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Multimode Laser Beam Characterization using Agile Digital-Analog Photonics

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ABSTRACT

Presented is a novel design of a multimode laser beam analyzer to enable beam measurements of minimum beam waist size, minimum waist location, divergence and the beam propagation parameter called M^2. Experimental results demonstrate these measurements for a 532 nm multimode test laser beam.

Keywords: DMD, Beam Analyzer, Multimode Beam Characterization

1. INTRODUCTION

Characterization of multi-mode laser beams is done using the M^2 beam propagation parameter [1-7]. Earlier methods require physical movement of the laser beam profiler assembly along the beam axis. This physical motion can lead to false readings due to system alignment and are prone to poor measurement reliability.

For the characterization of single mode Gaussian laser beams, recently, a beam analyzer using a Digital Micromirror Device (DMD) and an Electronically Controlled Variable Focus Lens (ECVFL) has been proposed and demonstrated [8-11]. This paper extends the earlier proposed DMD-ECVFL beam analyzer instrument for the characterization of laser beams using the M^2 beam propagation parameter.

2. PROPOSED ANALYZER

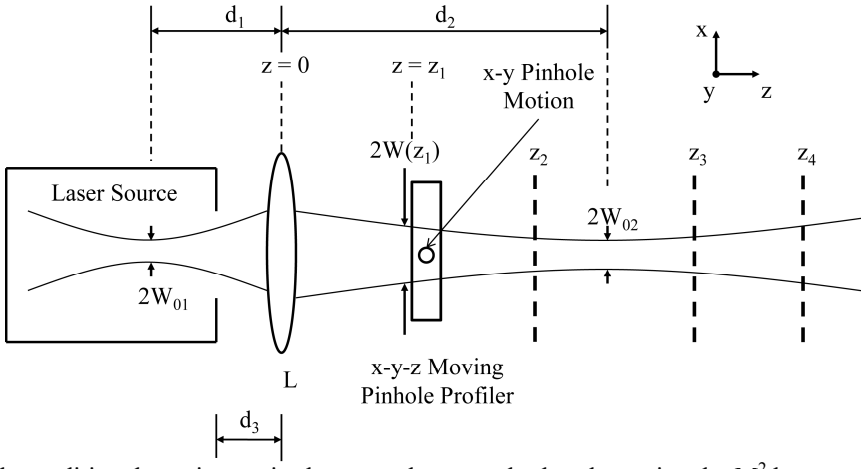


Fig. 1 The traditional moving optics beam analyzer method to determine the M^2 beam parameter.

Shown in Fig. 1 is the classic prior art method of an M^2 beam propagation parameter beam analyzer operation that requires motion of the profiler along the optical axis to take per ISO approximately ten measurements on each side of the minimum beam waist.

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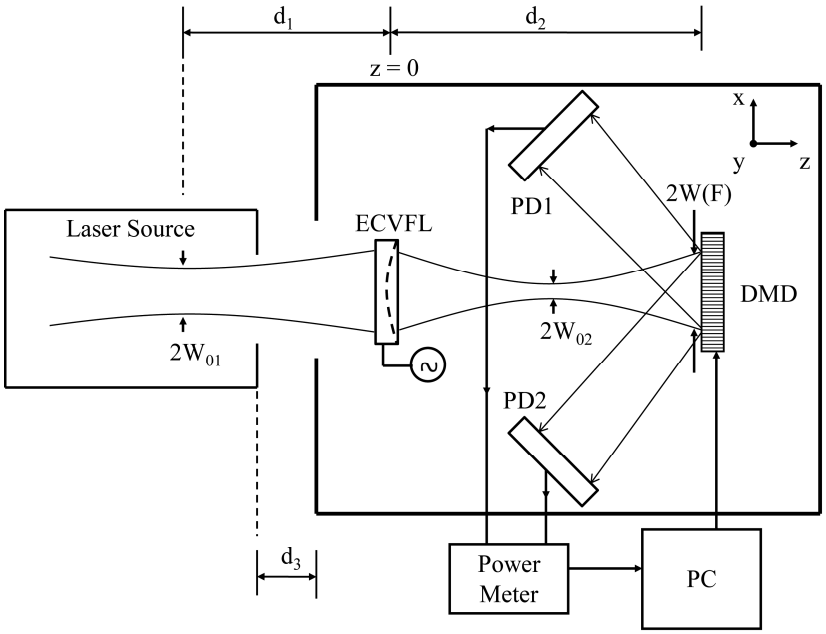


Fig. 2 The proposed multimode beam analyzer.

