A Report
On
Laser Characteristics

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Laser Beam Profile, Spot size and Beam Divergence

AIM

As the title suggests, we try to measure the Beam Spot size and Beam Divergence of a Laser beam using a detector in various ways. We also try and see that the beam profile is Gaussian.

APPARATUS

Diode laser modules, Breadboard or adjustable base, photo detector and output measurement unit.

1. THEORY

A laser is a device that emits light (electromagnetic radiation) through a process called stimulated emission. The term "laser" is an acronym for Light Amplification by Stimulated Emission of Radiation. Laser light is usually spatially coherent, which means that the light either is emitted in a narrow, low-divergence beam, or can be converted into one with the help of optical components such as lenses. Typically, lasers are thought of as emitting light with a narrow wavelength spectrum ("monochromatic" light). This is not true of all lasers, however some emit light with a broad spectrum, while others emit light at multiple distinct wavelengths simultaneously. The coherence of typical laser emission is distinctive. Most other light sources emit incoherent light, which has a phase that varies randomly with time and position.

A laser consists of a gain medium inside a highly reflective optical cavity, as well as a means to supply energy to the gain medium. The gain medium is a material with properties that allow it to amplify light by stimulated emission. In its simplest form, a cavity consists of two mirrors arranged such that light bounces back and forth, each time passing through the gain medium. Typically one of the two mirrors, the output coupler, is partially transparent. The output laser beam is emitted through this mirror.
Light of a specific wavelength that passes through the gain medium is amplified (increases in power); the surrounding mirrors ensure that most of the light makes many passes through the gain medium, being amplified repeatedly. Part of the light that is between the mirrors (that is, within the cavity) passes through the partially transparent mirror and escapes as a beam of light.
Laser diodes: A laser diode is a laser where the active medium is a semiconductor similar to that found in a light-emitting diode. The most common and practical type of laser diode is formed from a p-n junction and powered by injected electric current. These devices are sometimes referred to as injection laser diodes to distinguish them from (optically) pumped laser diodes, which are more easily produced in the laboratory.

1.1 Definitions

• Beam Spot Size: Beam Diameter is defined as the distance across the center of the beam

for which the irradiance(I) equals $1/e^2$ of the maximum irradiance. The spot size of the.

• Beam Divergence:The beam divergence of an electromagnetic beam is an angular measure of the increase in beam diameter with distance from the optical aperture from which the electromagnetic beam emerges. It is given by

$$\theta = (w_1 - w_2)/d$$

where w_1 and w_2 are the beam spot sizes of a laser bean mounted at two points separated by a distance d.

An optical cavity or optical resonator is an arrangement of mirrors that forms a standing wave cavity resonator for light waves. Optical cavities are a major component of lasers, surrounding the gain medium and providing feedback of the laser light. They are also used in optical parametric oscillators and some interferometers.

1.2 Few Details

Having, setup the definitions, let us try and look at the implications of both the quantities that we aim to measure. A Gaussian beam is a beam of electromagnetic radiation whose transverse electric field and intensity (irradiance) distributions are described by Gaussian functions. Many lasers emit beams with a Gaussian profile, in which case the laser is said to be operating on the fundamental transverse mode, or TEM_{00} mode of the laser's optical resonator. When refracted by a lens, a Gaussian beam is transformed into another Gaussian beam (characterized by a different set of parameters), which explains why it is a convenient, widespread model in laser optics. This is the reason why the dispersed beam which we get by using a disperser has a Gaussian Profile too. The electric Field Amplitude of a Gaussian beam can be given by

$$E(r,z) = E_0(w_0/w(z))\exp\{-r^2/w^2(z)\}\exp\{-ikz - ik\left(\frac{r^2}{2R(z)}\right) + i\zeta(z)\} \quad (1)$$

where r is the radial distance from the centre axis of the beam z is the axial distance from the beam's narrowest point (the waist)

$k=2\pi/\lambda$ is the wave number (in radians per meter)

w(z) is the radius at which the field amplitude and intensity drop to 1/e and $1/e^2$ of their axial values respectively

w_0 is the waist size.

From this the intensity or the irradiance can be calculated as follows

$$I(r,z) = \frac{|E(r,z)|^2}{2\eta} = I_0\{\frac{w_0}{w(z)}\}^2\exp\{\frac{2r^2}{w^2(z)}\} \quad (2)$$

where η is the characteristic impedance of the medium in which beam is propagating.

