LU5: Lab 1-5B3 Interference & Diffraction: Diffraction Grating and Thin Wire

REFERENCES:

- *Fundamentals of Light & Lasers* (OPTEC), 3rd edition.
- Mod 5, Laboratory 1-5B.3, pages 51-53.
- http://optecvideo.opteccrm.org, Video 18: Read these instructions and watch the videos before doing the lab.
  - Course 1: Fundamentals of Light and Lasers
  - Lab Activity Video
  - Choose Video #

THEORY:

A diffraction grating consists of a multitude of closely spaced narrow slits. An interference pattern will result when monochromatic light is incident on the grating. The pattern can be used to calculate the wavelength of the light or the spacing of the grating.

OBJECTIVE:

Use light with a known wavelength to calculate the line density of a diffraction grating from its diffraction pattern.
Determine the diameter of a very thin wire from the diffraction pattern it produces.
To do a comprehensive and precise Lab Write-up.
Take appropriate pictures (5 or more) to show/prove lab work.

EQUATIONS:

$\lambda = d \sin\theta$, therefore $d = \lambda / \sin\theta$

- d = slit spacing of the diffraction grating
- λ = wavelength of light incident on the grating
- θ = angle between beam to center bright spot and beam to first fringe on either side

$\theta = \tan^{-1}(y/D)$

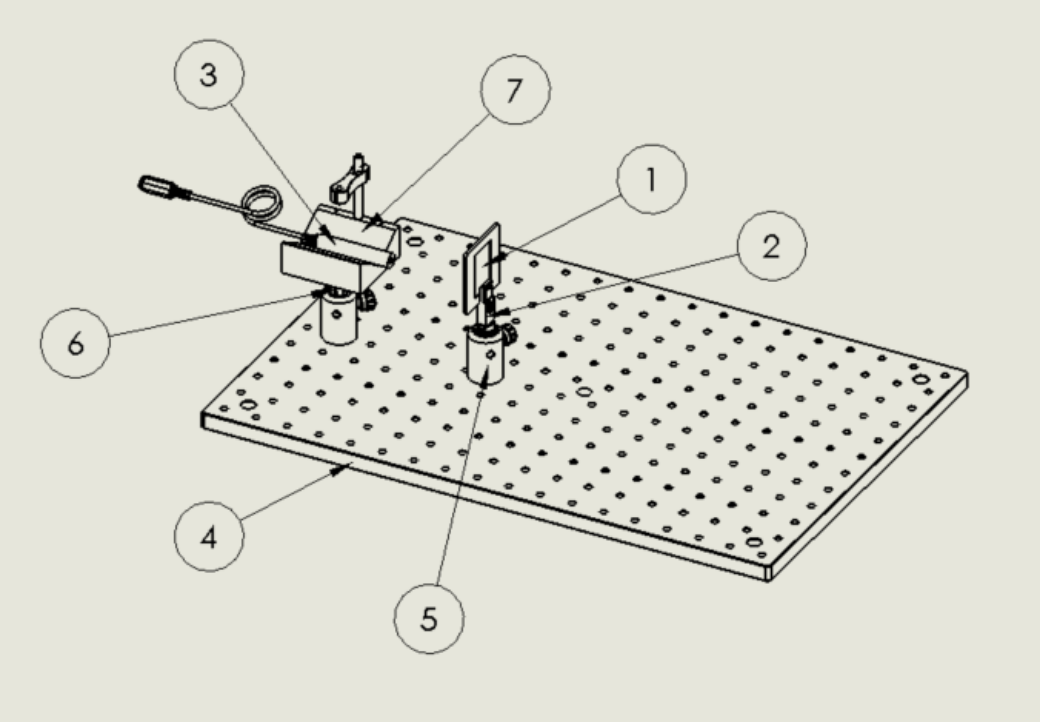
- θ = angle between beam to center bright spot & beam to first fringe on either side
- y = distance from the center bright spot to the first fringe on either side
- D = distance from the diffraction grating to the screen

$d = (\lambda D)/y$ valid for Fraunhofer diffraction around a small object

- d = diameter of object (very thin wire or hair)
- λ= wavelength of light incident on the object
- D = distance from the diffracting object to the screen
- y = distance from the center bright spot to the first fringe on either side

EQUIPMENT:

Diffraction Grating (key 1)
Filter Holder (key 2)
Laser Diode Module (key 3)
Laser Diode Power Supply
Lens Mount
Optical Breadboard (key 4)
(3) Post Holder (key 5)
(3) Post (key 6)
V-Clamp (key 7)



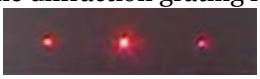
SET-UP: Read the entire SET-UP and PROCEDURE before starting the lab.

