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High-power Yb-doped multi-core ribbon fibre laser

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Recent advances in high power cladding-pumped fibre lasers have been dramatic with output powers of up to 1kW reported for a large-core Yb-doped fibre laser [1]. One of the main challenges for efficient power-scaling of fibre lasers is reducing the complexity and increasing the efficiency of the diode pump coupling scheme, whilst preserving the pump beam brightness. Also, as power levels increase it will necessary to increase the core area to avoid unwanted nonlinear processes and intensity-induced damage. Moreover, a fibre geometry which allows effective removal of waste heat to minimise the risk of thermally-induced damage will also be required. In conventional circular or D-shaped double-clad fibre designs it is necessary to re-shape the diode beam with roughly equal beam quality factors in orthogonal planes for efficient coupling into the fibre. This increases the complexity and the cost of the pump launching scheme and generally results in some reduction in pump power and brightness. One way to avoid the need for beam shaping is to use a rectangular fibre geometry with transverse dimensions, W_x and W_y, roughly given by $W_{x,y}$ $2M_{x,y}^2\lambda/\pi\theta$, where θ=arcsin(NA), and M_x^2 and M_y^2 are the beam quality factors for the pump in orthogonal planes. This approach is not practical for typical broad-area diodes and diode bars since the fibre dimensions required are very small and/or the aspect ratio is very large. However, for fast-axis collimated diode-stacks, with M_y^2~100 and M_x^2<1500 in the stacking and orthogonal directions respectively, the fibre required has dimensions of ~0.15mm by ~2mm, and hence can be manufactured in a relatively straightforward manner. This opens up the possibility of using much simpler pump beam conditioning and focusing optics with the prospect of improved overall efficiency. A further attraction of this fibre geometry is that it allows effective heat sinking for removal of waste heat, and a linear array of active-ion doped cores can be employed to increase the effective core area in combination with wavelength beam-combining [2] as a means for maintaining good beam quality.

In this paper we describe preliminary experiments on such a ribbon fibre and present preliminary results for laser performance. The fibre was fabricated in-house from a rectangular preform with ten Yb-doped alumino-silicate cores. The final fibre had transverse dimensions of 1.4mm by 0.23mm and was coated with a low refractive index (n=1.375) polymer outer-cladding resulting in a calculated NA for the pump guide of 0.49. The effective absorption coefficient and background losses for pump light at ~940nm were determined via a cut-back measurement to be 2.2dB/m and <0.07dB/m respectively. The ribbon fibre was tested in a simple laser configuration pumped by a fast-axis collimated 12-bar diode-stack using a simple pump coupling scheme comprising a combination of standard cylindrical and spherical lenses. The laser comprised a 5m length of ribbon fibre with a high reflectivity mirror butted to the non-pumped end of the fibre. The output beam was extracted from the pump in-coupling end of the fibre with the aid of a dichroic mirror. At the maximum launched pump power of ~260W the ribbon fibre laser produced ~100W of output power at ~1080nm. The output beams from individual cores were slightly multimode with M^2 in the range 2-3.8. The slope efficiency with respect to launched pump power (~43%) was somewhat lower than is typical for Yb-doped fibre lasers. This is believed to be due to the use of lower quality raw materials in this initial demonstration of the ribbon fibre laser concept. Thus, slope efficiencies approaching 80% should be achievable in an optimized design. The prospects for further improvement in performance and for the use of spectral beam-combining for improving output beam quality will be discussed.

References

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