LU6: LAB 1-6A: Measurement of Beam Diameter and Beam Divergence

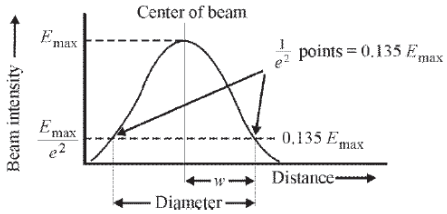
REFERENCES:

- *Fundamentals of Light & Lasers* (OPTEC), 2nd edition
- Mod 6, Laboratory 1-6A, pages 40 – 41.
- http://optecvideo.opteccrm.org, Video 20: Read these instructions and watch the videos before doing the lab.
  - Course 1: Fundamentals of Light and Lasers
  - Lab Activity Video
  - Choose Video #

THEORY:

Beam diameter and beam divergence are important specifications of a laser. They are generally specified as parameters of the laser when it is new and serve as beam quality indicators as the laser ages. They are important to determine beam intensity for safety and application suitability.

The cross-section profile of the beam intensity is usually bell shaped (Gaussian). One measure of **beam diameter** is the distance between the points on the curve where the intensity is $1/e^2$ (13.5 %) of the maximum value (e is a mathematical constant = 2.718. It is the inverse of the natural log function).



Beam divergence is a measure of how fast the beam is spreading out as it travels. It is determined by measuring the diameter at two different distances and computing the change in diameter over distance.

OBJECTIVE:

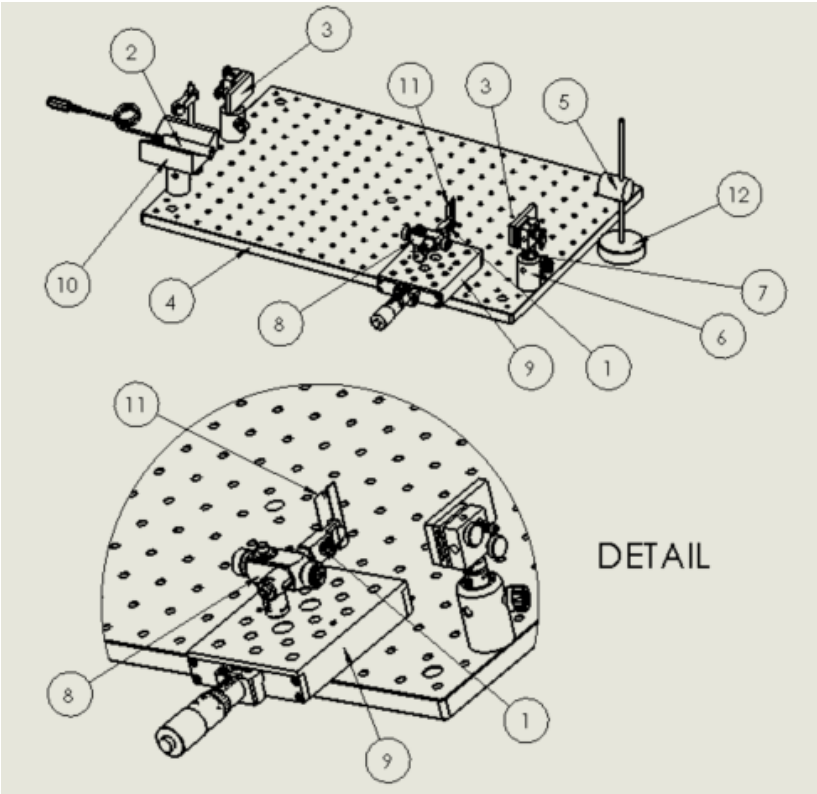
Measure the beam diameter and beam divergence of a laser beam.
Complete a comprehensive lab write-up.
Take appropriate pictures (5 or more) to prove/show lab work.

EQUATIONS:

$\theta = (D_2 - D_1)/ (L)$
θ = beam divergence in radians
D_1 = beam diameter at the first measurement distance (closest to the laser)
D_2 = beam diameter at the second measurement distance (farthest from the laser)
L = distance between the first measurement point (D_1 - closest to the laser) and the second measurement point (D_2 - farthest from the laser)

EQUIPMENT: Study the SET-UP diagram…twice.

