Digital mode selection using an intracavity SLM

L BURGER[1,3], I LITVIN[1] AND A. FORBES[1,2,3]
[1]CSIR National Laser Centre, PO Box 395, Pretoria 0001, South Africa
[2]School of Physics, University of KwaZulu-Natal, Private Bag X54001, Durban 4000, South Africa
[3]Laser Research Institute, University of Stellenbosch, Stellenbosch, South Africa
Email: lburger1@csir.co.za - www.csir.co.za

ABSTRACT

We describe the performance of twisted nematic liquid crystal (TN LC) spatial light modulators (SLMs) when used for intracavity beam shaping.

INTRODUCTION

Intracavity beam shaping allows the selection of a preferred mode as well as the compensation for intracavity aberrations, and has been demonstrated statically using diffractive optics, and dynamically using adaptive optics. An intracavity optically addressed SLM has also been used to manipulate the beam intensity profile[1]. We report the first laser incorporating an intracavity phase-only electrically-addressed spatial light modulator (SLM).

A performance evaluation of the laser reveals subtle properties of the SLM, which highlights the requirements and capabilities of an SLM or intracavity use.

Fig.1 illustrates the theoretical equivalence between a conventional 2-mirror resonator, and a resonator incorporating an SLM in the place of the back mirror, with the SLM phase pattern replacing mirror curvature.

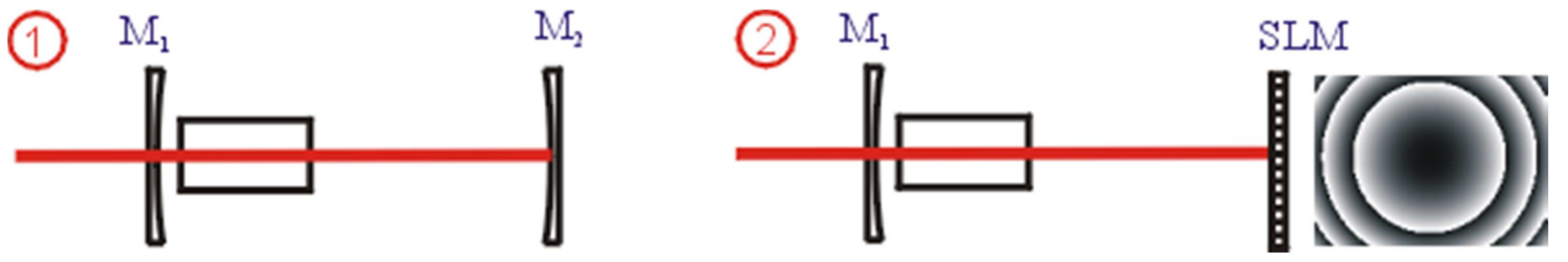


Fig. 1. Schematic representation of a (1) conventional and (2) SLM resonator.

SYSTEM DESCRIPTION

In order to evaluate the SLM resonator concept we selected an Nd:YAG crystal as our gain medium. The Nd:YAG rod was end-pumped using a cw 75W fibre-delivered 808nm Jenoptik diode laser. A flat-flat resonator configuration, incorporating a 4x beam-expanding telescope near the Holoeye HEO1080P SLM, was used. A Brewster window ensured correct polarization on the SLM. The beam was optimized and recorded using a Photon USBeamPro beam profiling system.

Fig. 2 shows the laser on an optical table.

