MEASURING GAUSSIAN BEAM DIAMETER

There are numerous ways to measure the diameter of a Gaussian laser beam. Ray tracing, multiphoton ionization yields, and fluorescence correlation spectroscopy all provide accurate results, but are oftentimes unpractical. They require sophisticated equipment, complicated analysis, or specific experimental operations. The knife edge technique is a simple, general method that can easily be adapted to a wide range of experiments.

In a way the knife edge method is derived from the pinhole methods so let's look at that first. The pinhole method uses a small pinhole (small relative to the size of the beam one is trying to measure) and is scanned across the laser beam. In this configuration, the pinhole measures the intensity (W/m²) of the beam over the aperture of the pinhole. By scanning the pinhole through the beam one can obtain a plot of intensity as function of beam radius. However, when the beam is small (laser beams can be as small as a few microns) using a pinhole a fraction the size of the laser beam is impractical. In this case one can use the sharp edge of a knife blade and scan it across the laser beam diameter, provide the beam has a Gaussian spatial distribution.

Effectively in this scenario one is eclipsing the beam more and more by slowly translating the knife edge into the beam. From this measurement and working out the surface integral of a sharp edge eclipsing a circle or Gaussian, one can obtain the beam size with this method. This was elegantly described by Koshrofian et al in 1983 (Applied Optics).

Experimental set-up
A single-edge razor blade is attached to a micrometer-driven translation stage to eclipse the laser beam. The intensity of the uneclipsed portion of the beam is measured with a detector.
REMEMBER: the cross section of a Gaussian beam is given by the function:

\[ I(r) = I_0 e^{-\frac{2r^2}{\omega_L^2}} \]

Where \( I(r) \) is the intensity as a function of radius, \( I_0 \) is the intensity at \( r = 0 \), \( r \) is the radius and \( \omega_L \) is the beam radius. The beam radius is defined as the radius where the intensity is reduced to \( 1/e^2 \) of the value at \( r = 0 \). This can be seen by letting \( r = \omega_L \).

The experimental data is obtained by moving the translator and knife in small increments to gradually allow less and less of the laser beam to strike the detector, effectively eclipsing the beam with the knife blade. The resulting graph is shown below.

Without going into the mathematics of how this is done, one can use the points in the beam where the energy or power is 90% and 10% of the total respectively, to calculate the Gaussian beam radius or diameter.
\[ \beta^{-1} = 0.552(\chi_{10} - \chi_{90}) \]

\[ d \text{ (diameter)} = 2\sqrt{2\beta^{-1}} \]