ESTIMATION OF LASER BEAM PARAMETERS

PROJECT REPORT

Submitted by

ALEENA M A

Register No: AB20PHY008

Under the guidance of

Dr. SANTHI A

Submitted to

Mahatma Gandhi University, Kottayam

In partial fulfillment of the requirement for the award of
BACHELOR'S DEGREE OF SCIENCE IN PHYSICS

ST.TERESA'S COLLEGE (AUTONOMOUS),

ERNAKULAM, KOCHI-682011

ST.TERESA'S COLLEGE (AUTONOMOUS), ERNAKULAM

B.Sc. Physics

PROJECT REPORT

Name: ALEENA M A
Register Number: AB20PHY008
Year of work: 2022-'23

This is to certify that this project "ESTIMATION OF LASER BEAM PARAMETERS" is the work done by ALEENA M.A.

Staff member in charge
Dr. Santhi A

Head of the department
Dr. Priya Parvathi Ameena Jose

Submitted for the university examination held in St. Teresa's College, Ernakulam.

Date: 25/04/2023

Examiners: 24/04/23

St. Teresa's College (Autonomous) * Department of Physics * Ernakulam

DECLARATION

I, Aleena M A final year B.Sc. Physics student, Department of Physics, St. Teresa's College, Ernakulam do hereby declare that this project work entitled "**Estimation of Laser Beam Parameters**" submitted to Mahatma Gandhi University, Kottayam in partial fulfillment of the requirements for the award of the degree of Bachelor of Science in Physics is a record of original work done by me under the supervision of Dr. Santhi A, Assistant professor, St. Teresa's College, Ernakulam

Place: Ernakulam

Date:

ACKNOWLEDGEMENT

First and foremost I would like to thank God Almighty for showering his blessings upon us on this endeavor,

I take this opportunity to thank Dr. Santhi A, Department of Physics, St. Teresa's College for the guidance given for the successful completion of the project.

I express our deep sense of gratitude to the Department of Physics, St. Teresa's College for extending the facilities and cooperation required from time to time. I take this opportunity to thank Dr. Priya Parvathi Ameena Jose, Head of the Department for her generous concern and support.

I express our deep sense of gratitude to all teaching and non-teaching staff of the Physics Department. St. Teresa's College for their kind cooperation.

INDEX

ABSTRACT
In this project, the rayleigh range and spot size of laser is observed.Intensity curve in different length is taken, with lens and without lens is also considered. Some parameters of the laser are obtained . The result was not correct due to some technical errors.

INTRODUCTION

A laser is a device that amplifies light and produces a highly directional, high-intensity beam that often has a very pure frequency or wavelength. It comes in size ranging from approximately one tenth the diameter of a human hair to the size of a very large building, in powers ranging from 10^{-9} to 10^{20} W, and in wavelengths ranging from the microwave to the soft X-ray spectral regions with corresponding frequencies from 10^{11} to 10^{17} Hz.

Laser has certain unique properties compared to ordinary sources of light, namely high monochromaticity, coherence, and directionality, though both sources emit electromagnetic radiation. Further a laser beam can travel long distances in air without being dispersed .

The word LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. It makes use of processes that increase or amplify light signals after those signals have been generated by other means. These processes include (1) Stimulated emission, a natural effect that was deduced by considerations relating to thermodynamic equilibrium, and (2) optical feedback that is usually provided by mirrors. Thus in simplest form, a laser consists of a gain or amplifying medium, and a set of mirrors to feed the light back into the amplifier for continued growth of the developing beam.

The beam of light generated by a typical laser can have many properties that are unique.When comparing laser properties to those of other light sources it can be ready recognised that the values of various parameters for laser light either greatly exceed or Or four elimination within our houses are much more restrictive than the values for many common light sources. We never use lasers for street illuminations, or for illuminations within our houses. We don’t use them for searchlights or flashlights or as headlights in our cars. Lasers generally have a narrower frequency distribution, or much higher intensity, or much greater degree of collimation, or much short pulse duration, than that available from more common types of light sources. Therefore we do use them in compact disc players in supermarket check out scanners in surveying instruments and in medical applications as a surgical knife or for welding detached retinas. We also use them in communications systems and in radar and military targeting applications, as well as many other areas. A laser is a specialized light source that should be used only when its unique properties are required.

Lasers are light beams that are powerful enough to travel miles into the sky and cut through lumps of metal. Although they seem like a recent invention, they have been with us for half a century. The first practical laser was built by Theodore H. Maiman at Hughes Research Laboratories in 1960. At the time, lasers were an example of cutting-edge technology. Today, we have lasers at our homes, offices and shopping centers.
The output of a laser is a coherent electromagnetic field. In a coherent beam of electromagnetic energy, all the waves have the same frequency and phase.

A basic laser consists of a chamber known as the cavity which is designed to reflect infrared, visible or ultraviolet waves so that they reinforce each other. The cavity can contain either solids, liquids or gases. The choice of the cavity material determines the wavelength of the output. Mirrors are placed at each end of the cavity. One of the mirrors is totally reflective, not allowing any of the energy to pass through them. The other mirror is partially reflective, allowing 5% percent of the energy to pass through them. Through a process known as pumping, energy is introduced into the cavity through an external source.

Due to pumping activity, an electromagnetic field appears inside the laser cavity at the natural frequency of the atoms of the material that fills the cavity. The waves are reflected back and forth between the mirrors. The length of the cavity is such that the reflected waves reinforce each other. The electromagnetic waves in phase with each other emerge from the end of the cavity having a partially reflective mirror. The output is a continuous beam, or a series of brief, intense pulses.

CHAPTER - 1 LASER BEAM

In most cases, a laser emits light in the form of a well directed light, which is called a laser beam. This means that the light dominantly propagates in a certain direction, typically with most of the optical power concentrated to a small area of the order of a square millimeter.