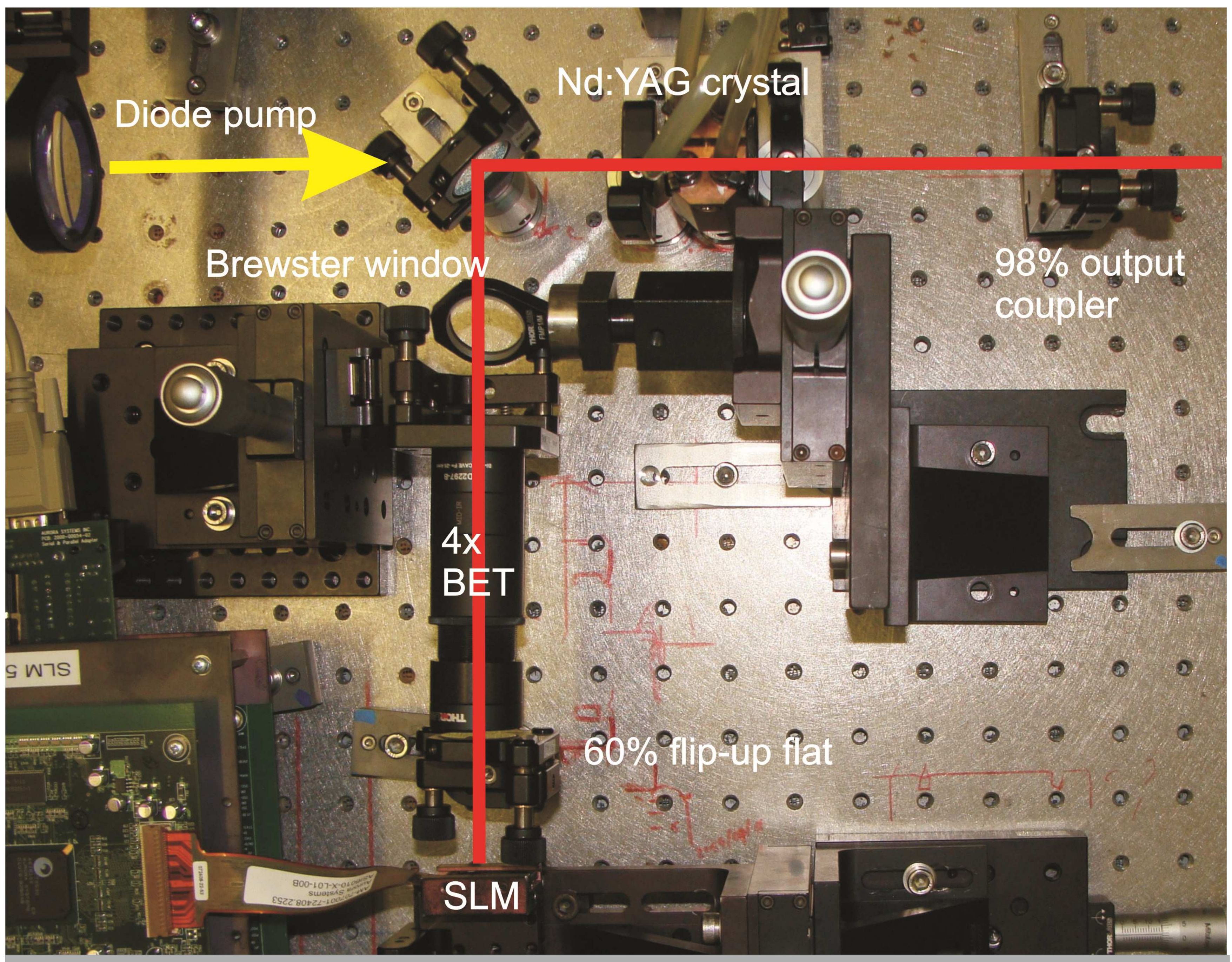


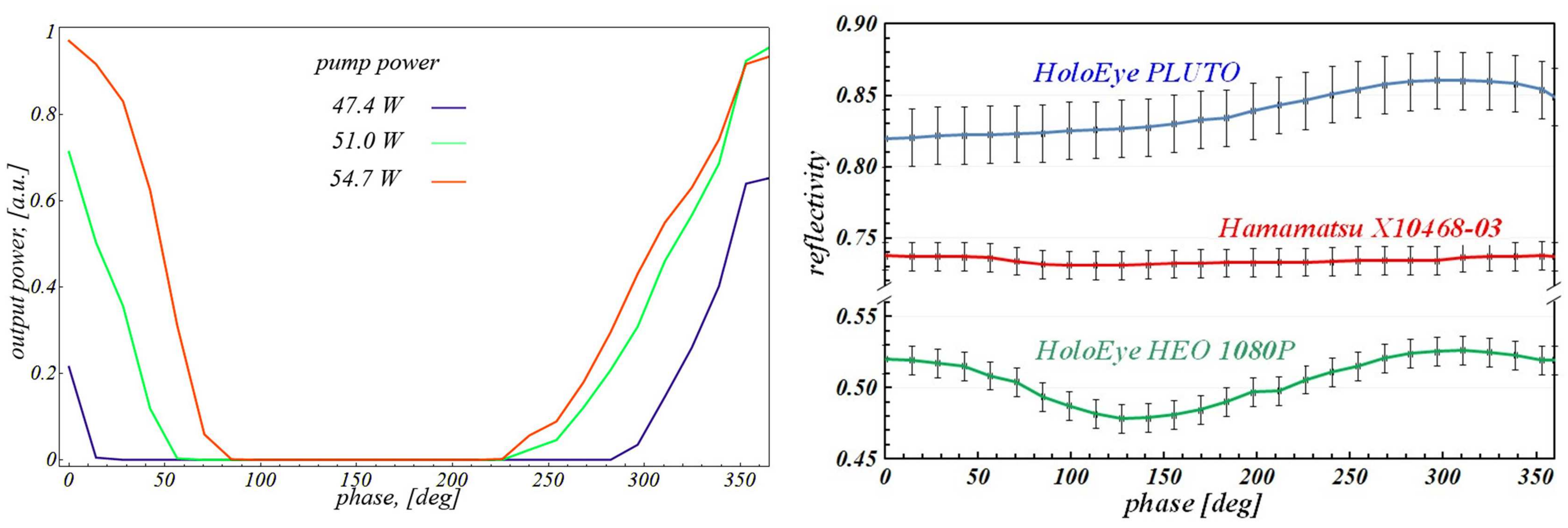
Fig. 2. Photo of the SLM laser (SLM: spatial light modulator, BET: beam-expanding telescope).

