Characteristics of Laser Beam

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Contents

1 AIM

To study the Gaussian nature of laser beam.
To evaluate the diameter of laser Beam(Spot size) .
To measure the divergence.
To Study the polarization nature of the laser.

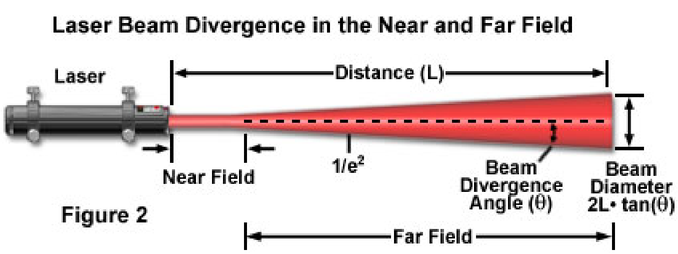
2 APPARATUS

Optical Rail, Kinematic Laser Mount, Diode Laser, Power supply for Laser, XYZ Translation Stage, Micrometer, Pinhole Detector, Output Measurement unit, Polariser

3 INTRODUCTION

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term ”laser” originated as an acronym for ”light amplification by stimulated emission of radiation”. The first laser was built in 1960 by Theodore H. Maiman at Hughes Research Laboratories, based on theoretical work by Charles Hard Townes and Arthur Leonard Schawlow. A laser differs from other sources of light in that it emits light coherently. Spatial coherence allows a laser to be focused to a tight spot, enabling applications such as laser cutting and lithography. Spatial coherence also allows a laser beam to stay narrow over great distances (collimation), enabling applications such as laser pointers. Lasers can also have high temporal coherence, which allows them to emit light with a very narrow spectrum, i.e., they can emit a single color of light. Temporal coherence can be used to produce pulses of light as short as a femtosecond.

4 DIAGRAM



5 THEORY

5.1 LASER

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. The laser was the first device capable of amplifying light waves themselves. The emitted laser light is a spatially coherent, narrow low-divergence beam. When the waves(or photons) of a beam of light have the same frequency, phase and direction, it is said to be coherent . There are lasers that emit a broad spectrum of light, or emit different wavelengths of light simultaneously. According to the encyclopedia of laser physics and technology, beam divergence of a laser beam is a measure for how fast the beam expands far from the beam waist. 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.

Lasers usually emit beams with a Gaussian profile. A Gaussian beam is a beam of electromagnetic radiation whose transverse electric field and intensity (irradiance) distributions are described by Gaussian functions.

For a Gaussian beam, the amplitude of the complex electric field is given by

$$E(r,z) = E_0 \frac{w_0}{w_{(z)}} \exp\left(\frac{-r^2}{w_{(z)}^2}\right) \exp\left(-ikz - ik\frac{r^2}{2R_{(z)}} + i\zeta(z)\right)$$

where, r - radial distance from the centre axis of the beam
z - axial distance from the beam's narrowest point
i - imaginary unit (for which i2 = 1)
k - wave number (in radians per meter).
w(z) - radius at which the field amplitude drops to 1/e and field intensity to 1/e2 of their axial values, respectively.
w(0) - waist size.
E0 = —E(0,0) —
R(z) - radius of curvature of the beam's wavefronts
(z) - Gouy phase shift. It is an extra contribution to the phase that is seen in beams which obey Gaussian profiles.

The corresponding time-averaged intensity (or irradiance) distribution is

$$I(r,z) = \frac{|E(r,z)|^2}{2\eta} = I_0 \left(\frac{w_0}{w_{(z)}}\right)^2 \exp\left(\frac{-2r^2}{w_{(z)}^2}\right)$$

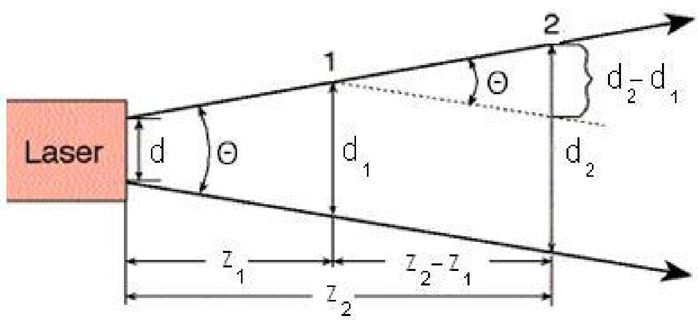
where I0 = I(0,0) is the intensity at the center of the beam at its waist.The constant is defined as the characteristic impedance of the medium through which the beam is propagating. For vacuum,
$\eta = \eta_0 \approx 377\ ohm$

5.2 Beam parameters:

Beam parameters govern the behaviour and geometry of a Gaussian beam. The important beam parameters are described below.

5.3 Beam divergence:

The light emitted by a laser is confined to a rather narrow cone. But, when the beam propagates outward, it slowly diverges or fans out. For an electromagnetic beam, beam divergence is the angular measure of the increase in the radius or diameter with distance from the optical aperture as the beam emerges. The divergence of a laser beam can be calculated if the beam diameter d1 and d2 at two separate distances are known. Let z1and z2 are the distances along the laser axis, from the end of the laser to points 1 and 2.

