Epitaxially grown Yb:KLu$(WO_4)_2$ composites for continuous-wave and mode-locked lasers in the 1 µm spectral range

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Yb^{3+} is a very promising activating ion possessing a number of advantages over Nd^{3+} for laser operation in the 1 µm spectral region which are related to its simple two-level energy scheme. The doping level in monoclinic $KRE^{3+}(WO_4)_2$ single crystals can reach the stoichiometric structure $KYb(WO_4)_2$, or KYbW, but thermo-mechanical limitations do not allow the fabrication and use of active elements with a thickness <100 µm corresponding to the absorption length (13.3 µm for KYbW). The closer ionic radii of Lu and Yb make $KLu(WO_4)_2$ (KLuW) potentially interesting as a passive host due to the possibility not only for doping with very high concentrations of Yb^{3+} but also for the growth of KYbW/KLuW epitaxies for one-dimensional cooling employing the thin-disk laser concept.

We applied Liquid Phase Epitaxy (LPE) in a vertical furnace with practically no axial gradient in order to obtain homogeneous epitaxial layers of Yb:KLuW. The composite crystal (1.1 mm KLuW substrate and 100 µm Yb:KLuW layer with 10% Yb/Lu-site) was studied under Brewster angle in an astigmatically compensated cavity with longitudinal Ti:sapphire laser pumping. Some continuous-wave laser output characteristics are presented in Fig. 1a. The maximum output power of 415 mW (T_{OC}=3%) corresponds to a maximum pump efficiency of 55% with respect to P_{abs}. The strongly reduced reabsorption lead to higher pump and slope (η) efficiencies in comparison to bulk Yb:KLuW. Even without cooling no damage of the epitaxial crystal occurred regardless of the high power levels (intracavity intensity exceeding 1 MW/cm^2) applied.

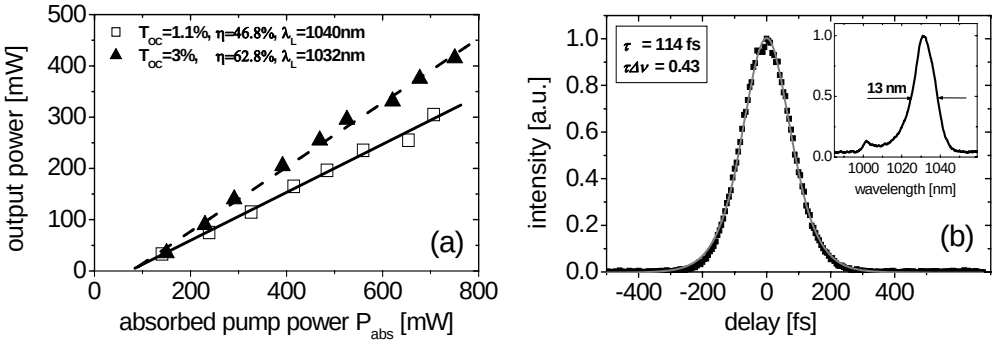

Fig. 1: Continuous-wave (a) and mode-locked (b) laser performance of the Yb:KLuW/KLuW epitaxial composite. The polarization is parallel to the N_m-optical axis.

Passive mode-locking was studied with a semiconductor saturable absorber mirror (SAM) in one of the cavity arms and two SF10 dispersion prisms in the other arm containing a T_{OC}=1.1% output coupler. Pulses as short as 114 fs (autocorrelation trace in Fig. 1b) at 1030 nm could be achieved with an average output power of 31 mW at a repetition rate of 101 MHz. The time-bandwidth-product of 0.43 is slightly above the Fourier limit which is related to the asymmetric spectrum generated (inset Fig. 1b).

The results presented indicate an improvement of about one order of magnitude in comparison to our previous results with analogous Yb:KYW/KYW epitaxies in the continuous-wave regime while passive mode-locking is reported for the first time with such a monoclinic epitaxial composite. Work is in progress to increase the doping level and decrease the thickness of the Yb:KLuW epitaxial layer.

Keywords: monoclinic double tungstates, epitaxial growth, ytterbium lasers, ultrafast lasers