LU3: LAB 1-1B: Determining the Wavelength of Red Light

REFERENCES:

- *Fundamentals of Light & Lasers* (OPTEC), 2nd edition
- Module 1, Laboratory 1-1B, page 37-38.
- http://optecvideo.opteccrm.org, Video 2
  - Course 1: Fundamentals of Light and Lasers
  - Lab Activity Video
  - Choose Video #

THEORY: A diffraction grating consists of a multitude of closely spaced parallel slits. Light passing through the grating will produce an interference pattern in a way similar to that produced by a double slit. If a monochromatic (single color) light beam is directed through the grating, a pattern will be formed with a bright fringe at the center and a series of bright fringes on each side of the center fringe. The wavelength of the light can be determined from this diffraction pattern.

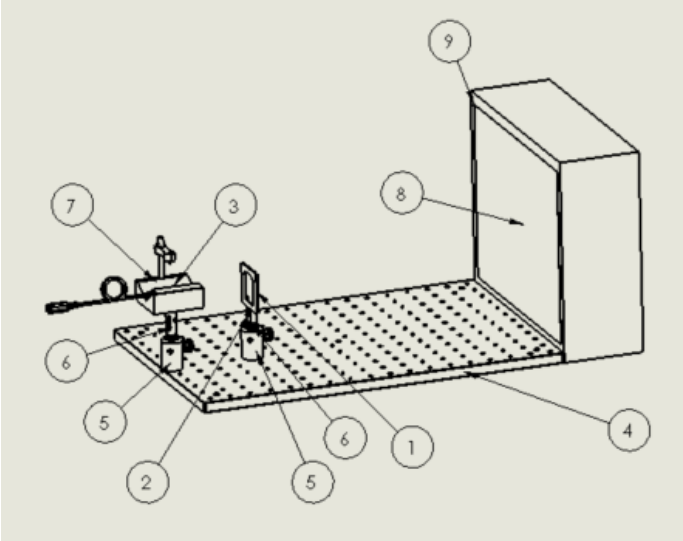
OBJECTIVE: Determine the wavelength of red light by analyzing the pattern generated by a diffraction grating.

EQUATIONS:

- $\lambda = d \sin \theta$
  - λ = Greek letter lambda, wavelength of incident light
  - d = distance between slits on the grating
  - θ = Greek letter theta, angle between a beam traveling straight through the grating (perpendicular to the surface of the grating) and a line from the center of the beam at the grating to the first bright fringe
- $\theta = \tan^{-1}(x/L)$
  - x = distance from the center fringe to the first bright fringe on either side
  - L = distance from the diffraction grating to the plane of the diffraction pattern (white paper)

EQUIPMENT:

- Diffraction Grating (key 1)
- Filter Holder, Dual (key 2)
- Laser Diode Module (key 3)
- Laser Diode Power Supply
- Optical Breadboard (key 4)
- (2) Post Holder (key 5)
- (3) Post (key 6)
- V-Clamp, Cylindrical Laser Mount (key 7)
- White paper (8-1/2" x 11") (key 8)
- Misc. hardware



SET-UP: Read the entire SET-UP, PROCEDURE, etc. and watch the VIDEO(s) before doing the lab.

1. Mount a post holder near the center of one edge of the optical board.
2. Assemble two post together and mount the assembly to the center hole on the bottom of the V-clamp.
3. Insert the V-clamp assembly in the post holder.
4. Mount a post holder on the breadboard in the same row of holes along the length of the board as the V-clamp.
   a. Mount it as close as possible to the V-clamp while allowing space to work.
5. Attach the filter holder to a post and insert the assembly in the post holder.
6. Attach a piece of paper to a beam block to mark fringe pattern positions.
   a. The paper should be wide enough to reach most of the width of the breadboard (8.5" x 11" will work).
   b. You may move the screen closer to the diffraction grating.
7. Mount the diode laser module in the V-clamp.
   a. Position the laser so the beam will project along the length of the board.
8. Insert the short edge of the diffraction grating in the filter mount.
   a. Adjust heights so that the laser beam will center on the grating.
9. Position the beam block with the paper a short distance from the diffraction grating.
   a. There should be at least three (3) red dots visible on the paper.

PROCEDURE:

1. **Always contain the laser beam. Keep direct and reflected beams away from yourself and others.**
2. Turn on the laser to produce a diffraction pattern on the paper.
    a. The pattern will consist of a center spot with a spot on either side of the center spot.
    b. There will be additional spots beyond the range of the paper.
3. Place a mark on the paper at the midpoint of the center spot.
4. Place marks on the paper at the midpoint of the first spot on either side of the center spot.
5. Turn off the laser.
6. Measure & record **in the Lab Write-Up** per below the distance (x) from the center spot to the first spot on either side.

    x_1 = _____mm x_2 = _____mm

7. Measure and record **in the Lab Write-Up** per below the distance (L) from the diffraction grating to the paper.

    L = _____mm

8. Take a picture of the white work sheet with the marked dots and distances and **include in Lab Write-Up**

CALCULATIONS:

1. All calculations are to be **included in Lab Write-Up**, showing the equation and answer obtained.
    a. Answers are to be recorded and labeled in a table **in the Lab Write-Up**.

2. Determine the angle θ from the equation: $\theta = \tan^{-1}(x/L)$.
    a. Use the average of x_1 and x_2 measured in the procedure for x.
    b. Use L as measured in the procedure.
        i. Record **in Lab Write-Up**.

    $\theta = \tan^{-1}(x/L) = \tan^{-1}$ (_____mm/_____mm) = _____°

3. The wavelength of the light (λ) can be determined from the equation: $\lambda = d \sin\theta$.
    a. The grating has 1000 lines/mm so d = line spacing = (1/1000) mm/line.
    b. Use θ calculated above.
        i. Record **in Lab Write-Up**.

    λ = d sinθ = (1/1000)(sin ____°)mm = _____mm

4. Multiply the result above by 10^6 to convert to nanometers (1 nm = 10^{-9} m = 10^{-6} mm).
    a. Record **in Lab Write-Up**.

    λ = _____nm

DISCUSSION:

- The wavelength of red light is around 650 nm.
    - The diode laser used here has a specified wavelength of ____nm.
- The wavelength can be determined from any of the fringes generated by the diffraction grating.
    - The general equation is $m\lambda = d \sin\theta_m$
        - m = diffraction order (number of fringes from the center)
        - θ_m is the angle between a line from the grating to the m fringe and a line from the grating to the center of the diffraction pattern.
- If a collimated beam of white light is used, the grating will disperse the light into colors.
- A similar effect is seen when light is reflected from a surface with closely spaced grooves such as a CD.