High power double-clad Tm-doped fibre laser with >12W single-mode output at 2μm

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Abstract : Efficient high power operation of a diode-pumped Tm-doped silica double-clad fibre laser at 2μm is reported. A single-mode output power of 12.2W for 38.3W of launched diode power at 787nm was achieved.

Summary

High power sources operating in the 2μm region have applications in medicine and LIDAR, and also provide an ideal starting wavelength for nonlinear frequency conversion to the mid-infrared (3-5μm) spectral region. For many of these applications the need for high power and high efficiency are also accompanied by the requirement for good beam quality. This combination of operating characteristics is often difficult to achieve in 'bulk' solid-state lasers due to strong thermal effects which degrade beam quality and reduce efficiency. Cladding-pumped fibre lasers offer an alternative route to power-scaling [1] with the attraction that heat generated due to the laser pumping cycle can be dissipated over a long length of fibre, minimising the risk of thermally induced damage. In addition, the output beam quality is determined by the waveguiding properties of the doped core, which can easily be tailored to produce a single-mode output. In this paper we report a Tm-doped silica fibre laser with a single-mode power of 12.2W for 38.3W of launched diode pump power. To the best of our knowledge, this is the highest power in the 2μm spectral region so far reported for a fibre laser.

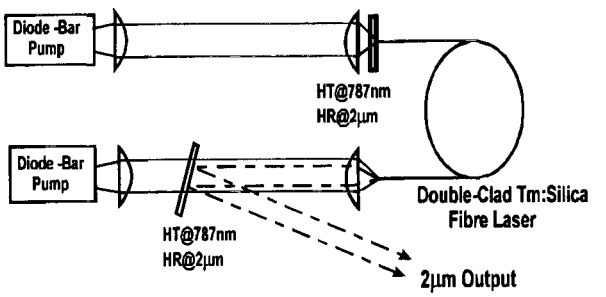

Fig.1

The experimental set-up is shown in Fig.1. The double-clad fibre was fabricated in-house with a 20μm diameter Tm-doped alumino-silica core (0.12 NA), which was slightly offset from the centre of the silica inner cladding to improve the pump absorption[2]. The inner cladding had an outer dimension of approximately 200μm, with a low refractive index (n=1.375) polymer outer cladding resulting in a calculated numerical aperture of 0.49. A small inner cladding size was chosen to minimise the cladding-to-core area ratio whilst ensuring a good launch efficiency for the diode pump. The fibre was pumped by two diode bars operating at ~787nm, where the effective absorption coefficient was measured to be ~4.6dB/m. The output from each bar was re-formatted using a two-mirror beam shaper [3] to equalise the M^2 values in orthogonal planes and so allow tight focussing into the inner cladding. The maximum combined pump power incident on the fibre ends was 48W, of which approximately 38.3W was launched into the fibre. The feedback for laser oscillation was provided by a dichroic mirror, with reflectivity >99.8% at ~2μm and high transmission (>93%) at the pump wavelength, butted to one of the fibre ends and by the Fresnel reflection at the other, uncoated, fibre end. The fibre laser output was collimated by a lens of

focal length 20mm (which also focusses the pump from one of the diode bars into the fibre), and was then incident on a second dichroic mirror to provide access to the output beam. The pump focusing lens was coated for high transmission (>99%) at the pump wavelength and was found to have a transmission of only 74% at 2μm. For a 6m length of fibre we measured a threshold pump power of 6.2W and obtained a maximum output power (before the collimating lens) of 12.2W for 38.3W of launched pump power (fig.2), corresponding to an optical efficiency of 32%. The slope efficiency (~38%) was very close to the Stokes efficiency (39%) suggesting that 'two-for-one' cross-relaxation may enhance the efficiency as is commonly the case in Tm-doped crystal lasers. Using a Merchantek beam scope the beam propagation factor, M^2 was measured to be < 1.1, confirming the single-mode nature of the fibre laser output.

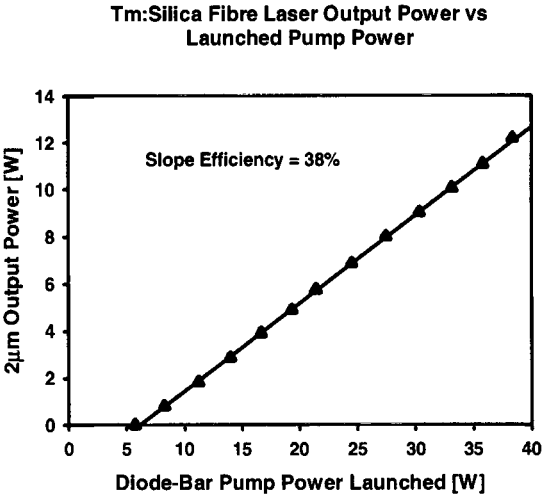

Fig. 2

With further optimisation of the pump in-coupling optics and the fibre laser design, including the use of a shorter fibre to reduce reabsorption loss, it should be possible to achieve a significant increase in output power. The combination of high power, high efficiency and diffraction-limited beam quality provided by double-clad Tm-doped fibre lasers in the 2μm region should make these sources attractive for a number of applications.

References

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3. W. A. Clarkson and D. C. Hanna, Opt. Lett., 21, 375 (1996).

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