[illegible] CLEO 93

FIRST LASER OPERATION AT 1.03 μm OF AN EPITAXIALLY GROWN Yb:YAG WAVEGUIDE

D.Pelenc, I. Chartier, B. Ferrand, C. Wyon
LETI (CEA-Technologies avancées), DOPT-SMDO
CENG - 85 X - F38041 GRENOBLE CEDEX

D.C. Hanna, A.C. Large, D.P. Shepherd, A.C. Tropper
Departement of Physics and Optoelectronics Research Centre,
University of Southampton, Highfield, SOUTHAMPTON SO9 5NH, UK.

This paper presents the 1.03 μm laser operation of a diode-pumped Yb doped YAG planar waveguide at room temperature. The fabrication of multilayer planar waveguides by Liquid Phase Epitaxy (LPE) and their characterization are described.

Laser results (82 mW threshold, 30% slope efficiency) obtained with a 2.9 % output coupler compares favorably with bulk results reported elsewhere.

One great scope of development on diode-pumped solid-state laser systems is miniaturization. In this context, ytterbium-doped materials offers several advantages. The existence of only two Yb excited states prevents up-conversion and excited-state-absorption processes and weakens the concentration quenching. It also improves the matching between the pump and emitted wavelength, decreasing thermal loading. Furthermore, in the case of Yb:YAG the large absorption linewidth (at 941 nm) is well fitted to diode pumping.

We report here the growth and laser operation of an Yb doped guide. This planar waveguide was composed of an active layer epitaxially grown on a pure YAG substrate, with a controlled refractive index step. Then, a cladding layer of pure YAG was grown in order to have a symmetric index profile.

Ytterbium substituted YAG films were grown by means of liquid phase epitaxy (LPE) in a similar way than to neodymium substituted YAG films [1,2]. In order to take full advantage of the waveguide geometry, films of few microns thickness should be fabricated but this requires a larger refractive index difference than the one only introduced by Nd. The interest of gallium substitution in the YAG structure has been demonstrated in a previous paper [3]. So in order to adjust the lattice mismatch (gallium substitution increases the lattice parameter), a gallium-lutecium codoping was performed. X-Ray analysis was used to monitor the doping level while the lattice mismatch ($\Delta a = a_s - a_f$) was controlled by X-Ray diffraction.

The refractive index difference between the epitaxial layer and the substrate was measured using a classical prism-film coupling technique (dark m-lines). The effect of each dopant on the refractive index was determined by testing films having various compositions. In Ga doped samples, the refractive index was found to increase linearly with concentration, with a slope of $0.84\ 10^{-3}$ per at. %. The increase due to Lu was found to be around $0.1\ 10^{-3}$ per at. % while the effect of Yb was too low to be measured on our samples.

The studied guide had an active layer of 14 μm thickness, a cladding layer of 21 μm and a refractive index difference of 10-2. It was cut to a length of 1.6 mm and its endfaces perpendicularly polished. The plane - parallel cavity was made by butting two thin mirrors on the endfaces. These lightweight mirrors were held in place by capillarity using an appropriate liquid [1]. The following transmissions were available : 1.1 %, 2.9 %, 4.6 %, 24.2 %.

The InGaAs 1W pumped diode (Spectra Diode Laboratories), emitting around 968 nm, was collimated by a lens of 6.5 mm focal length and of 0.62 numerical aperture. The beam was then fitted to the guide dimension using a 30 mm focal length lens. A

Silicon plate was used to separate the residual pump from the laser beam at 1.03 µm. The laser beam was multimode, and we measured its nearfield dimension using a CCD camera to be about 12 µm x 160 µm (approximate 1/e2 diameter). The absorbed pump power was estimated by shifting the pump spot from the absorbing active layer to the pure YAG substrate, then substracting the residual pump measured in each position.

