High Efficient LG_{p0} End Pumped Nd:YAG Laser

Sandile Ngcobo[1,2], Andrew Forbes[1,2] and Kamel Ait-Ameur[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]de Recherche sur les Ions, Les Materiaux et la Photonique, Universite de Caen, ENSICAEN, F1450 Caen, France
Email: sngcobo@csir.co.za - www.csir.co.za/nlc

INTRODUCTION

High average output power lasers has been of interest for many decades, especially for laser applications such as cutting, welding and drilling. In this work we demonstrate that the average output power of a given TEM_{00} laser could be increased significantly by inserting a binary Diffractive Optical Element (DOE) inside the resonator. The DOE will transform the intra-cavity mode to a discrete set of LG_{p0} modes for each high-order p while simultaneously increasing the average output power of the laser.

THEORETICAL ANALYSIS

The laser light intensity that is produced by the process of stimulated emission is expressed as :

$$I = I_0 e^{\sigma_{21} \Delta N_{21} L}$$

Where I_0 is the intensity of incident beam on the gain medium of length L (cm), and σ_{21} (cm^2) the emission cross section between the population density (cm^3) of N_2 and N_1 as shown in Fig.1.

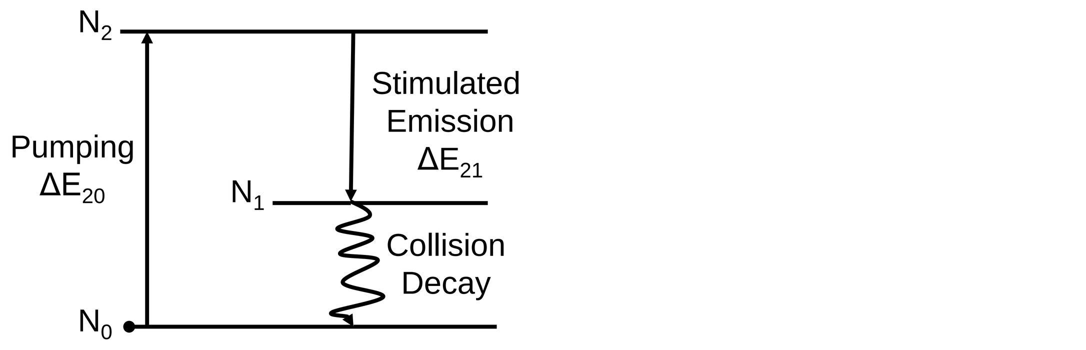

Figure 1: Simplified energy diagram of an atom showing excitation and emission processes

Intra-cavity increasing the volume of the oscillating laser mode will lead to a significantly increase in the average output power since there will be an increase in the overall population difference ΔN_{21}. Therefore transforming the fundamental TEM_{00} mode to a symmetrical Laguerre-Gaussian (LG) LG_{p0} mode of order p has been shown to increase the intra-cavity mode volume. The electrical field of the LG_{p0} modes can be expressed as:

$$E(r) = L_p\left(\frac{2r^2}{w^2}\right)\exp\left(-\frac{r^2}{w^2}\right),$$

where W is the width of the fundamental TEM_{00} or LG_{00} mode and L_p the Laguerre polynomials. Using the second order intensity moment, the increased in width size W_p of higher-order LG_{p0} modes when p increase can be expressed as:

$$W_p = W\sqrt{2p+1},$$

and for the beam propagation factor M^2 of such high-order LG_{p0} modes has also been shown in [1] that it can be also expressed as:

$$M^2 = 2p+1.$$

EXPERIMENTAL DESIGN

The ABCD matrix method was used to design the laser resonator in Fig.2.

