Experiment 0: Gaussian Beams

1 Background

The irradiance of a Gaussian beam is symmetric about the beam axis and varies with radial distance r from the axis as

$$I(r) = I_0 exp(-2r^2/w_0^2) \tag{1}$$

Here, w_0 is the radial extent of the beam where the irradiance has dropped to $1/e^2$ of its value on the beam axis, I_0.

A Gaussian beam has a waist, where w_0 is smallest. It either diverges from or converges to this beam waist. This divergence or convergence is measured by the angle θ which is subtended by the points on either side of the beam axis where the irradiance has dropped to $1/e^2$ of its value on the beam axis.

Under the laws of geometrical optics, a bundle of rays (a beam) converging at an angle of θ should collapse to a point. However, real beams of waves (for which the uncertainty principle holds) do not behave this way. At the intersection of the asymptotes that define θ, the beam diameter reaches a minimum value $d_0 = 2w_0$ (the beam waist diameter).

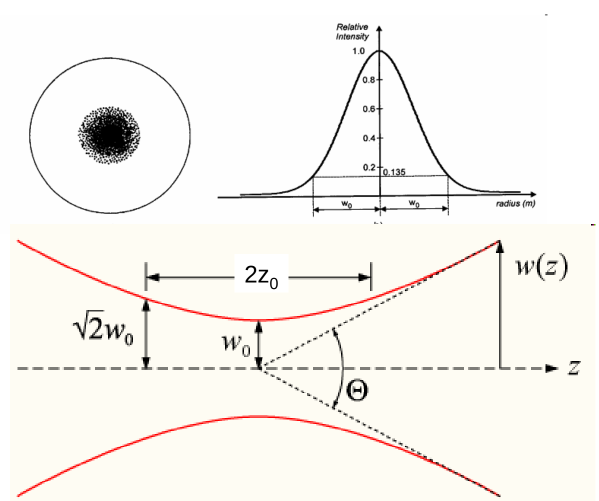

Figure 1:

The variation of the beam waist as a function of propagation distance z is:

$$w(z) = w_0 \sqrt{1 + \left(\frac{z}{z_0}\right)^2}, \tag{2}$$

where the "Rayleigh length" z_0 is given by:

$$z_0 = \pi \frac{w_0^2}{\lambda}, \tag{3}$$

and λ is the wavelength of the radiation.
The beam waist w_0 depends on the beam divergence angle as

$$w_0 = \frac{2\lambda}{\pi\theta}. \tag{4}$$

2 Experiment

CAUTION: Please be very careful when using a laser. DO NOT look directly into the laser aperture, and be especially careful when bending down to align optics.

The goal of this lab is to measure the transverse spatial profile of the Gaussian beam emitted by the laser to compute the divergence angle θ, beam waist w_0, and Rayleigh length z_0. However, the computer measures light intensity as a function of time, not detector distance. Therefore, you must first calibrate the scanner displacement vs time. Use the appropriate detector slit to increase the spatial resolution. Adjust for a reduction in photodetector signal by increasing the amplifier gain.

Rather than give explicit instructions on how to determine θ, w_0, and z_0, we expect you to design a procedure of your own, using only the transverse intensity profiles you measure in this lab. Be creative, if necessary!