OBSERVATIONS AND EVALUATION

We noticed that lasing occurred at a fixed pump current for a certain grey-level values of a uniform phase screen on the SLM (to simulate a flat mirror) at different grey levels, and that the output power level loops from 0 to 2π radians. We noted that the lasing band broadened with increasing pump power (Fig. 3(a)). No lasing occurred however for a Fresnel zone phase pattern (to simulate a curved back reflector), or for a linearly varying phase pattern (simulating tilt). This suggested that the SLM was behaving as an amplitude screen.

Measurement of the reflectivity of available SLMs revealed some degree of amplitude modulation in addition to expected phase modulation of the incident beam. We have established that attenuation properties of the current generation of phase-only SLMs constrain them to behave as amplitude screens rather than phase screens inside a laser resonator. The reason for this appears to be that the intracavity gain amplifies the small variations in reflectivity with grey level to the point that they dominate phase effects.

Identical behaviour is observed from both the older HoloEye HEO1080P with a 4% amplitude modulation, as well as from the newer Hamamatsu X10468, which has an amplitude modulation of less than 1%.



(a) (b)

Fig. 3. (a) Normalised plots of laser output power as a function of SLM phase for increasing pump powers, (b) SLM reflectivities showing amplitude modulation

To demonstrate that amplitude modulation was dominating any phase modulation effects we generated the modes shown in Fig. 4. The background grey level of each phase screen was chosen to be at the peak reflectivity, with the features at the minimum reflectivity grey level. The features behave as obscurations, which act to force the laser into a required mode. The near- and far-field beam patterns are identical, suggesting that the beams are TEM or Laguerre-Gaussian modes, and not simply intensity variations in one plane.