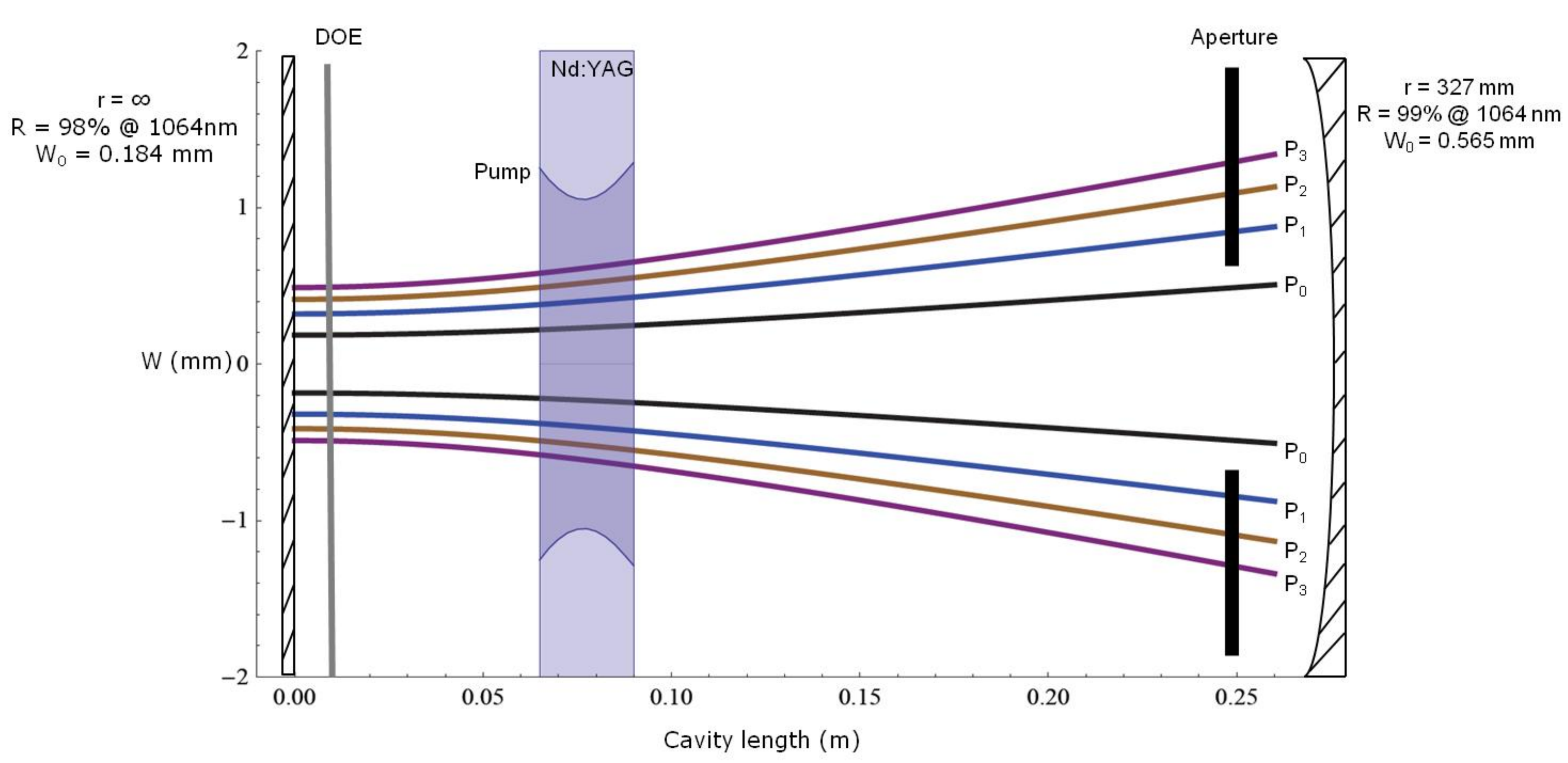

Figure 2: Scaled schematic diagram of the laser resonator designed.

RESULTS

The TEM_{00} mode width sizes on both sides of the resonator is of good agreement with the theoretical prediction over the pumping power range as shown Fig.3, with the slope efficiency showing no power fluctuation.

