EPITAXIAL GROWTH OF GARNETS FOR THIN FILM LASERS

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Abstract: Liquid Phase Epitaxy of YAG:Nd waveguides is presented. Epitaxial material is compared to Czochralski grown YAG:Nd. First laser results are given, including guided emission in a multimode layer.

1. Introduction.

Miniature lasers are the object of considerable research in optoelectronics. Among them, waveguide lasers hold out the advantage of low pump threshold (1). A planar waveguide laser consists of a thin film of laser material on a substrate of lower refractive index. We have realised such a structure by Liquid Phase Epitaxy (LPE) of YAG:Nd monocristalline films on pure YAG substrates and observed laser emission in transversal and longitudinal configurations. Furthermore, YAG:Nd epitaxial layers reach much higher Nd concentration than bulk crystals.

2. Liquid Phase Epitaxy.

The growing technique takes advantage of the property of $\text{PbO-B}_2\text{O}_3$ solutions to stand supersaturated without spontaneous nucleation occurring. Solutions of $\text{PbO/B}_2\text{O}_3/\text{Al}_2\text{O}_3/\text{Y}_2\text{O}_3/\text{Nd}_2\text{O}_3$ in respectively 90/7.5/1.9/0.49/0.11 typical atomic concentrations were kept several degrees under their saturation temperature in a two zones furnace designed to minimize the axial thermal gradient. Pure YAG (111) oriented substrates were dipped horizontally into the melt for several minutes with alternate rotation. Growth occurred on both sides of the substrate, at a typical rate of $1 \mu\text{m/mn}$, depending on the supercooling. More details on growth conditions can be found in (2).

YAG:Nd layers 5 to $160 \mu\text{m}$ thick were realised (table I). Depending on the melt, Nd concentration (measured by X-ray microprobe analysis) can reach 15%, whereas maximum concentration of Czochralski grown YAG:Nd is about 1%. Optical quality is fairly good but decreases for thicker layers or at higher growth rates. Lattice mismatch Δa increases linearly with Nd concentration. Lutetium substitution is studied, in order to minimize Δa .

Table I: Typical layers obtained by LPE.

$(\text{Nd/Y+Nd})_{\text{melt}}$ (%)	2,7	18,1	18,1	18,1	18,1	25	25	25	40
Thickness (μm)	8,7	5,3	34	100	160	9,2	11	80	7,7
$(\text{Nd/Y+Nd})_{\text{film}}$ from X analysis (%)	0,7					4,5	5,5		15
Δa $ a_{\text{subst.}} - a_{\text{film}} $ (10^{-4} nm)	0,45	1,1	5,1	2,1	1,6	7,8	8,9	8,8	29
$(\text{Nd/Y+Nd})_{\text{film}}$ from Δa (%)	0,7	1,5	3,6	1,9	1,7	4,6	5,1	5	15

3. Comparison between bulk and epitaxial material.

3.1. Spectral linewidth:

Comparison between the absorption linewidth around 590 nm confirms the epitaxial material quality even at high concentration (fig.1). Measurements on low concentrated layers lead to the same conclusion.

Fig. 1 Transmission spectra of bulk YAG:Nd and YAG:Nd epitaxial layers.

3.2. Luminescence lifetime:

Luminescence lifetime measurements have been performed with a 514.5 nm pump beam and are compared to bulk YAG:Nd on figure 2. Both behaviours are identical in the range 0 - 6%, the variation of $K_c (\propto C^2)$ being characteristic of the strong quenching existing in YAG:Nd (3).

Fig. 2 Quenching rate K_c versus Nd concentration for bulk YAG:Nd and YAG:Nd epitaxial layers.

$$K_c = 1 / \tau_l - 1 / \tau_r$$

τ_l : luminescence lifetime

τ_r : radiative lifetime (240 μs for Nd^{3+} in YAG).

4. Laser tests.

4.1. Transversal configuration:

We have performed transversal pumping laser tests in the plano-concave cavity represented in figure 3. Absorbed threshold are 30 mW and 85 mW and slope efficiencies are about 0.15% and 5% for two output mirrors, R_{max} and $T=2\%$ respectively. Thresholds are comparable to those obtained by D. Hanna in Southampton University on previous layers grown at the LETI.

4.2. Longitudinal configuration:

Owing to the increase of refractive index due to the substitution of Nd, the YAG:Nd layer can act as a waveguide. Pump guiding offers the advantage of a better overlap between pump and emitted modes, and therefore lower thresholds and higher slope efficiencies can be expected.

For simplicity, first laser trials were realised on a multimode waveguide layer 120 μm thick, 2% concentrated, with around 15 TE guided modes. The experimental setup was identical to that of figure 3, except that the sample, a 5x5 mm² piece optically polished on two opposite sides, was 90° tilted to be end-pumped.

Fig 3 Cavity for laser tests in transversal pumping configuration

Laser effect has been observed with an R-max coated output mirror. Threshold and slope efficiency measurements are in progress.

In order to obtain small size laser, multilayer dielectric layers will be deposited on each side of the sample. Diode pumping will also be studied to realize a monolithic device.

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