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Epitaxial Tm:YAG Waveguide Lasers at 2μm and Upconversion Fluorescence in the Blue and UV Regions

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Abstract

We report the growth and efficient, low threshold, diode-pumped, 2μm laser operation of Tm:YAG epitaxial planar waveguides. A room temperature avalanche upconversion process giving intense blue and uv fluorescence is also described.

Summary

Tm:YAG is an interesting laser system normally operated at 2.0μm which has laser radar and medical applications. It has a broad emission spectrum allowing significant tuning, a relatively long upper laser level lifetime giving good Q-switched performance, and a possible 200% pump quantum efficiency due to cross-relaxation processes allowing very efficient operation when pumping at 785nm[1]. However it also has a significant population in the lower laser level at room temperature leading to a relatively high threshold pump intensity requirement. Low loss YAG epitaxial waveguides doped with Nd, Yb and Er have previously been reported with results that indicate that quasi-three-level lasers are good candidates for waveguide laser operation because the extra propagation loss introduced by the waveguide is less significant when there is already an absorption loss at the laser wavelength. We report the growth by liquid-phase epitaxy of Tm^{3+} doped YAG planar waveguides, with various concentrations (4 to 10 at.%) and active layer thicknesses (6 to 30μm). The 2μm laser performance of these guides was investigated using two plane mirrors butted directly to the end faces of the waveguides to form the resonator cavity. Both diode array (1W GaAlAs SDL diode emitting at 785nm) and Ti:sapphire pumping have been used. For diode pumping the best initial results have been obtained with a 6.6at.% doped, 4mm long and 14.6μm thick epitaxial layer. An absorbed power laser threshold of 48mW and a slope efficiency of 32% was achieved with 2% output coupling. With 12% output coupling the threshold and slope efficiency rose to 136mW and 48% respectively. For Ti:Sapphire pumping using a 1.8% output coupler thresholds as low as 8mW and slope efficiencies of around 30% were achieved in a range of different waveguides. This laser performance appears to be comparable to the best results published until now for bulk crystals despite the fact that guidance is occurring in only one plane. The prospects for channel waveguides fabricated from these low loss epitaxial thin films therefore seem most promising.

Tm:YAG is also of interest as a possible upconversion laser operating in the blue region. Bulk upconversion lasing at 486nm has already been reported at temperatures <30K. We report very intense blue and uv fluorescences at 485nm ($^1G_4 \rightarrow {}^3H_6$), 460nm ($^1D_2 \rightarrow {}^3F_4$) and 367nm ($^1D_2 \rightarrow {}^3H_6$) at room temperature for Tm:YAG epitaxial waveguides under single beam cw laser excitation at 616.4nm. These upconversion pumped emissions present all the features of the photon avalanche process: excitation only resonant between excited states ($^3F_4 \rightarrow {}^1G_4$) and a critical excitation intensity which corresponds to a slowing and a change of the rise shape of the transient signals. The most intense blue emission is obtained with the 6.6at.% doped waveguides and, among them, the thinnest guide (6.93μm) shows the best efficiency. It's interesting to note that the power threshold above which the avalanche occurs is even lower than in the bulk material.

1. L. Esterowitz, Optical Engineering **29**, 676 (1990).