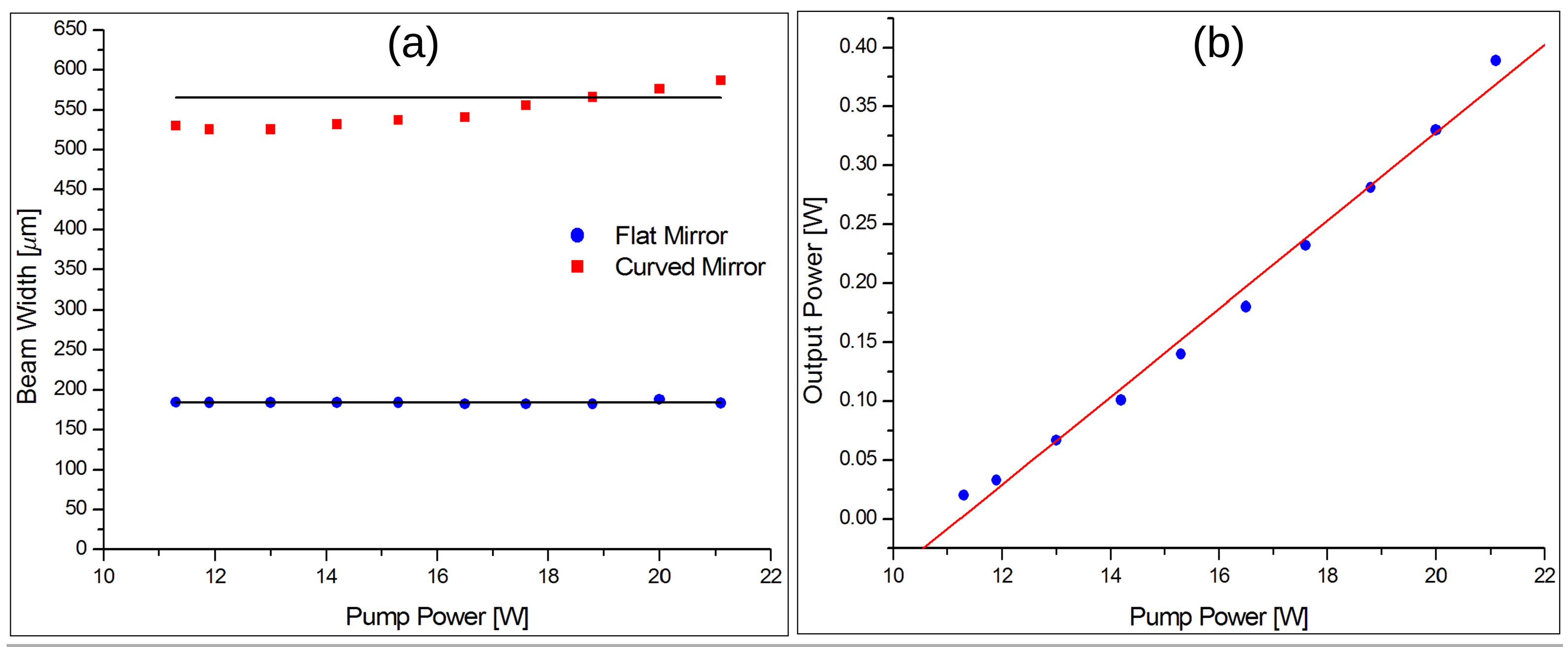

Figure 3: a) The TEM_{00} mode width sizes at different pump powers where the solid line is the theory solutions and dots are experimental data. b) TEM_{00} laser output power on the flat mirror at different pump powers.

The generated LG_{p0} mode width sizes and M^2 values are of very good agreement with the theoretical values as shown in Fig.4 on the flat mirror.

