LAKE FOREST COLLEGE
Department of Physics

Physics 115 **Experiment #12: Diffraction** Spring 2025

Name: Ilana Berlin
Partner: N/A
Date: 4/20/2025
Table:

Preliminary Instructions

Create a folder for you and your lab partner on Teams. Save a copy of these instructions for each student to that folder. Include your name in the filename. As you edit this document put your text in a different color. Save one copy of the Excel template with both your and your partner's name included in the filename.

Experimental Purpose

The purpose of this experiment is to study the behavior of diffraction gratings and use the diffraction patterns to measure the wavelength of the laser light.

Background

A grating consists of many closely spaced narrow slits. When a laser is directed through these slits, an interference pattern results as shown in the diagram below. The angular position of the *m*-th bright spots is given by

$$d\sin\theta_m = m\lambda \quad (1)$$

where *d* is the spacing between slits in the grating and λ is the wavelength of the laser light.

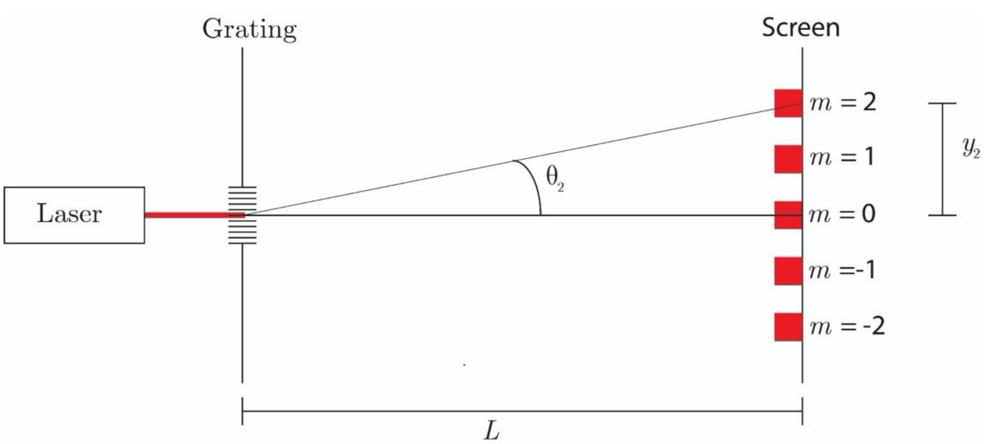


Figure 1: Schematic diagram of light passing through a grating. *L* is the distance from the grating to the screen. Discrete intensity maximum seen on a screen are labeled by an integer *m* counting from the center of the pattern. The position of the *m*-th maximum relative to the center of the pattern is denoted as y_m.

Warning: The laser is a device that can produce an intense, narrow beam of light at one wavelength. Never look directly into the laser beam or its reflection from a mirror, etc.

Procedure:

