Diffraction Measurements

Objective

Part I: To use a diffraction pattern to determine the thickness of a human hair.
Part II: To calculate and compare the spacing between the tracks on a CD and a DVD by using the media as diffraction gratings.

Equipment

Helium-neon laser, a slide for hair, a CD, a DVD, a clamp, a lab stand and a meter stick.

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. The governing equations are the same as for the single and double slit experiment,

$$d\,sin(\theta) = n\,\lambda \qquad \text{CD/DVD} \qquad (1)$$

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

where a is the width for the hair, d is the slit spacing for CD/DVD, 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 relating 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 hair is shown in Figure 1 and the CD/DVD is shown in Figure 2.

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

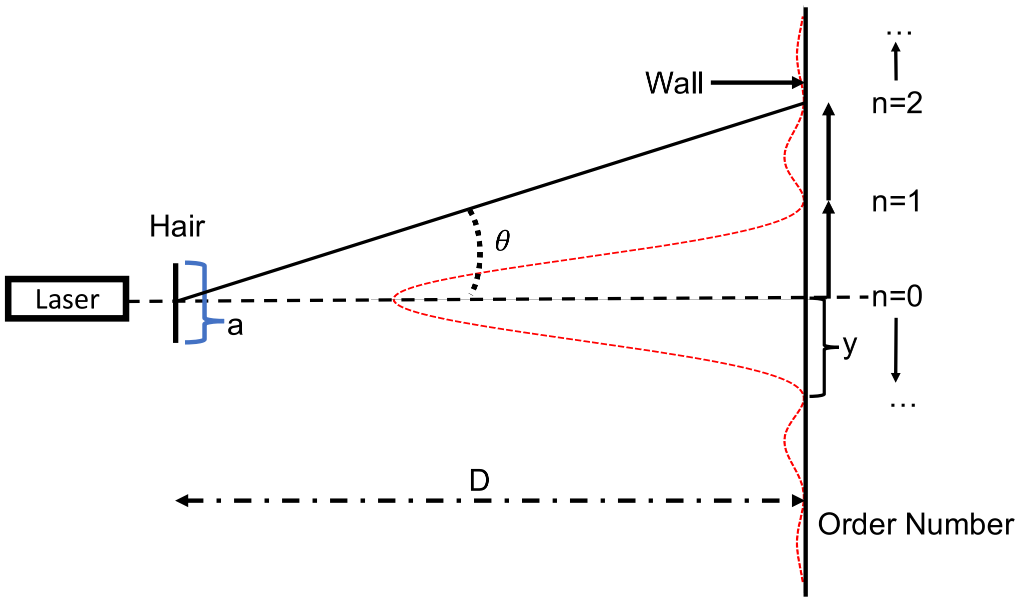

Figure 1: Hair Setup: a is the slit space, D is the distance from the slit to the wall, the peaks(maxima) are the bright spots and troughs(minima) are the dark spots.

Procedure

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

Step 0: Record the given value for the wavelength of your laser.

Part I:

Step 1: Insert a hair in the empty slide mount.

Step 2: Shine the laser through the hair: A diffraction pattern can be produced on the wall. It is similar to the one produced by a single slit. **The laser beam must be incident on the hair and perpendicular to the hair.** Set up the lab as shown in the diagram, Figure 1. 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 zeroth order maximum (n=0). The distance you will be projecting the beam after it has passed through the hair is D: Record the distance between the hair and the wall. **This distance should be close to the length of the table.**