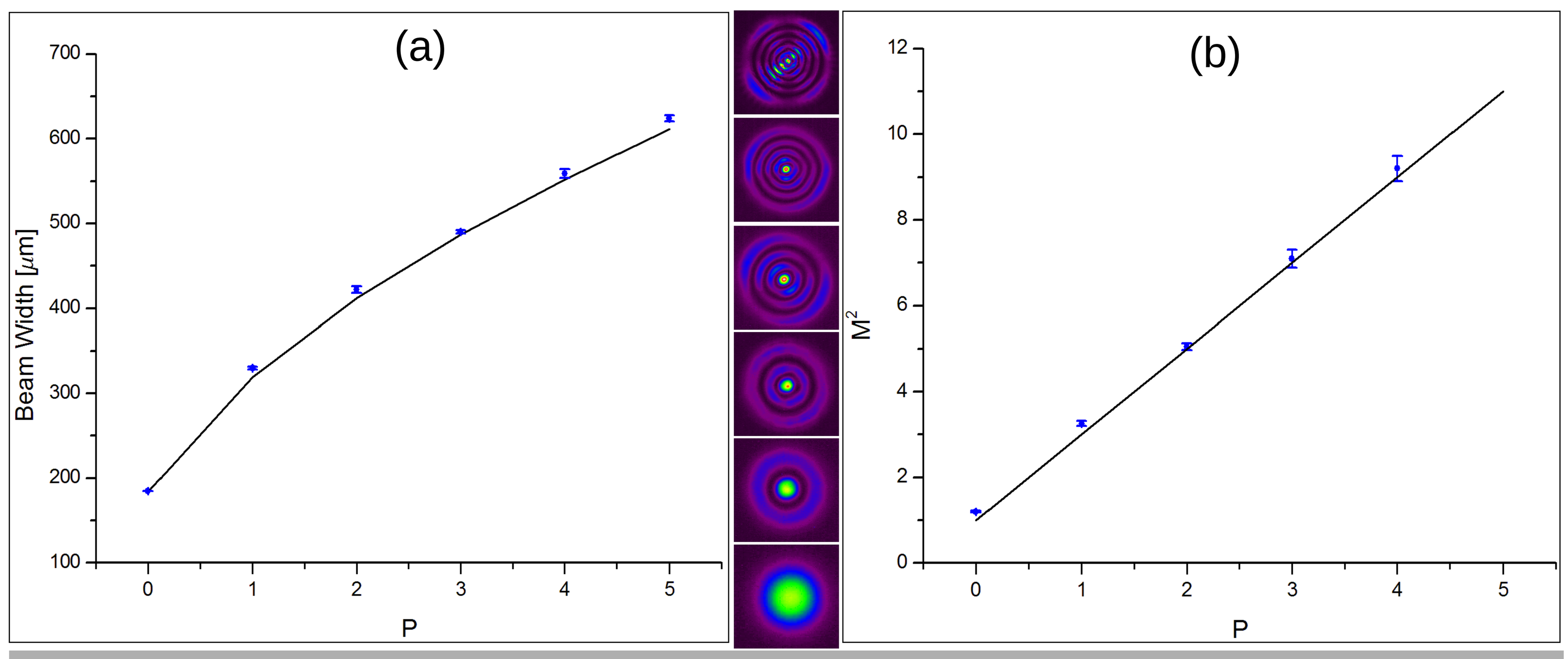

Figure 4: a) The beam width sizes and b) M^2 values of LG_{p0} modes from the flat mirror, where the line is the theory solution and the dots are experiment data. The mode profiles from the bottom-up of LG_{00} to LG_{50} modes are shown in the imaged inserted between the two graphs.

The slope efficiency in Fig.5 is shown to increase from 1.1% for LG_{00} to 4.4% for LG_{50} as the mode width size increases as theoretically predicated. The threshold is shown to also increase as LG_{p0} increases.