Laser beams are often close to Gaussian beams, where the transverse profile of the optical intensity can be described with a Gaussian function, the width of which varies along the propagation direction.

Generally, laser beams exhibit a high degree of spatial coherence, which is related to a high beam quality. As a result, one obtains good focusability and the potential to form collimated beams with very low beam divergence.

A laser beam of visible light with sufficiently high power may be visible when propagating in air. This is because a tiny portion of the optical power is scattered by dust particles and/or density fluctuations in the air and can therefore reach the observing eye. When the laser beam hits some diffusely scattering object, such as a white screen, a much brighter spot is seen on that screen, since most of the optical power is scattered at this point.

SEMICONDUCTOR DIODES

Semiconductor diode lasers are unique when compared to other types of lasers. They are very small, they operate with relatively low power input, and they are very efficient. They also operate in a different way in that they require the merging of two different materials and the laser action occurs in the interface between those two materials. One of the materials has an excess of electrons and the other material has a deficit of electrons or an excess of holes. When a forward bias voltage is placed across this junction, electrons are forced into the region from the n-type material and holes are forced into the junction from p-type material. These electrons with a negative charge and the holes with a positive charge are attracted to each other, and when they collide they neutralize each other and in the process emit recombination radiation. The electrons in the n-type material exist at a higher energy than the holes. This energy difference is designated as the bandgap of the material: the amount of energy that is released when the recombination radiation process occurs. Different material combinations have different bandgaps and thus emit different wavelengths of light.

CHAPTER - 2 GAUSSIAN BEAM

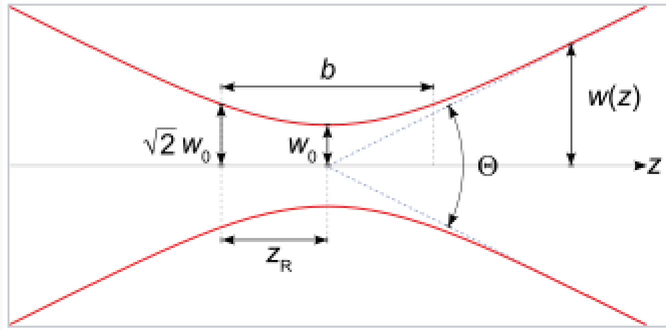
A Gaussian beam is a beam of electromagnetic radiation with high monochromaticity whose amplitude envelope in the transverse plane is given by a Gaussian function; this also implies a Gaussian intensity profile. This fundamental transverse Gaussian mode describes the intended output of most lasers, as such a beam can be focused into the most concentrated spot. When such a beam is refocused by a lens, the transverse phase dependence is altered; this results in a different Gaussian beam. The electric and magnetic field amplitude profiles along any such circular Gaussian beam (for a given wavelength and polarization) are determined by a single parameter: the so-called waist w_0. At any position z relative to the waist (focus) along a beam having a specified w_0, the field amplitudes and phases are thereby determined.

The equations below assume a beam with a circular cross-section at all values of z; this can be seen by noting that a single transverse dimension, r, appears. Beams with elliptical cross-sections, or with waists at different positions in z for the two transverse dimensions (astigmatic beams) can also be described as Gaussian beams, but with distinct values of w_0 and of the $z = 0$ location for the two transverse dimensions x and y.

BEAM PARAMETERS

The geometric dependence of the fields of a Gaussian beam are governed by the light's wavelength λ (*in* the dielectric medium, if not free space) and the following beam parameters, all of which are connected as detailed in the following sections.

BEAM WAIST



Gaussian beam width $w(z)$ as a function of the distance z along the beam, which forms a hyperbola. w_0: beam waist; b: depth of focus; z_R: Rayleigh range; Θ: total angular spread

The shape of a Gaussian beam of a given wavelength λ is governed solely by one parameter, the beam waist w_0. This is a measure of the beam size at the point of its focus ($z = 0$ in the above equations) where the beam width $w(z)$ (as defined above) is the smallest (and likewise where the intensity on-axis ($r = 0$) is the largest). From this parameter the other parameters describing the beam geometry are determined. This includes the Rayleigh range z_R and asymptotic beam divergence θ, as detailed below.

RAYLEIGH RANGE AND DEPTH OF FOCUS

The Rayleigh distance or Rayleigh range z_R is determined given a Gaussian beam's waist size:.

$$z_R = \frac{\pi w_0^2 n}{\lambda}.$$

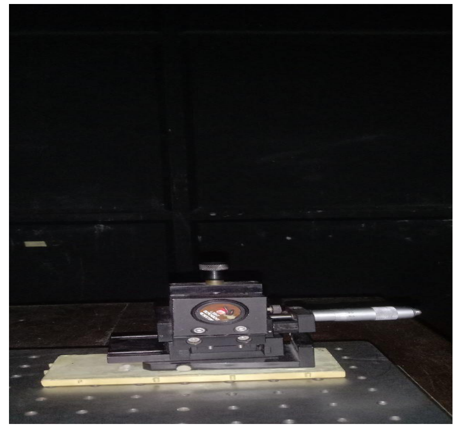
Here λ is the wavelength of the light, n is the index of refraction. At a distance from the waist equal to the Rayleigh range z_R, the width w of the beam is $\sqrt{2}$ larger than it is at the focus where $w = w_0$, the beam waist. That also implies that the on-axis ($r = 0$) intensity there is one half of the peak intensity (at $z = 0$). That point along the beam also happens to be where the wavefront curvature ($1/R$) is greatest.

The distance between the two points $z = \pm z_R$ is called the confocal parameter or depth of focus of the beam.

