EXP.NO: 3

Name of experiment: Parameters of the Laser Beam

Purpose of experiment:

1. Find the Gaussian Shape of the beam.
2. Measure the spot size.

Apparatus: Optical Bench, Optical Rail, He-Ne Laser, Detector with micro positioner .

Theory:

The spatial distribution of the irradiance of a laser beam is of prime importance in many applications. For example, laser drilling requires beams of particular diameter so that holes of the proper size can be drilled. Laser ranging requires well-collimated beams that diverge slowly as they travel away from the laser .Almost all applications require the uniform spatial distribution of irradiance produced by the Gaussian, or TEM_{00} mode.

TEM_{00} is termed the “uniphase”or pure Gaussian mode because it is the only transverse mode in which all the light is in one phase at any given time. This uniphase mode is the only mode in which all laser light is spatially coherent, resulting in the following three important characteristics of this mode:

- -It has a lower beam divergence than other modes. Lower divergence is important to the transmission of beam over large distance, as, for example, in laser ranging.
- It can be focused to a spot smaller than other existing modes. This is important in an application such as drilling.
- Its spatial coherence is ideal for applications that depend upon the interference of light. Other modes cannot be used because they lack adequate spatial coherence.

Transverse electromagnetic modes:

The longitudinal modes of a laser describe the variations in the electromagnetic field along the optical axis of the laser cavity. A complete description of the electromagnetic field requires that variations in directions perpendicular to the optical axis also be considered. Electromagnetic field variations perpendicular to the direction of travel of the wave are called "transverse electromagnetic modes" or "TEM modes.

Figure 1 indicates the profile of a TEM00 laser beam. Since the irradiance of the beam decreases gradually at the edges, specification of beam diameter out to the points of zero irradiance is impractical. The "**beam diameter**" is defined as "the distance across the center of the beam for which the irradiance (E) equals $1/e^2$ of the maximum irradiance ($1/e^2$ = 0.135)." The "spot size" (ω) of the beam is "the radial distance (radius) from the center point of maximum irradiance to the $1/e^2$ point." These definitions provide standard measures of laser beam size.

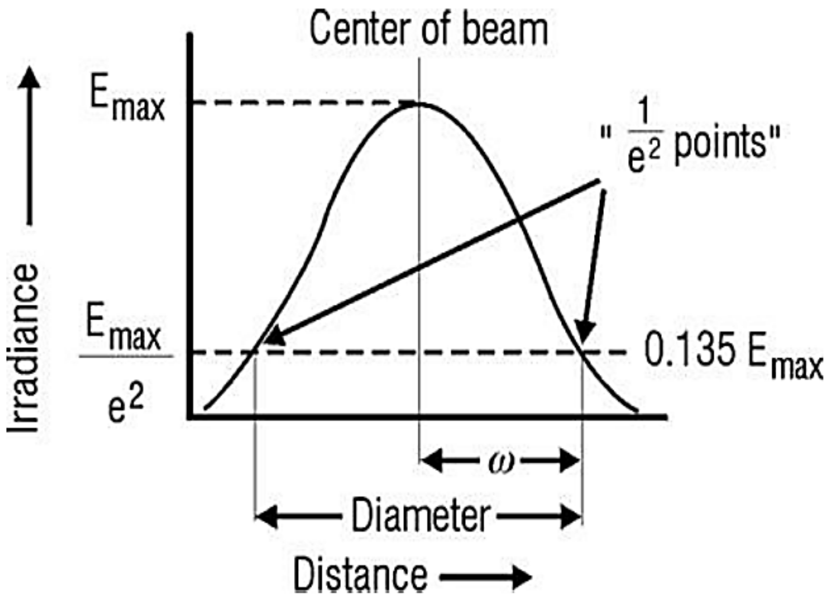


Fig. 1 Definitions of beam diameter and spot size (ω)

Transmission of a beam through an aperture:

If a laser beam is centered upon a circular aperture, the edges of the beam may be truncated as illustrated in Figure 2. The fraction of beam power transmitted

$$T = 1 - e^{-2(r/\omega)^2}$$

through the aperture is given by:

where:

T = Fractional transmission.

r = Radius of aperture.

