3.7 What is M^2?

M^2 or Beam Propagation Ratio, is a value that indicates how close a laser is to being a single mode TEM_{00} beam, which in turn determines how small a beam waist can be focused. For the perfect Gaussian TEM_{00} condition the M^2 equals 1.

For a laser beam propagating through space, the equation for the divergence θ_0 of an unfocused beam is given by:

$\theta_0 = M^2 4\lambda/\pi D_0$ (D_0 is the waist diameter of the laser beam)

For a pure Gaussian TEM_{00} beam M^2 equals 1, and thus has no impact on the calculation. The calculation of the minimal beam spot after the lens is then:

$d_0 = 4\lambda/\pi\theta$ (θ is the beam divergence after the lens)

Again with M^2 equal to 1, the focused spot is diffraction limited. For real beams, M^2 will be greater than 1, and thus the minimum beam waist will be larger by the M^2 factor.

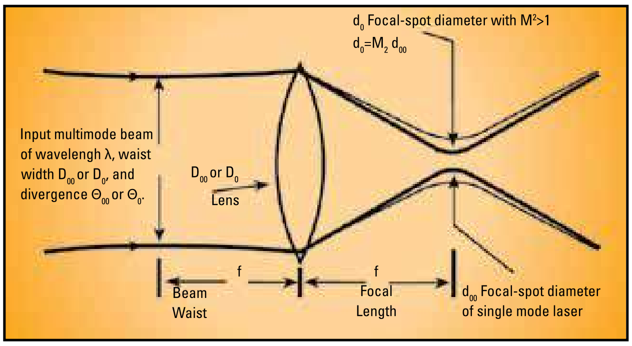

Figure 1 - Characteristics of a laser beam as it passes through a focusing lens

How is M^2 measured?

M^2 cannot be determined from a single beam profile measurement. The ISO/DIS 11146 requires that M^2 be calculated from a series of measurements as shown in figure 1. M^2 is measured on real beams by focusing the beam with a fixed position lens of known focal length, and then measuring the characteristics of the artificially created beam waist and divergence.

To provide an accurate calculation of M^2, it is essential to make at least 5 measurements in the focused beam waist region, and at least 5 measurements in the far field, two Rayleigh ranges away from the waist area. The multiple measurements ensure that the minimum beam width is found. In addition, the multiple measurements enable a “curve fit” that improves the accuracy of the calculation by minimizing measurement error at any single point. An accurate calculation of M^2 is made by using the data from the multiple beam width measurements at known distances from a lens, coupled with the known characteristics of the focusing lens.

M^2 Measurement Solutions

Ophir-Spiricon have a number of solutions for the measurement of M^2 ranging from simple manual processes to fully automated dedicated instruments, depending on the frequency of the need to measure M^2 of lasers and laser systems. We have a system that will meet most needs, whether for research and development of new laser systems, manufacturing quality assurance, or maintenance and service of existing systems.

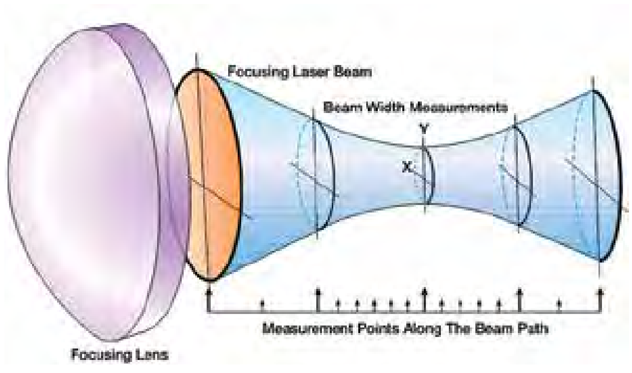

Figure 2 - focusing laser beam