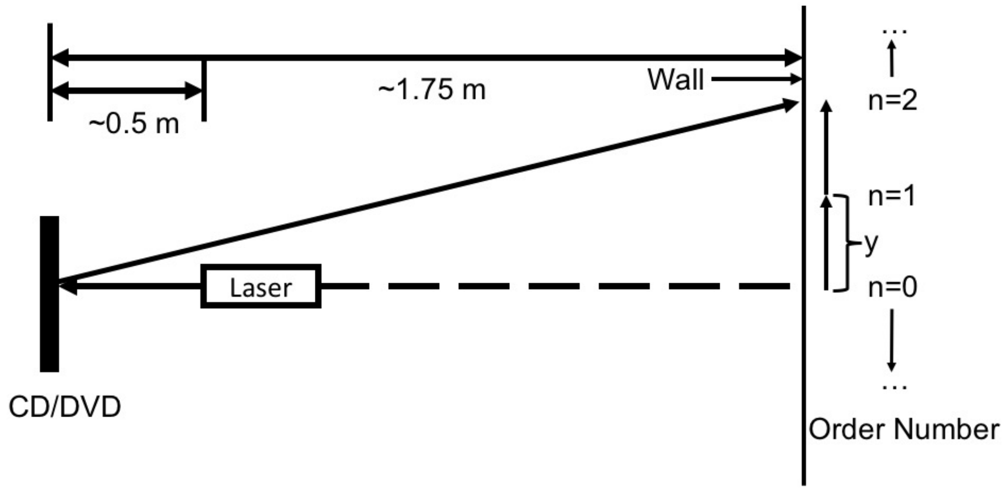

Figure 2: CD/DVD Diagram Setup.

Step 3: Observe diffraction pattern on the wall. You may have to rotate the hair 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 4: Use the diffraction pattern to determine the best estimate of the distance between the central bright maximum and the first minimum. Compute the corresponding angle (θ), $\sin(\theta)$, and thickness of the hair (a).

Part II:

In this experiment you will reflect a laser off an optical disk along the normal to the surface of the disc. The interference pattern will be used to calculate an experimental measure of the track spacing on the disc.

Step 1: Set your lab up as shown in Figure 2. The distance you will be projecting the beam after it reflects off of the disc is approximately 1.75 meters. **Carefully measure the distance D from the disc to the wall.**

Step 2: Place the CD in the holder and shine the laser beam with 0° incident angle onto the CD's surface and find the interference pattern on the wall. You may have to move the CD to get the laser to strike in the correct position to give you a **horizontal** diffraction pattern.

Step 3: Measure the location of the maxima relative to the central bright spot (n=0). Use the first 2 maxima(n=1) on either side and the central maximum for your calculations. For the CD, also use the second 2 maxima(n=2) on either side of the the central maximum.

Step 4: Repeat the above procedure for the DVD. Use the first maximum and the central maximum for your calculation.

Graphs and Diagrams

1. Draw the interference pattern observed with the CD and the diffraction angles, labeling each of the maxima with their order number: The bright central one is zero, the first ones on either side are 1st order, the next ones are 2nd order, etc.
2. Repeat the drawing for the DVD.
3. Using your data and the question 2 below, plot the order number(n) versus $\sin(\theta)$ for the CD only.

Questions and Calculations

Part I:
1. Use your data for the location of each dark spot and the distance from the hair to the wall to find the best estimate of the angle θ between the central maximum and the first minimum. Compute $\sin(\theta)$ also. **Deduce the diameter of the hair, a.**

Part II:
2. Use your data for the location of each bright spot and the distance from the disc to the wall to compute the angle θ between the central maximum and other maxima. **Compute $\sin(\theta)$ and track spacing, d**. Do this for both interference patterns (CD and DVD).
3. From graphs 3, find the ratio of the CD's track spacing to the wavelength of the laser light. From your data, find the ratio of the DVD's track spacing to the wavelength of the laser light, d/λ. Compute the track spacing on both discs and compare them. Are the spacings the same or are they different? Discuss any significant differences you find. Given that a CD has a capacity of 700 MB and a DVD has a capacity of 4700 MB, do your spacings make sense?
4. Why do maxima (bright spots) and minima (dark spots) appear when light is reflected back from the CD? Should there be just a bright spot on the wall, just from the reflection?
5. How many times the thickness of a human hair is the distance between the tracks of each disc?

DATA SHEET

wavelength(λ) of the laser = ____________________

Part I: Hair

Distance between the hair and the wall: D = ____________________
Distance between the central maximum(n=0) and first minimum(n=1): y =__________

$\tan(\theta)$	θ (deg)	$\sin(\theta)$	a

Part II:

CD: D = ____________________

Order number				
y				
$\tan(\theta)$				
θ (deg)				
$\sin(\theta)$				
d				

DVD: D = ____________________

Order number		
y		
$\tan(\theta)$		
θ (deg)		
$\sin(\theta)$		
d		