Diffraction

Objective

Part I: To use the interference pattern produced by a double slit to calculate the wavelength of the light source being used.
Part II: To use the diffraction pattern produced by single slits to determine the wavelength of the light source being used.

Equipment

Helium-neon laser, glass slide with optical double slits (with different spacing), glass slide with optical single slits (with different slit width), meter stick, tape and paper.

Background

Young's double slit experiment was a seminal experiment that proved that light behaves like a wave through showing that they diffract and interfere. Diffraction is when coherent waves bend around apertures(i.e. single slits, double slits, etc.) and cause a radial spreading of the waves. Interference is when multiple waves overlap producing **bright bands** or **maxima** and **dark bands** or **minima**. Diffraction and interference happens with all waves not just light, i.e. ocean waves, sound waves, etc. For both the single slit(S.S.) and double slit(D.S.) experiment similar equations are used,

$$d\,sin(\theta) = n\,\lambda \qquad \text{Double Slit} \qquad (1)$$

$$w\,sin(\theta) = n\,\lambda, \qquad \text{Single Slit} \qquad (2)$$

where w is the slit width for the single slit, d is the slit spacing for the double slit, λ is the wavelength, and θ is the angle that the wave is diffracted. n is an integer number(0, ±1, ±2, ±3, ...) that corresponds to either the **bright spots(D.S.)** or **dark spots(S.S.)**. θ can be found by related the distance from the slit to the wall(D) and the distance from the central bright spot(Δy) and the corresponding bright or dark spot(y). To find θ use Equation 3. A representative diagram for the double slit is shown in Figure 1 and the single slit is shown in Figure 2.

$$\theta = arctan\left(\frac{\Delta y}{D}\right) \quad \text{or} \quad \theta = arctan\left(\frac{y}{D}\right) \qquad (3)$$

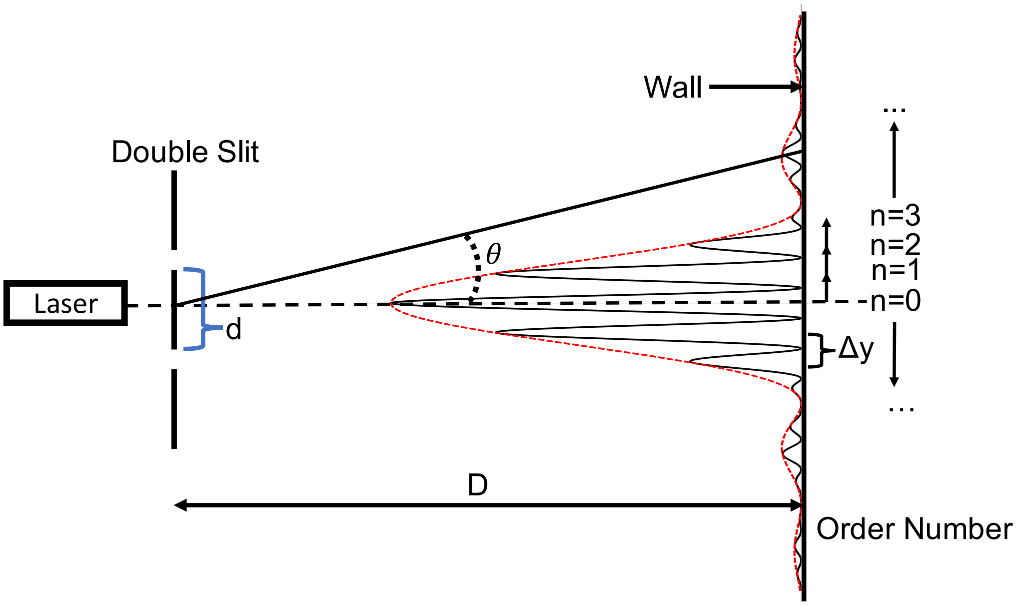

Figure 1: Double Slit Setup: d is the slit space, D is the distance from the slit to the wall, the peaks(maxima) are the bright spots and troughs(minima) are the dark spots.

Outline

Caution: Laser light can damage your eyes! DO NOT look into the beam or at any intense reflections from the beam.

Part I:
Step 0: Record the given value for the wavelength of your laser. **This is written on the laser!**

Step 1: Choose one double slits(A, B, C or D) and set up the lab as shown in Figure 1. Your data will consist of measuring the locations of the various **maxima (bright spots)** produced. The locations of these maxima are referenced from the location of the zeroth order maximum(n=0). D is the distance from the slit to the wall: This distance should be close to the length of the table. Measure D and record.

Step 2: Shine the laser through **one** of the double slits available making sure that both slits are covered by the beam. Record the distance between the slits **d (slit space)**.

Step 3: Record the interference pattern on the wall. You may have to rotate the slits slightly to get the sharpest pattern. Tape a piece of paper to the wall so that you can

draw as many lines(bright spots) as possible at the locations of the maxima. **DO NOT make any marks on the wall!**

Important note: A bright spot of the interference pattern may be mixed with a dark spot of the single slit diffraction pattern and therefore may not be visible: You should draw your interference pattern **assuming that the distance between two bright spots remains constant** in the small angle approximation, by adding the "missing" bright spots of your interference pattern.

