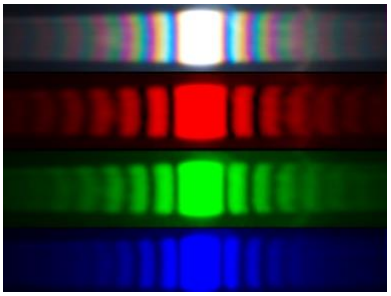


Lab Sim 04: Diffraction of Light

Introduction

A grating takes single-slit diffraction and double-slit interference to its inevitable conclusion: what happens if you use a very large number of very closely spaced slits? Ask an astronomer, and you'll get a very different answer than if you ask a materials scientist. An astronomer uses diffraction to separate starlight into its spectrum, which reveals tons of information about the star's composition. A materials scientist will diffract x-rays through solid matter and tell you all about its crystal structure.

Objectives

- Observe the diffraction of laser light of multiple wavelengths
- Compare the effects of different grating slit-spacings
- Measure the angle of diffracted light and use it to calculate the wavelength of the laser
- Analyze the measurement techniques, identify sources of error, and suggest improvements
- Apply the diffraction geometry to an unknown grating and determine its slit spacing

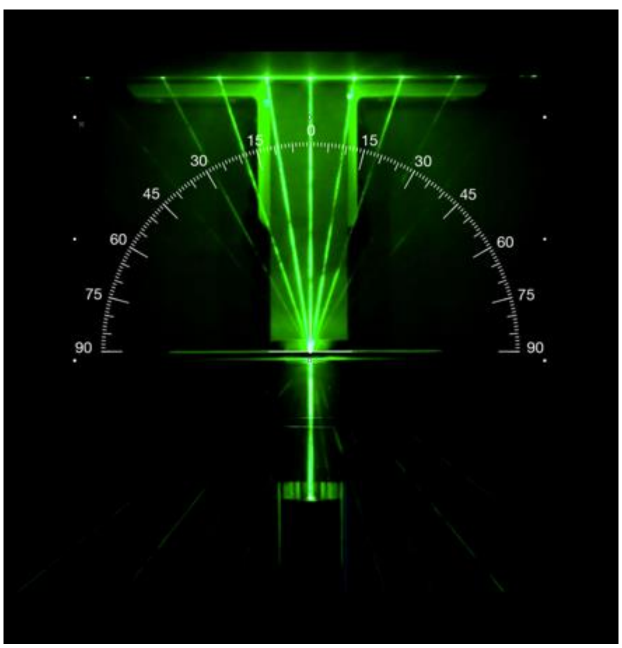
Pivot Interactives

This exercise requires the online simulation (Lab 04: Diffraction). You should sign in to your Pivot account and choose the correct Interactive from the PHYS 1420 selection.

Measuring the Pattern

The second video allows you to control the laser wavelength and the diffraction grid spacing. For this exercise, you should choose one wavelength and measure the diffraction using the same laser, but then testing the array of different gratings.

You may choose whichever wavelength you prefer, but your results might be more accurate with the longer wavelength lasers.



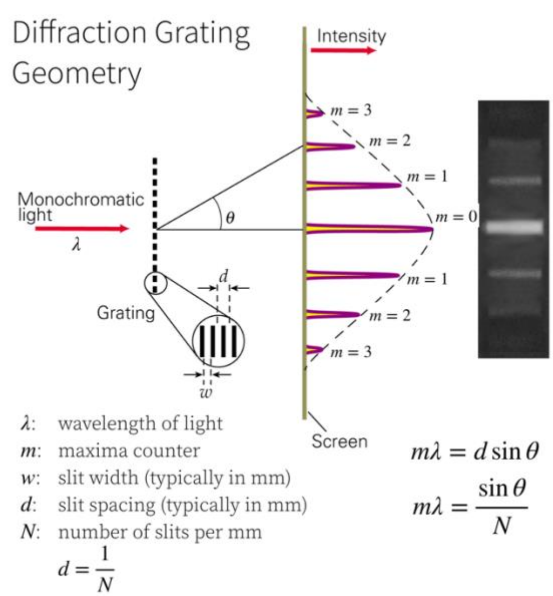
When you position the protractor to measure your angles, notice that it can be both resized and rotated. You might need to adjust the position of the protractor in between trials.

1) (0 points) Which laser are you using to make your measurements?
   A. Violet: $\lambda = 405\text{nm}$
   B. Green: $\lambda = 532\text{nm}$
   C. Red: $\lambda = 635\text{nm}$

Let's set up the geometry of the diffraction problem, then play with the math just a bit to put it into a form that graphs easily and gives us a meaningful slope!

The grating is described by N, given in lines/mm. The value we need is d, which is: $d = \frac{1}{N}$. This is the slit spacing in mm.

The angle θ is what you will measure for as many of the maxima m as are visible. It won't be the same for each grating.



The diffraction equation is $d\sin\theta = m\lambda$. Notice that if we just re-order the terms and squint a little, we get something useful:

$y = mx$ becomes: $d\sin\theta = (\lambda)m$

So, if we plot $d\sin\theta$ on the y–axis and m on the x–axis, we should get a line whose slope is the wavelength λ.

2) (10 points) Measure and record the data for each grating using the same laser. You will have the same value for d for all the data from one grating while m and θ are increasing. Then, when you switch gratings, d changes, and you begin again with m and θ.

Slit Spacing d (m)	Maxima m (unitless)	Angle θ (°)

You will need to add a column to the table where you calculate $d \sin\theta$. Watch your units! Make sure you have d in meters (not millimeters!).

Measuring the Wavelength

Plot $d \sin\theta$ as a function of m. Make sure you perform the linear regression on the data.

3) (2 points) What is the experimental value for the wavelength of your laser? Express your answer in nanometers ($1\text{nm} = 10^{-9}\text{m}$).
4) (1 point) Compare your slope in nanometers to the known wavelength. Is your value within the range of the known uncertainty?
   A. Yes!
   B. No!
5) (2 points) Calculate the percent error in your experimental average: $\%error = \left[\frac{\lambda - \lambda_{av}}{\lambda}\right] \times 100$, where λ is the given wavelength of the laser, and λ_{av} is the slope of your graph
6) (5 points) I suggested that using the longer wavelength lasers might yield more accurate results. Why? Or, conversely, why would the *shorter* wavelength yield *less* accurate results?

Determining the Slit Spacing For a Grating

In the third set of videos, three wavelengths of laser are diffracted by a grating with unknown line spacing.

In this exercise, you will be using the same slit plate each time but switching to different lasers.

7) (10 points) Collect the data as you did previously, assuming that the wavelength λ is known, but the slit spacing d is not.

Wavelength λ (m)	Maxima m (unitless)	Angle θ (°)

To calculate:

$m\lambda = d\sin\theta$ or $\sin\theta = \frac{m\lambda}{d}$ becomes

$\sin\theta = N(m\lambda)$ or $N = \frac{\sin\theta}{m\lambda}$

You will need to add a column to your data table to calculate N in lines/mm. Watch your units!

8) (2 points) Calculate the average line spacing, N_{av}.
9) (3 points) How close did you get? If the actual slit spacing is $N = 500\text{lines/mm}$, what is your percent error?

When you have completed this lab exercise in Pivot, please be sure to submit your responses. This lab is due no later than Thursday, 21 July 2022, at 11:59 PM CDT.