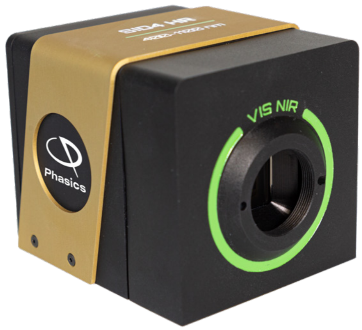
Phasics
The phase control company

HIGH RESOLUTION BEAM CHARACTERIZATION

ISO COMPLIANT M² IN ONE SHOT



By quantifying how a beam departs from a perfect Gaussian TEM00, the beam propagation ratio M^2 is a meaningful parameter to assess the quality of a laser beam. 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.

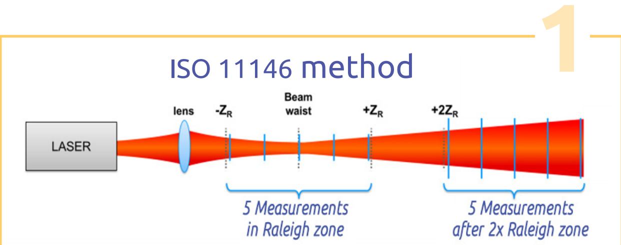
PHASICS high resolution wavefront sensors offer a **simple way to measure the M².** In one single acquisition giving both phase and intensity, an M^2 value that **fully complies with the ISO 11146 standard** is obtained. This innovative method **applies to any beam,** even single shot laser.

SINGLE SHOT M² MEASUREMENT

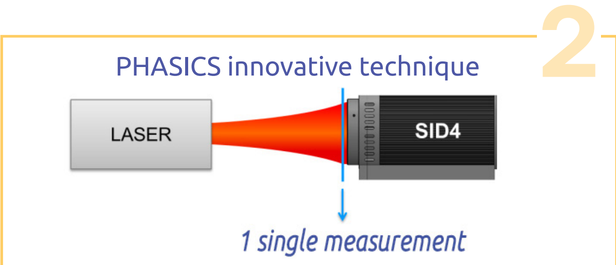
Based on a patented technology, the **quadriwave lateral shearing interferometry**[2], PHASICS wavefront sensor measures at once both the intensity and phase fields of a laser beam. By applying light propagation equations, the full electromagnetic field is retrieved in any arbitrary plane. In particular, 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**.



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.



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 M² 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 lasers.**

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 at 632.8 nm wavelength and an M2 close to 1 was used. A first series of measurements was done by **strictly following the requirements of 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 measurements 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 figure 3 shows the results for M² 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 great flexibility for its positioning.

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

M² measurement comparison in term of repeatability and reproducibility

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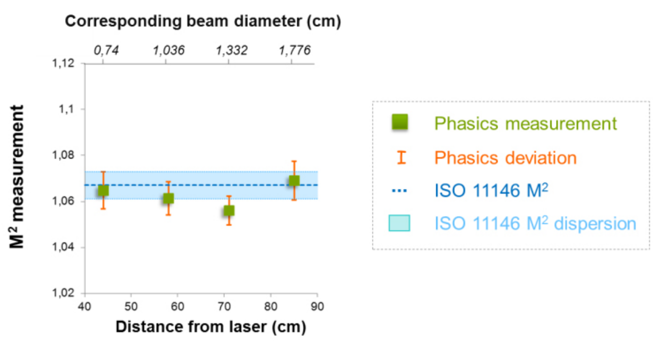
The M² values measured by Phasics method (green square on the left graph) agree with the one obtained by the ISO11146 method (represented by the dash blue line) whatever the distance from the laser is.



Similar measurements were realized for a **laser of a M² far from 1. Again, the results of both techniques match.** These two series of measurement proved that the **PHASICS method for M² 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)*

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[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 M2 analysis using Shack-Hartmann Measurements", J. Phys. D: Appl. Phys. 34 2414 (2001)*

Phasics
The phase control company

PHASICS S.A.
Bâtiment Mercury I – Espace Technologique
Route de l'Orme des Merisiers
91190 Saint Aubin
FRANCE
Tel: +33(0)1 80 75 06 33
www.phasics.com | contact@phasics.com

PHASICS CORP.
5277 Manhattan Circle
Suite 102
Boulder CO 80302
USA
Tel: +1 415 610 9741