Fig.2 shows the proposed multimode laser beam characterization. The DMD acts as the moving pinhole image plane point sampler while the ECVFL acts as the variable focal length lens. The test beam reflections to PD1 and PD2 are based upon the digital tilt states of the DMD micromirrors. The propagation of a laser beam can be analytically described using the fundamental Gaussian beam mode and the M^2 parameter. In general, multimode beam radii at the beam waist can be written as

$$W(z) = Mw(z) \tag{1}$$

where $w(z)$ is the embedded fundamental Gaussian mode second-moment radius definition of the beam irradiance. Starting with the analysis for the fundamental Gaussian beam, the multimode beam can be described. Using software control, the DMD realized pinhole scans across the test beam at the DMD plane and the instrument calculates the beam waists $W_H(F,d_2)$ and $W_V(F,d_2)$ for the horizontal and vertical directions. This process is continued until four or more beam waist measurements for different F values have been taken to provide a good data fit. The curve fitting gives values for W_{01}, d_1, and M^2. Hence, using the proposed Fig.2 instrument, the multimode test beam is completely characterized.

3. EXPERIMENT

To calibrate the multimode laser beam, the Fig. 1 classic method was implemented using a high power λ = 532 nm Nd:YAG frequency doubled laser source with a lens L of focal length 15 cm, and a DMD based profiler. The required beam irradiance $I(x,y)$ measurements were taken at multiple d_2 values along the z axis. Using the DMD profiler with this measured d_2 dependent $I(x,y)$ data and using the analyzer design equations, the experimentally deduced values of $W_v(F,d_2)$ and $W_H(F,d_2)$ are computed. The parameters W_{01}, d_1, M^2 are found to be equal to 241.47 μm, -44.39 cm, 1.337 and 302.93 μm, -48.48 cm, 2.095 for the horizontal and vertical directions, respectively.

The proposed multimode beam analyzer in Fig. 2 was setup. The ECVFL used is a Varioptic Artic France liquid lens with the F adjusted from 8 cm to 36 cm. Using the DMD profiler with this F dependent measured $I(x,y)$ data and using design equations, the experimentally deduced values of $W_v(F,d_2)$ *and* $W_H(F,d_2)$ are computed. Next curve fitting the data to the design equation, the parameters W_{01}, d_1, and M^2 are found to be equal to 257.61 μm, -46.53 cm, 1.600 and 326.67 μm, -48.99 cm, 2.587 for the vertical and horizontal directions, respectively. The proposed design is compared with the traditional method in Table 1. It is seen from Table 1 that the two instrument experimental difference is within this two

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micromirror tolerance for W_0 for which the difference is 16.14 μm and 23.74 μm for the vertical and horizontal directions, respectively.

Table 1. Multimode Beam Propagation Parameters via the experimentally demonstrated traditional and proposed analyzers.

	Horizontal		Vertical	
	Traditional	**Proposed**	**Traditional**	**Proposed**
W_0 **(μm)**	302.93	326.67	241.47	257.61
Θ **(mrad)**	2.342	2.682	1.875	2.103
d_1 **(cm)**	-48.48	-48.99	-44.39	-46.53
z_{R1} **(cm)**	25.87	24.36	25.76	24.50
M^2	2.095	2.587	1.337	1.600

4. CONCLUSION

A multimode beam analyzer using electrically controllable ECVFL and a programmable digital spatial light modulator has been successfully designed and demonstrated. Experiments conducted with a 532 nm laser beam show that the multimode beam parameters using the proposed analyzer closely match traditional mechanically moving scan method.

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