Physics Lab 21: Interference and Diffraction of Light

Goals: Improve communication, teamwork, and note-taking abilities; Observe, quantify, and apply the interference patterns of light from thin films, single slits, two slits, multiple slits, and barriers; Find fun with physics phenomena.

Equipment: Red Diode Laser (laser level), ring stand, clamps, blocks; (glass) Cornell Slitfilm Slide, holder, and schematic; Paper & tape for screen; Tape measure/meter stick; Rulers; Empty slide holder, tape, and single hair; Demonstration Station: Sodium vapor lamp, regular lamp, glass slides, Newton's rings apparatus, soap film and wire ring.

Groups & Lab Notebook: Lab trios. Lab notebook should serve as a ***stand-alone*** representation of what you did and what you learned.

Part 0: Overview & Equipment Orientation
Important safety information provided during the opening discussion, along with orientation to experimental set-up.

Part 1: Demonstration Station – Thin Film Interference If this station is too crowded, move on and come back to it. You will work with an instructor at this station. Under a monochromatic sodium vapor lamp and/or a standard light source, observe thin film interference in a soap film in air and in an air film between plates of glass. Observations only.

Part 2: Single Slit Patterns

1. Orient the Cornell slits at a slight angle so that any reflections are aimed down and not up. Orient so that the A window (see schematic) is in upper left corner as seen from point of view of laser. Fix height of the laser such that by moving the slits horizontally (by sliding on the table) and vertically (by moving up and down the ring stand), the fixed laser beam can go through every slit pattern (one at a time). Make sure that the laser beam emerging from the slits reaches your taped-up screen unobstructed, and that your working area isn't in another group's line of sight.
2. Aim the laser through the A window, and observe the pattern on the screen. Don't move the slit location. Without changing its height, move just the laser closer to and further from the slit (and thus also the screen). Does anything noticeable happen to the brightness of the pattern on the screen? To the size/shape of the pattern on the screen?
3. Still with the laser through the A window, keep the laser position fixed, but now move the slit (don't change its height) closer to and further from the laser (and thus also the screen). Does anything noticeable happen to the brightness of the pattern on the screen? To the size/shape of the pattern on the screen?
4. Hopefully the previous two steps have shown you that the distance between the laser and the slits (and thus the distance between the laser and the screen) doesn't matter very much, but that the distance between the slits and the screen is what matters. This is because the slits act as sources of light when the laser passes through them.
5. Fix the slit and screen distance. Measure this distance carefully, and record it as L. <u>Do not change this distance for the duration of lab.</u>
6. Aim the laser through the A window again. Observe the pattern on the screen. It might help to use a separate piece of paper to shade the pattern from any overhead or other room light. You should observe a central bright spot. You might also observe dimmer side spots (if not, that's ok). Use a ruler to measure the width of the central bright spot. If you can see the dimmer side spots, then measure from the middle of the dark region to the left of the central spot to the middle of the dark region to the right of the central spot, and call that the width. If you can't see the dimmer side spots, then measure the width of the central bright spot as best you can.
7. The B, C, D, and E windows get narrower and narrower, as you can see from just looking at the Cornell slitfilm directly and also from looking at the schematic. <u>BEFORE</u> making any measurements, discuss in your group what you think will happen to the width and brightness of the central bright spot as the single slit width narrows. <u>WRITE DOWN YOUR PREDICTIONS</u>.
8. Shine the light through the B window, and measure the width of the central bright spot. Repeat for C, D, E. Also, window F (which is in a different column, see schematic).
9. Record your date in a table with three columns, where the first column is the slit width (recall that you calculate the slit width by taking the number to the side of the pattern on the schematic and multiplying by 0.04393 mm and also note that these are nominal values), the second column is the width of the central bright spot, and the third column is a note about whether you obtained the width of the central bright spot by measuring the center-to-center distance from the neighboring dark spots or just from the central bright spot itself.

Part 3: Double Slit Patterns

1. Previously, you had a single window, or opening, or slit. Next, you will explore what happens if you "open another window", in other words, what happens if you have two slits. Look at the upper right hand corner (marked E), which is a single slit, in principle identical to the single slit E in the lower left hand corner (that's why they have the same label). Below this slit E in the upper right hand corner are a series of two slits, with the same width for each slit, but

with increasing space between the slits (these are like two windows each of the "same size" but with increasing distance between the windows.). The distance d between the slits is written on the schematic.