CHAPTER-3 EXPERIMENT

APPARATUS USED:

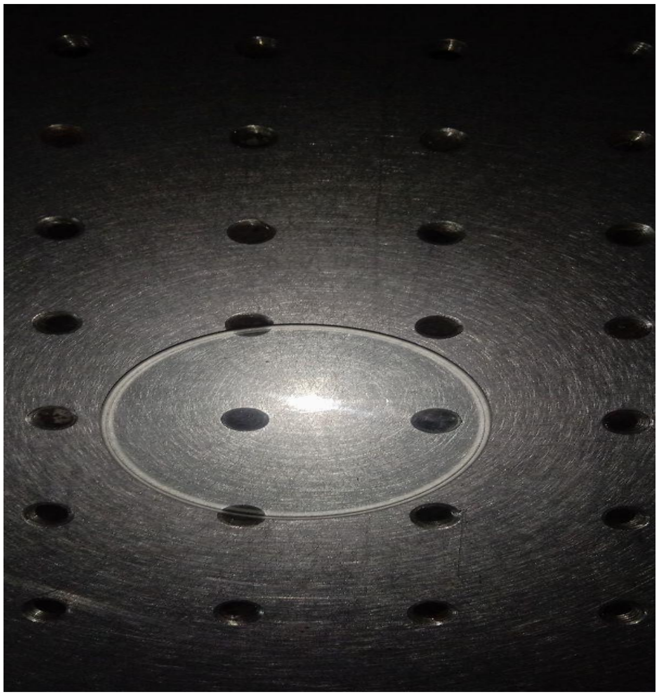
LASER SOURCE

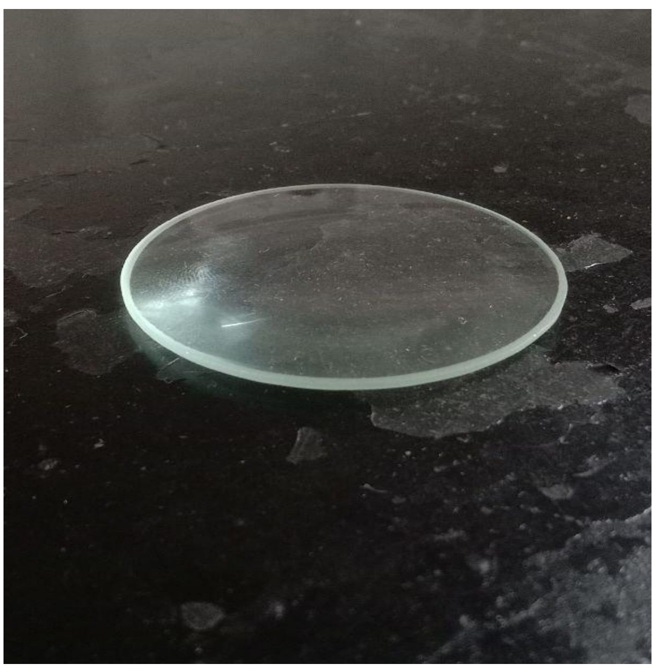


LASER DETECTOR

DETECTOR OUTPUT

LASER POWER SUPPLY





LENS

PROCEDURE

Determination of Spot Size and Rayleigh Range

The laser source is placed in line with the light-detecting microscope at a distance of 20 cm from the sensor of the microscope.

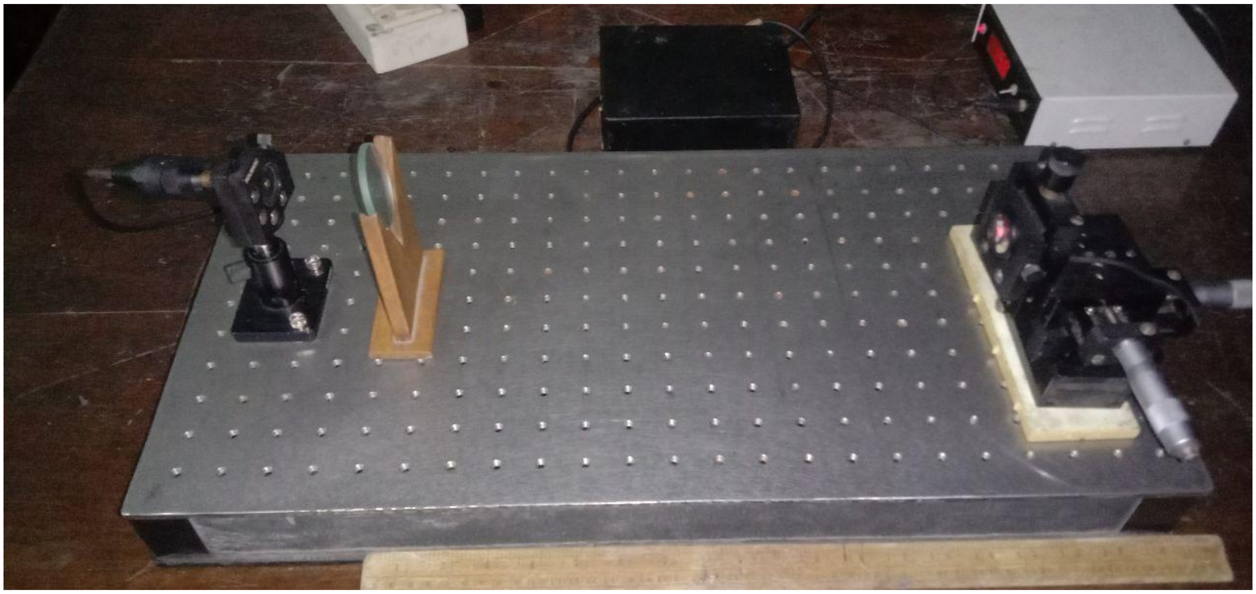
The laser light is allowed to fall on the sensor of the microscope and focused exactly at the center of the sensor by adjusting the vertical and horizontal movements of the microscope.

