

Diffraction grating experiments

Warning: Never point any laser into your own or other people's eyes.



Materials and tools

- Diffraction glasses (diffraction grating 1000 lines/mm)
- Flashlight
- Laser pointers (red, green, blue)
- Other light sources (light bulbs, arc lamps, etc.)
- Rulers
- White paper for screen
- Binder clips
- Graphing paper or computer graphing tools
- Scientific calculator

In these experiments you will use diffraction glasses to perform measurements of light diffraction. Diffraction is a phenomenon that is due to the wave-like nature of light.

Predict

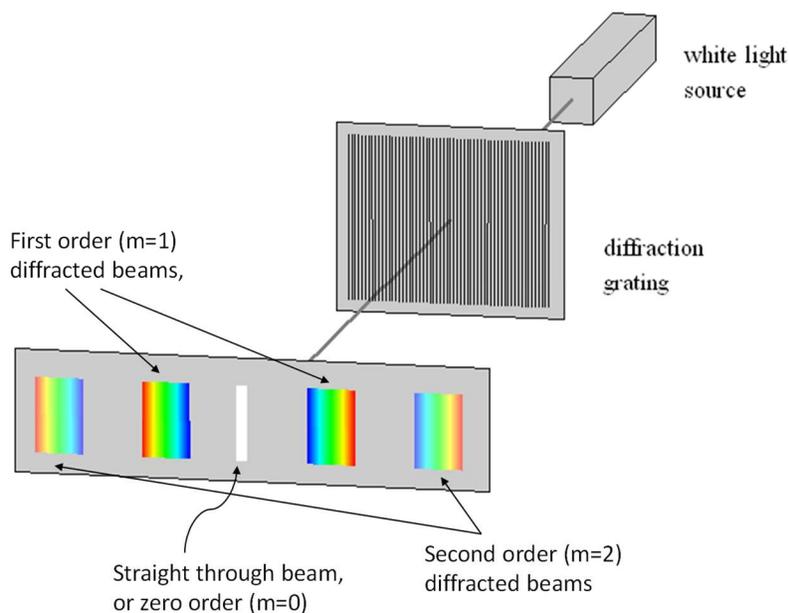
1. What do you think will happen when you shine white light through a prism and why? Draw a picture to show your predictions.

When white light goes through a diffraction grating (diffraction glasses), different colors are bent a different angles, similar to how they are bent by a prism.

2. (a) What do you think will happen when you shine red laser light through the diffraction glasses?
(b) What do you think will happen when you shine blue laser light through the diffraction glasses?
(c) Draw a picture to show your predictions.

Experiment setup

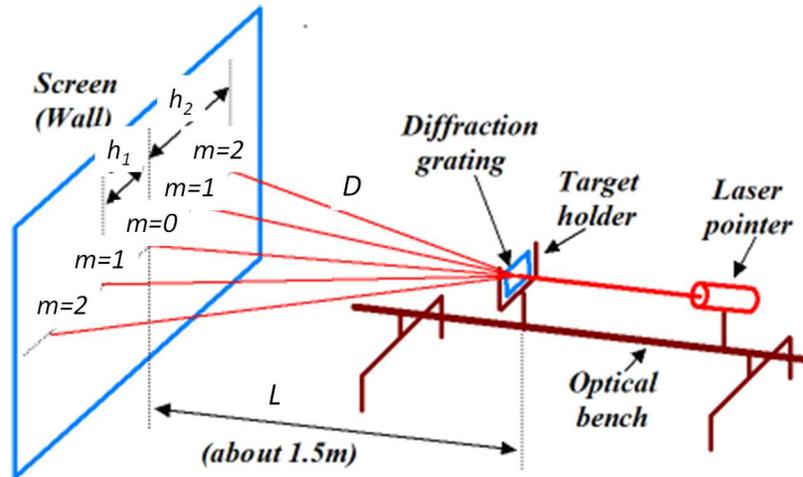
1. For a projection screen, use a white wall, or use binder clips to make a white screen out of paper.
2. Use binder clips to make your diffraction glasses stand up.
3. Secure a light source with tape as needed.
4. Insert a piece of colored plastic between the source and the diffraction grating as needed.



Observation

1. Shine white light through the diffraction glasses and observe the pattern projected on a white screen. Adjust the angle between the beam of light and the glasses to get a symmetric pattern as in the figure above. Describe the pattern. Identify the straight-through (strongest un-bent) beam, and the bent (or diffracted) beams by the bright spots they make on the screen.
2. Use a ruler to measure the distance between the glasses and the white spot on the screen (called "L" in the picture below). Try not to move the glasses and white screen for the rest of the experiments.