Filter Holder (key 1)
Laser Diode Module (key 2)
Laser Diode Power Supply
(2) Mirror (key 3)
Optical Breadboard (key 4)
Photometer, Digital (sensor, key 2)
(3) Post Holder (key 6)
(5) Post (key 7)
Right-Angle Clamp (key 8)
Translation Stage (key 9)
V-Clamp (key 10)
Razorblade (key 11)
Stand, Photometer Sensor (key 12)
Misc. Hardware



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

1. Position the breadboard with the long dimension oriented left to right (landscape view).
2. Use a post holder and post to mount the V-clamp in the third row of holes from the bottom/left corner.
3. Place a beam block at the right end of the board to contain the laser beam.
4. Mount the laser diode in the V-clamp
5. Mount a post holder at the right end of the board in the same row of holes as the V-clamp.
6. Mount another at the left end of the board in the fifth row of holes from the far side.
    a. Mount posts on the two mirror assemblies and insert the mirrors into the post holders.
    b. These will be used to reflect the beam to get a longer beam path over the board.
7. Turn on the laser.
8. Adjust the first mirror to retroreflect the beam back to the laser, then rotate to direct the beam to the second mirror.
9. Adjust the second mirror to retroreflect the beam back to the first mirror and laser, then rotate it (post and mirror assembly) to direct the beam straight down the length of the breadboard.
10. Assemble the photometer sensor on the it's stand and place if just off the right end of the breadboard.
    a. Position it so that the laser beam is centered on the sensor.
11. Mount the filter holder on a post, then insert the post into the right-angle clamp.
    a. See "DETAIL" bubble in equipment set-up drawing.
12. Mount the translation stage between the laser and the first mirror.
    a. Mount it in the fourth row of holes from the mirror and in the second and third holes from the edge of the board.
        i. The stage will extend over the edge of the board.
13. Mount the remaining post directly (no post holder) on the translation stage.
    a. Mount it in the hole at the center of the stage (between the access holes to mount the stage) farthest from the mirror.
14. CAREFULLY insert the *sharp edge* of the razor blade in the filter holder.
    a. Use the right-angle clamp to mount the assembly on the translation stage.
    b. See "DETAIL" bubble in equipment set-up drawing.
15. Adjust the translation stage micrometer to 0.0".
16. Adjust the posts in the right angle clamp so that the sharp edge of the blade is not touching and just outside the far edge of the beam.
    a. Position the blade so it will start to block the beam when the stage micrometer is turned clockwise.

PROCEDURE: Read the complete procedure before following it.

NOTE: Each measurement will be done three (3) times and recorded and averaged. The recorded average will be used in calculations.

Beam divergence is measured by comparing two beam diameters at two different distances from the laser and comparing them. Any definition of beam diameter will produce the same result as long as it's consistent between measurements. For the beam diameters at D_1 and D_2, this lab will use the distance measured on the micrometer between the 86.5% point (step 4) and the 13.5% point (step 5).

1. **Measure** the total (unblocked) power ($\mathbf{P_{max}}$) of the laser beam.
    a. Be sure the beam is centered on the photometer sensor and that neither the direct nor the reflected beam is hitting the razor blade.
        i. **Record** in The Lab Write-Up in a table like the one below.
        ii. More columns will be needed.
2. One edge of the beam will be at the point where the razor blade blocks 13.5% of the beam (100% - 13.5% = 86.5% of the beam unblocked). The other edge will be where the razor blade blocks 86.5% of the beam (100% - 86.5% = 13/5% of the beam unblocked). Use the average of $\mathbf{P_{max}}$ from the previous step to **calculate** these numbers and **record** them in the table below.

P_{max}	mW
Power at 13.5% blocked (P_{max} x 0.865)	
Power at 86.5% blocked (P_{max} x 0.135)	

3. Use the translation stage to slowly move the razor blade into the laser beam.
    a. Watch this to know how to read an inch micrometer: https://www.youtube.com/watch?v=oiAutIoi5YE
4. Move the razor blade to a position where the photometer displays the **power level of P_{max} x 86.5%**.
    a. Do this step a total of three times, **record each, calculate average and record.**

   b. **Record** the micrometer position of the translation stage for each power measurement in the Lab Write-Up.
      i. **Calculate average and record.**
5. Continue to move the razor blade into the laser beam until the photometer displays the **power for P_{max} x 13.5%**.
   a. **Record** the micrometer position in the Lab Write-Up.
6. **Accurately measure and record** the location (L_1) of the razor blade from the front of the laser at D_1.
7. Relocate the translation stage on the board so that the sharp edge of the blade is in the laser beam between the second mirror and the detector. With the detector located as in Set-Up #10, **position the stage as close to the detector as reasonable**. Adjust the razor blade as in Set-Up steps 15 & 16.
8. **Repeat** Procedure steps 3 – 6 for this position and record all results per D_2 and L_2.

Distance from the laser to the razor blade (mm)	Micrometer Position at 13.5% (in) Convert to mm	Micrometer Position at 86.5% (in) Convert to mm	Beam Diameter (in)	Beam Diameter (mm)	θ in radians
First Position L_1 =			D_1 =	D_1 =	Specified:
Second Position L_2 =			D_2 =	D_2 =	Calculated:
$L = L_2 - L_1$ L = mm					

CALCULATIONS:

1. **Subtract** the smaller micrometer reading from the larger to calculate the beam diameters in inches & mm. do the same for the L's.
   a. **Record** the results in the table above.
2. Use **$\theta = (D_2 - D_1)/ (L)$** & values from the table above to **calculate and record** the beam divergence.
3. What is the beam divergence specified for kit's ThorLabs CPS635R diode laser?
4. **Compare and analyze** your results.