LEOS 2001

Submission

0256

15W DIODE-PUMPED TM:YAG DOUBLE-CLAD WAVEGUIDE LASER

J.I.Mackenzie, *Student Member, IEEE*, S.C.Mitchell[1], R.J.Beach[1], H.E.Meissner[2] and D.P.Shepherd

Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK.

Tel: +44 23 80593136, Fax: +44 23 80593142, email: jim@orc.soton.ac.uk

[1] Maxios Laser Corporation, 4749-A Bennett Drive, Livermore CA 94550, U.S.A.

[2]Onyx Optics Inc., 6551 Sierra Lane, Dublin CA 94568, U.S.A.

Abstract

We report a 15W Tm:YAG double-clad planar waveguide laser operating at 2.02μm, with diffraction limited beam quality in the guided axis. A plane wave model for laser performance was found to be in excellent agreement with the experimental results.

15W DIODE-PUMPED TM:YAG DOUBLE-CLAD WAVEGUIDE LASER

J.I.Mackenzie, *Student Member, IEEE*, S.C.Mitchell[1], R.J.Beach[1], H.E.Meissner[2] and D.P.Shepherd

Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK.

Tel: +44 23 80593136, Fax: +44 23 80593142, email: jim@orc.soton.ac.uk

[1] Maxios Laser Corporation, 4749-A Bennett Drive, Livermore CA 94550, U.S.A.

[2]Onyx Optics Inc., 6551 Sierra Lane, Dublin CA 94568, U.S.A.

Summary

Laser sources with wavelengths around 2μm are of interest for medical, commercial, and remote sensing applications. Typically, high average powers coupled with good beam quality are desirable for these applications. Diode-pumped planar waveguides are an attractive solution for efficient and compact lasers, with excellent thermal properties and good prospects for power scaling due to their slab geometry [1].

Here, we present results for a planar direct-bonded double-clad waveguide comprised of a Tm:YAG core, un-doped YAG inner-cladding, and sapphire outer-cladding layers. The YAG/sapphire numerical aperture is sufficient to capture most of the highly divergent radiation of a laser diode, thus allowing a side-pumped arrangement with two proximity-coupled λ_p=785nm, 20W diode bars, as shown in figure 1. This simple and efficient pumping scheme, combined with the thin waveguide dimension, leads to a high pumping intensity, as required for efficient operation of quasi-three-level laser systems. Additionally, pumping from both sides, with the width of the waveguide approximately one absorption length, produces a relatively uniform gain distribution. Dielectric mirrors were coated directly onto the end faces of the waveguide structure, forming a plane-plane resonator with 10% output coupling.

