Diffraction and Interference

Spring 2024

Introduction

This lab consists of three self-contained experiments. Each experiment demonstrates some aspect of the principle of diffraction and interference. The order in which you perform these experiments does not matter.

I. *The diffraction pattern of one and two slits*:

In this experiment you will see the diffraction and interference patterns resulting from single-slit and double-slit apertures, and then observe the effect of increasing the slit width and the spacing between slits. ***Note****: lasers are used in this experiment; exercise caution at all times!*

a. One optical bench projects a laser beam through a single narrow slit. Sketch the pattern that appears on the screen. You can represent the image viewed by drawing small circles or ovals.

b. Slowly rotate the disc *counterclockwise* and observe the change in the pattern as the slit width increases (stop turning the disc when the pattern disappears). Sketch the pattern with the slit width at its widest setting. Describe how the pattern changed as the width increased. Please reset the disc to its initial position!

c. The other optical bench projects a laser beam through a pair of closely spaced slits; each slit is the same width as the single slit on the first optical bench. Sketch the pattern observed

d. Discuss the effect of adding the second slit on the pattern compared to that viewed in part (a).

e. Slowly rotate the disc *counterclockwise*; this will increase the separation of the slits (the width of each slit remains constant). Move closer to the screen and look closely at the pattern observed when the separation is at its widest, sketch it and again describe how the pattern changed.

f. *Reset both discs to their initial positions when finished*.

II. *The wavelengths of red and green diode lasers:*

The diffraction pattern of very many extremely narrow slits (instead of one or two as above) is a set of images of the incoming light source, bent at angles depending on the wavelength, as given by *Eqn. 1*:

$$m\lambda = d\left(\sin\theta\right) \qquad (Eqn.\ 1)$$

where **d** is the spacing between the slits, $\boldsymbol{\theta}$ is the angle, **m** = 0, ±1, ±2 . . . is the *order* of the image observed, and λ is the wavelength of light. You will calculate the wavelength of the green and red light emitted from each diode laser. ***Note****: lasers are used in this experiment as well; exercise caution at all times!* PLEASE DO NOT ROTATE THE WHEEL THAT CONTAINS THE GRATING OR CHANGE ITS POSITION ON THE OPTICAL BENCH!

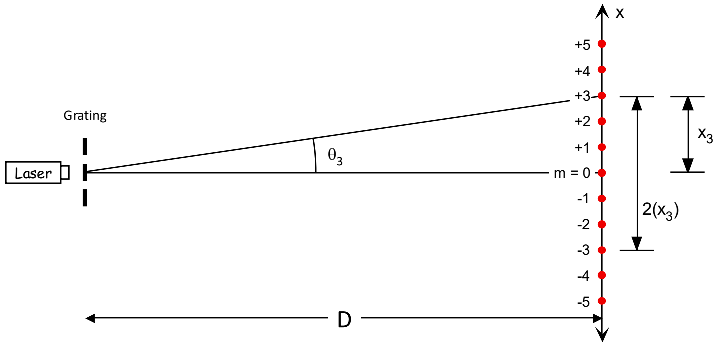

Figure 1: Images produced on a screen when laser light passes through a diffraction grating

a. Each optical bench is set so that the laser shines through a diffraction grating with spacing **d** = 0.0125 *cm*. Measure the distance **D**, from the point directly below the aperture wheel (*not* the pointer on the aperture wheel support!) to the front of the screen (**Figure 1**). Check that **D** is the same for each bench.

b. Create a data table in your journal with the following headers, with space for values of **m** from 1 to 5. You will need a separate table for each laser:

m	$2(x_m)$ (*cm*)	x_m (*cm*)	λ (*cm*)	λ (*nm*)
1				

c. The screens of each optical bench are touching each other. Tape a piece of graph paper across both screens, then carefully mark the centers of the bright spots that appear; mark the position for images **m** = 0 to ±5 for both colors. While the paper is still on the screen, make a note of the spot corresponding to the zeroth dot (it's in the center, and a little brighter than the others). Mark this set of images with the color of the laser used and then remove the target sheet.

d. The spacing of the spots is small, so to improve the accuracy of the results, measure the distance $2(x_m)$ for each matching pair of images (**m** = ±1, ±2 . . .), as shown in **Figure 1**, then calculate the distance x_m for all 5 orders. Do this for both lasers.