Red diode laser

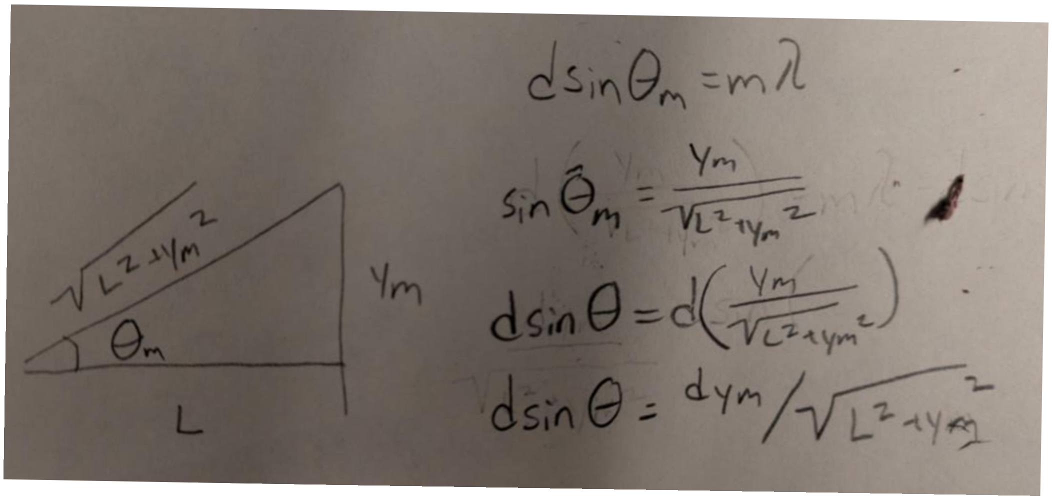
1. Position the red diode laser on the optical rail roughly 50 cm from the screen. Ensure that the line from the laser to the grating is perpendicular to the flat board, which will be used as a screen. Tape a white piece of paper to the screen.
2. Use the meter-stick to position the diffraction grating on the optical rail L=40 cm from the screen.
3. Move the grating in the holder so that the laser beam passes through the 100 lines per mm grating and towards the screen. Adjust the grating to be perpendicular to the laser beam.
4. Use the given line density (100 lines per mm) to calculate the spacing between lines, d. Convert this line spacing into nm.
5. You should see several bright spots on the screen. The center spot is the $m = 0$ spot. The center of this central spot is defined to have a position $y_0 = 0$. The spots on the right are denoted as $m = 1$, $m = 2$, etc. The spots on the left are denoted as $m = -1$, $m = -2$, etc. See Figure 1 for more details.
6. Mark the centers of the observed spots with a pencil and label them by their order number, m.
7. Measure the distance from the center of each of these spots to the center of the central spot and record them in your Excel sheet. For $m = -1$, $m = -2$, etc., the positions are negative. Measure as many spots as you can see. Add additional rows to the spreadsheet if necessary. **Take a picture of the observed pattern and paste it here.** As always, include a caption.

Figure 1. Light Patterns of a red laser. Each mark represents a bright spot. The black mark represents the original bright spot when the laser does not pass through a diffraction grating. The red marks represent the bright spots when the laser passes through a grating 100 lines/mm and the blue marks represent the bright spots when the laser passes through a grating with 300 lines/mm.

8. Turn off the laser by unplugging the power pack from the wall.
9. Use trigonometry to show Equation 2. **Include your derivation here**.

$$d\ \sin\theta_m = \frac{d\ y_m}{\sqrt{L^2 + {y_m}^2}} \qquad (2)$$

Figure 2. Diffraction Grating equation derivation. Sin θ_m can be calculated using trigonometry; sin is the opposite over the hypotenus. L is the length between the screen and the diffraction grating and y_m is the distance between the point m and the point of origin y_o. D is 1/line density, m is the integer number of points from the origin and λ is the wavelength of the light.



10. Use an Excel formula of equation 2 to calculate $d \sin\theta_m$ for each of your data points.
11. **Paste Table I of your Excel sheet here.**

RED LASER	d (mm)	d (nm)
100 lines/mm	0.0100	10000.0

L (cm)	m	y_m (cm)	d $\sin\theta_m$ (nm)
41.5	4	10.9	2540.34
	3	8.18	1933.88
	2	5.50	1313.81
	1	2.75	661.20
	0	0.00	0.00
	-1	-2.50	-601.320
	-2	-5.20	-1243.29
	-3	-7.95	-1881.45
	-4	-10.9	-2540.34

Table 1. Red Laser 100 lines/mm measurements. D was calculated by dividing 1 by the line density, 100 lines/mm. The length between the diffraction grating and the screen, L was measured with a yard stick. The distance between the origin and the points m away , y_m was measured with a ruler. Dsin was calculated using the equation derived above.

