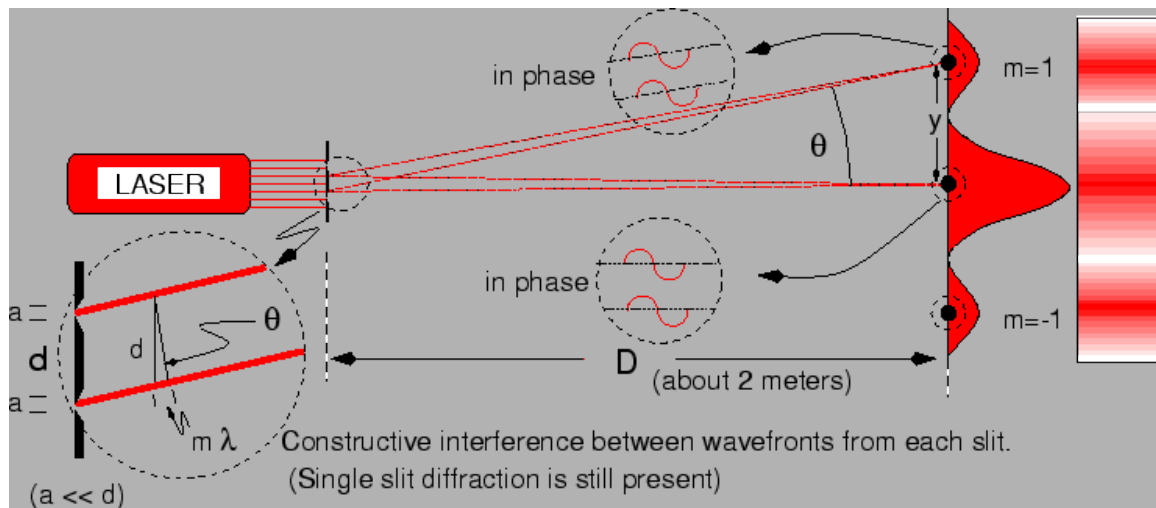
same shape illuminated in the same manner. That is, except for the intensity of the central spot, the pattern produced by a diffracting opening of arbitrary shape is the same as a conjugate (the inverse pattern) of the opening would produce.

### Double Slit



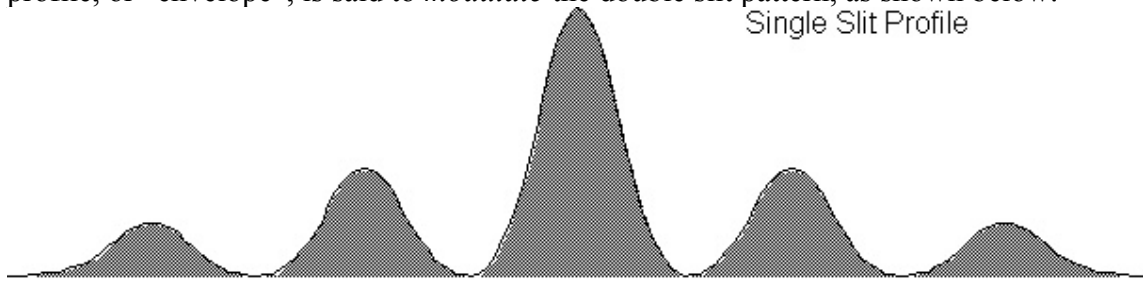
$$d \sin \theta = n \lambda; m = 0, 1, 2, 3, \dots$$

Here  $d$  is the distance between the slits,  $\theta$  is the angular deflection between the adjacent bright spots (as measured from the central maxima on a screen far away). Technically,  $\theta$  is the very small angular deflection between the \*small\* center bright spot (within the single-slit profile), but the distances between any two adjacent bright spots is the same.  $\lambda$  is the wavelength of the incoming light and  $m$  is the *order* of the minima. Do note that the angles are a lot smaller than that of the single-slit; from the diagram above, you can see that about 13 of them fit within the single-slit profile. Also see the diagram below:



Note that the above diagram shows an *idealized* double slit, which ignores the single slit character of each of the two single slits. A *true* double slit would exhibit closely spaced

dark and light areas (fringes), superimposed over the single slit pattern. The single slit profile, or “envelope”, is said to *modulate* the double slit pattern, as shown below:



Single Slit Profile



Single Slit Plus  
Double Slit Profile

### Diffraction Grating



$$d \sin \theta = n \lambda ; m = 0, 1, 2, 3, \dots$$

The equation here is the same for the double slit case, except that  $d$  represents *the spacing between grating lines (distance)*. You will have to calculate this from the table below, which lists *lines per unit distance*. The situation is still very similar to the double slit because there are many lines interfering constructively; the resulting diffraction pattern is therefore very sharp.



Clockwise from top left - Single Slit, Double Slit, Diffraction Grating

**SLIDE SPECIFICATIONS**

**Single Slit slide:**

PATTERNS	A	B	C	D
NO. SLITS	1	1	1	1
SLIT WIDTH	.02 mm	.04 mm	.08 mm	.16 mm

**Double Slit slide:**

PATTERN	A	B	C	D
NO. SLITS	2	2	2	2
SLIT WIDTH	.04 mm	.04 mm	.08 mm	.08 mm
SLIT SPACE	.250 mm	.500 mm	.250 mm	.500 mm

**Diffraction Gratings:**

80, 100, 300, and 600 lines/mm. Calculate  $d$ , the line spacing for each line.

## Activities

You will use a human hair (which one lab partner will provide) and three slides (single slit, double slit, diffraction grating) to investigate interference and diffraction. Measuring the distance from the slide to the screen and the distance from the central maxima to the maxima or minima in question will give you the angle with some calculation; remember that you can utilize small angle approximations only if the distance from the slide to the screen is large compared to the distance from the minima/maxima to the central maxima.

### A. Single Slit

Devise an experiment to measure the wavelength of the laser light using a single slit. **Use at least two single slits of different widths and average your results.** Note that in the equation, the only unknown variable is  $\lambda$  while the other variables are known or measurable. Remember that the equation gives the positions of the **minima**.

### B. Double Slit

Devise an experiment to measure the wavelength of the laser light using a double slit. **Use at least two double slits of different spacings and average your results.** Note that in the equation, the only unknown variable is  $\lambda$  while the other variables are known or measurable. Remember that the equation gives the positions of the **maxima** and that you should measure the distances between the *small* dark areas inside the single slit envelope, not the large-spaced distances between the single slit envelope minima. Since these distances are smaller than that of the single slit, you may wish to measure the width of the central single-slit envelope and divide by the number of slits therein – this is similar to determining the thickness of a single page of a book by measuring the book's thickness and dividing by the number of pages.

### C. Diffraction Grating

Devise an experiment to measure the wavelength of the laser light using a diffraction grating. **Use at least two diffraction gratings of different spacings and average your results.** Note that in the equation, the only unknown variable is  $\lambda$  while the other variables are known or measurable. Remember that the equation gives the positions of the **maxima** and that  $d$  is the *spacing between grating lines* (specification is given as *number of lines per unit distance*).

D. Measure the thickness of a human hair

Devise an experiment to measure the thickness of a human hair. You or your one of your lab partners will have to provide the hair. Explain how your experiment will measure the thickness and show all your calculations. You will need the wavelength you determined previously.