ω = Spot size (radius of beam to $1/e^2$ points).

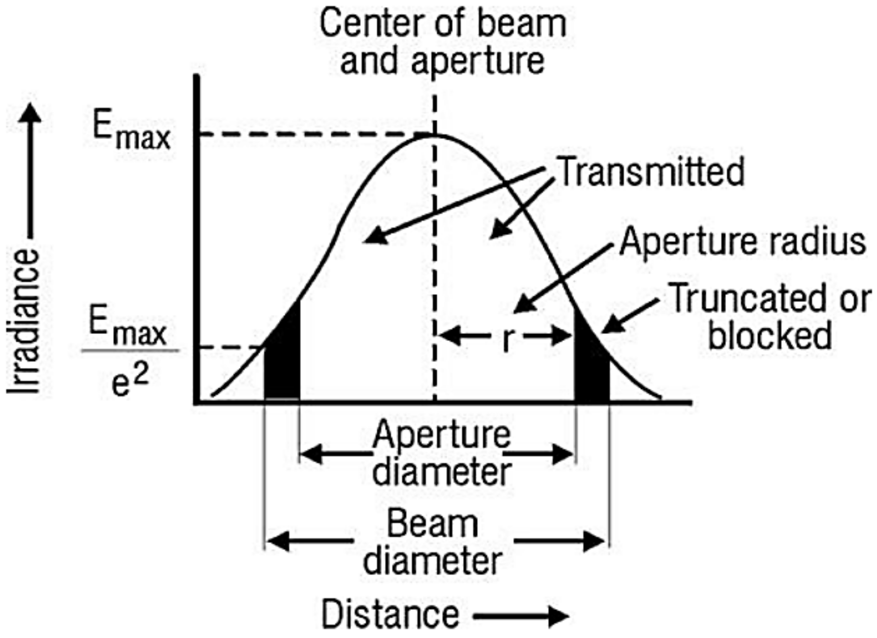


Fig. 2 Transmission through a circular aperture

In some situations, it is useful to be able to calculate the ratio of the aperture radius all of those are lower case r to the beam spot size (w) from a knowledge of the beam power transmitted through a given aperture. In that event, one can rearrange Equation 1 as follows:

$$r/\omega = \left(\frac{-\ell n(1-T)}{2}\right)^{1/2}$$

Where

r = Radius of aperture

w = Spot size of laser beam passing through aperture

T = Fractional transmission (T passing/T incident)

Figure 3 is a transmission curve based upon Equation 1A. The horizontal scale gives the ratio of aperture diameter (2r) to beam diameter (2w). The vertical scale is calibrated in percent of transmission. The transmission curve can be used with a calibrated aperture to determine the diameter of a laser beam.