12. Move the grating to direct the laser through the grating marked 300 lines/mm. Repeat steps 4-10 with the new grating and record your results in Excel Table II. **Paste Table II here.**

RED LASER	d (mm)	d (nm)
300 lines/mm	0.00333	3333.33

L (cm)	m	y_m (cm)	d sinθ_m (nm)
41.5	2	16.4	1225.08
	1	7.75	611.91
	0	0.00	0.00
	-1	-7.95	-627.15
	-2	-16.7	-1244.39

Table 2. Red Laser 300 lines/mm measurements. D was calculated by dividing 1 by the line density, 300 lines/mm. The length between the diffraction grating and the screen, L was measured with a yard stick. The distance between the origin and the points m away , y_m was measured with a ruler. Dsin was calculated using the equation dsin = dy_m/sqrt(L^2 + y_m^2).

13. Copy data from both Tables I and II into Logger Pro to make a plot of $d\ \sin\theta_m$ vs m. Note that you will have multiple data points at the same values of m. These data points should be nearly on top of each other. Adjust the data size and style to best show this data.
14. Fit the data to a proportional function. Adjust the fit parameters box to increase the font size and adjust the number of decimal places shown. **Paste a copy of your graph with the fit here.**

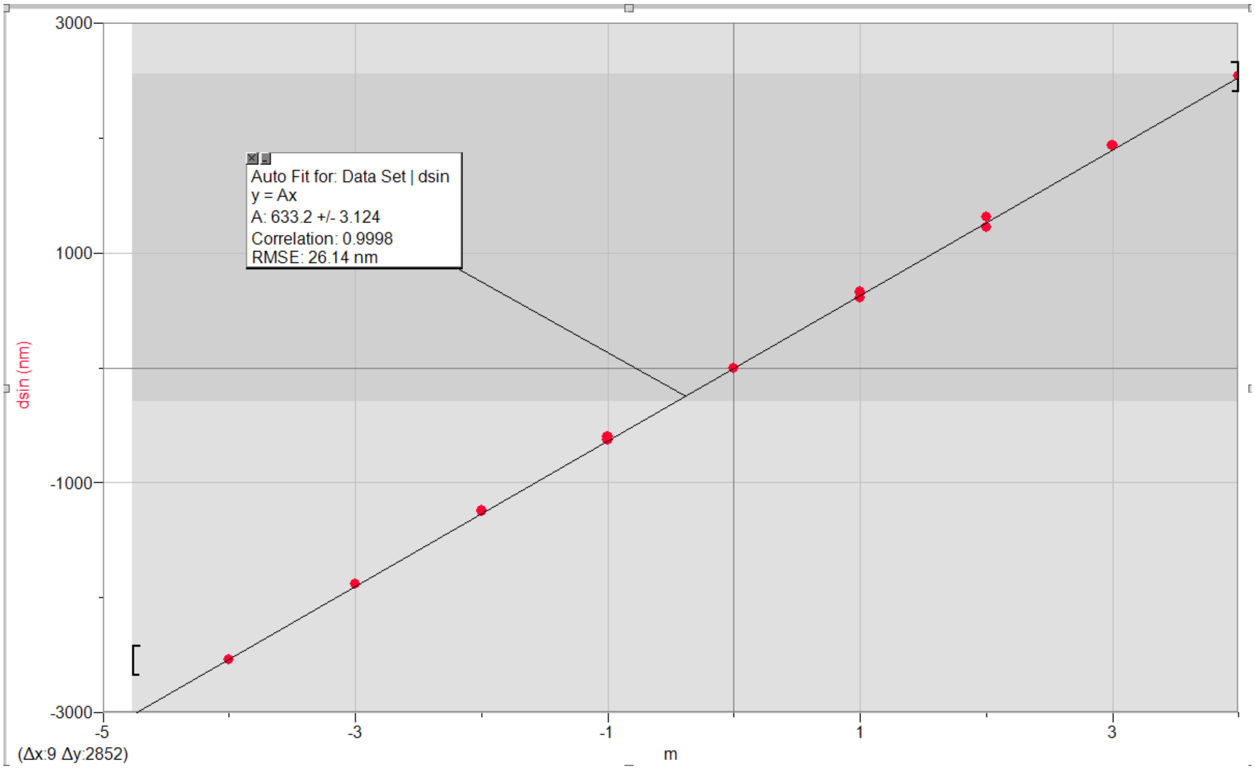


Figure 3. Red Laser Wavelength fitted line. The number of points away from the origin is on the x axis and dsin is on the y axis. The coefficient a is equal to the calculated wavelength of the red laser. High correlation indicates that the line has a close fit to the data.

