ADVANCES IN ACTIVE FIBRES FOR HIGH-POWER AND HIGH-BRIGHTNESS FIBRE SOURCES

J. K. Sahu, S. Yoo, A. J. Boyland, A. Webb, M. Kalita, Y. Jeong, J. Nilsson, and D. N. Payne
Optoelectronics Research Centre, University of Southampton, SO17 1BJ, U.K.
jks@orc.soton.ac.uk

Abstract: This paper reviews the progress in rare-earth doped fibre technology towards power scaling of high-brightness fibre sources.

SUMMARY

After the successful implementation of erbium doped fibre amplifiers (EDFAs) in telecommunications, the area of high-power, cladding-pumped fibre lasers and amplifiers have seen a major field of operation of rare-earth doped fibres. High power sources have numerous industrial, military, and medical applications. Fibre lasers particularly benefit from a geometry that makes the thermal management less critical than bulk solid-state lasers. Moreover, the output beam quality in fibre lasers is greatly determined by the waveguiding properties of the core in the fibre.

Power scaling in a fibre laser relies on a double clad fibre (DCF) geometry. The conventional DCF comprises of 3 layers. The inner-most layer, which is the fibre core, possesses the highest refractive index. The inner cladding next to the core, has a refractive index higher than that of the outer cladding, which acts as a waveguide for the pump beam. The large cross-sectional area of the inner cladding allows a multimode laser diode as a pump source in the DCF structure, which is a great advantage compared to the core pumping counterpart. The rare-earth doped core is excited by the pump beam and generates a signal wavelength in the stimulated beam while propagating the core. Therefore, the core parameters, i.e. core size and Numerical Aperture (NA), determine signal beam quality, and are usually tailored for single-mode operation. Moreover, the fibre is designed to be suitable for power-scaling. For example, in order to cope with the multi-kW level of output power, the fibre core needs to be large enough to overcome the nonlinear effects like stimulated Raman scattering and to prevent the optical damage, that both result from the high power density in the core.

The ytterbium-doped fibre laser (YDFL), due to its excellent optical to optical conversion efficiency, leads the output power for fibre based lasers. Multi-kilowatts of CW output power [1] and mega-watt level of peak powers in ns-pulsed regime at 1.06 μm, with a high beam quality, have already been achieved in YDFLs. The remarkable progress in fibre laser output power was made possible due to the advances in fibre technology, including the development of large-mode-area (LMA) fibre design and fabrication, and availability of high-power multimode pump diodes. High power fibre lasers also require non-photodarkened fiber [2], in order to improve the performance and reliability of the laser.

Fibre lasers operating at eye-safe region have, over the past years, seen significant progress too. For example, an Er/Yb co-doped fibre laser has reached 0.3 kW of output power at 1.55 μm [3]. Also, 0.8 kW from a Tm-doped fibre laser in the 2 μm wavelength region was reported [4]. To date, high power fibre sources depend on the rare earths Yb, Nd, Er, and Tm.

Three-level fibre lasers are challenging to realize through cladding-pumping, for example YDFL at 980 nm. The relatively low pump absorption of cladding-pumped fibres, contrary to core-pumped fibres, and the competing amplified spontaneous emission of Yb in the longer wavelength range, 1030 – 1080 nm, with lower threshold, remain the key obstacle to power-scaling of 980 nm YDFLs. To overcome this, a modified waveguide design is required. In a YDFL, based on a depressed clad hollow optical fibre (DCHOF) waveguide design, where the non-zero fundamental mode cut-off of the core waveguide was utilized to suppress the competing 1030 – 1080 nm emission band of Yb, 3 W of output power in a diffraction limited beam ($M^2 \sim 1.09$), at 980 nm was demonstrated.

This presentation will review the advances in active fibre design and fabrication suitable for power scaling of cladding-pumped fibre lasers.

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