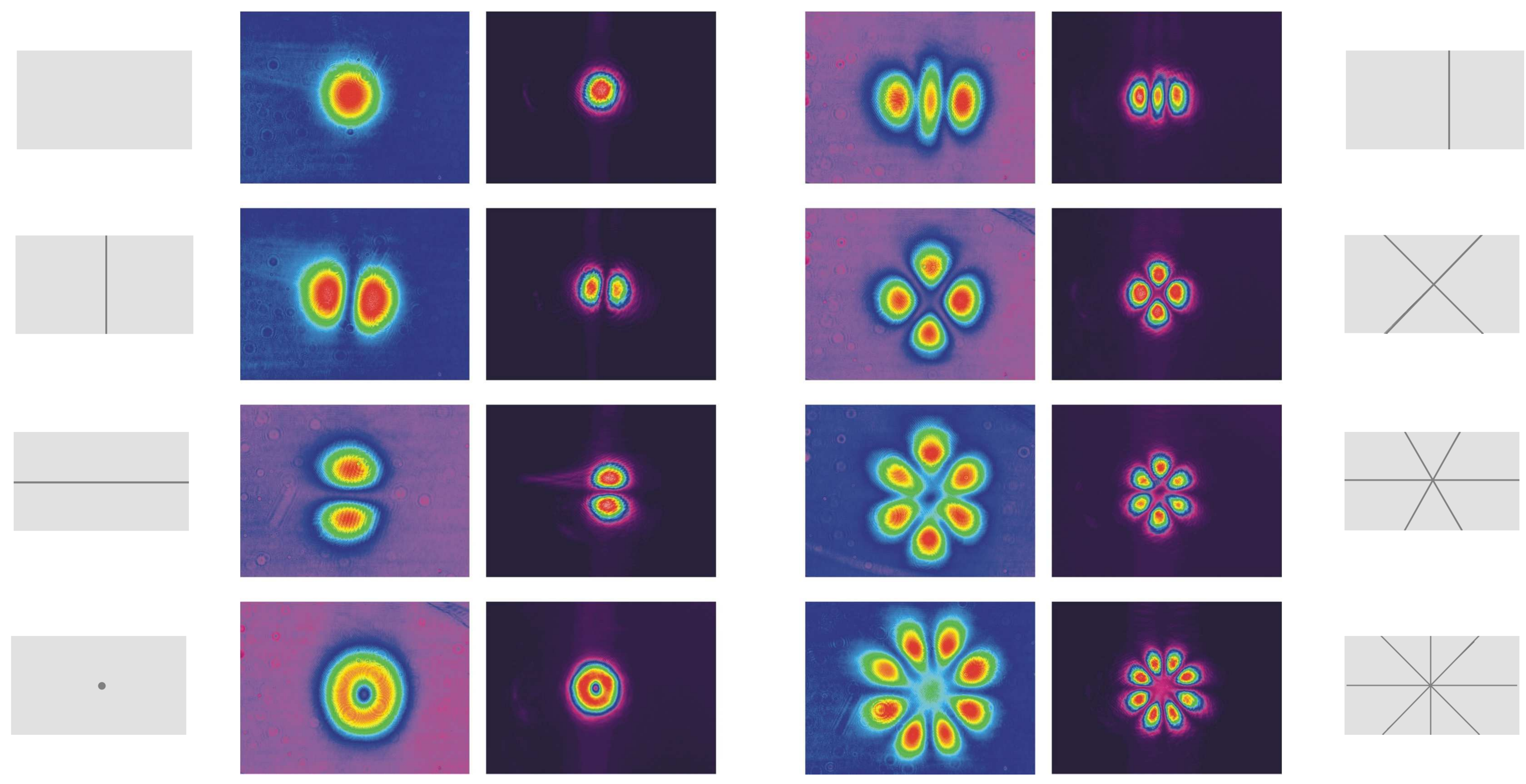


Fig. 4. Near- and far-field laser beams produced by the associated SLM phase screens.

We implemented a modal decomposition on the 8-petal mode by executing an inner product of the incoming field with a phase pattern on an SLM set to exp($il\phi$), where the azimuthal component (l) of the phase pattern on the SLM was varied from –5 to +5, and the weighting of the azimuthal harmonics found by an optically executed inner product. We found that the intensity at the centre of the beam has some value for phase patterns of l equal to -4 or +4 and is null for all other values of l. Fig. 5 shows that the field is an equally weighted superposition of harmonics with l of –4 and +4, and zero for all other harmonics. This confirmed that the 8-petal field is composed of a coherent superposition of two vortex beams of equal but opposite helicity.