15. **Show that we expect the slope of this fit to be the wavelength of the light**.
16. Record the wavelength obtained from your fit and its uncertainty into Excel Table III. Use a ratio test to compare your measured wavelength to the nominal value. **Paste table III here.**

measured wavelength (nm)	measured wavelength unc (nm)	nominal wavelength (nm)	nominal wavelength unc (nm)	Ratio test
633.2	3.124	642	7	0.869

Table 3. Measured and Nominal Wavelength Comparison. The measured wavelength and uncertainty come from the fitted line above. The nominal wavelength and uncertainty were given. The measured wavelength and the nominal wavelength agree according to the ratio test.

Green diode laser

17. Replace the red diode laser with the green diode laser. Observe the pattern.
18. Repeat steps 3-16 for both the 100 lines/mm and 300 lines/mm grating. Record your results in Excel Table IV-VI. **Paste the data tables and plot here**.

GREEN LASER	d (mm)	d (nm)
100 lines/mm	0.01	10000

L (cm)	m	y_m (cm)	d sinθ_m (nm)
41.5	6	13.1	3010
	5	11.2	2606
	4	8.85	2086
	3	7.18	1705
	2	4.95	1184
	1	2.25	541.4
	0	0.00	0.00
	-1	-1.95	-469.4
	-2	-4.28	-1026
	-3	-6.58	-1566
	-4	-8.95	-2108
	-5	-11.3	-2627
	-6	-13.5	-3093

GREEN LASER	d (mm)	d (nm)
300 lines/mm	0.003333	3333.3

L (cm)	m	y_m (cm)	d sinθ_m (nm)
41.5	3	22.4	1583.3
	2	14.2	1079.1
	1	7	554.4
	0	0	0.0
	-1	-6	-477.0
	-2	-12.9	-989.4
	-3	-21.9	-1555.7

measured wavelength (nm)	measured wavelength unc (nm)	nominal wavelength (nm)	nominal wavelength unc (nm)	Ratio test
520.9	4.096	517	12	0.24

Table 4. Green Laser Measurement and Wavelength Comparison. The values of d, L, y_m, and dsin were all calculated using the same method that was used with the red laser. More bright spots were clearly visible when using the green laser so more points could be measured. The measured wavelength of the green laser agrees with the nominal wavelength according to the ratio test.

