MIT World Peace University

Physics

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Measurement of Beam Divergence of a Laser Beam

Experiment No. 4

Prepared By

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Pledge

I solemnly affirm that I am presenting this journal based on my own experimental work. I have neither copied the observations, calculations, graphs and results from others nor given it to others for copying.

Signature of the student

1 Aim

To measure the peak power and beam divergence of a given laser beam

2 Apparatus

1. He-Ne Laser
2. Optical Bench
3. Laser Beam Analyzer with Sensor
4. Micrometer Screw Arrangement

3 Significance of the Experiment

One of the characteristics of laser is high directionality/parallelness. Thus the diameter of the laser at any position should be same. However, laser has a small divergence due to diffraction effects. This experiment provides an easy and accurate method to measure the divergence of a laser

4 Theory

4.1 Lasers

Laser is an extremely coherent, monochromatic, directional, focusable, polarized and powerful light. These extraordinary features make it greatly applicable in day-to-day life, science and technology. A few notable applications of laser include medical diagnosis and treatments, fiber optic communications, CD-ROMS, CD players, laser printers, defense, cutting, welding, drilling, surveying, aligning etc. Laser is produced due to stimulated radiation; a process where a resonating photon stimulates the de-excitation of an excited atom. This results in to emission of two coherent photons, which are identical in all respects. These photons further stimulate the de-excitation of other excited atoms and this continues to generate an avalanche of coherent photons. For stimulated emission to take over spontaneous emission and stimulated absorption, a few conditions are necessary. These are availability of metastable state (life time = 10-3 sec), population inversion (greater number of atoms in metastable state than in lower energy state) and enough number of photons in the cavity (mirrors).

4.2 He-Ne Lasers

He-Ne laser is a low power, continuous gas laser, which is used in supermarket scanners, student laboratories and holography. The active system is neon, which is pumped electronically via helium in a resonant cavity made of discharge tube (Fig. 5.1) . The main lasing occurs in neon between the levels E6 (metastable) and E3 which produces an intense coherent beam of red color (wavelength 6328o). (refer Fig 5.2). The population of photons necessary for stimulated emission is maintained by mirrors (one is semitransparent) on both sides. Brewseter windows are used to polarize the laser light.

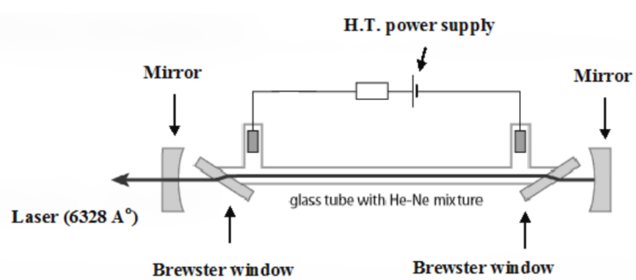


Fig. 5.1: Schematic diagram of He-Ne laser

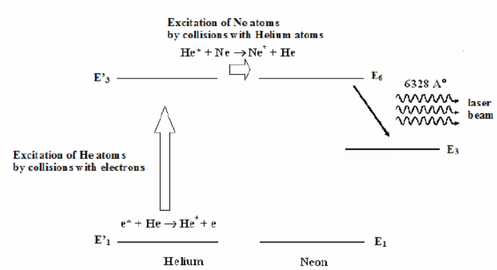


Fig. 5.2. The simplified energy level diagram of He-Ne laser

5 Procedure

1. The power in laser beam follows Gaussian distribution with peak value at center.
2. Mount the sensor of LBA on optical bench at a distance relatively closer to laser beam, say 10 cm. Let this distance be d_1 . Adjust sensor so that laser is incident exactly on the centre of the