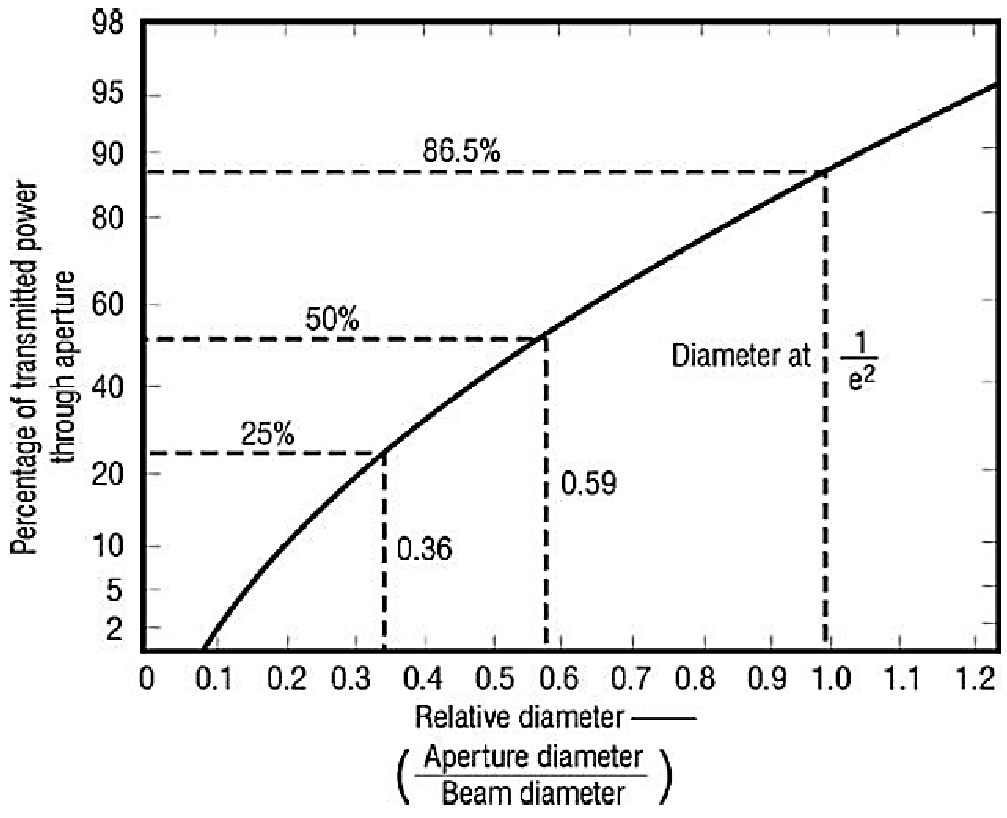


Fig. 3 Percentage of transmitted power through an aperture

Determining Laser Spot Size when focused by a lens:

When light passes through circular openings such as pin holes or apertures, light spread out and diverges. When light is focused by a lens, the light does not focus to a geometrical point; instead it focuses to a tiny spot of some diameter, surrounded by alternate bright and dark rings, the entire image referred to as an AIRY diffraction pattern. The wave theory of light explains the behavior of the spreading of light passing through aperture as well as the focusing of light as AIRY patterns rather than geometrical points. This is generally handled under the concepts of diffraction of light waves.

As such, diffraction theory set a lower limit on the amount of beam divergence that occurs when a laser beam passes through an effective aperture. Thus, any real optical system, containing imperfections in optical lenses, variation in the index of refraction along the atmosphere path of propagation and so on, the divergence is greater than that predicted by Equation 3.

$$\theta = \frac{1.27\lambda}{d}$$

In the same way, the spot size of a focused laser beam, , is predicted by diffraction theory to be of a value given by Equation 4, However, for real optical systems and real lenses, the focused spot is d' in fact, larger than that predicted by Equation 4.

So diffraction-limited optics sets the ideal limit for such results as expected beam divergence of expected focal spot size. When you use relationships such as Equation 3 and 4, to calculate beam divergence θ or focused spot size d', be aware that you are obtaining the "best" values possible in view of light diffraction.

In fact, for your "real" optical systems, the beam divergence θ and spot sized d' will both be larger than the equations predict. Real optical systems are therefore poorer in performance than those limited only by diffraction. We often refer to such real systems as many-times diffraction limited. For example, if Equation 3 predicts a beam divergence of θ = 1 milliradian for your systems, but you actually measure θ=5 milliradians, you can conclude that your system is 5-time diffraction limited.

$$d' = f\theta$$

where:

