Measurement of the laser beam M^2 parameter using a novel device incorporating a liquid lens

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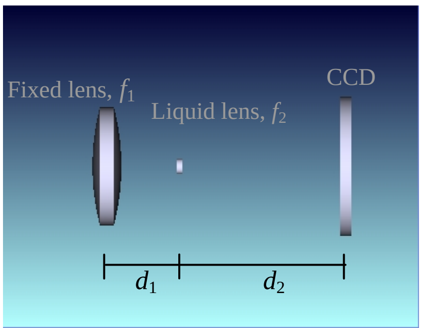
Introduction

In many laser applications the parameter M^2 is key to understanding system performance. Various commercial measurement systems exist that utilize a number of technologies each having a trade-off in size or performance against the accepted methodology described in the International Standards Organisation (ISO) documents ISO 11146 series [1,2,3]. We investigate a compact, novel device for the measurement of M^2, incorporating a commercially available liquid lens technology (Varioptic, France). The device performance is compared both theoretically and experimentally against the accepted ISO standard.

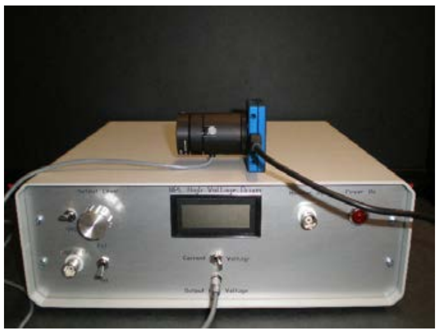
Novel M^2 measurement device

The M^2 device is constructed using an arctic 416 variable focus liquid lens produced by Varioptic [4], a fixed focal length lens and a CCD camera; the combined system is only 65 mm in length (see fig 1). The Varioptic lens technology works on the electrowetting principle [5] and is electrically operated by the application of an a.c. voltage. The focal length of the lens can be adjusted between –11 to 13 dioptres by altering the amplitude of the drive voltage between 0 – 60 Volts. We drive the lens using a function generator and custom-built amplifier where the output voltage is accurately measured using a digital voltmeter. The liquid lens is calibrated using an optical system employing a Shack-Hartmann wavefront sensor.

To measure the M^2 of a laser beam it is aligned along the optical axis of the device and the focal length of the liquid lens is scanned through its optical range. Measurements of the beam widths incident on the CCD are made for a number of lens focal lengths using the converging second moment method [6]. The M^2 parameter can then be calculated from the acquired data.



(a)

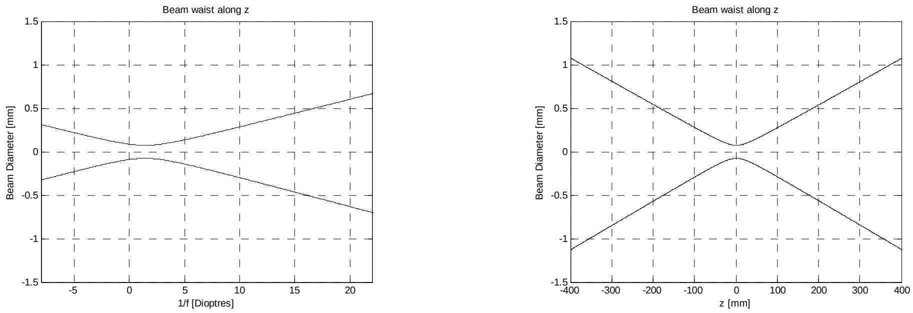


(b)

Fig 1. (a) Schematic optical layout of novel M2 device. (b) Image of novel M2 device with custom high voltage amplifier.

Theoretical and experimental verification

A propagation model based upon Fresnel diffraction of a Gaussian beam is implemented to verify the instrument design against the ISO standard ensuring that an M^2 equal to 1 is achieved for a TEM_{00} beam (see fig 2). Measurements were made on a number of lasers using the device and these were also compared against the ISO methodology. The limiting device performance was explored through the associated uncertainties.



(a) (b)

Fig. 2. (a) Theoretical beam diameters achievable across the focal range of the M^2 meter for a TEM_{00} beam. (b) Beam diameters as calculated by the ISO method.

Conclusions

We have developed and demonstrated a compact novel device for the measurement of laser beam M^2 parameter based upon the use of a liquid lens. Through the implementation of modeling the device performance can be optimised based upon the limiting uncertainties obtained through experimental measurement. The device performance has been compared to that of the accepted ISO method.

References

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