On the interference pattern, label the maxima with their order number(n) by labeling the center of the central bright spot "zero" and counting outward in both directions. Use only positive numbers. **Deduce the best estimate of the distance between two maxima(Δy), i.e. measure distance between each bright spot or measure a set distance and divide by number of bright spots.**

Step 4: Rotate the slits, keeping the beam perpendicular to the glass face. Write down what you see.

Part II:

Step 5: Replace the double slit frame by the single slits frame.

Step 6: Shine the laser through one single slit (A) making sure that the slit is covered by the beam. When light passes through a single slit, a diffraction pattern is produced on the wall. The laser beam must be incident on the slit and perpendicular to the glass face. Set up the lab as shown in Figure 2. Your data will consist of measuring the locations of the various **minima (dark spots)** produced. The locations of these minima are referenced from the location of the central zeroth order maximum(n=0).

Record the distance between the slit and the wall, i.e. D. This distance should be close to the length of the table.

Step 7: Record the single slit diffraction pattern on the wall. You may have to rotate the slit slightly to get the sharpest pattern. Tape a piece of paper to the wall so that you can draw lines at the location of the central maximum and at the location of each minimum. **DO NOT make any marks on the wall!**

Label each destructive minimum by labeling the first one next to the central bright spot "one" and counting outward in both directions. Use only positive numbers.

Step 8: Record the **slit width w**.

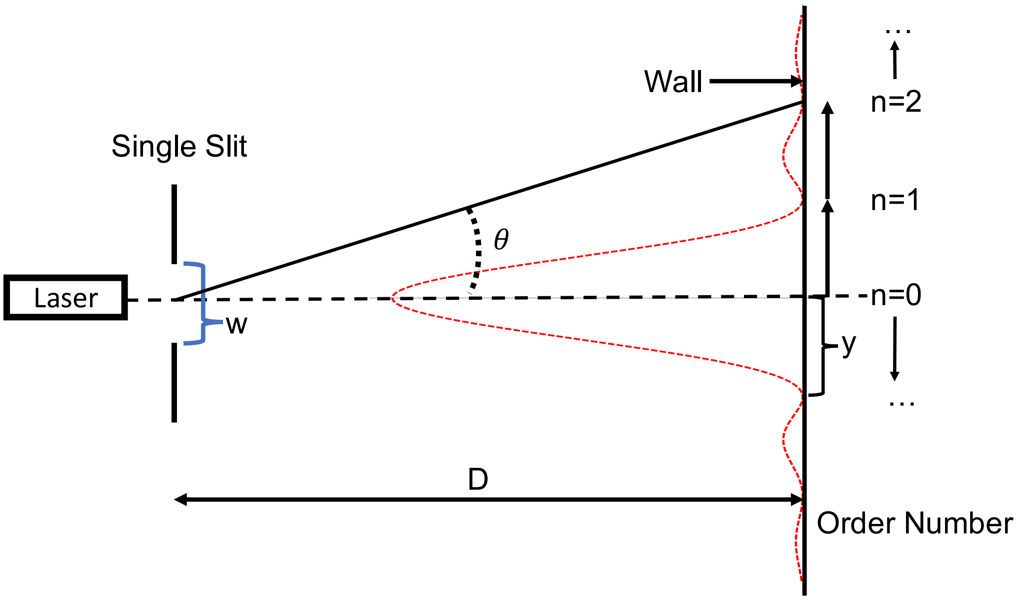

Figure 2: Single Slit Setup: w is the slit width, D is the distance from the slit to the wall, the peaks(maxima) are the bright spots and troughs(minima) are the dark spots.

Step 9: Repeat step 6, 7 and 8 for all the other slits(B,C and D).

Step 10: For each slit, use the single slit diffraction patterns to determine the best estimate of the distance between the central bright maximum(n=0) and the first minimum(n=1). Compute the corresponding angle, θ, and compute $\sin(\theta)$ as well.

Graphs and Diagrams

Part I and II: Attach all the patterns to the lab report.
Part II: Using your data for the 4 slits A, B, C, and D, plot $\sin(\theta)$ versus 1 over the slit width, 1/w.

Questions and Calculations

Part I:
1. Using your interference pattern, compute the best estimate of the distance between two maxima(Δy).
2. Using the previous result and the distance from the slits to the wall(D), compute the angle between the central maximum (order 0) and the next maximum (or order 1), θ. Compute $\sin(\theta)$ also.

3. Using answers from Q1, Q2 and n equals 1, calculate the wavelength(λ) of the laser light. Compare with the given value.
4. What happened when you rotated the slits? Explain.
5. Why do maxima (bright spots) and minima (dark areas) appear when light is passed through the slits? Why don't we observe just two bright spots on the wall separated by the same distance as the slits?
6. Thomas Young used a single slit for the light to pass through before it hit the double slits, why don't we use a single slit before the double in our experiment? Hint: What is the difference between the light sources?

Part II:
7. Using your graph(sin(θ) vs 1/w) deduce the wavelength of the laser light. Compare with the given value.
8. What is the difference between interference and diffraction?
9. What does this experiment tell us about light?

DATA SHEET

Part I: Double Slit

wavelength(λ) of the laser(given value) = ____________________
Distance between the slit and the wall: D = ____________________
d(slit space) = ____________________
Distance between maximum: Δy =________

tan(θ)	θ (deg)	sin(θ)	λ

Step 4: Observation:

Part II: Single Slit

D = ____________________

Slit Letter	w(slit width)	y	tan(θ)	θ (deg)	sin(θ)
A					
B					
C					
D					