Thulium-doped Yttria Planar Waveguide Laser Grown by Pulsed Laser Deposition

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Lasers operating in the 2 micron wavelength region are of particular interest for various applications in remote sensing/LIDAR, materials processing, and medical treatments. Thulium-doped media have several attractive features for generating light in this wavelength band, including a broad emission bandwidth, long-lived metastable states, absorption bands matched to high-power 0.8 µm diode-pump sources coupled with the potential for high quantum-efficiency due to a 2-for-1 cross-relaxation process. The sesquioxide crystal family is of considerable interest as a potential host due to their excellent thermo-optic characteristics and spectroscopic properties. A key challenge for this host material is its high-temperature growth requirements (some in excess of 2500 K for bulk crystals); as such there has been limited success in fabricating these crystals commercially. Here we report the first growth and lasing results (to the best of our knowledge) of a crystalline $Tm{:}Y_2O_3$ waveguide, fabricated via pulsed laser deposition (PLD).

A $Tm{:}Y_2O_3$ film of thickness ~12 µm was deposited on a 1 cm^2 $Y_3Al_5O_{12}$ substrate. The PLD source was a KrF excimer laser, producing ~2 Jcm^{-2} pulses incident upon a Tm:doped ceramic yttria target in an oxygen atmosphere at a gas pressure of 4×10^{-2} mbar. During deposition the substrate was heated to ~1000 ºC via a CO_2 laser at a wavelength 10.6 µm, leading to crystalline growth, highly textured in the (222) orientation, as determined via X-ray diffraction. The Tm concentration in the film was determined to be ~2.5 at.% by energy dispersive X-ray analysis. Two opposing facets were polished plane and parallel for subsequent laser experiments, leading to a final waveguide length of 8mm. The fluorescence spectrum was measured from the film's end facet when face pumped by a 795 nm diode laser, Fig. 1, consistent with that obtained from bulk $Tm{:}Y_2O_3$ [1].

Longitudinally pumped by a Ti:sapphire laser tuned to an absorption peak at 797nm, the $Tm{:}Y_2O_3$ waveguide laser operated around 1951 nm, depending upon the cavity arrangement. An aspheric-lens was used to couple the pump light into the active layer, generating a spot radius of ~4 µm at the waveguide facet. Using a thin pump-in-coupling high-reflectance (HR) mirror attached to the input facet and various bulk output coupling mirrors, the best laser performance is shown in Fig. 2. The highest output power was achieved with a bulk 15% transmitting output coupler mirror positioned in close proximity to the waveguide end facet, giving 35 mW out for 600 mW of incident pump power on the pump-coupling lens, and a slope efficiency of 9 %. The waveguide propagation loss was determined to be ~2 $dBcm^{-1}$ by measuring the laser's relaxation oscillation frequency at various pump power levels.

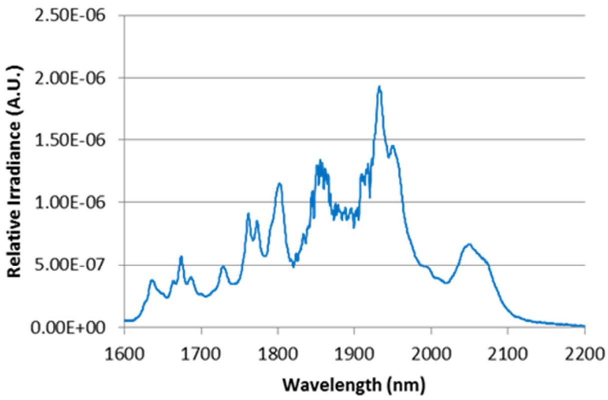

Fig. 1: $Tm{:}Y_2O_3$ waveguide fluorescence spectrum.

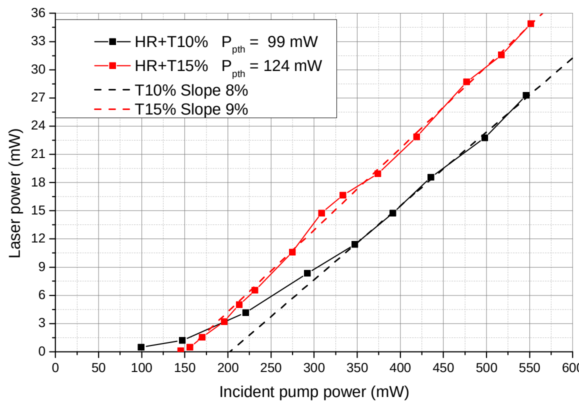

Fig. 2 Laser output power versus incident pump power.

We will discuss the laser performance and growth of this first $Tm{:}Y_2O_3$ crystalline waveguide, and further progress in reducing losses and improving the output powers, including growth of multilayer structures for high power operation.

References

[1] L. Fornasiero, N. Berner, B. Dicks, E. Mix, V. Peters, K. Petermann, and G. Huber, "Broadly Tunable Laser Emission from $Tm{:}Y_2O_3$ and $Tm{:}Sc_2O_3$ at 2 µm," in *Advanced Solid State Lasers*, M. Fejer, H. Injeyan, and U. Keller, eds., Vol. 26 of OSA Trends in Optics and Photonics (Optical Society of America, 1999), paper WD5.