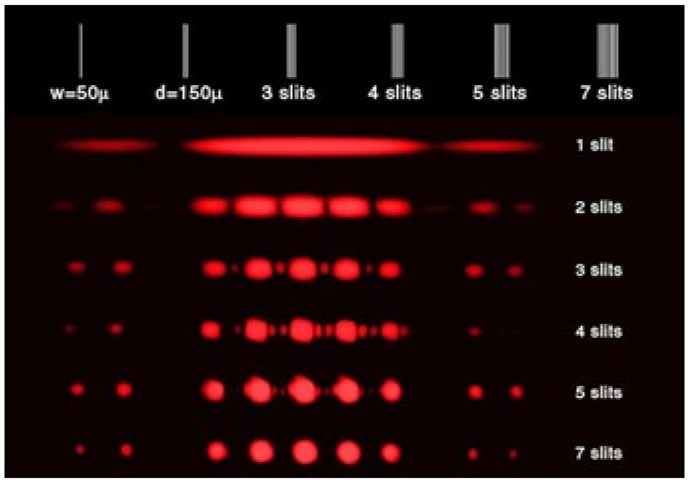
Lab 4

Finding Patterns in Intensity



Physical Models: Diffraction and Interference Patterns, Small Angle Approximation

Analysis Tools: Linear Fitting, Weighted Slope Formula, Weighted Slope Uncertainty

Experimental Systems: Laser pointers, PASCO green diode laser, Flashlight, Diffraction Wheel, Interference Wheel

Equipment: PASCO Optics Track, Screen

Safety Concerns: Please be careful not to look directly into any light sources or to shine them haphazardly at other groups! Be careful to moniter how the lasers reflect off of the PASCO wheels. Absolutely do not use the "strobe" setting on the flashlights, since this may cause harm to others, including *epileptic seizures*.

Introduction

In previous labs we've used various light sources, including laser pointers, to study how light rays bounce off mirrors or bend through lenses. In these investigations we've mostly neglected an important attribute of light: it's a wave. We've been able to neglect light's wavelike character because the wavelengths of visible light are very small. In this lab, by shining light through very small slit patterns, its wavelike properties will be revealed, and we'll be able to quantitatively measure them.

In particular, in your prelab you learned about diffraction in the case of a single slit. A model was presented:

$$\Delta y_{dark} = \lambda \frac{L}{a} \tag{4.1}$$

Where Δy_{dark} is the distance between dark fringes in the pattern produced by light of wavelength λ passing through a slit of size a and then traveling a distance L to a screen.

This relation will provide the model for us to test.

Part 1. Single Slit Diffraction

Notice that the diffraction equation presented in the introduction has the form of:

$$y = mx \tag{4.2}$$

Where $y = \Delta y_{dark}$ and the other variables can be included in x and m. For example we could take $x = L/a$ in which case $m = \lambda$. Or $x = \lambda L/a$ in which case $m = 1$. This allows us to test the model using the new analysis tools you learned this week for linear fitting.

Quick Check: Let's first set things up and see if we can observe the relevant physics. Fix the PASCO diffraction wheel into the optics track at one end.

At the other end, place the viewing screen. Set the PASCO wheel to one of the "Single Slits". Now pick one of the lasers and shine it through the slit onto the screen. Do you see a pattern like one on the previous page?

Try the other two laser colors. Does the size of the pattern change?

Try it with the flashlight. Do you still see a pattern? Why not?

Designing Your Experiment: Now design a high precision experiment to test the model as precisely as possible.

- To simplify things, you may use the beaker clamp to hold the light sources steady.
- The more measurements you take, and the wider the range of measurements you take, the more confident you can be in your measurement. Try as many different slit widths a and distances L as possible. For a given a and L measure as many Δy_{dark} as possible.
- You may want to tape some paper onto the viewing screen so that you can mark locations on the pattern with a pencil.
- Treat reported values as if they were digital measurements, so that e.g. $a = 0.02$ mm means $a = 0.02 \pm .01$ mm.

The laser wavelengths are reported by the manufacturer to be:

$$\lambda_{red} = 650 \pm 20nm \tag{4.3}$$

$$\lambda_{green} = 530 \pm 20nm \tag{4.4}$$

$$\lambda_{violet} = 425 \pm 20nm \tag{4.5}$$

Check in with Another Group: Briefly discuss your plans with another group. They may provide you with additional ideas and feedback. Note one similarity and one difference between your approaches.

