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Cladding-pumped Yb-doped helical-core fibre lasers and amplifiers

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Summary:

Over the last few years there has been very rapid progress in scaling output power from cladding-pumped fibre lasers and amplifiers [1]. One of the key issues to address for further power-scaling of single-mode operation will be to increase the core area in order to avoid the need for excessively long fibres for efficient pump absorption, and to raise the threshold for unwanted nonlinear processes and optical damage, whilst maintaining robust single-mode operation. At the moment, this is generally achieved by employing a multimode large-mode-area core design with a low numerical aperture in combination with bend loss suppression of higher-order modes [2] to promote single-mode operation. However, scaling to higher power levels will require an even larger core diameter and a larger inner-cladding diameter to accommodate more pump power, making it increasingly difficult to coil the fibre with a small enough diameter to use bend-induced loss as an effective means for suppressing higher-order modes. An alternative approach for achieving single-mode operation in a large-core fibre laser/amplifier is to employ a fibre with a helical core trajectory within the inner-cladding. In a preliminary demonstration of this approach, we recently reported a core-pumped Yb-doped helical-core fibre laser with 350mW of single-mode output at 1047nm [3]. Here, we report a highly efficient cladding-pumped Yb-doped helical-core fibre laser at 1043nm with a much higher single-mode output power of ~60.4W and preliminary results for a cladding-pumped Yb-doped helical-core fibre amplifier seeded by a single-mode Yb:YAG laser at 1050nm.

The Yb-doped helical-core fibres used in our work were fabricated in-house in a relatively straightforward manner by spinning a preform with an offset core during fibre drawing process. For the fibre used in the laser configuration, the core diameter, core NA, core offset, pitch and inner-cladding diameter were 30μm, 0.087, 100μm, 8.5mm and 275μm respectively. The fibre was coated with a low refractive index polymer outer-cladding to provide a high numerical aperture of ~0.49 (calculated) for the inner-cladding pump guide. A relatively simple resonator configuration was employed consisting of a length of the helical-core fibre under investigation with feedback for lasing provided by a cleaved fibre end facet at the pump in-coupling end of the fibre and, at the opposite end of the fibre, by an external cavity comprising collimating and focussing lenses and a plane mirror with high reflectivity at ~1-1.1μm. Pump light was provided by a diode-stack source at 976nm and the effective pump absorption coefficient was measured to be 5.8dB/m. This allowed a relatively short length of fibre (~2.8m) to be used for efficient pump absorption. The fibre laser output was extracted with the aid of a dichroic mirror. The fibre laser reached threshold at a launched pump power of ~10W and produced 60.4W of output for 92.6W of launched pump power. At pump powers well above threshold the slope efficiency reached ~84%, which compares favourably with best slope efficiencies routinely achievable with more conventional straight-core Yb-doped double-clad fibre lasers. The centre lasing wavelength and emission linewidth were 1043nm and 9nm respectively, and the beam quality factor (M^2) was measured to be less than 1.4 at highest output power level. It should be noted for an Yb-doped straight-core fibre laser with identical core design that the output beam was multimode with M^2=3.6.

An Yb-doped helical-core fibre of similar design, but slightly longer pitch (~9.2mm) and larger inner-cladding diameter (~300μm), was also tested in an amplifier configuration with seed power provided by a low power, single-mode, diode-pumped Yb:YAG laser operating at 1050nm. In this case a 3m length of helical-core fibre was used and approximately 500mW of 1050nm light from the Yb:YAG laser was coupled into the fibre core. Pump light from the diode-stack source was launched into the opposite end of the fibre. It is worth noting that it is not usually necessary to angle-polish the fibre end facets of helical-core fibres to suppress parasitic lasing, since the core path is at an angle (in this case ~6) to the fibre axis. Using this arrangement we obtained a maximum output power of 92.4W from the fibre amplifier for 142W of launched pump power corresponding to a slope efficiency of 73%.

At present the power levels achievable from our Yb-doped helical-core fibre laser and amplifier are limited by the maximum pump power that can be launched into the inner-cladding. Thus, with a higher brightness and higher power pump source, and a modified fibre design with a larger inner-cladding size, it should be possible scale output power to much higher levels whilst maintaining high overall efficiency and robust single-mode operation.

References

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