- Repeat the experiment with several laser pointers. Describe the bright spots you see on the screen in the Observations column of the table below. Why do you think the spots look different from the case of the flashlight? Find the bright spots corresponding to the un-bent and bent beams.



- For each different light source use a ruler to measure the distance between the straight-through (unbent beam) and the diffracted beams (called " h "). Write these values on the table below.
- Using graph paper or a computer graphing program, plot h as a function of given light wavelength, λ , for all your laser pointers. Do you see a relationship between them? Describe it in words.
- Insert a piece of colored cellophane plastic (called a filter) between the white light from the flashlight and the diffraction grating. Write your observations in the table below. Repeat with a different filter. What do you think the colored plastic does to light?

Going further

- Calculate and fill in the table below the hypotenuse of the right angle triangle made by the straight-through beam, the diffracted beam, and the line connecting the two corresponding bright spots on the screen, $= \sqrt{h^2 + L^2}$.
- Calculate $d \times h / D$ and fill it in the table below for each measured light source. " d " is a property of the glasses called grating spacing. It usually is given in lines per millimeter. In your case $d = 1/1,000 \text{ lines/mm} = 10^{-6} \text{ m} = 1 \mu\text{m} = 1000 \text{ nm}$.

$d \times h/D$ is often written using the angle θ between the straight-through beam and the diffracted beam and the sine trigonometric function as $d \times h/D = d \times \sin \theta$.

9. Plot $d \times h/D$ as a function of given light wavelength and compare the two values. Write your observations here.

The law of diffraction predicts that these two quantities are equal. Do you agree? Why, or why not?

Light source	λ =light wavelength (nm)	L = Distance from glasses to screen (mm)	h = Distance from $m=0$ to $m=1$ beams on screen (mm)	$D = \sqrt{h^2 + L^2}$	$d \times h/D$	Observations
Flashlight						
Red laser	635 nm					
Green laser	520 nm					
Blue laser	445 nm					
Blue-violet laser	405 nm					
White light/red filter						
White light/blue filter						

Take-home fun activities:

Use different kinds of diffraction glasses to look at light sources at home such as light bulbs, stove fire, candle, camp fire, fireworks, etc. How do you think the various diffraction glasses are different?

Explanation: Ripples of light

The diffraction glasses are holographic diffraction gratings. Diffraction gratings are made of many fine transparent vertical stripes (1,000 lines/mm), or slits, like in the picture below, not visible to the naked eye. When light goes through a grating, it does something different than when going through a simple piece of glass (we say it diffracts). On the other side of the grating, you will see a straight-through (un-bent) beam containing all colors (called zero order diffracted beam, or $m=0$ beam), and additional light beams bent with respect to the straight-through beam (called first order diffracted beams, or $m=1$). There are two such first order diffracted beams, one on each side of the straight-through beam. In these diffracted beams, the colors are separated due to diffraction. So for a white light (such as from a flashlight), you will see a rainbow. For laser pointers, you may also see higher order diffracted beams ($m=2,3, \dots$), or beams bent even more on each side of the un-bent beam, but they usually get too faint fast.

How does the diffraction grating work?

You may have heard of light as being made of particles called “photons”. Light is also like a wave. Imagine ripples on a pond. They have peaks and valley that move on the surface. The distance between two neighbor peaks (or two neighbor valleys) is called the **wavelength**. What we see as different “colors” are actually light of different wavelengths. The wavelengths of visible light are very small (400-700 nm, $1 \text{ nm}=10^{-9} \text{ m}$).

When two ripples meet, we say they interfere. Depending on how the peaks and valleys come together, interference can make much larger waves (called **constructive** interference). They can also make much smaller waves than the original ones, or no wave at all (called **destructive** interference)



Diffraction happens because light is also a wave. Each of the many slits of the diffraction grating emits light in all directions. If the distance between the slits is very small, light coming from the slits doesn't just add up. For special angles, the peaks of the waves from all slits arrive at the same time giving a bright spot. For all other angles, both peaks and valleys arrive at the same time, and there is no significant net light.

The bending angle for bright spots increases with the light wavelength. Red light has longer wavelength than blue light, so the red diffracted beam will be found at a larger angle than the blue diffracted beam, or the red dot will be further away from the blue dot on the screen. As a result, the colors composing white light are spread out at different angles that we see as a rainbow. The effect is similar with the prism effect, but the reason for the spreading of the colors is very different.

Diffraction Grating

The maxima of the diffraction pattern are defined by

$$\sin \theta = \frac{m\lambda}{d}, \quad m = 0, 1, 2, \dots \quad \left[\begin{array}{l} \text{diffraction grating,} \\ \text{principal maxima} \end{array} \right]$$