Final adjustment of the microscope is done by vertical and horizontal screws that are provided to get maximum intensity as observed in the relative light intensity meter. The value of relative intensity is noted for all the readings of the microscope and recorded in the table.

A graph is drawn for the corresponding values taking distance along the x-axis and intensity of light along the y-axis. The spot size of the laser and rayleigh range is found after the calculations.

The experiment is repeated for various distances, viz 25 and 30 cm between the source and sensor. In each case the readings are given in the table.Spot size and Rayleigh ranges for all the distances are found out from the graph.

The experiment is also done using the convex lens of focal length of 20 cm. The distance between the sensor and the convex lens is adjusted to be 20 cm and the corresponding measurements are taken by the vertical adjustments of the microscope.The procedures are done as mentioned above. The values for different distances are found and the Rayleigh range is found out.



OBSERVATIONS:

Distance=20 cm

Lateral Displacement	Maximum Relative Light Intensity(mA)
0	0
0.5	0
1	0
1.5	0
2	0
2.5	0
3	0
3.5	0

4	0
4.5	0.1
5	0.1
5.5	0.1
6	0.1
6.5	0.1
7	0.2
7.5	0.3
8	0.9
8.5	2.2
9	4.5
9.5	7.4
10	10.6
10.5	13.6
11	15.8
11.5	16.3
12	17.2
12.5	17.6
13	16.6
13.5	14.6
14	8.2
14.5	4.9
15	2.4
15.5	1
16	0.3

16.5	0.2
17	0.2
17.5	0.1
18	0.1
18.5	0.1
19	0.1
19.5	0.1
20	0.1
20.5	0.1
21	0.1
21.5	0
22	0
22.5	0
23	0
23.5	0
24	0
24.5	0
25	0

DISTANCE=25 cm

Lateral Displacement	Maximum Relative Light Intensity(mA)
0	0
0.5	0
1	0
1.5	0

2	0
2.5	0
3	0
3.5	0
4	0
4.5	0.1
5	0.1
5.5	0.1
6	0.1
6.5	0.1
7	0.1
7.5	0.1
8	0.2
8.5	0.3
9	0.8
9.5	1.8
10	3.2
10.5	5
11	7.2
11.5	9.3
12	11.4
12.5	12.5
13	12.2
13.5	10.7
14	8.4

14.5	6
15	3.7
15.5	2
16	0.7
16.5	0.3
17	0.2
17.5	0.1
18	0.1
18.5	0.1
19	0.1
19.5	0.1
20	0.1
20.5	0.1
21	0.1
21.5	0.1
22	0.1
22.5	0
23	0
23.5	0
24	0
24.5	0
25	0

DISTANCE=30 cm

Lateral Displacement	Maximum Relative Light Intensity(mA)
0	0
0.5	0
1	0
1.5	0
2	0
2.5	0
3	0
3.5	0
4	0.1
4.5	0.1
5	0.1
5.5	0.1
6	0.1
6.5	0.1
7	0.1
7.5	0.1
8	0.2
8.5	0.3
9	1
9.5	2.1
10	3.5
10.5	5.4
11	7.6

11.5	9.6
12	11.5
12.5	11.9
13	11
13.5	9.2
14	7.1
14.5	4.6
15	2.6
15.5	1.1
16	0.4
16.5	0.3
17	0.2
17.5	0.1
18	0.1
18.5	0.1
19	0.1
19.5	0.1
20	0.1
20.5	0.1
21	0.1
21.5	0.1
22	0.1
22.5	0.1
23	0
23.5	0

24	0
24.5	0
25	0

READINGS USING LENS

Focal Length=20 cm

Distance=20 cm

Lateral Displacement	Maximum Relative Light Intensity(mA)
0	0.1
0.5	0.1
1	0.1
1.5	0.1
2	0.1
2.5	0.1
3	0.1
3.5	0.1
4	0.1
4.5	0.1
5	0.1
5.5	0.1
6	0.2
6.5	0.2
7	0.3
7.5	0.3

8	0.3
8.5	0.4
9	0.7
9.5	0.7
10	1.1
10.5	4.5
11	9.4
11.5	12.2
12	13.4
12.5	13.5
13	12.2
13.5	10
14	6.4
14.5	2.6
15	0.7
15.5	0.5
16	0.4
16.5	0.3
17	0.3
17.5	0.2
18	0.2
18.5	0.2
19	0.2
19.5	0.1
20	0.1

20.5	0.1
21	0.1
21.5	0.1
22	0.1
22.5	0.1
23	0.1
23.5	0.1
24	0.1
24.5	0.1
25	0.1

Distance=23 cm

Lateral Displacement	Maximum Relative Light Intensity(mA)
0	0.1
0.5	0.1
1	0.1
1.5	0.1
2	0.1
2.5	0.1
3	0.1
3.5	0.1
4	0.1
4.5	0.1
5	0.1
5.5	0.1

6	0.2
6.5	0.2
7	0.2
7.5	0.3
8	0.4
8.5	0.4
9	0.6
9.5	0.9
10	1.5
10.5	3.1
11	3.8
11.5	5.8
12	9
12.5	10.6
13	10.1
13.5	7.9
14	4.1
14.5	2.6
15	0.9
15.5	0.6
16	0.4
16.5	0.3
17	0.3
17.5	0.3
18	0.2

18.5	0.2
19	0.2
19.5	0.2
20	0.2
20.5	0.1
21	0.1
21.5	0.1
22	0.1
22.5	0.1
23	0.1
23.5	0.1
24	0.1
24.5	0.1
25	0.1

