Amplification of a radially-polarised beam in an Yb:YAG thin slab

C. R. Smith, S. J. Beecher, J. I. Mackenzie, W. A. Clarkson

Optoelectronics Research Centre, University of Southampton, SO17 1BJ, UK

Cylindrical-vector beams with radial polarisation have attracted growing interest in recent years owing to their unique properties and a wealth of applications. One very promising application area is in the field of laser processing of materials (e.g. cutting and drilling), where it has been shown that radially-polarised beams can yield a significant enhancement in cutting efficiency combined with improved surface finish quality. However, scaling to the power levels required whilst preserving polarisation purity is very challenging, with efforts to date focused on the use of lasers or amplifiers with cylindrical symmetry (i.e. rod or fibre).

In this paper, we explore an alternative strategy for power scaling radially-polarised output using a planar (thin-slab) amplifier geometry, and show that very high radial polarisation purity can be maintained in an architecture that has the potential to be operated at very high powers. The advantages of thin-slab gain media for mitigation of deleterious thermal effects are well-known, but, to the best of our knowledge, have not been investigated in the context of amplifying radially-polarised light. The experimental set-up (shown in Fig. 1) comprises a radially-polarised seed source and a double-pass end-pumped Yb:YAG thin slab amplifier.

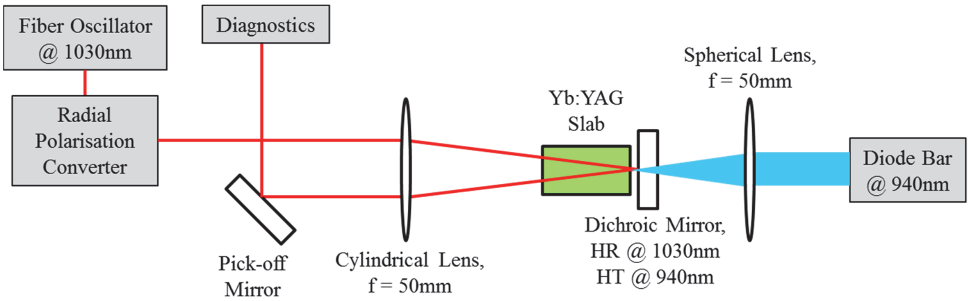

Fig. 1 Schematic of the amplifier arrangement.

The seed source employs a tunable, linearly-polarised Yb-doped fibre laser operating at 1030nm, followed by an S-waveplate and a 2 m length of few-mode fibre to convert from a linearly-polarised fundamental (LP_{01}) to radially-polarised TM_{01} doughnut beam (see Fig. 2), with a measured polarisation purity of 91% and $M^2 = 2.3$. The latter was focused into the Yb:YAG thin-slab amplifier using a cylindrical lens to approximately spatially-match the highly-elongated inversion region with a 10:1 aspect ratio produced by end pumping with a diode-bar at 940 nm. After double-passing the slab the output was re-collimated with the cylindrical lens to yield a circular beam with a doughnut-shaped intensity profile.

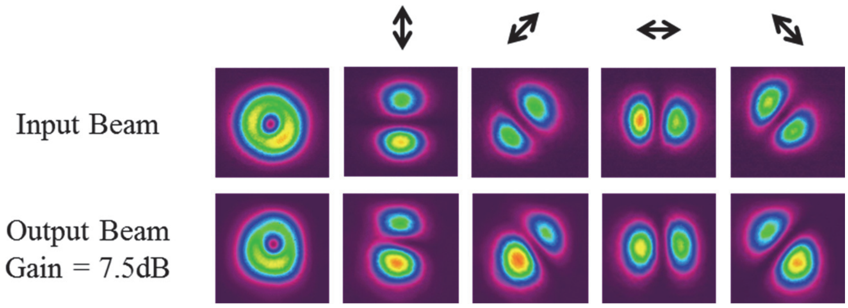

Fig. 2 Intensity distributions of the input beam (top) and amplified beam (bottom) after a linear polariser aligned at the angles indicated.

At the maximum incident pump power of 50W, we obtained a small-signal gain of 9dB with 50mW of incident seed power and a power gain of 5.4dB for 1.25W of seed power. Fig. 2 shows the beam profile for the seed input and amplified output beams, and shows the profile after an analyser polariser aligned at the angles shown by the arrows. This confirms that there is a minimal degradation in beam quality, whilst the polarisation purity is maintained at 91% after amplification. The slight increase in the M^2 parameter to ~2.65 was attributed to imperfect spatial overlap of the pump and seed beams. These results show planar thin-slab amplifiers provide an attractive alternative means for increasing the output power from radially-polarised sources. Further optimisation of the slab design, pump geometry and higher pump power should allow scaling to very high power levels to meet the needs of a range of emerging applications.