The thresholds are plotted in fig.1, as a function of - Ln R_1R_2. Following the Findlay-Clay method , we deduce the intracavity losses to be 0.13. This compares quite well with the reabsorption losses, calculated to be 0.14 for a bulk Yb:YAG sample of the same length. The output power versus absorbed pump power is plotted in fig. 2, for 1,1 % and 2,9 % output couplers. Our highest output power of 60 mW for an absorbed pump of 300 mW is obtained for the 2.9 % output coupler. This result compares well with those previously published for a diode pumped bulk Yb:YAG laser (25 mW for 340 mW absorbed power and a 3 % transmission). The slope efficiencies being comparable in both cases (30%), the difference observed in output is mainly due to a lower threshold in the guided laser.

Some recent experiments using to pump the guide a TEM $_{00}$ Ti-Sapphire laser have confirm these promising results. Thresholds as low as 12 mW and slope efficiencies of 30 % were measured. Moreover these first results should be improved by optimizing the output coupler transmission and the shape of the pump beam. To more precisely model the behaviour of this laser, we are also going to measure the stimulated emission cross-section from fluorescence spectra.

The authors are grateful to B. Chambaz, J.P. Vassali, B. François, F. Laugier for waveguide preparation and to S. Valette, J.J. Aubert and J.C. Vial for helpful discussions.

[1] I. Chartier, B. Ferrand, D. Pelenc, S.J. Field, D.C. Hanna, A.C. Large, D.P. Shepherd, and A.C. Tropper, Opt. Lett. 17, 810, (1992).
[2] B. Ferrand, D. Pelenc, I. Chartier and Ch. Wyon, J. of Crystal Growth, (1993), to be published, .
[3] P. Lacovara, H.K. Choi, C.A. Wang, R.L. Aggarwal and T.Y. Fan, Opt. Lett 16, 1089, (1991).

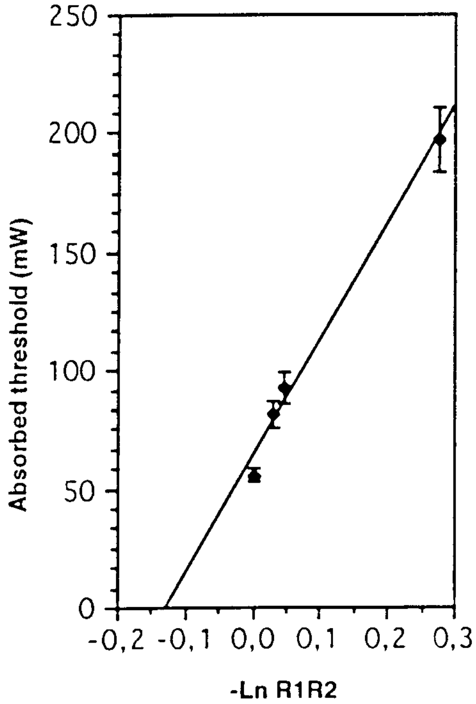

FIGURE 1

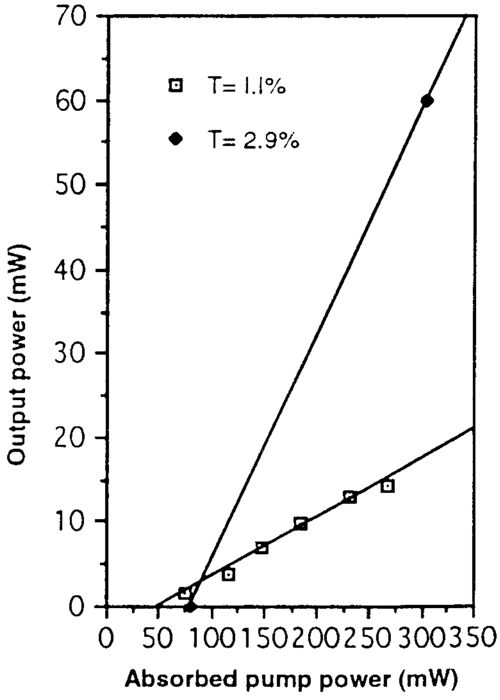

FIGURE 2