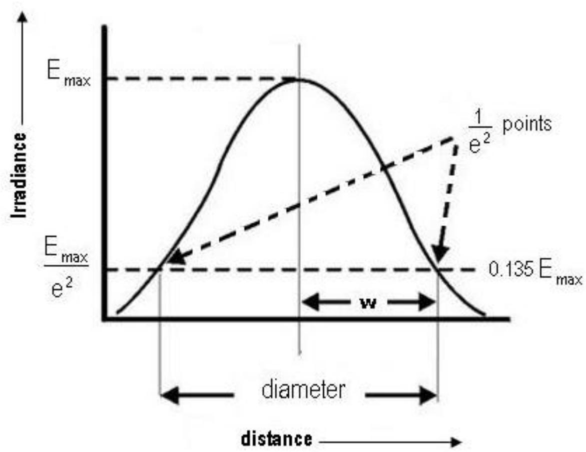


Usually, divergence angle is taken as the full angle of opening of the beam. Then,
$$\Theta = \frac{d_2 - d_1}{z_2 - z_1}$$
Half of the divergence angle can be calculated as
$$\theta = \frac{w_2 - w_1}{z_2 - z_1}$$
where w1 and w2 are the radii of the beam at z1 and z2. Like all electromagnetic beams, lasers are subject to divergence, which is measured in milliradians (mrad) or degrees. For many applications, a lower-divergence beam is preferable.

5.4 spot size

Spot size is nothing but the radius of the beam itself. The irradiance of the beam decreases gradually at the edges.

The distance across the center of the beam for which the irradiance (intensity) equals 1/e2 of the maximum irradiance (1/e2 = 0.135) is defined as the beam diameter. The spot size (w) of the beam is defined as the radial distance (radius) from the center point of maximum irradiance to the 1/e2 point.



Gaussian laser beams are said to be diffraction limited when their radial beam divergence is close to the minimum possible value, which is given by

$$\theta = \frac{\Theta}{2} = \frac{\lambda}{\pi w_0}$$

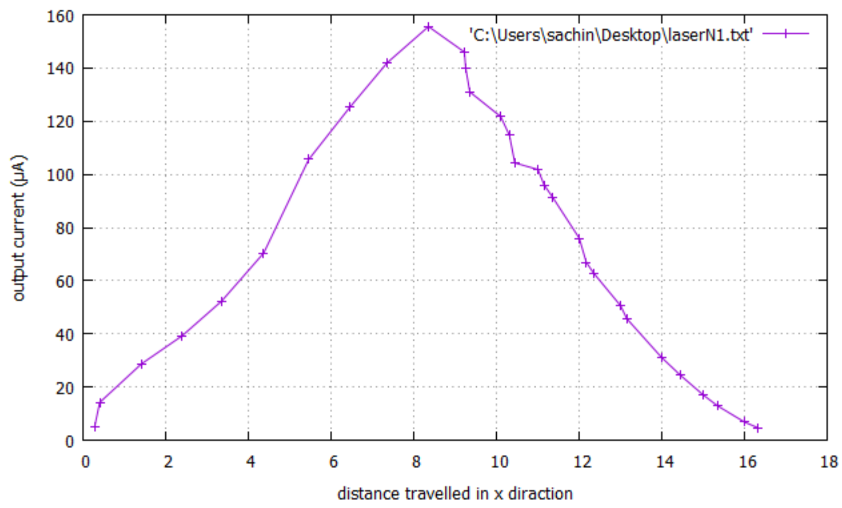
where is the wavelength of the given laser and w0 is the radius of the beam at the narrowest point, which is termed as the beam waist.

6 MEASUREMENT

6.1 We have taken the length of beam spot along Y-axis and width along X-axis.

At z=372mm

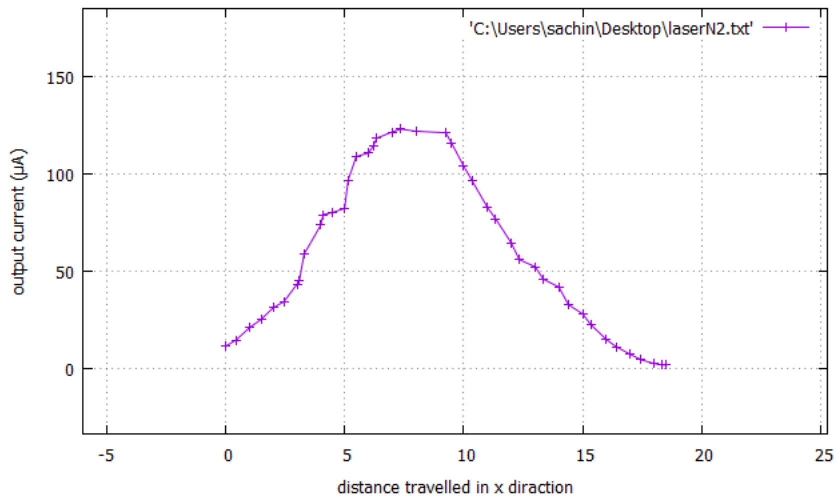
x (mm)	current (μ A)
.27	5.2
.39	14.2
1.40	28.7
2.39	39.3
3.34	52.3
4.36	70.4
5.45	105.6
6.45	125.3
7.35	142
8.35	155.6
9.22	146
9.25	140
9.35	131
10.10	121.7
10.31	114.7
10.44	104.3
11	101.8
11.	15 96
11.35	91.5
12	76
12.17	66.9
12.35	62.8
13	50.6
13.15	45.7
14	31.0
14.45	24.4
15	17
15.35	12.9
16.0	6.8
16.32	4.7



