Who Needs M^2?

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Laser processing puts an increasing demand on beam quality for the process to be cost-competitive. Merely profiling the beam and comparing the profile to a Gaussian fit is no longer adequate, because it does not guarantee a diffraction-limited beam. A 'Gaussian fit' calculation can deceive the user into assuming propagation properties that will not exist in practice. Thus, the Gaussian fit method can lull the user into a false sense of security of laser performance.

What measurement does provide this information? The answer is the "Beam Propagation Factor" M2, that quantitatively compares the propagation characteristics of the actual beam to those of a pure TEM0,0 Gaussian beam. This relationship allows the user to predict the exact focused spot size for a given input beam width and lens focal length, the irradiance of the focused spot, the Rayleigh range over which the beam is relatively collimated, and the far field divergence of the beam. While the M2 concept has been known for many years, the popularity of making this measurement is now more prevalent with the introduction of fully automated instrumentation.

WHY IS THIS IMPORTANT?

The focused spot size and irradiance of a laser beam have profound effects on processes. Nonlinear processes are typically proportional to the Irradiance squared or cubed. Thus, a beam with an M^2 of 1.4 (producing an irradiance one half that of a perfect beam) would REDUCE the nonlinear reaction to LESS THAN ONE QUARTER of a beam with an M^2 of 1. In very fine hole drilling, a beam with an M^2 of 1.4 would drill holes 1.4 times larger than a diffraction-limited beam.

It is essential for users to know what they can expect from their process. Knowing the M^2 of the laser beam enables the scientist or production manager to make accurate predictions of what to expect.

Until recently, making an accurate M^2 measurement has been a tedious procedure, because the M^2 value cannot be found with a single measurement. It requires that the beam pass through a focusing lens, and at least ten beam width measurements be made along the propagation axis. The results of these measurements are fitted to a curve which is then used to calculate the M^2 value. The ISO committee has defined a methodology however, that provides a reliable measurement of M^2 that can be used with confidence by anyone. The first is to perform the measurement so that the lens is stationary and the sensor moved through the waist of the beam. If the sensor is stationary and the lens moves, the reliability of the calculation is restricted to an input beam that is well collimated over the focusing lens translation range. If the beam is either diverging or converging, then the M^2 measurement can be incorrect and very misleading.

The second part of the ISO definition is that the width of the laser beam needs to be measured by the Second Moment method. Patented algorithms calculate the Second Moment width, which is difficult to do because of non-laser background signal and off-axis laser light. Only the Second Moment beam width measurement conforms to the laser beam propagation equation, and thus is the only measurement that provides reliable and consistent measurements of M^2.

Spiricon produces the M2-200, a fully automated M^2 measuring instrument that complies with all ISO procedures. This system is capable of analyzing both CW and pulsed lasers. With the addition of a FireWire CCD camera, the instrument can be operated by almost anyone. This instrument calculates all the necessary measurements in a few minutes, and stores the data and all the beam profiles for future reference.

ENABLING TECHNOLOGY

Using M^2, both laser manufacturers and laser users can achieve much greater confidence in being able to predict the performance of the laser beam. The M2-200 is in wide use by many laser manufacturers who measure the M^2 of each laser shipped, and can offer a very tight specification on this parameter. Because commercial instrumentation is now readily available for M^2 measurement, it is much easier for the end user to accurately evaluate this important parameter for themselves. Thus experiments come much closer to meeting the expectations of the laser scientist, and industrial users are much better able to predict what the laser will do in a given application.

Which beam is better?
Only M^2 can tell.