# Fundamentals of $M^2$ Beam Propagation

## $M^2$ MEASUREMEMNT

The beam propagation factor is a common single parameter that characterizes the whole beam as it propagates through space. According to ISO standard 11146, this parameter could be defined by several measurement techniques based on beam profiling along several points of the propagating beam. The standard defines several measurement techniques, all of which are based on beam profiling measurements using devices such as cameras, knife-edge and slits.
Multiple instruments have been developed to measure the propagation factor and M2 on production lines and in the laboratory. There are two main measurement requirements: One is the measurement of focused beams, and the second is measurement of collimated laser beams. For the latter, the fundamental operating principle is the focusing of the incoming laser beam by a lens, creating a waist position and a divergent beam on its two opposite sides. By scanning and calculating the $W_0$ beam waist at a focal point and the divergence in a far region many times the Raleigh range, one can determine an accurate value for M2 measurement. For focused beams, the principle is similar and the focal point of the system is scanned along with its divergence angle to create the focal beam characteristics such as beam size, depth of focus, M2, etc. Duma offers a full line of measuring instruments dedicated to perform such measurements for low and high power systems.

### The importance of beam quality measurements

In such application as laser material processing, printing, cutting, digital information read\write laser systems, M2 is a very important factor, since the beam profile and intensity distribution can dictate the overall material processing performance or the data storage capability per given volume. Frequently on certain applications, especially in high power ones, the M2 term is replaced by the beam parameter product (BPP) i.e. the product of beam radius at the beam waist and the far field beam divergence angle. The M2 factor, as will be shown on the following formulas, will also include the wavelength. The best possible beam quality is a diffraction-limited Gaussian beam having an M2 equal to 1.

$$M^2 = \frac{\theta * \pi * W_0}{\lambda}$$

Wherein:

$$\text{BPP} = \theta * \omega_0$$

$M^2$ could be derived from the second formula by dividing the BPP by the BPP of an ideal Gaussian beam at the same wavelength.

## DUMA OPTRONICS' SOLUTION

Duma Optronics offers two models for $M^2$ measurement:

1) For measuring collimated beams
2) For automatic measurement of focused beams, primarily for high power measurements.

The key features of direct measurements of collimated beams are as follows:

- **Interchangeable apertures** - to support large and small apertures
- **Accurate alignment** - due to a special mechanical dual axis alignment where the pivoting point is located exactly at the aperture center. Thus, adjustment will not affect beam location on aperture center.
- **Extremely long scanning stroke** – for accurate measurements over a long range based on a unique technology of double folded reflection to prevent an oversized structure.
- **Intuitive and user-friendly** software – a typical measurement cycle, as shown by

figure 1, will display W & V directions along the propagation axis, as well as 2D\3D reconstruction. Moreover, the software will continuously show the folding optics location in real time.

A full set of accessories will enable measurement of low and high power as well as various wavelengths up to 2.7 micrometers.

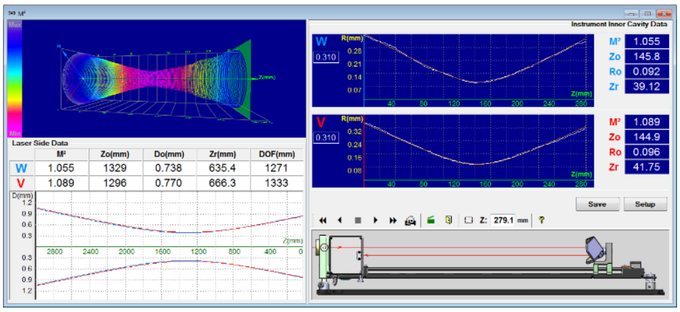


**Figure 1**

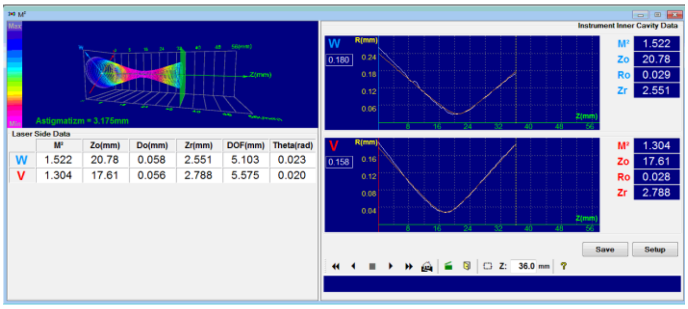


**Figure 2**

For focused beams applications, a different instrument is used, with capabilities of measuring focused beams of a few Watts to 4 kWatt and more with similar software features. See next section for high power laser beam measurements.