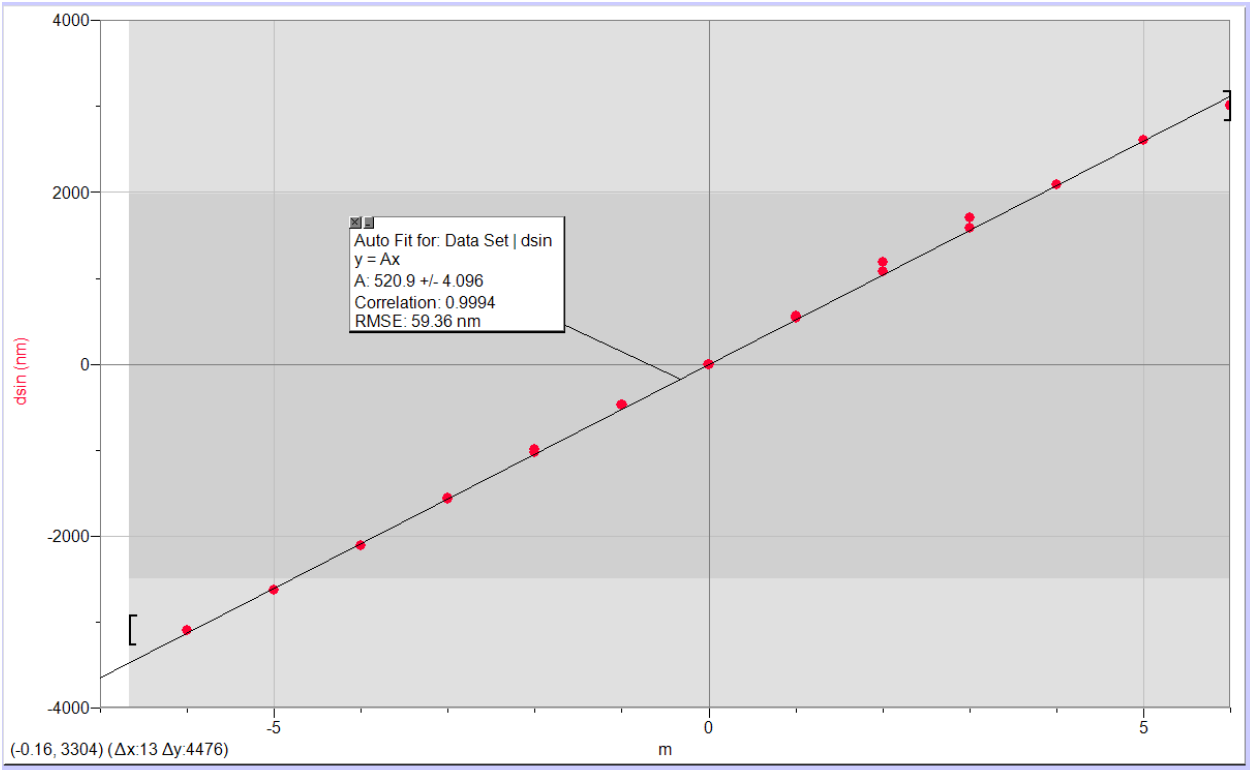


Figure 4. Green Laser Wavelength fitted line. The number of points away from the origin is on the x axis and dsin is on the y axis. The coefficient a is equal to the calculated wavelength of the green laser. High correlation indicates that the line has a close fit to the data.

Questions:

1. Describe what happens to the diffraction pattern when the number of lines per mm of a diffraction grating is increased for fixed distance *L* and fixed laser wavelength λ. Try it.

When the line density of the diffraction grating increased with constant distance and wavelength then the distance between the bright spots increased.

2. Describe the difference in the observed patterns for the green and red lasers for fixed diffraction grating line spacing *d* and fixed distance *L*. Try it.

The green laser created a more condensed pattern. There were more bright spots that were closer together than the pattern created by the red laser in the same conditions.

3. Describe how the diffraction pattern on the screen would change if the distance *L* increases while keeping the laser wavelength and the line spacing of the grating fixed. Try it.

As L decreased the bright sports get more condensed and as L increased the bright spots spread out more. This make sense as L in in the denominator.

Conclusion:

Summarize what you conclude from the results of your experiment.

Using the pattern created by various diffraction gratings we can determine that a red laser have a wavelength of 633.2 ±3.1 nm and a green laser has a wavelength of 520.9±4.1 nm. Both these values agree with the nominal values of the laser.

The pattern created by a diffraction grating depends on the line density of the grating, the wavelength of the light passing thought it, and the distance from the grating to the screen. It would be interesting to see if/how the pattern differs when projected onto different materials such as water.

Final remarks

Adjust the formatting (pagination, margins, size of figures, etc.) of this report to make it easy to read. Save this report as a PDF document. Upload it to the course Moodle page. Double check that your Excel sheet, graphs, and Logger Pro files are saved in your folder on the Team. Clean up your lab station. Put the equipment back where you found it. Make sure that you logout of Moodle and your email, then log out of the computer. Check with the lab instructor to make sure that they received your submission before you leave.