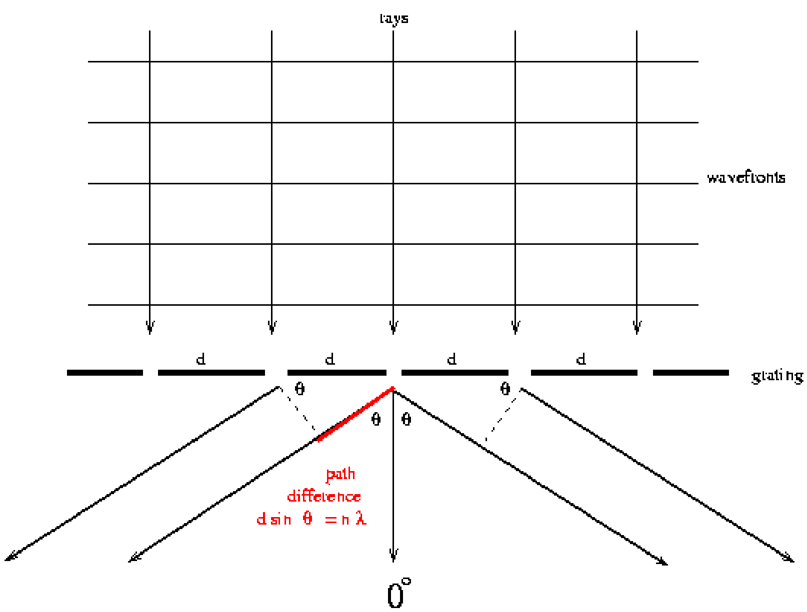
Diffraction Experiment

Purpose: To use diffraction to find the wavelengths of the helium-neon, red diode, and green diode lasers.

Background and Method:

A diffraction grating is a small piece of plastic on which are scribed parallel lines very close together. A parallel bundle of rays falls on the grating. Rays and wavefronts form an orthogonal set so the wavefronts are perpendicular to the rays and parallel to the grating as shown.

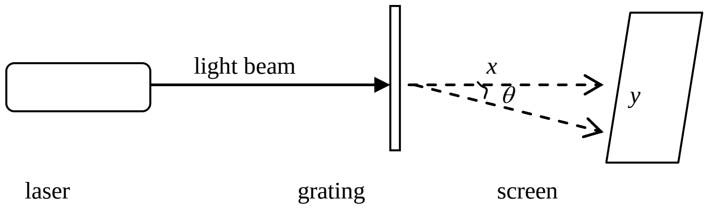


Utilizing Huygens' Principle, which is that every point on a wavefront acts like a new source, each transparent slit becomes a new source so cylindrical wavefronts spread out from each. These wavefronts interfere either constructively or destructively depending on how the peaks and valleys of the waves are related. If a peak falls on a valley consistently (called destructive interference), then the waves cancel and no light exists at that point. On the other hand, if peaks fall on peaks and valleys fall on valleys consistently (called constructive interference), then the light is made brighter at that point.

Consider two rays which emerge making an angle θ with the straight through line. Constructive interference (brightness) will occur if the difference in their two path lengths is an integral multiple of their wavelength (λ) i.e., difference = nλ where n = 1, 2, 3, ... Now, a triangle is formed, as indicated in the diagram, for which

$$n\lambda = d \sin(\theta)$$

and this is known as the DIFFRACTION GRATING EQUATION. In this formula θ is the angle of emergence (called deviation, D, for the prism) at which a wavelength will be bright, d is the distance between slits (note that d = 1 / N if N, called the grating constant, is the number of lines per unit length) and n is the "order number", a positive integer (n = 1, 2, 3, ...) representing the repetition of the spectrum. Thus, the colors present in the light from the source incident on the grating would emerge each at a different angle θsince each has a different wavelength λ. Furthermore, a complete spectrum would be observed for n = 1 and another complete spectrum for n = 2, etc., but at larger angles.



$n\lambda = d \sin \theta$ $\theta = \tan^{-1} (y/x)$

n = order number
λ = laser wavelength
d = slit width or slit spacing
θ = angle of beam from central maximum for given order bright line
y = distance from central maximum to given order bright line
x = distance from diffraction grating to central maximum

- Do not assume a small-angle approximation for θ, i.e., that $\sin \theta \approx \theta$. Instead, measure x and y and calculate the angle.
- Make angle measurements and calculations for the first three orders (if possible) for each laser and each diffraction grating.
- Repeat angle measurements and calculations using three diffraction gratings of different slit spacings.
- Perform the above 9 trials for each of the three lasers, averaging the calculated values of wavelength to report a wavelength for each laser.
- Calculate a percent error for your reported value of laser wavelength for each laser.

Analysis:

Some suggested ideas to incorporate into the analysis include:

- What is the effect on the projected pattern of changing distance between laser and diffraction grating or changing distance between diffraction grating and projection screen?
- How does the pattern change with changes in laser color?
- How does the pattern change with changes in slit spacing?
- How does the pattern change if the grating is rotated?
- Why are only 2 or 3 orders visible for some gratings? (Substantiate your answer with a sample calculation.)
- How do the diffraction slit spacing widths compare to the wavelengths being examined?
- Which laser color produced best results?
- Discuss the precision *vs* accuracy of your results.