SID4

HIGH RESOLUTION BEAM CHARACTERIZATION

ISO COMPLIANT M^2 IN ONE SHOT

By quantifying how a beam departs from a perfect Gaussian TEM_{00}, the beam propagation ratio M^2 is a meaningful parameter to assess a laser beam quality. The reference method for its measurement is described in the paragraph 9 of the ISO 11146-1 standard[1]. Based on several intensity acquisitions at different positions along the propagation axis, this procedure is very time consuming and strongly depends on the operator. Moreover it cannot deliver real time data, even when automated, and hardly applies to fluctuating or low repetition rate lasers.

Phasics high resolution wavefront sensor offers a **simple way to measure the M^2**. In one single acquisition giving both phase and intensity, a M^2 value that **fully complies with the ISO 11146 standard** is obtained. This innovative method **applies to any beam**, even single shot laser.

"SINGLE SHOT M^2 MEASUREMENT"

Based on a patented technology, the **quadriwave lateral shearing interferometry**[2], Phasics' wavefront sensor measures at once both the intensity and phase fields of a laser beam. By applying light propagation equations, the full electromagnetic field is retrieved in any arbitrary plane. In particular, the **beam waist W_0** and the **intensity angular dispersion Θ** can be calculated with the usual ISO 2nd moment method. Then the M² is derived from the so-called Siegman formula[3]:

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

The Phasics technique has the advantage to provide **enough measurement points** to accurately calculate the M^2 factor. Indeed, unlike the Shack-Hartmann sensor[4] that suffers from its poor resolution, the Phasics technique does not cut off high frequencies on the phase map so the M^2 is **not under-estimated** and shows **no artifact**. The sensor is also robust even in low light conditions, so it can characterize **spatially modulated beams**.

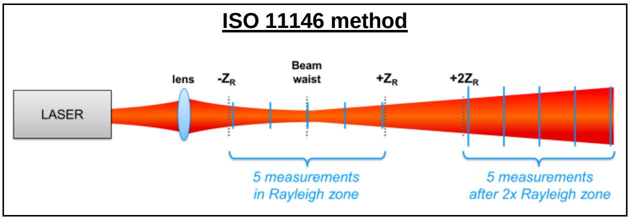

Figure 1: ***In the ISO 11146 method, the beam width must be measured along the optical axis at 5 various positions distributed within the Rayleigh length and 5 others beyond two times the Rayleigh length. At each location, 5 measurements have to be done. The beam width is calculated based on second order moment. A hyperbolic fit then provides the M^2 value.***

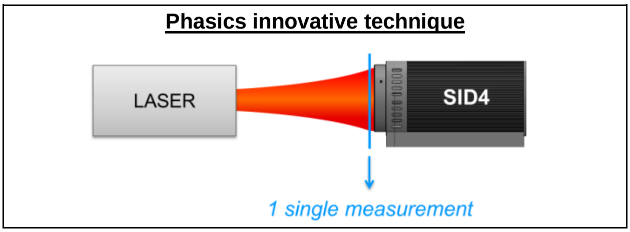

Figure 2: ***Phasics' sensor is placed anywhere along the optical axis where the beam fits the sensor aperture. Therefore the sensor can handle rapidly diverging beam for which the diameter at a distance above 2 Rayleigh lengths may be too large to be measured with the ISO 11146 method.***

More importantly, unlike the ISO standard method, the Phasics technique does not require scanning along the optical axis. Thus it offers an **instantaneous M^2 measurement** that enables a reliable characterization of **pulsed lasers.** It also eases the integration in a **laser production line**. Moreover, the Phasics technique does not require measuring at a specific axial distance. So it does not impose the use of a lens to image the waist and can apply to **rapidly diverging laser.**

"IN PROVEN COMPLIANCE TO ISO 11146 STANDARD"

The compliance to the ISO 11146 standard was proven by comparing the Phasics method outcomes to those of the standard method. To do so, a He-Ne laser of 632.8 nm wavelength and a M^2 close to 1 was used. A first series of measurement were done by **strictly following the requirements of the paragraphs 6 to 9 of the ISO 11146-1 standard**[1] so as to validate the set-up.

The Phasics sensor was placed on the same set-up and aligned following a rigorous procedure guided **by the software solution**. It validates that the set-up enables getting a result in agreement to specifications by checking the beam size, the light level, the background subtraction.

Then, series of measurement were alternately done following the standard and the Phasics methods. Additionally the Phasics sensor was moved at various axial positions from the laser to test the reproducibility when the axial position varies. For each position, 10 independent measurements were realized for repeatability assessment. As shown on the table below, **the outcomes match within 0.4%, which is below both techniques reproducibility.** Moreover, both methods have the **same reproducibility.** The right figure shows the results for M^2 measurement when varying the sensor position. The Phasics technique offers a **large possible distance range to place the sensor**. Combined with its compactness, this allows a great flexibility for its positioning.

	ISO method	Phasics
Mean value	1.067	1.063
Repeatability	0.006	0.001
Reproducibility	0.006	0.007

Table 1: ***M^2 measurement comparison in term of repeatability and reproducibility***

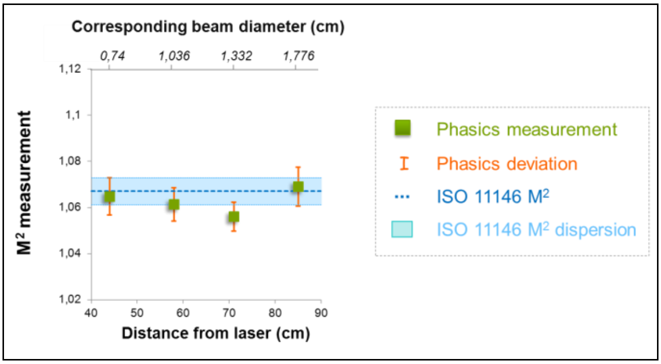

Figure 3: ***The M^2 values measured by Phasics method (green square on the left graph) agree with the one obtained by the ISO11146 method (represented by the dash blue line) whatever the distance from the laser is.***

Similar measurements were realized **for a laser of a M^2 far from 1. Again, the results of both techniques match**. These two series of measurement proved that the **Phasics' method for M^2 measurement is completely in agreement with the ISO 11146 standard** both in terms of expected repeatability and accuracy.

REFERENCES

[1] ISO Standard 11146, "Lasers and laser-related equipment – Test methods for laser beam widths, divergence angles and beam propagation ratios" (2005)

[2] J. Primot, N. Guérineau, "Extended Hartmann test based on the pseudoguiding property of a Hartmann mask completed by a phase chessboard", Appl. Opt. 39, p. 5715-5720 (2000).

[3] A. E. Siegman, "Defining, measuring, and optimizing laser beam quality", Proc. SPIE 1868, 2 (1993)

[4] B.J. Neubert *et al*, "On the problem of M^2 analysis using Shack-Hartmann Measurements", *J. Phys. D: Appl. Phys.* **34** 2414 (2001)