For free space it is nearly 377. The divergence of a beam can be calculated if one knows the beam diameter at two separate points (w_1,w_2), and the distance (d) between these points. The beam divergence is given by

$$\theta = \arctan\left(\frac{w_2 - w_1}{2d}\right) \tag{3}$$

For the laser we observe that the divergence is very less. So, we can approximate tanθ to θ.Hence giving

$$\theta = (w_1 - w_2)/d \tag{4}$$

The divergence of a laser beam is proportional to its wavelength and inversely proportional to the diameter of the beam at its narrowest point.

2. PROCEDURE

We have a laser and a detector (for measuring the intensity) set on an optical breadboard. Firstly, we start wit the alignment of the laser beam. We can do this by slowly adjusting the laser in it’s support while checking the intensity pattern along two virtual horizontal lines at different heights on the beam cross-section. As we are provided with a beam which is considerably divergent , we have to first make the beam as parallel as possible by constructing a telescope. This is done by fixing one lens infront of the laser diode and then moving the other lens at some distance from the first lens to obtain a fairly parallel beam. For the alignment of the laser beam we first mark the position of the laser and then try to get the laser beam at the same position after keeping the first lens. This can be done by adjusting the height of the lens. The same procedure is followed for the second lens. Once alignment is over we can make the beam parallel. After this is done, we fix a distance for the detector and take intensity measurements of the beam along a horizontal line passing the point with the maximum intensity. Similar readings can be taken for the vertical orientation of the laser beam too. For calculating the beam divergence, we calculate the maximum intensity of the beam, which helps in calculating the beam spot size, at different distances from the laser with the help of the optical bread board. These can also be tabulated and the resulting calculations lead to the necessary results.

