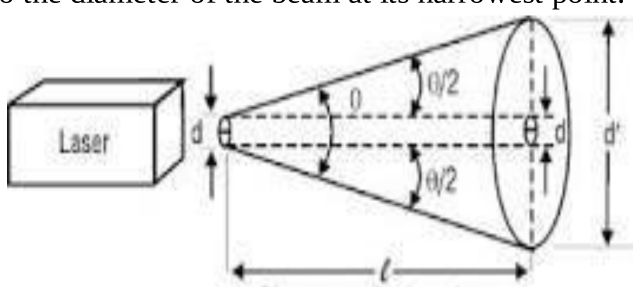
Experiment No. 7

Aim: -To determine the divergence of laser beam.

List of Equipment Used:
Table 1: List of Equipments

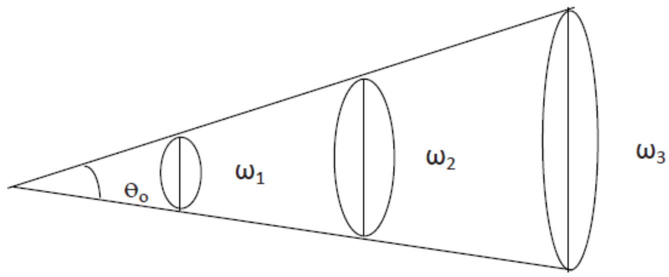
S.N.	**Equipment**	**Range**	**Quantity**
1.	Power supply/Operating voltage	5mV/3-12V	1
2.	Diode laser	650nm	1
3.	Stand	NA	1

Introduction/Theory: The term LASER is the acronym for Light Amplification by Stimulated Emission of radiation. It is a mechanism for emitting electromagnetic radiation via the process of stimulated emission. There are lasers that emit a broad spectrum of light, or emit different wavelengths of light simultaneously. A laser beam with a narrow beam divergence is greatly used to make laser pointer devices. Generally, the beam divergence of laser beam is measured using beam profiler. Like all electromagnetic beams, lasers are subject to divergence, which is measured in mill radians (milliradian) or degrees. For many applications, a lower-divergence beam is preferable. The divergence of a laser beam is proportional to its wavelength and inversely proportional to the diameter of the beam at its narrowest point.



Divergence of a laser beam

One of the chief advantages of a laser is that it produces a beam of light whose edges are parallel. Any deviation from perfect parallelism eventually causes the beam to diverge and spread out its energy, becoming weaker and weaker with distance.



In this figure, Z-axis is chosen as direction of propagation of laser beam and origin is chosen at the point where waist size is minimum. Since Gaussian beam remains Gaussian at all locations, thus the waist size W_1 of the beam at a distance Z is given by the relation:

$$\theta_o = W_1/Z \text{ or } W_1 = \theta_o Z$$

$$W_1^2 = \theta_o^2 Z^2$$

Similarly, W_1, W2 and W_3 are the diameters circles of the laser spot formed at distance (Z+D) and (Z+2D) respectively from the origin, Then

$$\theta_o = W_2 / (Z+D) \text{ or}$$

$$W_2 = \theta_o(Z+D)$$

$$\text{Or } W_2^2 = \theta_o^2 (Z+D)^2$$

$$\text{And} \quad \theta_o = W_3 / (Z+2D)$$

$$\text{OR} \quad W_3 = \theta_o(Z+2D)$$

$$W_3^2 = \theta_o^2 (Z+2D)^2$$

But the laser source cannot be a point source. It has a finite size through small.

Here W_1 = minimum waist size, $\theta_o$is the angle of divergence

To find the angle of divergence θ_o, we set up three equations:

$$W_1^2 = \theta_o^2 Z^2 \text{(i)}$$

$$W_2^2 = \theta_o^2 (Z+D)^2 = \theta_o^2 Z^2 + 2Z\,\theta_o^2 D + \theta_o^2 D^2 \qquad \text{(ii)}$$

$$W_3^2 = W_o^2 + \theta_o^2 (Z+2D)^2 = \theta_o^2 Z^2 + \theta_o^2 (4D^2) + 4ZD\,\theta_o^2 \qquad \text{(iii)}$$

From (i), (ii) and (iii), we have

$$W_1^2 - 2W_2^2 + W_3^2 = 2\,\theta_o^2 Z^2$$

$$\theta = \frac{1}{D}\sqrt{\frac{W_1^2 - 2W_2^2 + W_3^2}{2}}$$

Formula used: The angle of divergence is given by

$$\theta = \frac{1}{D}\sqrt{\frac{W_1^2 - 2W_2^2 + W_3^2}{2}}$$

Precautions:

(i) Spot size should be measured accurately.

(ii) Laser light should not fall directly to the eyes of the observer.

Procedure:

(i) Arrange the apparatus as shown.

(ii) Pencil, draw the circular spot on the paper and measure the vertical and horizontal diameters of the circular spot. Calculate the mean of both values to get the accurate value of the diameter. This is the waist size W_1

(iii) Now distance screen in the direction of beam propagation by a known distance D (total distance from laser becomes Z+D) and measure spot size W_2 as measured in previous step.

(iv) Now displace screen further away by same value D, so the new distance becomes (Z+2D). Measure spot size W_3

(v) Put the values in the formula and calculate laser divergence.

Observations & Calculations:

Table2:

(i) Initial distance between laser and screen Z=....50.....cm

(ii) Displacement of screen D=.......25.....cm

S. No.	**Distance (cm)**	**Diameter (cm)**	$\theta = \frac{1}{D}\sqrt{\frac{W_1^2 - 2W_2^2 + W_3^2}{2}}$ **(milliradian)**
1.	Z=50	0.00501	0.00020
	Z+D= 75	0.00334	
	Z+2D=100	0.008161	

The angle of divergence of the diode laser is ______milliradian

Result(s): The angle of divergence of the diode laser is ______milliradian.

Conclusion: Since this angle is very small (in the range of milliradian), we conclude that laser beam is highly directional as compared to ordinary light source.