Conducting Your Experiment: Go for it. Above all, try to minimize uncertainty as much as you can! Remember you want to get conclusive t-scores and to test the model over a wide range of inputs.

Make a Plot: For this lab, you should plot your y vs. x data in excel or other software. Make sure to "set intercept=0".

Check in with Another Group: Check back in with the same group you discussed things with before. How do your results compare? Note two similarities and/or differences between what you found, and use this to inform your proposals for future iterations.

Forming a Conclusion: What did you find? Was the model accurate? If it wasn't, is there any way you can modify it slightly so it would be?

Part 2. Finding Patterns

Regardless of what you found in Part 1, we'll continue to investigate other patterns to see if they obey the equation:

$$\Delta y = \lambda \frac{L}{a} \tag{4.6}$$

But since other patterns may look different, we'll need to define Δy differently.

Additionally, if you find that the model 4.6 is not accurate, you should propose a new model:

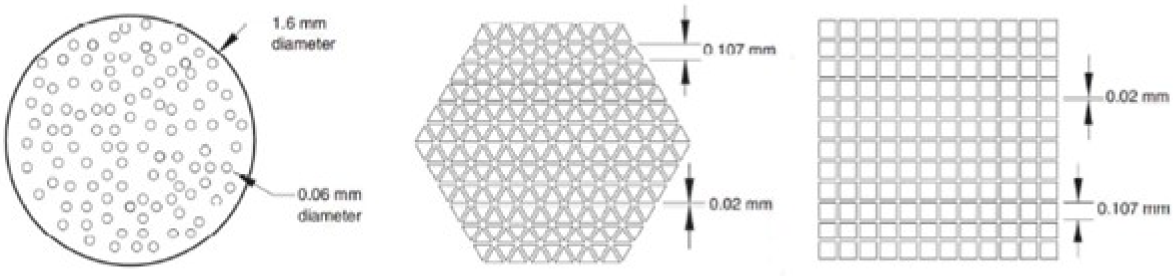
$$\Delta y = g(\lambda \frac{L}{a}) \tag{4.7}$$

Where g is a dimensionless constant of your choice. *Hint: This is a good option if your data is linear but the slope is different than expected and you're confident your data is correct.*

Quick Check: Change the diffraction wheel to one of the "circular aperture" settings. Try shining the red laser through the circular slit. You should see a new pattern that's different from the slits we were using before. Try the green and violet lasers too.

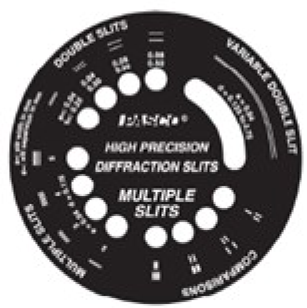
Does the pattern change in about the same way as it did for the slits? In order to think critically about this question you'll need to define a Δy. Pick two points on the pattern and use them to define Δy. For example it could be the distance from the center of the pattern to one of the rings, or the distance between dark spots.

Now swap to one of the "Square", "Hex", "Dots" or "Holes" apertures.



Your choice. Define a Δy for the new pattern. Does it get bigger or smaller roughly the same way as it did in Part 1?

There's also another wheel with multiple slit patters. Take a look at it to see your options.



Design a high-precision experiment to test to see if two new patterns also obey some version of the relation:

$$\Delta y = \lambda \frac{L}{a} \tag{4.8}$$

Where you will define Δy yourself. One of the two new patterns must be the "Circular Apertures". The other can be anything else on either of the two wheels. Keep in mind:

- Depending on how you define Δy there may only be one measurement per pattern or many
- Depending on which pattern you use, you may also need to redefine a or there may be no definition of a available at all (then what?)

Conducting Your Experiment: Conduct the experiment as planned. As always, make sure to minimize uncertainty.

Make a Plot: For this lab, you should plot your y vs. x data in excel or other software. Make sure to "set intercept=0".

If you find the model does not work as expected, is there a way you could modify it that would eliminate the discrepancies with the data?

Forming a Conclusion: What did your experiment reveal? Was the model accurate? Again, if it wasn't, is there any way you can modify it slightly so it would be?

Writing Up Your Lab Notes for Submission

Write up your notes for Part 1 and Part 2 in an organized way according to the rubric provided.