2. Shine the laser through slit E in the upper right hand corner. This pattern should look familiar to you, as you produced it using the other E window in the previous part. Sketch a scale diagram of the pattern in your notebook, with the scale indicated. If you can, one group member may also choose to take a picture (have the ruler in the picture for scaling purposes) to share for inclusion in your lab notebook, but also draw a scale diagram.
3. <u>BEFORE</u> making any measurements, discuss in your group what you think will happen to shape of the central bright spot when you "open another window" when shining the laser through G, H, I, and J. <u>WRITE DOWN PREDICTIONS</u>.
4. Shine the laser through G. Make sure the laser illuminates both windows as equally as possible. What do you notice? Look carefully. If you're not sure you are seeing a difference, try shining through H, I, or J until you do. Or, call Krishna.
5. Shine the laser through G. Starting from the central maximum (this should be the center-most bright spot), measure the distance to as many of the following as you can see: from the center of the central maximum to the center of the first side maximum (either side, shouldn't matter, $m = 1$), from the center of the central maximum to the center of the second side maximum ($m = 2$), and from the center of the central maximum to the center of the third side maximum ($m = 3$). You might find it easier to identify the center of the neighboring dark spots (the minima) and measure those; it is safe to assume that the maxima are in between the minima. If you can, one group member may also choose to take a picture (have the ruler in the picture for scaling purposes) to share for inclusion in your lab notebook.
6. Repeat for H and for I OR J (no need to do both I and J).
7. Organize in a table with 4 columns: d (written immediately below the patterns on the schematic), and the distances from the central maximum to the $m = 1$ maximum, $m = 2$ maximum, and $m = 3$ maximum.
8. Pick one of the G, H, I, or J patterns that was easiest to see and measure, shine the laser through that window, and draw scale diagram of the pattern in your notebook, with the scale and distances indicated. It is true that you might have photographs, but they might not print out well. Include a hand-drawn scale diagram for one of G, H, I, or J patterns in your lab notebook.

Part 4: Multiple Slit Patterns

1. F, K, L, M, and N are identical slits, evenly spaced, but increasing in number (so this is like opening more and more windows that are the same shape and size and evenly spaced). Shine the laser through each of F, K, L, M, and N. What do you observe? Look carefully. Check with Krishna to make sure you've noticed the important features.
2. Pick any two of K, L, M, and N (just two are enough), and take pictures, make measurements, and draw scale diagrams.
3. The middle row varies, with different numbers of slits, widths, and spacing. Choose 2 to shine the laser through. What do you observe? No need for quantitative measurements.

Part 5: Application – Width of Hair

1. Obtain a hair from a group member (look on shoulders or coats, in hats, or pluck from your own head). The hair should be long enough that it can be taped in a slide holder. Tape the hair so it is parallel to one side.
2. Place the slide in the holder. Orient the slide so the hair is vertical. Make sure the hair/screen distance is the same as the slit/screen distance you used for the rest of your measurements. Shine the laser on the hair. Observe the pattern on the screen. Does it resemble any patterns you saw earlier?
3. It turns out that the diffraction pattern for a barrier is the same as the diffraction pattern for a single slit. Measure the width of the central bright spot, as you did in Part 2.

<u>ANALYSIS</u>:

1. For single slit diffraction, the locations y of the minima adjacent to the central bright spot are given by:
$$a\frac{y}{L} = m\lambda$$
where a is the width of the slit, y is the location of the minima, L is the distance from slit to screen, λ is the wavelength of incident light, and here $m = \pm1, \pm2, \pm3, \ldots$ You measured the width of the central bright spot; half that width gives you distance to the first side minimum. Is your Part 2 data consistent with the above model for single slit diffraction?
2. Use the previous analysis to determine the width of the hair used in Part 5.
3. For double-slit interference, the locations y of the maxima adjacent to the central bright spot are given by:
$$d\frac{y}{L} = m\lambda$$
where d is the distance between the slits, y is the location of the maxima, L is the distance from slit to screen, λ is the wavelength of incident light, and here $m = 0, \pm1, \pm2, \pm3, \ldots$ You directly measured the locations of the adjacent maxima. Is your Part 3 data consistent with the above model for double-slit interference?