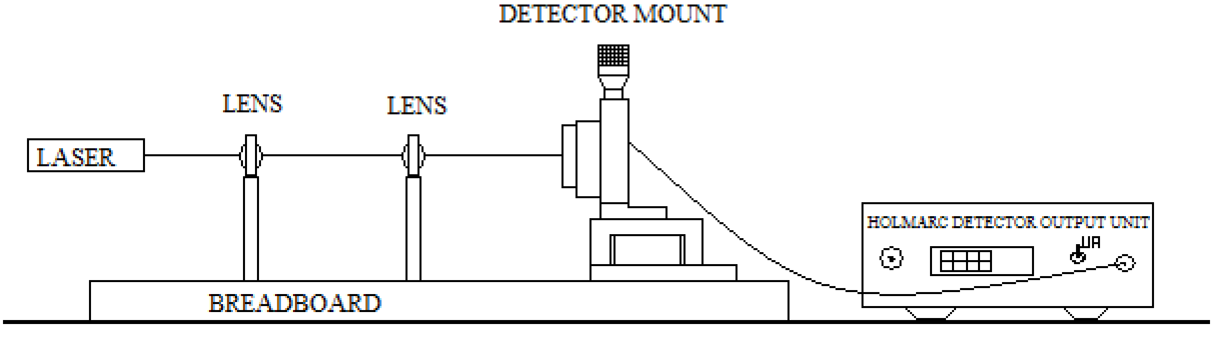

Fig.1

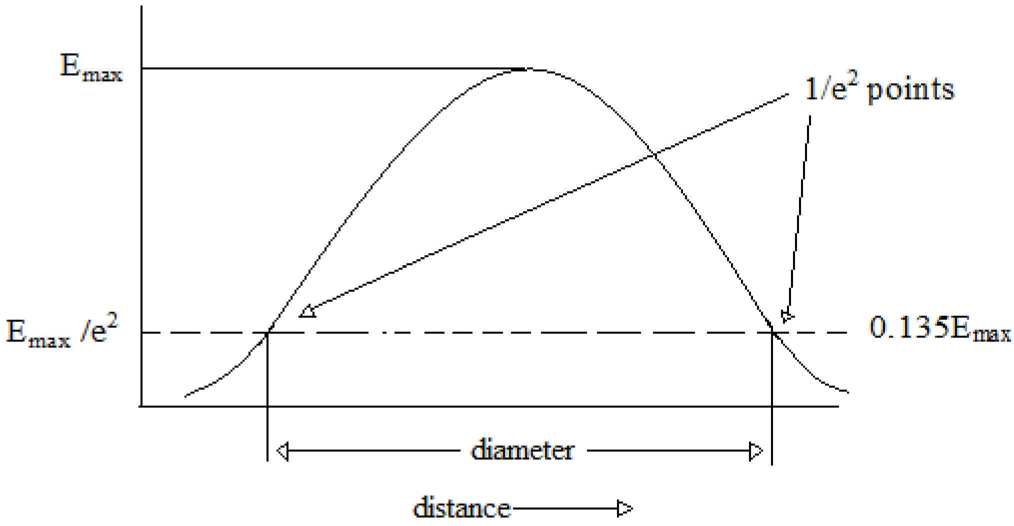

Fig.2

Table I

Distance	Current (μA)

Thus from the graphs plotted for the various values of current by keeping the detector at different distances from the laser diode, we can calculate the cross section of the laser beam at these points and thus calculate the divergence.

FEW OBSERVATIONS

- Observed the Gaussian nature of beam laser using laser diode and evaluated the beam spot size.
- Observed the laser beam divergence and plotted the graph.

Power distribution of laser beam

AIM
To determine the power distribution within the laser beam.

APPARATUS
A diode laser, a knife edge mounted on a micropositioner, a photo detector, bread board.

THEORY
This method of power distribution determination evolves the measurement of power past a knife edge which is slowly inserted into the beam. Let us assume that laser is oscillating in TEM_{00} mode so that the spatial distribution of the beam is Gaussian. Let P_0 be the total power in the beam of spot size $2W_0$ .the intensity distribution I(x,y) , measured perpendicular to the direction of propagation is given by

$$I(x,y) = \left(\frac{2p_0}{\pi w_0^2}\right)\exp\left(-\frac{2(x^2+y^2)}{w_0}\right) \qquad (1)$$

The power transmitted past a knife-edge blocking off all points for which x<a is therefore given by

$$\int_{-\infty}^{\infty}\int_{a}^{\infty} I(x,y)dx\,dy = \left(\frac{p_0}{2}\right) erfc\left(\frac{a_0\sqrt{2}}{w_0}\right) \qquad (2)$$

Where **a** is the depth of knife-edge in the beam. Therefore the integrated power past knife-edge is given by complementary error function. This method uses all points of intensity distribution.

DIAGRAM

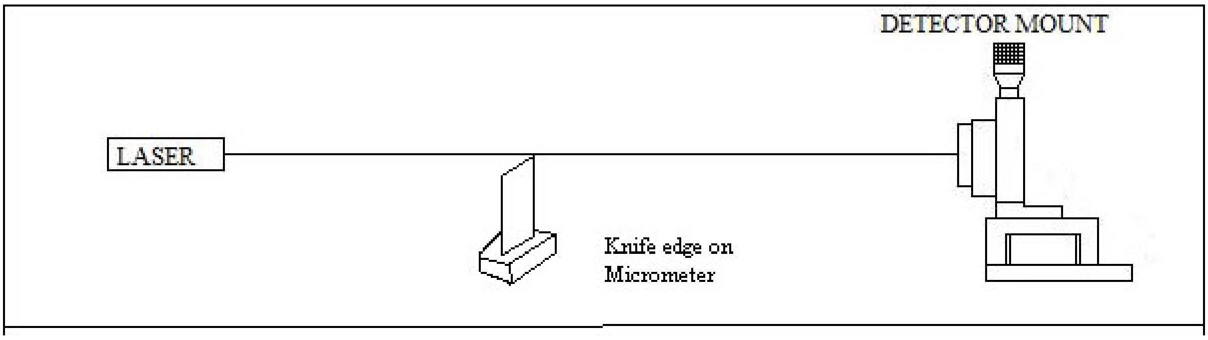

Fig.1

PROCEDURE
a) Diode laser is mounted on the laser mount.

b) Photo detector is mounted such that the laser falls on the pinhole of the detector.

c) The ammeter reading corresponding to maximum is noted.

d) The knife edge is mounted on micropositioner perpendicular to the beam at any plane.

e) The knife edge is inserted and corresponding intensity values are plotted.

f) Relative power is found and relative power is plotted versus position of knife edge.

Table I

Knife Edge Position	Intensity

Result

Power distribution within the laser beam has been determined.

Precautions

1) Ensure that eyelevel is always higher than the laser beam.
2) Ensure that beam is propagating parallel to the breadboard plane.