PHY 252 Fall 2013 Practical Lab: Diffraction

Objectives

- To measure the wavelength of an unknown laser beam using diffraction.

Apparatus

- Optical bench, laser mounted on the bench, screen mounted on the bench, single slit diffraction wheel, 2 meter sticks.

Documents

- This document of instructions to be brought with you to the lab.
- The pre-formatted spreadsheet on the lab computer for data-entry provided at the lab.
- A worksheet containing the questions provided at the lab.

Theory

When light passes through a single slit, it diffracts around the edges of the slit creating a characteristic pattern with peaks of high intensity and valleys of darkness where there is no light. In the limit in which the angle subtended by the projected vertical position on the screen and the slit is small and where the distance to the diffraction minima is much less than the distance from the slit to screen, then the small angle approximation can be used:

$$x_n = \frac{n\lambda D}{a} \tag{1}$$

Here, x_n = the distance from the central maximum to the nth minimum
λ = wavelength of the light
D = distance from the slit to the screen
a = slit width

Procedure

1. Mount the single-slit wheel in the path of the laser beam (between the laser and the screen). Attach a piece of paper across the screen where you see the diffraction pattern. The pattern is most easily seen with the slit near the laser and the screen far away. Try different single slits and observe their diffraction patterns on the screen.
2. Choose a slit that gives a diffraction pattern of reasonable size— spread out enough that you can see three or more diffraction minima on either side of the principle maximum. Measure the distance from the slit to the screen (D) and record the labeled slit width in an Excel spreadsheet at the top.
3. On the paper, carefully mark the positions of the center of the principal maximum and the center of several orders of diffraction minima on either side of it.
4. Take note of the slit width that you chose on the wheel and enter that value into the Excel spreadsheet at the top. Don't bother with an uncertainty for this quantity.
5. Measure the distance of each minimum from the principal maximum (x_n) and record them in an Excel spreadsheet. Program Excel to calculate the wavelength (λ) using Eq. 1. Use negative (x_n) and n for the positions to the left of the principal maximum.
6. Have Excel calculate the mean value of the wavelength and the standard deviation of the mean value, s at the bottom. Use the standard deviation of the mean value as the uncertainty in your wavelength (λ) as shown on the spreadsheet. (Use a 10% uncertainty if you can't calculate the standard deviation for a loss of 2 points. Indicate which on the worksheet.)

Checklist:

1. **Bring this document with you to class. (Otherwise, –2 points.)**
2. Set up the optical bench as indicated in step 1 and 2.
3. Mark and measure the minima and enter the data in the spreadsheet as in steps 3, 4, and 5.
4. Calculate the mean of your wavelength measurements and enter it on the worksheet.
5. Calculate the uncertainty in your spread of wavelength measurements as in step 5.
6. Indicate on the worksheet whether you did or did not use your calculated uncertainty. If not, lose 2 points and use ±10% as the uncertainty.
7. Enter your final wavelength mean value including uncertainty on the worksheet.
8. Calculate on the worksheet whether your measured value is consistent with the accepted value as shown on the spreadsheet. This must be an actual consistency calculation and is worth 8 points.

Point values:

1. Data sheet — 12 points (10 if the standard deviation is not used)
   a. *Entering D, a* — *2 points*
   b. *Question 1 on worksheet* — *2 points*
   c. *Entering distance data* — *4 points*
   d. *Calculating mean* — *2 points*
   e. *Calculating standard deviation* — *2 points*
2. Consistency calculation: — 8 points

Total: 20 points

Here is a screen shot of the spreadsheet that will be on your workstation in the lab:

Diffraction and Interference

Wavelength of laser light 0.000532 ± 0.000001 mm
(532 ± 1 nm)

Measure quantities — *Calculate the others*

Single-slit Diffraction

Distance from the slit to the screen D		mm
Labeled slit width		mm

Order of Diffraction Minimum n	Distance from principle maximum X_n (mm)	Calculated laser wavelength (mm)	
1			
2			
3			
-1			
-2			
-3			
	Mean laser wavelength		mm
	s		mm

s =STDEV(cell1:cellN)/SQRT(N),
where N refers to the total number of measurements)

USING UNCERTAINTIES TO COMPARE DATA AND EXPECTATIONS (from Appendix A)

One important question is whether your results agree with what is expected. Let's denote the result by r and the expected value by e. The ideal situation would be $r = e$ or $r - e = 0$. We often use Δ (pronounced "Delta") to denote the difference between two quantities:

$$\boxed{\Delta = r - e} \tag{1}$$

The standard form for comparison is always *result - expected*, so that your difference Δ will be negative if your value is lower than expected, and positive if it is higher than expected.

This comparison must take into account the uncertainty in the observation, and perhaps, in the expected value as well. The data value is $r \pm \delta r$ and the expected value is $e \pm \delta e$. Using the addition/subtraction rule for uncertainties, the uncertainty in $\Delta = r - e$ is just

$$\boxed{\delta\Delta = \delta r + \delta e} \tag{2}$$

Our comparison becomes, "is zero within the uncertainties of the difference Δ?" Which is the same thing as asking if

$$\boxed{|\Delta| \leq \delta\Delta} \tag{3}$$

Equation (2) and (3) express in algebra the statement "r and e are compatible if their error bars touch or overlap." The combined length of the error bars is given by (2). $|\Delta|$ is the magnitude of the separation of r and e. The error bars will overlap (or touch) if r and e are separated by less than (or equal to) the combined length of their error bars, which is what (3) says.