Power scaling of cladding-pumped Tm-doped silica fibre lasers

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Cladding pumping of fibre lasers is generating much interest as a route to high output power with the attraction of a geometry allowing simple thermal management. The waveguiding properties of the core can be easily tailored to ensure a single-spatial-mode output free from the problem of thermal lensing which has hindered brightness-scaling in conventional ‘bulk’ solid-state laser sources. Output powers from fibre lasers are however ultimately limited by damage to the core due to its small size. There is limited scope for increasing the core size whilst maintaining good output beam quality and immunity from thermal effects. One attractive solution is to use multiple fibres and wavelength-combine their outputs using an intracavity diffraction grating. This technique, recently applied to Yb-doped fibre lasers to produce 223 mW of output power at ~1μm [1], exploits the large gain bandwidths that are typical for glass hosts. Thus, this scheme offers the potential for scaling fibre laser powers to much higher levels than have been reported hitherto.

Here we present preliminary results for a wavelength-combined Tm-doped silica fibre system with 11 W output power in the 2μm spectral region. Tm-doped silica fibre lasers offer excellent potential for power-scaling via this route owing to a very broad linewidth (~300 nm) and relatively high lasing efficiencies [2]. Our set-up (Fig.1) used four double-clad Tm-doped silica fibres, each ~4 m in length with a Tm-doped alumino-silicate core of diameter of 20 μm and 0.12NA, and a non-circular silica inner-cladding of outer dimension 200 μm coated with a low-index polymer outer-cladding. Each fibre was butted to a mirror with high reflectivity at ~1.8-2.1 μm and high-transmission (~94%) at the pump wavelength. The opposite ends of the fibres were cleaved and arranged adjacent in a linear array with core-to-core separation of ~200 μm. Each fibre was pumped by a beam-shaped diode-bar with wavelength in the range 790-797 nm. The outputs from the fibres were collimated and then incident on a diffraction grating with 600 lines/mm positioned 25 mm from the lens. The first-order diffracted beam was then incident on a plane output coupler of reflectivity ~45% from ~1.8-2.1 μm to provide feedback for laser oscillation.

The principle of operation is that that grating selects the operating wavelength of each of the four fibre lasers so as to produce a single combined beam incident on the output coupler. Without grating feedback, the four lasers using only the 3.6% Fresnel reflections for feedback produced a combined output power of approximately 23.6 W for a total launched pump power of ~85 W. With grating feedback, a maximum combined output power of 11 W was achieved on four lines at wavelengths, 1967 nm, 1976 nm, 1985 nm and 1994 nm. The power reflected from the grating in zero order was ~5 W, indicating that a grating with higher first-order reflectivity would allow higher output power. By adjusting the grating angle, the centre wavelength could be tuned over a range of 68 nm from 1952 nm to 2020 nm with output power >9 W across the entire range. In this preliminary work the tuning range was limited by the onset of lasing from the fibre end-face Fresnel reflections (3.6%) when the external cavity feedback falls below this level. This also restricted the choice of output coupler to one with higher reflectivity than would be optimum for high output power. Thus, an increase in output power and extension of the wavelength tuning range should be achievable by suppressing the end-face feedback (e.g. using angle-cleaved faces or antireflection coatings). Also, with a longer focal length collimating lens and a larger aperture grating, the wavelength separation of the fibre lasers can be reduced, allowing more lasers to be wavelength-combined. With the relatively simple modifications described above this fibre laser scheme offers the potential for scaling to power levels in excess of a hundred watts in a single high quality beam.
Abstract:

Wavelength-combining of four cladding-pumped Tm-doped silica fibre lasers in an external cavity has yielded 11 W of output power in a single output beam in the 2 µm spectral region for ~85 W of launched diode power.