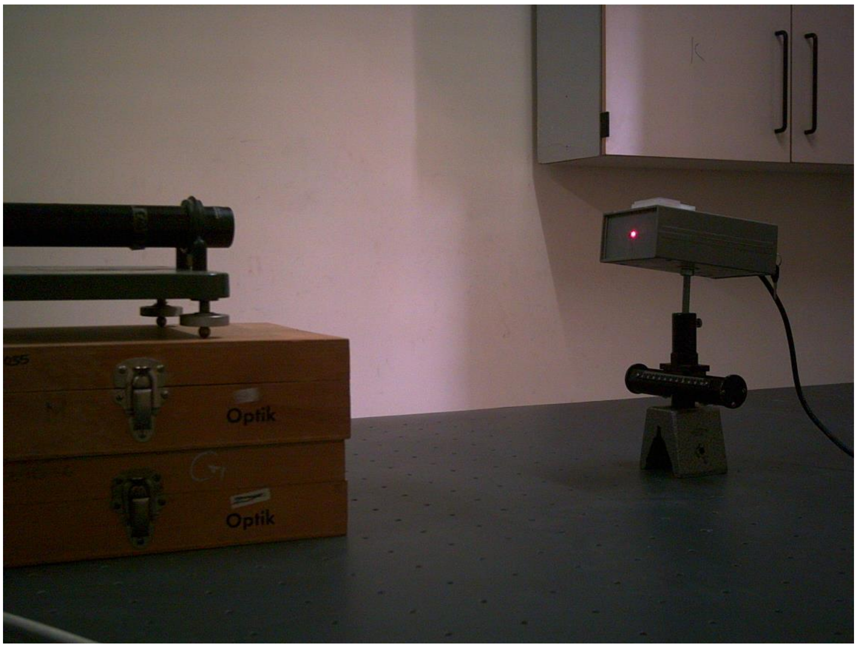
d' = Diameter of focused spot.

f = Focal length of lens

θ= Full-angle beam divergence.

Procedure:

1. Arrange the setup as below.



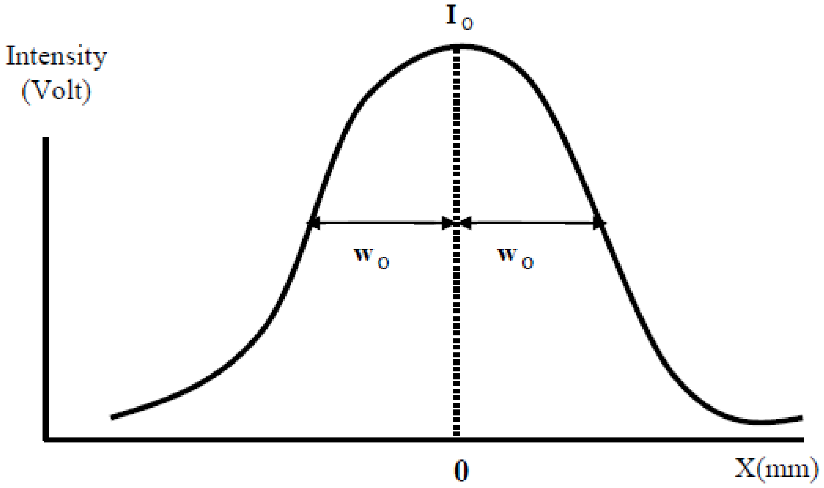
Experimental Photos

2. Take the Maximum reading from the pointer of the detector I_o (in volt) and take its corresponding reading from the micro position (x) .

3. Move 0 – 5 mm Steps from the micro position (x), left and right ,and take the corresponding readings of the detector as shown in table below .

Left		Right	
Micro position (x)	Detector (I)	Micro position (x)	Detector (I)

4. Draw a graph between the distance at x-axis and the voltage at y-axis to have the Gaussian shape as figure below .



5. Calculate I from the relation :

$I = I_o \times {}^{1}/_{e^2}$

6. From the graph , give the spot size ω_o of the laser beam .

Discussion:

1. Draw and label a diagram of the beam profile of the uniphase (Gaussian) mode. Indicate spot size and beam diameter on the diagram.

2. An Nd:YAG laser has a beam divergence of 2.0 mrad. The beam is focused by a lens of focal length 2.5 cm .Find diameter of focused spot.