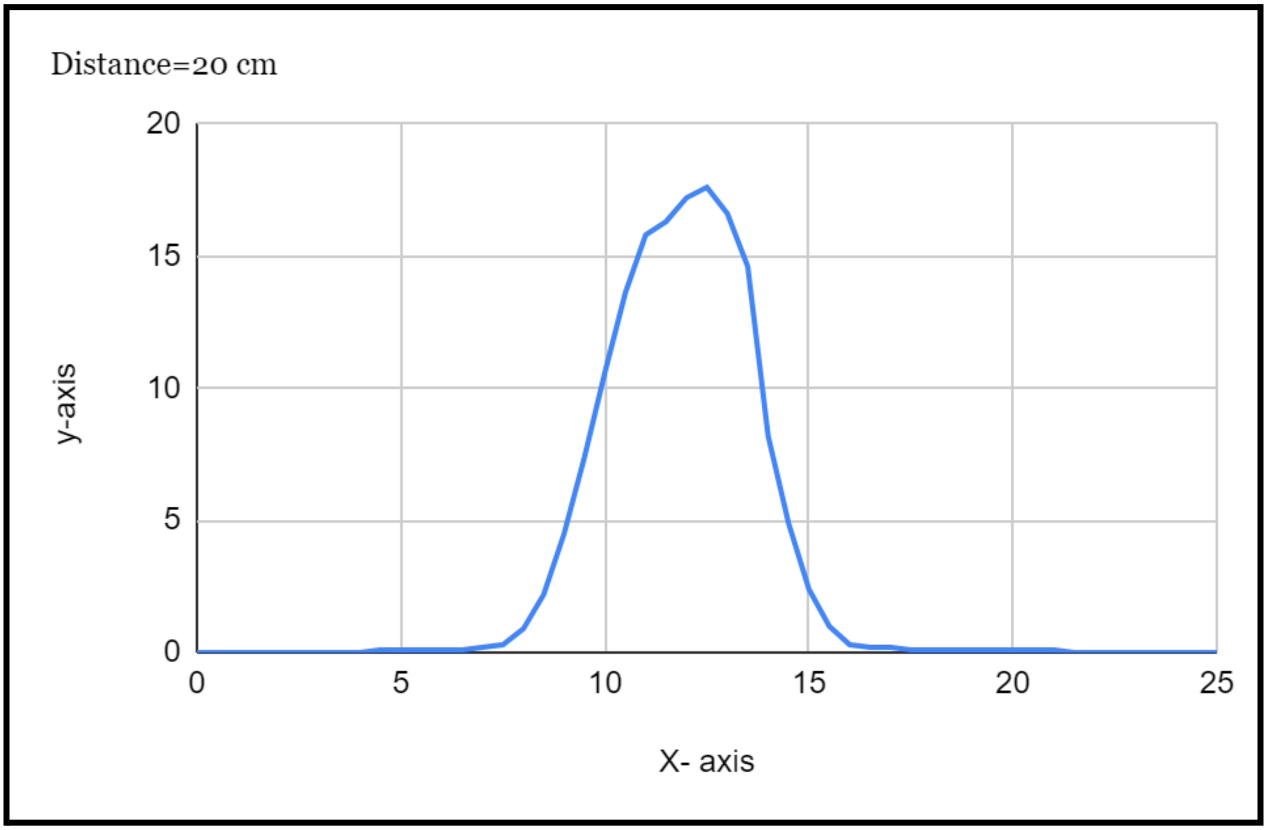
Distance=17 cm

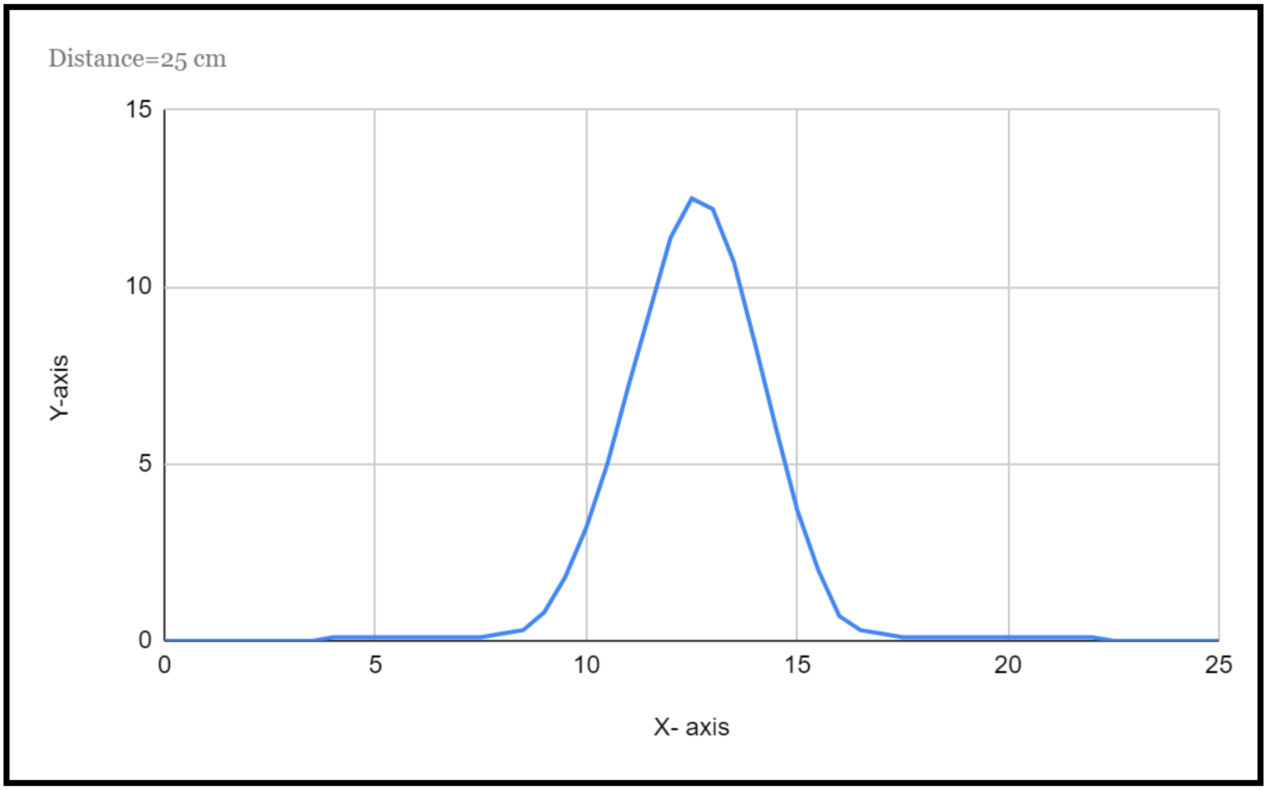
Lateral Displacement	Maximum Relative Light Intensity
0	0.1
0.5	0.1
1	0.1
1.5	0.1
2	0.1
2.5	0.1
3	0.1
3.5	0.1

