LU3: LAB 1-3A: Irradiance

REFERENCES:

- *Fundamentals of Light & Lasers* (OPTEC), 2nd edition
- Module 3, Laboratory 1-3A, pages 31-33.
- http://optecvideo.opteccrm.org, Video 8
  - Course 1: Fundamentals of Light and Lasers
  - Lab Activity Video
  - Choose Video #

THEORY: Electromagnetic radiation (light) irradiance is power per unit area. Irradiance is an important concern in laser safety. The potential for eye or skin damage relates to the irradiance of the laser beam. A laser beam focused to a smaller area (higher irradiance) is a higher risk than the unfocused beam. Conversely, a laser beam viewed over the same area but with a diverging beam (decreasing irradiance) will have decreasing risk as the beam diverges.

OBJECTIVE: Measure the power and irradiance of a laser beam. Measure the irradiance of a diverging laser beam to show that the irradiance is decreasing with an expanding beam. Analyze the results.

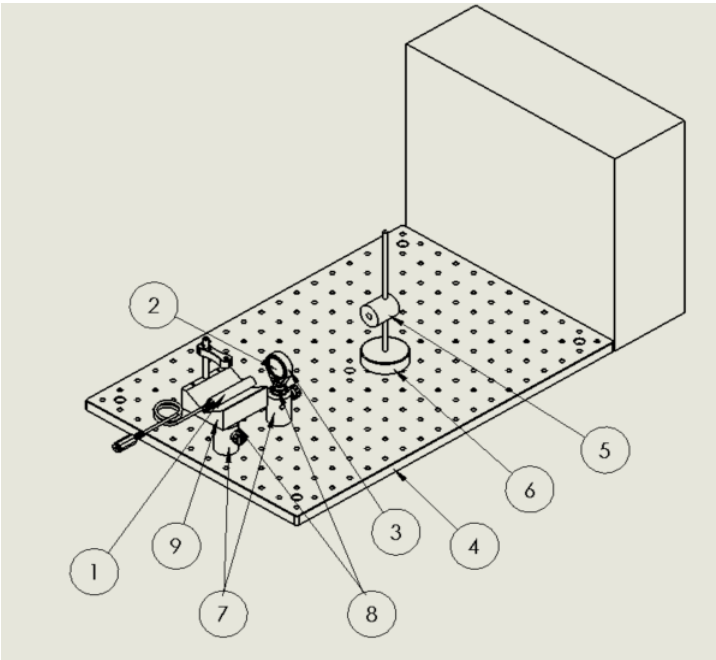
EQUATIONS:

- $E = P/A$
  - E = Irradiance
  - P = Power of the laser beam
  - A = Area of the laser beam

- $A = \pi r^2 = \pi d^2/4$
  - A = area of a circle
  - r = radius of a circle
  - d = diameter of a circle

EQUIPMENT:

- Laser Diode Module (key 1)
- Laser Diode Power Supply
- Lens, Negative (key 2)
- Lens Mount, Fixed (key 3)
- Optical Breadboard (key 4)
- Photometer Detector/Sensor (key 5)
- Stand, Photometer Detector (key 6)
- (2) Post Holder (key 7)
- (2) Post (key 8)
- V-Clamp (key 9)
- Misc. Hardware



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

1. Mount a post holder near the midpoint of a short end of the breadboard.
2. Mount a post in the center hole on the bottom of the V-clamp.
3. Place the V-clamp assembly in the post holder on the board.
4. Place a non-reflecting beam block at the end of the board opposite the V-clamp to contain the laser beam.
5. Mount the laser diode module in the V-clamp.
   a. Position it so the beam propagates along the length of the board.
6. Assemble the digital photometer sensor on to the stand supplied with the photometer.
7. Adjust the height of the photometer sensor so that the laser beam centers on the sensor.
8. Mount the second post holder in the path of the laser beam about 50mm from the laser.
9. Assemble the negative lens (diverging lens) into the lens holder and mount a post to the holder.
   a. This assembly is in part B.
   b. Do not mount it in the post holder for part A.