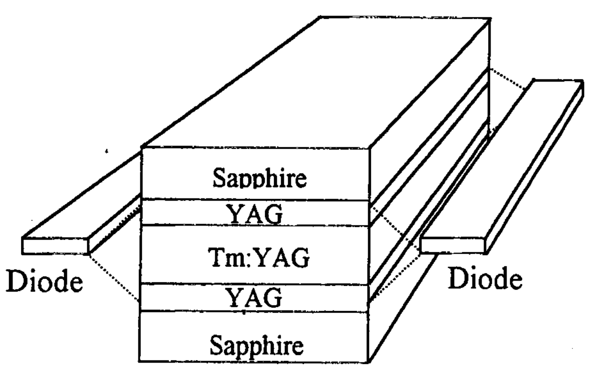

Figure 1: Proximity-coupled, diode-pumped, double-clad Tm:YAG waveguide

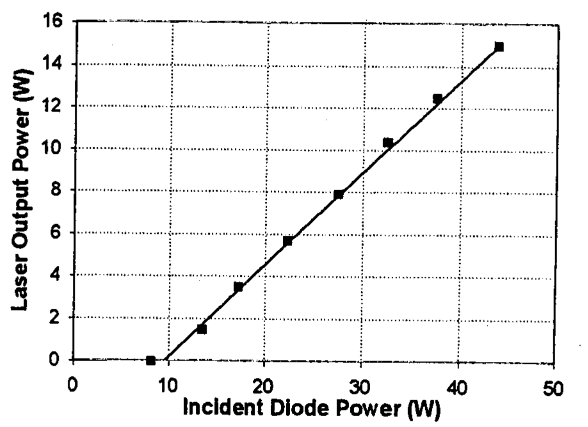

Figure 2: Experimental and theoretical output power as a function of input power

With 44W of pump power we obtained an output of 15W at 2.02μm, corresponding to an optical to optical efficiency of 34% and a slope efficiency of 44%, with respect to incident power, as illustrated in figure 2. Such a high slope efficiency is possible due to cross relaxation energy exchange processes between neighbouring Tm^{3+} ions, leading to a quantum yield of ≈ 2. The laser output was diffraction-limited in the guided axis due to gain selection of the fundamental mode from the multimode double-clad structure [1]. However, the 5mm-wide gain region in the unguided plane led to highly multimode output in this axis.

A plane-wave energy model based on the approach proposed by Beach [2], accounting for ground state depletion, gain saturation, cross relaxation, and up-conversion processes, is found to be in excellent agreement with measured results. Two main variables were used to fit the experimental data; they were the waveguide propagation loss and the up-conversion rate coefficient. The propagation loss was determined to be 0.05dBcm^{-1}, this is lower than that reported for similar Nd, and Yb doped structures operating at 1μm (<0.2dBcm^{-1}) [3], and comparable to the loss for bulk Nd:YAG (0.03dBcm^{-1}) [4], also at 1μm. Secondly, the up-conversion rate coefficient was found to be $k_{u/c}=3.6\times10^{-24} m^3 s^{-1}$, well matched to previously reported values [5, 6]. Another benefit of this modelling is that it allows mapping of the de-excitation channels for the absorbed power. This analysis verifies that up-conversion power loss is a limiting factor for laser performance when decreasing the output coupling reflectance.

A 1D temperature profile across the waveguide structure was calculated to determine the heat loading attributed to non-radiative de-excitation of the population inversion. Here, the slab-like thermal properties of the planar waveguide are shown to be beneficial, for example the calculated thermal induced surface stress is three orders of magnitude smaller than the associated fracture limit. The implications of this modelling, both thermal and lasing, are discussed in relation to power scaling to the 100W level, as are methods for controlling the spatial quality of in the non-guided axis, with the goal of achieving diffraction limited, high power, compact waveguide laser sources.

References:

[1] D. P. Shepherd, S. J. Hettrick, C. Li, J. I. Mackenzie, R. J. Beach, S. C. Mitchell, and H. E. Meissner, "High-power planar waveguide lasers," *J. Phys. D: Appl. Phys.*, in press, vol. 34, 2001.

[2] R. J. Beach, "CW theory of quasi-three level end-pumped laser oscillators," *Optics Communications*, vol. 123, pp. 385-393, 1996.

[3] C. L. Bonner, T. Bhutta, D. P. Shepherd, and A. C. Tropper, "Double-clad structures and proximity coupling for diode-bar- pumped planar waveguide lasers," *IEEE Journal of Quantum Electronics*, vol. 36, pp. 236-242, 2000.

[4] T. Nishimura and T. Omi, "Relation between laser characteristics and Nd ion concentration in Nd:YAG," *Japanese Journal of Applied Physics*, vol. 14, pp. 1011-1016, 1975.

[5] L. B. Shaw, R. S. F. Chang, and N. Djeu, "Measurement of up-Conversion Energy-Transfer Probabilities in $HoY_3Al_5O_{12}$ and $TmY_3Al_5O_{12}$," *Physical Review B*, vol. 50, pp. 6609-6619, 1994.

[6] G. Rustad and K. Stenersen, "Modeling of laser-pumped Tm and Ho lasers accounting for upconversion and ground-state depletion," *IEEE Journal of Quantum Electronics*, vol. 32, pp. 1645-1656, 1996.