window of the sensor. Align the sensor, till LBA reads power closest to 2.0 mW

3. Now move the sensor laterally so that the beam falls on the edge of the window of the sensor. LBA will now read zero.

4. Using micrometer screw, move the sensor-window gradually across the laser beam. Note the increasing powers in the beam (mW) at various screw positions (mm) as per table 5.1. At certain stage, the power in LBA will reach peak and then will start decreasing, even though the screw is moved in the same direction. Note the decreasing powers at various advanced screw positions. Note that the screw should be moved in only one direction throughout the observations. For measuring the screw positions, use following procedure

$$Screw\ position = X = MSR + VSR \times LC\ mm \tag{1}$$

Where MSR is the reading on the main scale, which is closest to the edge of the screw. VSR is the vernier scale reading, which is the sequence number of the division on the screw which coincides with the line on main scale. LC is the least count of micrometer screw gauge

$$LC = \frac{Smallest\ distance\ on\ the\ main\ scale}{Number\ of\ divisions\ on\ the\ vernier\ scale} = \frac{\ldots mm}{\ldots} = \ldots mm \tag{2}$$

5. Repeat the entire procedure from 2 to 4, by placing the sensor at d_2 cm, sufficiently away from d_1(say by 50 cm). Record these observations in table 5.2

6. Plot the graph of power (mW) Vs position (mm) for observation table 5.1 (for d_1). Identify the peak power P_m. Also identify a point on power axis corresponding to $P_m/2$. Draw a horizontal line starting from $\frac{P_m}{2}$.. This line will intersect the Gaussian curve at two points having X co-ordinates X_1 (mm) and X_2 (mm). The quantity D_1 (mm) = $(X_2 - X_1)$ i.e. Full Width at Half Maximum (FWHM) gives the effective diameter of laser when the distance between LBA and laser is d_1 cm. (refer sample graph in Fig. 5.3 a)

7. Plot the graph of power (mW) Vs position (mm) for observation table 2 (for d_2). Repeat the procedure explained in step 6 and calculate the diameter D_2 (mm) of the laser beam at the position d_2. (refer a widened graph in Fig 5.3b)

8. The Gaussian distribution at the position d_2 will be slightly wider than that at position d1 . Consequently the diameter D_2 of the laser beam at the position d_2 will be greater than diameter D_1 at the distance d_1. Calculate the divergence of laser beam by using the formula and procedure in 'Calculations'

6 Observations

Table (3.1): Observations, Calculations and Results.

Observation table 4.1 **Powers at different positions at a distance** d_1= …….. cm			**Observation table 4.2** **Powers at different positions at a distance** d_2= …….. cm		
Sr. No.	**Power in LBA, P (mW)**	**Position of micrometer X (mm)**	**Sr. No.**	**Power in LBA, P (mW)**	**Position of micrometer X (mm)**
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		
7			7		
8			8		
9			9		
10			10		
11			11		
12			12		
13			13		
14			14		
15			15		
16			16		

7 Calculations

$$
\begin{aligned}
\text{Divergence } &= \frac{(D_2 - D_1)\,\text{mm}}{(d_2 - d_1)\,\text{cm}} \\
&= \frac{(D_2 - D_1)\,\text{cm}}{(d_2 - d_1)\,\text{cm}} \times 10^{-1} \\
&= \frac{(\ldots\ldots\ldots - \ldots\ldots)}{(\ldots\ldots\ldots - \cdots\ldots\ldots)} \times 10^{-1} \\
&= \ldots\ldots\ldots\ldots\,\text{rad} \\
&= \ldots\ldots\ldots\ldots\ldots\,\text{rad} \times \frac{180}{3.14}\frac{\text{deg}}{\text{rad}} \\
&= \ldots\ldots\ldots\ldots\,\text{deg} \\
&= \ldots\ldots\ldots\ldots\ldots\,\text{deg} \times 60\frac{\text{min}}{\text{deg}} \\
&= \ldots\ldots\,\text{min}
\end{aligned}
$$

8 Results

Sr. No.	Physical quantity	Value	Unit
1	Peak power the laser beam (at $d_1 \ldots$cm)		mW
2	Divergence of laser beam		min

