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# In-Plane Diode-Bar Pumped, Multi-Watt, $Nd:Y_3Al_5O_{12}$ Planar Waveguide Lasers

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## Abstract

We report monolithic, planar, $Nd:Y_3Al_5O_{12}$ waveguide lasers pumped by a 20W diode-bar giving output powers of 6W and 3W from end and side-pumped geometries respectively. Control of the output mode quality is also investigated.

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There is a growing interest in using planar waveguides for high-power diode-pumped laser devices due to their geometrical compatibility and good thermal management capabilities. Here we report on our progress in constructing and characterising diode-bar, end and side-pumped Nd:YAG waveguide lasers.

A 20W diode-bar was collimated in the fast divergence axis using a fibre lens. The beam had measured $M^2$ values of 2.3 and ~2300 in the fast and slow axes respectively. A cylindrical lens array was used to obtain a line focus at the input face of the waveguide. Spot sizes of 8µm and 1.3mm were measured in the guided and non-guided directions respectively. The waveguide used in our initial investigations was grown by liquid-phase epitaxy (LPE) and consisted of an 80µm thick Nd:YAG core with undoped YAG cladding and substrate layers. The 5mm length of waveguide was sufficient to absorb most of the pump light when end-pumped. A laser cavity was formed by directly coating mirrors onto the plane parallel end-faces of the waveguide. The input face was nominally highly reflecting at the laser wavelength, 1.064µm, while the output face had a 5% transmission. We obtained a laser output power of 6W, with a slope efficiency of 39% with respect to incident power. The output beam $M^2$ values varied slightly with the launch conditions and typical values of 4x160 were measured in the guided and non-guided directions respectively.

The originally 6mm wide guide was then cut into two pieces, 3mm and 1.5mm wide. With the same end-pumping scheme, output powers of 3W and 2.2W respectively were obtained. The lower output power is presumably due to less efficient launching of the pump light into the narrower width waveguides. However a decrease in $M^2$ values was also observed in the non-guided direction to typical values of 85 and 30 respectively. The 1.5mm guide therefore actually gave the brightest output. In order to improve the beam launch efficiency whilst maintaining lower $M^2$ values we moved to a side-pumped geometry. It was found that the $M^2$ values were indeed maintained but that no improvement in output power was achieved. This was probably due to a worse overlap and perhaps a smaller pump absorption (although a mirror was used to give a double pass of the pump).

In a separate approach to output beam mode control we have used a ~50nm Au film deposited on the surface of a 8.3µm core size Nd:Ga:Lu:YAG planar LPE waveguide. The coating induces higher losses in all the TM modes of the waveguide and the higher order TE modes. Pumping with a Ti:Sapphire laser, we obtained linearly polarised, TE, output from this device. We also observed a >2 times decrease in the $M^2$ of the output beam in the guided direction to a near-diffraction limited output ($M^2$=1.2), without any noticable degradation of laser performance.

These initial studies show that a degree of mode control is possible and future work will concentrate on combining these methods, with others such as unstable resonators to produce a diode-bar pumped, high-power, close to diffraction limited laser output. We will also use much smaller core-size waveguides and fibre/rod lens launching optics.