Part A: Power and irradiance of a laser beam

PROCEDURE:

1. **Always contain the laser beam. Keep direct and reflected beams away from yourself and others.**
2. Compare the power specification of the laser to the capability of the photometer to assure NO DAMAGE to the photometer detector/sensor.
    a. The Output Power of the laser is on the Product Data Sheet packed with the laser.
    b. The photometer spec sheet or the scale on the face of the photometer will determine its capability.
3. Set the scale on the photometer to the highest range (least sensitive) to reduce damage potential.
4. Place the photometer sensor several centimeters (cm) in front of the laser.
5. Turn on the laser and align the photometer sensor with the laser beam.
    a. Center the beam on the small hole in the face of the sensor.
6. Press and hold the on/off switch on the photometer.
    a. Wait a few seconds for the reading to stabilize.
    b. Turn the range selector switch to a more sensitive range if the reading is within the range of the new setting.
    c. Do not select a range that will be overloaded.
        i. Overloaded is explained in the photometer's manual.
7. Measure and record the laser's power (measured & specified) in a table **in the Lab Write-Up per below.**
    a. Compare it to the output power specified in the laser spec sheet.
        i. Are they equal?
        ii. If not, explain why **in the Lab Write-Up**.

        P (measured) = _____ P (specified) = _____

8. Measure the diameter of the laser beam three (3) times.
    a. Accomplish this with the ruler in the path of the beam at the photometer sensor.
        i. Be careful of reflections.
    b. Record the three (3) beam diameters and then average them **in the Lab Write-Up**.
        i. The average value to be used in $A = \pi d^2/4$ (use 3.1416 for π).

        d_1 = _____ d_2 = _____ d_3 = _____ d_{avg} = _____

CALCULATIONS:

1. All calculations are to be included **in Lab Write-Up**, showing the equation and answer obtained.
    a. Record & label the answers in a table **in the Lab Write-Up**.
2. Use $E = P/A$ to determine the Irradiance of the laser beam.
    a. Use $A = \pi d^2/4$ to calculate the area of the beam.
3. Use the measured value of P.
    a. Be sure to pay attention to units.
    b. Express the Irradiance in mW/cm^2.

    A = _____ E = _____

Part B: Irradiance of a diverging beam

PROCEDURE:

1. Place the diverging lens assembly in the post holder in front of the laser.
2. Adjust the lens position so that the laser beam is in the center of the lens.
    a. Light reflected from the lens should be reflected directly back into the laser aperture.
3. Move the photometer sensor to a position in the beam so that the beam is big enough to completely fill the small hole in the photometer sensor.
4. Create a chart like the one below **in the Lab Write-Up**.
    a. Measure & record the distance from the lens to the face of the photometer sensor **in the Lab Write-Up**.
5. Measure & record the power of the laser beam in the chart **in the Lab Write-Up**.
6. The area of the measured beam is the area of the sensor.
    a. Measure the diameter of the small hole in the photometer sensor and calculate the area (A) of the sensor (or use the aperture diameter given in the photometer spec sheet).
    b. Record both **in the Lab Write-Up**.

    d = _____ A = _____
7. Calculate the irradiance, E, and enter the result **in the in the Lab Write-Up** per the chart below.
8. Move the photometer to three additional positions at increasing distances from the laser (allow room for a fifth position).
    a. Center the laser beam on the sensor and measure the power at each position.
        i. Record the distance from the lens and the power (P) **in the Lab Write-Up**.

9. Calculate and record the irradiance (E), for each position in the first four lines of the chart below using the area of the sensor (step 6) for each calculation **in Lab Write-Up.**
10. Draw a graph of irradiance (E), versus distance from the lens. Include **in Lab Write-Up**.
11. Select a photometer sensor position beyond positions used above.
12. Measure and record the distance from the lens to the new position on the fifth line (position 5) **in Lab Write-Up**.
13. Use the graph to predict the irradiance of the expanded beam at the fifth position.
14. Measure the power (P) and calculate the irradiance, E, at the fifth position and include **in Lab Write-Up**.
    a. How does the measured value compare with the prediction? Include **in the Lab Write-Up**.

Position	Distance (mm)	Power, P (mW)	Irradiance, E (mw/cm^2)
1			
2			
3			
4			
5			Predicted: Measured:

DISCUSSION:

- The lens of the eye focuses light on the retina.
- The increase in irradiance (optical gain) is about 100,000 times.
- An irradiance of 1mW/cm^2 entering the eye will have an irradiance of 100W/cm^2 (100,000 mW/cm^2) at the retina.
- A laser beam with a higher power than the photometer is capable of reading can be analyzed by using an attenuator or filter to reduce the power of the beam.
- The meter reading is then adjusted to compensate for the reduction in intensity.