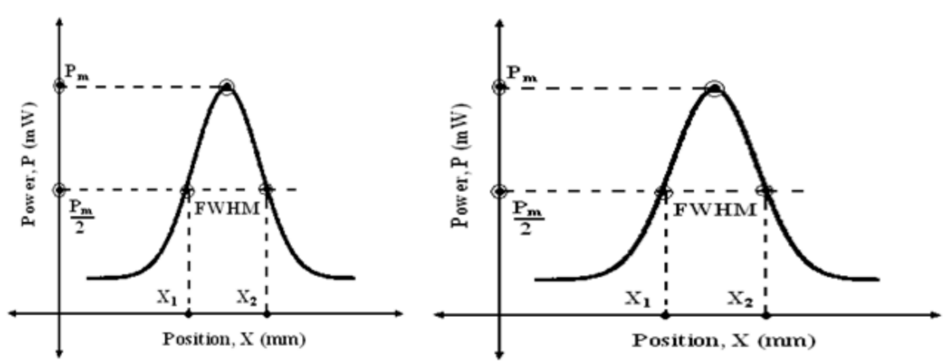
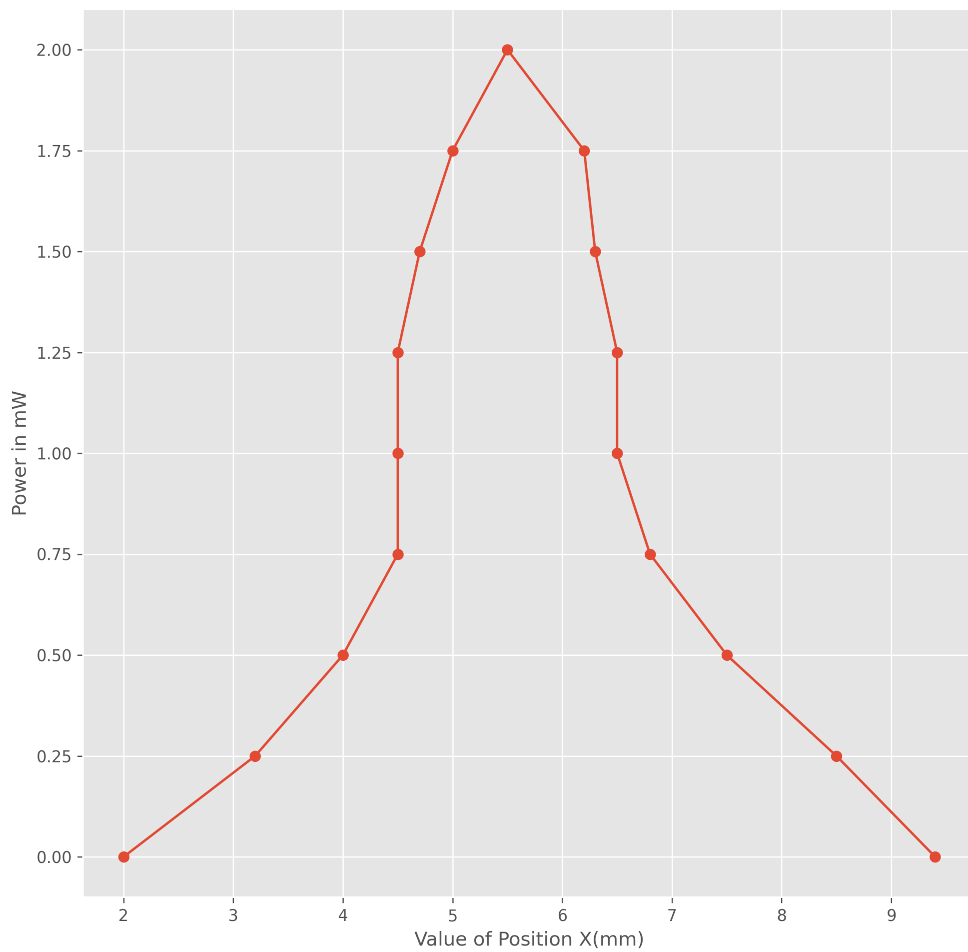