e. The angle θ is sufficiently small so that the *small angle approximation* can be applied:

$$\sin\theta \approx \tan\theta = \frac{x}{D}$$

Applying this approximation to *Eqn. 1* gives us the following (*Eqn. 2*):

$$m\lambda = d\left(\frac{x_m}{D}\right) \qquad (Eqn.\ 2)$$

Use *Eqn. 2* to calculate the wavelength, λ for each order image (in *cm* and *nm*), and then calculate the average of the five values (in *nm*). Repeat for the other laser, and then compare your averages with the accepted wavelengths: $\lambda_{\text{Red Laser}} = 650$ *nm*; $\lambda_{\text{Green Laser}} = 532$ *nm*. *If your error is more than about 5%, you should recheck your measurements of **D** and **x**!*

f. *The target sheet should be included with your journal (or your partner's).*

III. *The color limits of vision:*

At the back of the lab there is an incandescent bulb mounted on the wall. You will be measuring the range of wavelengths that you can see by examining the span of the *continuous spectrum* on the left side of the bulb.

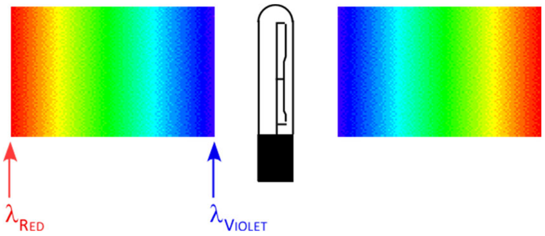

Figure 2: Incandescent bulb as it appears when viewed through a diffraction grating

a. Hold one of the 2×2 slide gratings (d = 1900 *nm*) so that you can read the label on the slide and look through the grating at the incandescent bulb. You will see a pattern similar to that depicted in **Figure 2**.

b. A meter stick is placed behind the bulb, with a pointer indicating a distance x = 1.0 *m* from the filament in the bulb (**Figure 3**). While looking at the bulb through the grating, move closer to or farther away from the bulb until the *outermost edge* of the red area is located at this pointer. Measure your distance **D** from the bulb by using a 2-*m* stick as a "staff" to mark your position along the meter sticks taped to the floor.

c. Repeat your distance measurement for the *innermost edge* of the violet region. Have each person in your group take these measurements so that you can compare your results.

d. Note that the angles are sufficiently large so that you *can't* use the small angle approximation for this experiment! Use trigonometry to calculate θ at each position (see **Figure 3**), and then use *Eqn. 1* to calculate the wavelengths of the most extreme red and violet that you can see (what is the value of **m** for this experiment?).

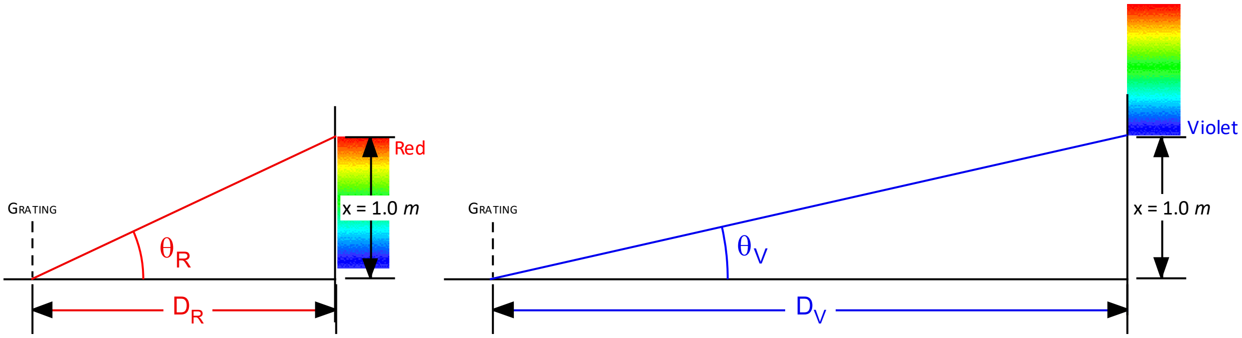

Figure 3: Measuring the angle of the most extreme red and violet ends of the continuous spectrum

e. Calculate the % difference between your measured wavelengths to the theoretical color range of vision: 400 *nm* (violet) – 700 *nm* (red). Record your partner's measured values of λ and briefly comment on any significant differences.

Important note: Keep in mind that *purple* and *violet* are not the same colors. Purple is a mixture of red and blue, while violet is a primary color. *Be sure to use the correct terminology*.