Surface and buried planar waveguide lasers based on $KY(WO_4)_2:Yb^{3+}$

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Monoclinic $KY(WO_4)_2$ crystals doped with Yb^{3+} (KYW:Yb) are well known as gain media for high-power and femtosecond solid-state lasers. In particular, the Yb^{3+} ion in KYW exhibits an absorption maximum near 981 nm with a cross-section approximately 15 times larger than that of YAG:Yb. Beside bulk KYW:Yb crystals, intensive research is being conducted towards KYW:Yb thin layers. Recently, the growth of KYW:Yb thin layers on KYW substrates and their continuous-wave (CW) laser operation under longitudinal pumping normal to the layer has been demonstrated [1]. The advantages of the thin-layer geometry can be fully exploited in a waveguiding structure, in which high pump-power densities and excellent overlap of pump and resonator modes are obtained. This approach requires the fabrication of high-quality KYW:Yb layers on suitable substrates with close-to-perfect interfaces to ensure low-loss propagation.

Our KYW:Yb thin layers were grown by liquid-phase epitaxy (LPE), with $K_2W_2O_7$ as a solvent and undoped KYW crystals with laser-grade polished (010) faces as substrates. Single-crystalline layers with thicknesses d = 10 to 100 µm and Yb^{3+} concentrations ranging from 1.2 to 2.4 at% were produced. Several active layers were overgrown by 20-µm thick undoped KYW overlays in order to obtain buried active structures with symmetric refractive-index profile in the waveguide structure. One buried (d = 17 µm) and two surface waveguides (d = 17 µm and d = 35 µm) with polished end- and surfaces, each about 6 mm long, were selected for laser experiments.

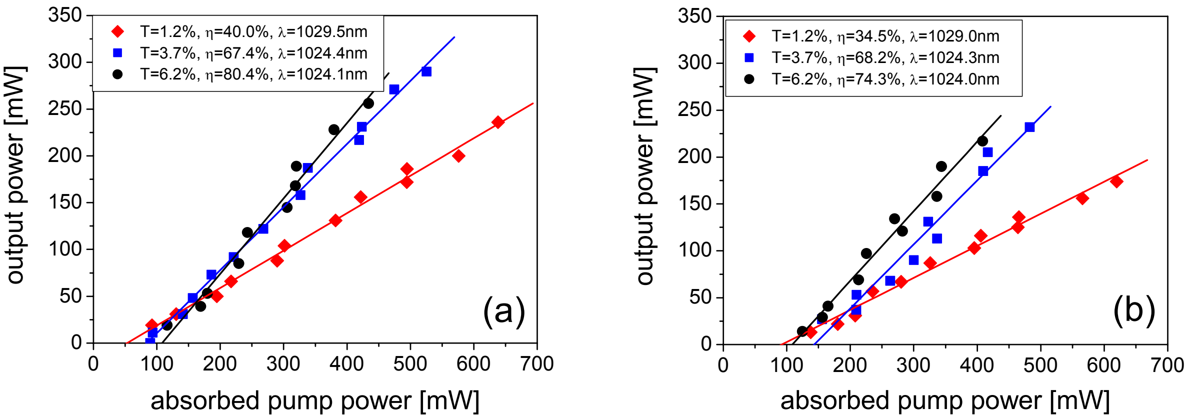

Fig. 1: Output power versus absorbed pump power of surface (a) and buried (b) KYW:Yb planar waveguide lasers for different transmissions of the output coupler

The planar KYW:Yb waveguides were positioned at Brewster's angle between two 10-cm folding mirrors in a Z-shaped laser cavity such that the resonator waist is located at both end-faces of the waveguide and negligible diffraction losses occur for the resonator mode at the waveguide interfaces. The waveguide orientation corresponded to propagation approximately along the N_g principal optical axis and polarization along the N_m axis. The pump source was a tunable CW Ti:Sapphire laser. The maximum pump power incident on the crystal was limited to 1.5 W at 980 nm.

Independent of the chosen output coupler transmission (T - see Fig. 1), stable CW oscillation near λ = 1025 nm could be achieved for all waveguides investigated. The best laser performance was achieved with the 17-µm thin surface waveguide doped with 1.2 at% Yb^{3+}. Its laser threshold was reached at an absorbed pump power of about 80 mW. Using a 3.7%-transmission output coupler the maximum output power amounted to 290 mW, resulting in a slope efficiency of η = 67.4%. The maximum slope efficiency of 80.4% was obtained for T = 6.2%, corresponding to a pump efficiency of 58.9% (Fig. 1a). The laser performance of the three planar waveguides was rather similar, as can be seen in Fig. 1b, where the output characteristics of the buried waveguide (2.4 at% Yb^{3+}) is presented. Laser emission close to the diffraction limit was achieved for the investigated highly multimode planar waveguide structures.

In conclusion, highly efficient CW laser emission based on thin layers of $KY(WO_4)_2:Yb^{3+}$ grown by liquid-phase epitaxy was demonstrated at room temperature.

[1] A. Aznar, R. Solé, M. Aguiló, F. Diaz, U. Griebner, R. Grunwald, V. Petrov, Appl. Phys. Lett. **85** (2004) 4313.