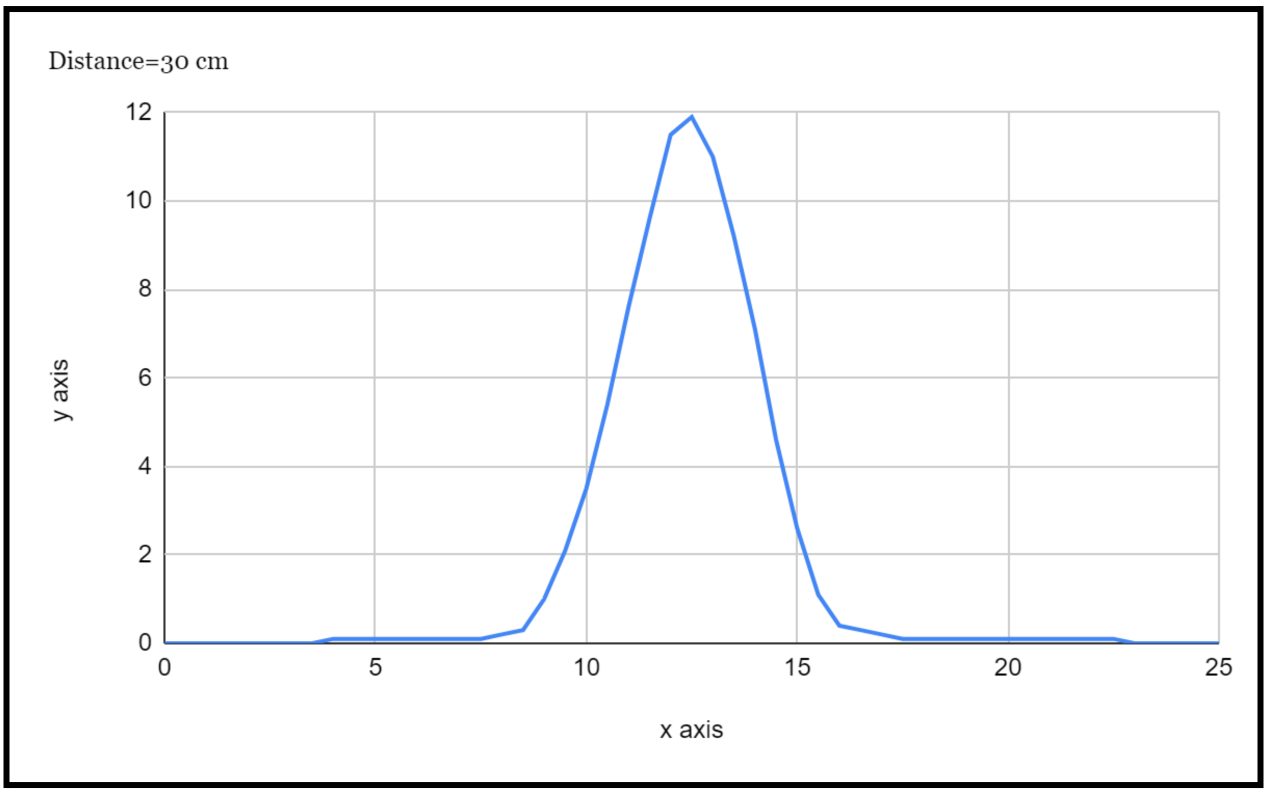
4	0.2
4.5	0.2
5	0.2
5.5	0.2
6	0.3
6.5	0.3
7	0.4
7.5	0.7
8	0.7
8.5	0.8
9	1.1
9.5	1.4
10	2.3
10.5	4
11	5.9
11.5	9.1
12	9.3
12.5	11.1
13	9.5
13.5	6.1
14	3.8
14.5	1.9
15	1.3
15.5	0.9
16	0.8

16.5	0.6
17	0.5
17.5	0.4
18	0.4
18.5	0.4
19	0.3
19.5	0.3
20	0.3
20.5	0.2
21	0.2
21.5	0.2
22	0.1
22.5	0.1
23	0.1
23.5	0.1
24	0.1
24.5	0.1
25	0.1