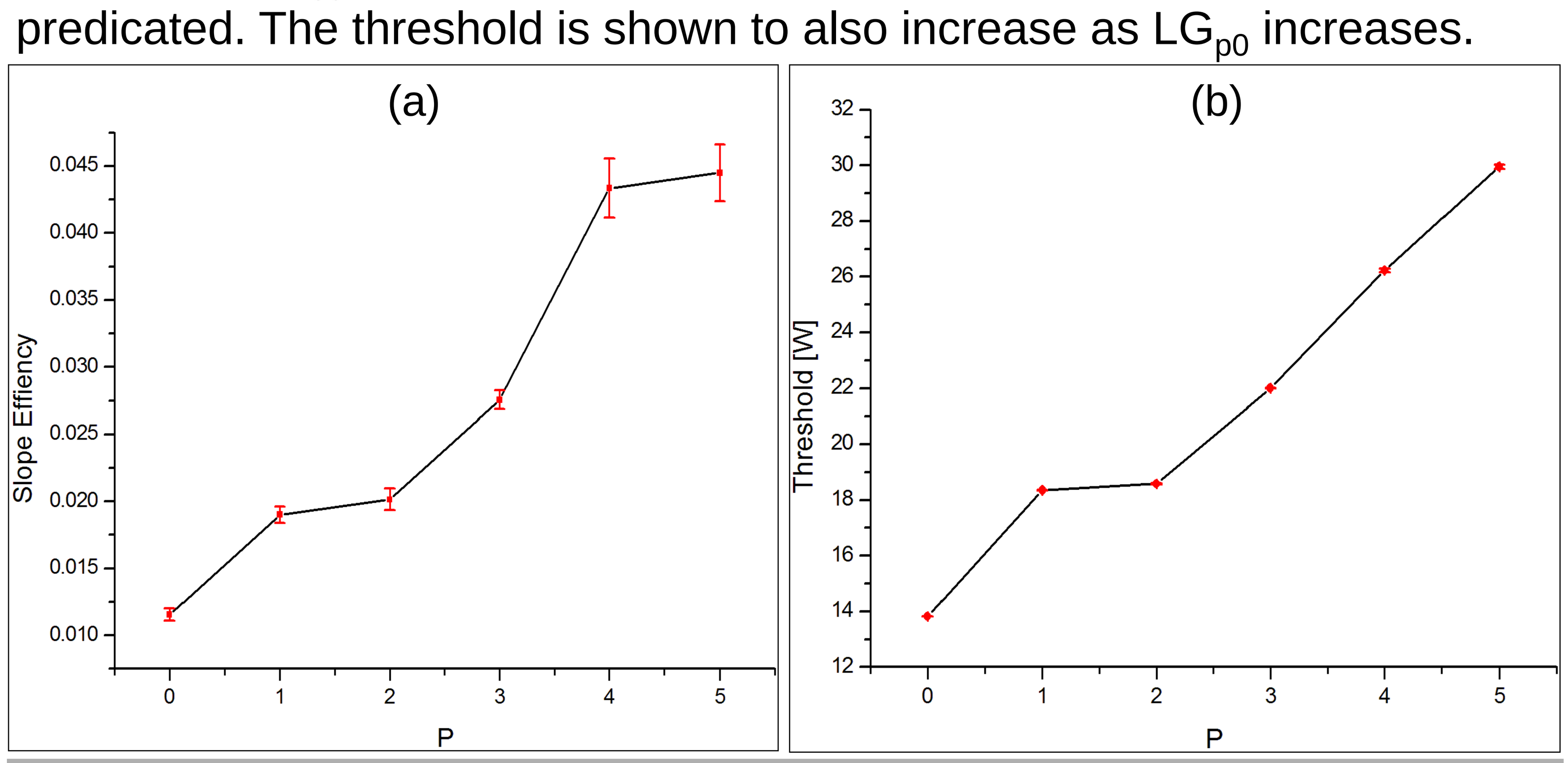

Figure 5: a)The slope efficiency and b) the threshold of LG_{p0} modes from the curved mirror.

Conclusion

We have been able to show that the laser becomes 4 times more efficient when High-Order LG_{50} mode is forced to oscillate inside the resonator compared to the fundamental LG_{00} mode.

Reference

[1] A. Hasnaoui, A. Bencheikh, M. Fromager, E. Cagnoit, K. Ait-Ameur, *Creation of a sharper focus by using a rectified TEM_{p0} beam*, Optics Communications **284** (2011) 1331-1334.