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THERMALLY DIFFUSED WAVEGUIDES IN YVO_4

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Summary

Lasers based on planar optical waveguides have recently generated interest for use as high-average-power sources, due to a combination of attractive features including high optical gain, good thermal-power handling and compatibility with the geometry of high-power diode pump sources [1,2]. However, high-power diode pumping of monolithic plane-plane waveguide cavities generally leads to multi-mode output. One possible route to controlling the spatial output of such devices is through the use of tapered waveguides [3]. For devices of a few centimetres in length, adiabatic expansion can be achieved up to widths of a few hundred microns. This leads to structures compatible with end-pumping by broad-stripe diodes or, for higher power, side-pumping by diode bars. The latter route requires a very strong absorption of the diode emission, as the absorbing length is only a few hundred microns. Thus we have investigated thermal diffusion in YVO_4 as a potential waveguide fabrication technique that is compatible with the patterning required for tapered waveguides.

As a starting point, the thermal diffusion of Nd^{3+} and Gd^{3+} ions is studied in order to obtain the essential diffusion characteristics necessary to calculate the conditions required for fabrication of waveguides suitable for laser action at 1.064μm. Nd^{3+} is studied both for localised doping as the active laser ion and as a potential refractive index modifier. We also choose to study Gd^{3+} diffusion as an index modifier in order to give the potential for separate control of the index and gain distributions.

Six undoped YVO_4 substrates of dimension 18 by 18 by 3 mm in the a, b and c axes respectively, were used to characterise this process. The 18mm by 18mm polished surface of the substrates was coated with a layer of Nd or Gd and the diffusions were performed in a resistance furnace, in a dry oxygen atmosphere. Secondary ion mass spectroscopy was used to determine the diffusion profile through the depth of the diffused layers and hence the diffusion coefficients at the two temperatures used (1400°C and 1600°C). This data, together with estimates of the index change due to the Nd and Gd doping, allows prediction of the conditions required to fabricate lasing waveguides. The validity of these predictions was confirmed by observation of the properties of one of the Nd diffused samples, which gave a waveguide for propagation of light at wavelengths up to 514nm. The fluorescence spectroscopy of the Nd^{3+} doped samples was also studied and found to be very similar to that of bulk samples. The prospects for compact, diode-pumped lasers based upon these diffusion results will be discussed.

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

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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 also 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, with a Tm:YAG core, un-doped YAG inner cladding, and sapphire outer cladding layers. The YAG/sapphire numerical aperture is sufficient to contain the highly divergent radiation of a laser diode, allowing a side-pumped arrangement with two proximity-coupled λ_p=785nm 20W diode bars, as shown in figure 1. Thus we obtain efficient pumping in a very simple and compact configuration. The thin waveguide dimensions lead to a high pumping intensity, as required for efficient operation of quasi-three level laser systems. Pumping from both sides of the waveguide is also useful in producing a relatively uniform gain distribution. Mirrors were directly coated onto the end faces of the waveguide structure, forming a plane-plane resonator with 10% output coupling.

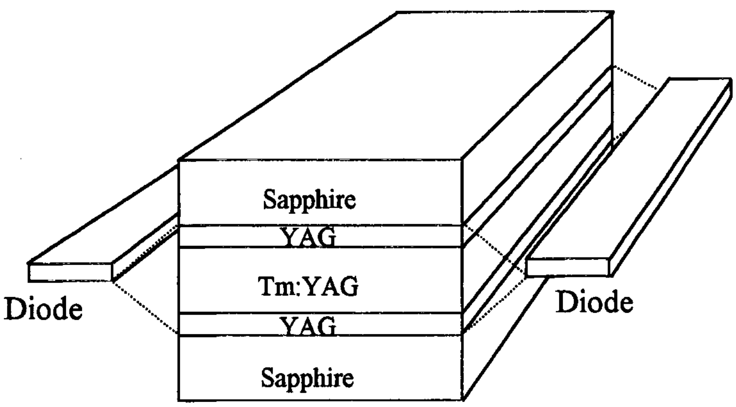

Figure 1 Proximity-coupled, diode-pumped, double-clad Tm:YAG waveguide

In Tm:YAG cross relaxation processes enable the quantum yield to approach 2, i.e. 2 laser photons for one pump photon. Thus slope efficiencies greater than the Stokes efficiency ν_l/ν_p=0.39 are possible. For 44W of pump power we obtained 15W at 2.02μm , corresponding to an optical to optical efficiency of 34% and a slope efficiency of 61% with respect to absorbed power. The beam quality of the waveguide laser 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 a highly multimode output in this axis. The prospects for further power scaling and improved beam quality will be discussed.

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 dielectric waveguide lasers," in press J. Phys. D : Appl. Phys. 34, (2001).