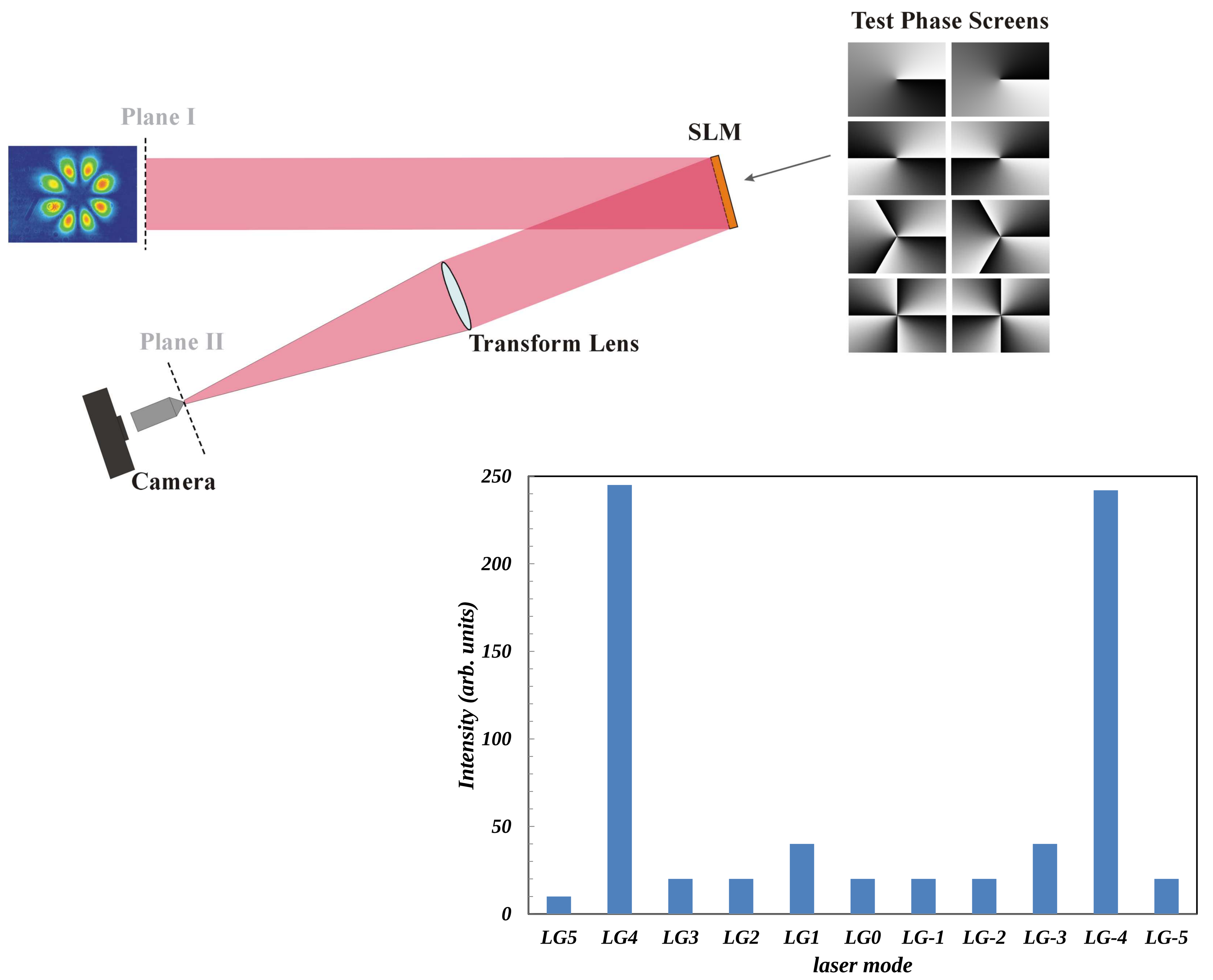


Fig. 5. Experimental setup and results of mode decomposition experiment of 8-petal beam

DISCUSSION

While we have developed the first laser with intracavity "phase-only" SLM. We have ascertained that an SLM behaves not as a phase modulator but as an amplitude modulator inside a laser resonator, due to a small residual variation in reflectivity with phase. We found this effect with both the older generation HoloEye HEO1080P as well as with the newer generation Hamamatsu X10468 SLMs. See comparison in Table 1.

Nevertheless, we have demonstrated that this device can be used to digitally select for a number of transverse and radial modes. The advantage of this device over the traditional method of placing mechanical obscurations in the resonator is the ease with which an obscuration can be generated and manipulated on an SLM.

	Resolution (pixels)	Area (mm)	Amplitude variation (%)	Avg Reflectivity (measured)	Damage threshold (W/cm²)
HoloEye HEO1080P	1920 x 1080	15 x 8	4	54 %	2
HoloEye PLUTO	1920 x 1080	15 x 8	4	84 %	2
Hamamatsu X10468	792 x 600	16 x 12	<1	74 %	20

Table 1. Comparison of specifications of the HoloEye PLUTO and Hamamatsu LCOS SLMs

REFERENCES

[1] Bourderionnet, J., Huot, N., Brignon, A. & Huignard, J. "**Spatial mode control of a diode-pumped Nd:YAG laser by use of an intracavity holographic phase plate**". Opt. Lett. **25**, p.1579-1581 (2000).
[2] Naidoo, D., Aït-Ameur, K, Forbes, A., "**Intra-cavity vortex beam generation**," Proc. of SPIE Vol. 8130 813009-1 (2011).