6.2 We have taken the length of beam spot along Y-axis and width along X-axis.

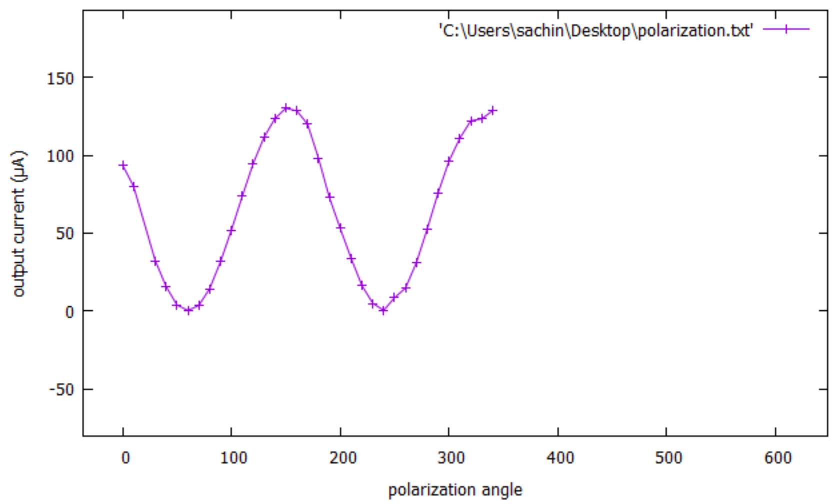
At z=322mm

x(mm)	current (μ A)
0	11.6
.44	14.8
1	21.1
1.49	25.4
2	31.4
2.45	34.5
3	43.5
3.10	45.5
3.30	59.0
4	73.9
4.10	79.3
4.49	80.4
5	82.5
5.15	97.1
5.49	109.2
6	111
6.20	114.5
6.35	118.7
7	121.8
7.35	123.3
8	122.2
9.25	121.4
9.49	116.1
10	104.3
10.35	96.8
11	83
11.35	77
12	64.7
12.34	56.1
13	52.5
13.35	46.1
14	42
14.40	33
15	28.2
15.35	22.6
16	15
16.40	11.4
17	7.4
17.45	4.6
18	2.7
18.35	2
18.49	1.9


'C:\Users\sachin\Desktop\laserN2.txt'
output current (μA)
150
100
50
0
-5
0
5
10
15
20
25
distance travelled in x diraction

6.3 polarization angle v/s current

Angle(°)	current (μ A)
0	93.7
10	80.2
30	32.4
40	15.7
50	3.8
60	0.4
70	3.5
80	14.3
90	31.6
100	51.9
110	73.8
120	94.7
130	111.6
140	123.6
150	130.2
160	128.6
170	120.1
180	98.2
190	73
200	53
210	33.8
220	16.2
230	4.9
240	0.4
250	8.6
260	14.7
270	31.0
280	52.7
290	76.0
300	96.4
310	111.1
320	122.2
330	123.4
340	128.6



7 CALCULATION

7.1 Spot size

1. For z=372mm
From the data maximum current is 155.6 μA at x=8.36mm
So $\frac{1}{e^2}$ of the maximum current =21.058μA at x=0.862 approximately.
Then d_{x1} = (8.35-0.8620)mm=7.488mm
So, radius of the spot at x_1 is 7.488mm
2. For z=322mm
From the data maximum current is 123.3 μA at x=7.35mm
So $\frac{1}{e^2}$ of the maximum current= 16.686μA at x=0.557 approximately.
Then d_{x2}= (7.35-0.557)mm= 6.793mm
So, radius of the spot atx_2 is 6.793mm

7.2 Divergence angle

Divergence angle $\theta = \tan^{-1}(\frac{d_{x2}-d_{x1}}{z_2-z_1})$ =$\tan^{-1}(\frac{7.488-6.793}{372-322})$=$\tan^{-1}$(0.01116)=0.6394 radian=36.65 degree

8 CONCLUSION

From the graph of output current vs distance traveled in X direction we saw that the nature of the graph is Gaussian.We calculate the divergence angle which is equal to 0.2371 degree.
From the graph of Output current vs Polariser angle we found that the laser beam is linearly polarised.

9 PRECAUTION

1. We should not look directly to the laser.
2. Pin hole ditector should be adjusted in such a way that when it is moved from left to right it should pass through exactly center of the spot.

10 REFERENCE

1. Optics by N.Subrahmanyam and Brijlal
2. www.google.com
3. wikipedia
4. Lab manual