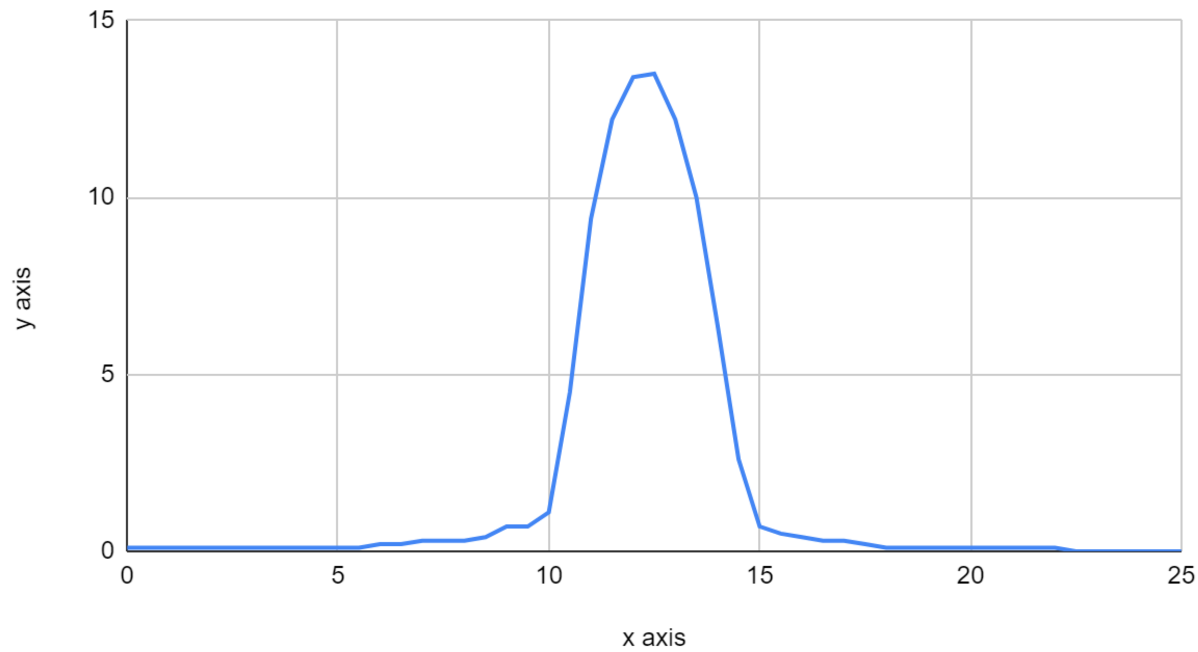
GRAPHS



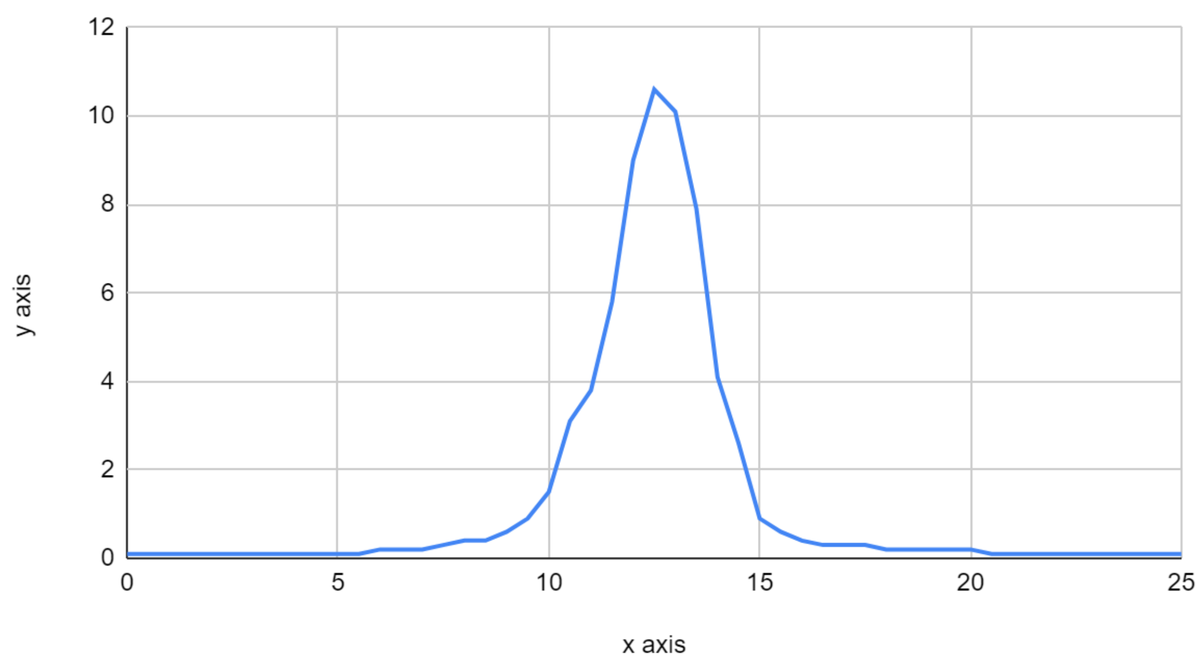

Distance=25 cm
Y-axis
15
10
5
0
0
5
10
15
20
25
X- axis

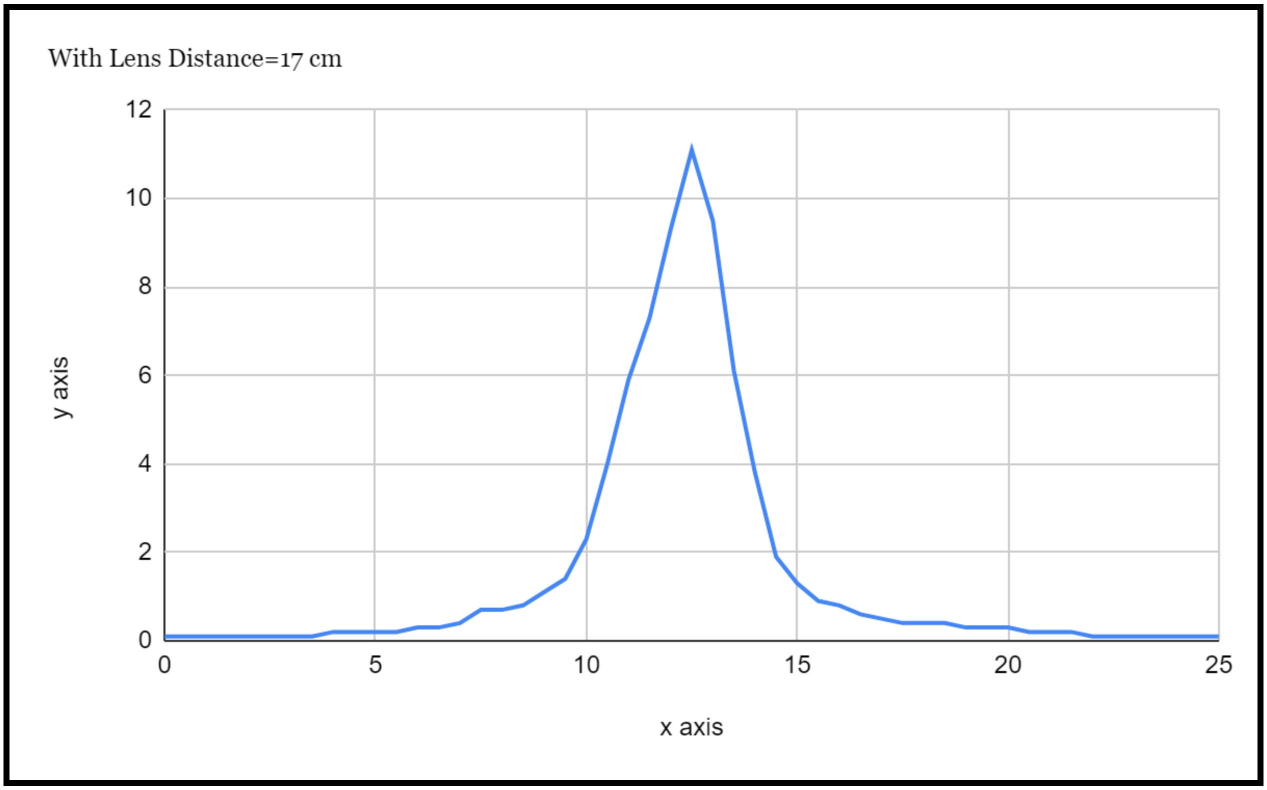

Distance=30 cm
y axis
12
10
8
6
4
2
0
0
5
10
15
20
25
x axis

With Lens Distance=20 cm



With Lens Distance= 23 cm




With Lens Distance=17 cm
y axis
x axis
0
2
4
6
8
10
12
0
5
10
15
20
25

CALCULATIONS:

I_0- Maximum Intensity

W_0- Beam waist

f- Focal length

D- Beam width

λ- Wavelength of laser

Without Lens:

Distance =20 cm

Spot size = I_0/e^2

$=17.6/e^2 = 2.3819$

Distance=25 cm

Spot size = I_0/e^2

$=12.5/e^2 = 1.6875$

Distance=30 cm

Spot Size=I_0/e^2

$=11.9/e^2=1.6065$

With Lens of Focal Length 20 cm:

Distance=17 cm

Spot Size=I_0/e^2

$=11.1/e^2=1.4985$

$w0 = f\lambda/D$

$=20x10^{-2}x650x10^{-9}/(5.3/2)x10^{-3}$

$=4.905x10^{-5}$ m

$Z_r = 1/2kw0^2$

= $1/2x(2\pi/\lambda)(4.905x10^{-5})^2$

=0.01165m

Distance=20 cm

Spot Size=I_0/e^2

=$13.5/e^2$

=1.8225

$w0 = f\lambda/D$

=$20x10^{-2}x650x10^{-9}/(4.6/2)x10^{-3}$

=$5.65x10^{-5}$ m

$Z_r = 1/2kw0^2$

= $1/2x(2\pi/\lambda)(5.65x10^{-5})^2$

=0.0154m

Distance=23 cm

Spot Size=I_0/e^2

=$10.6/e^2$

=1.431

$w0 = f\lambda/D$

=$20x10^{-2}x650x10^{-9}/(4.9/2)x10^{-3}$

=$5.306x10^{-5}$ m

$Z_r = 1/2kw0^2$

= $1/2x(2\pi/\lambda)(5.306x10^{-5})^2$

= 0.0136m

RESULT:

Without Lens:

Distance	Spot Size
20 cm	2.3819
25 cm	1.6875
30 cm	1.6065

With Lens of Focal Length 20 cm:

Distance	Spot Size	Rayleigh Range(m)
17 cm	1.4985	0.01165
20 cm	1.8225	0.0154
23 cm	1.431	0.0136

DISCUSSION

The observed laser beam parameters such as Spot size and Rayleigh range are not in their theoretical limits. It can be because of some instrumental defects. We have also found out the beam waist.

CONCLUSION

The laser has revolutionized many areas of science and society, providing bright and versatile light sources .In manufacturing, lasers are used for cutting,engraving,drilling and marking a broad range of materials.Lasers are typically identified by their gain medium and often classified by the radiating species that give rise to stimulated emission.Here semiconductor diode type of laser is used.A semiconductor laser is often referred to as a laser diode since it operates like a diode with current flowing in the forward direction of the junction.These lasers are mostly used in optical data storage. Laser occurs in a wide variety of media with output characteristics that posses an even greater degree of variation.

REFERENCES

- Laser Fundamentals by William T. Silfvast
- Principles of Lasers by O Svelto
- Laser Systems and Applications
- www.sciencedirect.com
- www.rp-photonics.com