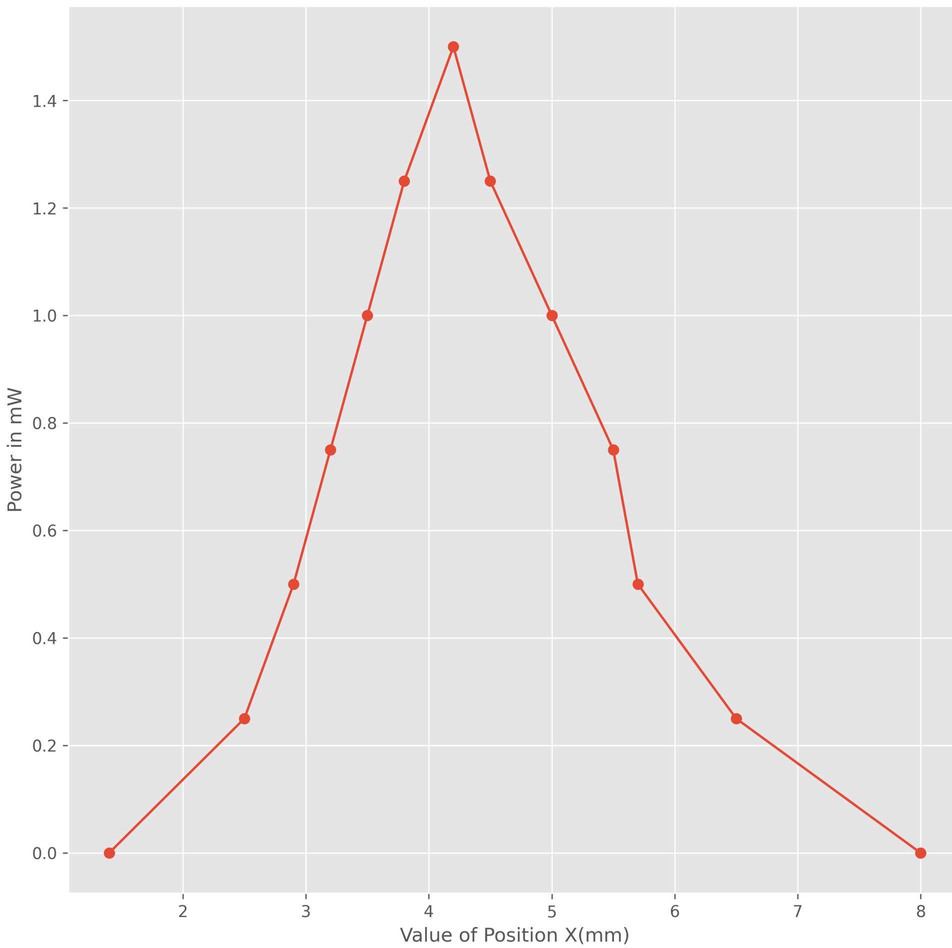
Figure 4.3 Calculation of (a) diameter *D1* at position *d1 (b)* diameter *D2* at position *d2*

9 Graphs

9.1 Plot between *Power*(mW) vs *Position*$x(mm)$ at Distance d1 = 100 cm



9.2 Plot between *Power*(mW) vs *Position*$x(mm)$ at Distance d2 = 80 cm



10 My Understanding of the Experiment

A Laser is an almost monochromatic unidirectional beam of light, that has been amplified by stimulated emission of Radiation. It has great significance in the medical and engineering world. One of the main reasons for this, is that it is a powerful beam of light that travels highly in the same direction and for a long distance. This is an experiment to verify that fact, and measure the divergence of the laser beam after travelling a certain distance. That can be calculated by a laser beam analyser.