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# High-power and tunable operation of a diode-bar-pumped double-clad Tm-doped silica fibre laser at 2$\mu$m

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**Abstract**

A cladding-pumped Tm-doped fibre laser produced 14W of output at 2$\mu$m for 36.5W of launched pump at 787nm. Wavelength tuning from 1.87$\mu$m to 2.03$\mu$m at power levels >1.8W for 16W of pump is also reported.

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Solid-state sources with high output power in the 'eyesafe' 2$\mu$m spectral region have applications in medicine and LIDAR, and also provide an ideal starting wavelength for nonlinear frequency conversion to the mid-infrared (3-5$\mu$m) spectral region. For many of these applications high efficiency and good beam quality are also required. This combination of operating characteristics is often difficult to achieve in conventional 'bulk' solid-state lasers due to thermal effects, which degrade beam quality and reduce overall efficiency. Double-clad fibre lasers offers an alternative means for scaling to high power [1],[2] with the advantage that thermal loading is distributed over a long length of fibre minimising the risk of damage, and the beam quality is determined by the waveguiding properties of the core, which can easily be tailored to produce a single-mode output.

The fibre used in our experiments was fabricated in-house and had a Tm-doped alumino-silicate core of diameter 20$\mu$m and 0.12NA, and an inner cladding with outer dimension ~200$\mu$m. The latter was coated with a low index (n=1.375) polymer outer cladding resulting in a high numerical aperture of 0.49 (calculated) for the inner cladding. The fibre was pumped from opposite ends by two diode-bars at 787nm. The output from each bar was re-formatted by two-mirror beam shapers [3] to allow efficient coupling into the inner cladding. The effective absorption coefficient for the pump light was measured to be 0.46dB/m. Feedback for laser oscillation was provided by a dichroic mirror with high reflectivity (>99.8%) at 2$\mu$m and high transmission (85%) at 787nm, butted to one end of the fibre, and by the 3.5% Fresnel reflection from the other cleaved fibre end. For a fibre length of 4.5m, the threshold pump power was 5.8W (launched), and at the maximum pump power of 36.5W (launched) the fibre laser produced 14W of output at a 1.998$\mu$m. We measured a beam quality factor, $M^2<1.1$, confirming the single-mode nature of the output beam. The slope efficiency with respect to launched power (~46%) was greater than the Stokes efficiency (~39%), suggesting that `two-for-one' cross-relaxation [4] may enhance the efficiency as is commonly the case in Tm-doped crystal lasers.

Tunable operation of the Tm-doped fibre laser was investigated using a modified arrangement with a single diode-bar pump source, a shorter length of fibre (~1.7m) to reduce re-absorption loss, and a diffraction grating to provide the required wavelength selection. In preliminary experiments, wavelength tuning from 1.87$\mu$m to 2.03$\mu$m (i.e. over a range of 160nm) at power levels >1.8W was achieved for a maximum pump power (launched) of ~19W (15.8W absorbed). At a wavelength of 2.00$\mu$m the output power was > 2.3W. Further extension of the tuning range and a significant increase in output power should be achievable through optimisation of the pump in-coupling optics and the fibre laser design. The combination of high power, high efficiency, diffraction-limited beam quality and wide tunability available from cladding-pumped Tm-doped fibre lasers should make these devices attractive for a wide range of applications.

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