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 223mW 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 11W 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 (>300nm) and relatively high lasing efficiencies [2]. Our set-up (Fig.1) used four double-clad Tm-doped silica fibres, each ~4m in length with a Tm-doped alumino-silicate core of diameter of 20μm and 0.12NA, and a non-circular silica inner-cladding of outer dimension 200μm coated with a low-index polymer outer-cladding. Each fibre was butted to a mirror with high reflectivity at ~1.8-2.1μm and high-transmission (>94%) at the pump wavelength. The opposite ends of the fibres were cleaved and arranged adjacently in a linear array with core-to-core separation of ~200μm. Each fibre was pumped by a beam-shaped diode-bar with wavelength in the range 790-797nm. The outputs from the fibres were collimated with a single 25mm focal length lens and then incident with slightly different angles of incidence on a diffraction grating with 600 lines/mm positioned 25mm from the lens. The first-order diffracted beam was then incident on a plane output coupler of reflectivity ~45% from ~1.8-2.1μm 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 23.6W for a total launched pump power of ~85W. With grating feedback, a maximum combined output power of 11W was achieved on four lines at wavelengths, 1967nm, 1976nm, 1985nm and 1994nm. The power reflected from the grating in zero order was ~5W, 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 68nm from 1952nm to 2020nm with output power >9W 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.

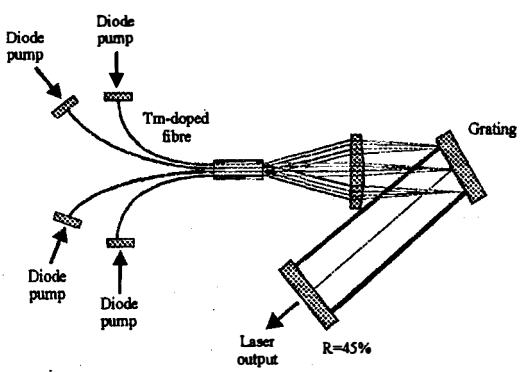

Fig.1 Wavelength-combined Tm-doped silica fibre

References

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2. R. A. Hayward, W. A. Clarkson, P. W. Turner, J. Nilsson, A. B. Grudinin and D. C. Hanna, "Efficient cladding-pumped Tm-doped silica fibre laser with high power single-mode output at 2μm," Electron. Lett., vol.36, 711-712 (2000).

Abstract:

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