1. Mount a post holder near the midpoint at one end of the breadboard.
2. Assemble two posts together and attach them to the center hole on the bottom of the V-clamp.
3. Place the V-clamp assembly in the post holder.
4. Mount the filter holder on a post and insert it into a post holder. Don't mount the post holder on the board.
5. Mount the diffraction grating in the filter holder, center to center.
6. Mount the lens holder on a post and insert it into a post holder. Don't mount the post holder on the board. Lay the assembly aside (to be used in the second part of the lab).
7. Position a screen assembly opposite the laser output to observe the diffraction pattern.
8. Mount the laser diode in the V-clamp.

PROCEDURE (Part 1): Read this complete procedure before following it.

Determine the *line density* of a diffraction grating, **compare** to the given line density and **justify** the difference.

1. Always contain the laser beam. Keep direct and reflected beams away from yourself and others.
2. Adjust the laser so that the beam is projected down the length of the board to the screen.
3. Place the diffraction grating in the laser beam very close to laser. Adjust heights as necessary. Align the grating so that it is perpendicular to the laser beam.
4. A diffraction pattern of symmetric bright spots will be projected on the screen. Adjust screen to contain 3 dots.
    a. If the pattern is vertical, rotate the diffraction grating for a horizontal pattern.



5. **Measure 3 times and record** in the Lab Write-Up the metric distance (D) from diffraction grating to screen.
6. **Measure and record** the metric distance from the center bright fringe to the center of the first bright fringe on either side. Record the distances as y_{left} and y_{right}. Then **calculate and record** the average, $y_{avg.}$
7. **Take a picture(s)** of resultant set-up and include in Lab Write-Up. Include picture of the diffraction pattern.

CALCULATIONS (Part 1):

1. Use $\theta = \tan^{-1}(y_{avg}/D)$ to **calculate and record** the fringe angle for the diffraction grating. Use the average value of y from Step 6 of the Procedure and the value of D recorded in step 5.
2. Use $d = \lambda/\sin\theta$ to **calculate and record** the slit **spacing** of the diffraction grating.
    a. Use θ from above and λ of the laser used.
3. The *line density* of the diffraction grating is the **reciprocal** of the line spacing.
    a. Line Density of the Diffraction Grating = 1/d = _____lines/mm where d is the slit spacing. **Calculate/record.**

PROCEDURE (Part2):

Determine the diameter of a very thin wire (the diameter of the wire must be known).

1. Tape the wire in a straight, vertical position across the lens holder.
    a. After completion of lab, remove the wire and clean the tape residue with wet wipe.
2. Position the wire in the laser beam so that a diffraction pattern is formed on the screen.

3. **Measure & record (3 times and average)** the distance (D) from the wire to the screen
4. Distances between any adjacent fringes will be nearly the same as the distance from the center bright spot to the first fringe on either side. Ignore the center bright spot and take measurements of the distance between adjacent bright fringes. **Measure** four sample readings. **Record** the measurements and **calculate** the average, y_{avg}.

    $y_{sample\ 1}$ = _____mm $y_{sample\ 2}$ = _____mm $y_{sample\ 3}$ = _____mm

    $y_{sample\ 4}$ = _____mm y_{avg} = _____mm
5. The distance between bright spots will be much smaller than for the grating. For this reason, θ will be much smaller. You may approximate that $\sin\theta = \tan\theta$ in this case.
    a. The equation then simplifies into $d = L^* \theta/y$. Since the diffraction angle is so small, it is better to take the AVERAGE distance between bright spots for s and IGNORE the centermost spots.

CALCULATIONS (Part 2):

1. Use $d = (\lambda m D)/y_m$ to calculate the diameter (d) of the wire. Use λ of the laser used, m = 1, and the average y from Step 4 of the Procedure (Part 2) for y_m. d = _____