

# Continuous-wave lasing of Yb:NaLa(WO<sub>4</sub>)<sub>2</sub> at room temperature

J. Liu, M. Rico, U. Griebner, V. Petrov

Max-Born-Institute for Nonlinear Optics and Ultrafast Spectroscopy, 2A Max-Born-Str., D-12489 Berlin, Germany,  
Phone: ++49-30-63921272, Fax: ++49-30-63921289, E-mail: [petrov@mbi-berlin.de](mailto:petrov@mbi-berlin.de)

J. M. Cano-Torres, F. Esteban-Betegón, M. D. Serrano, C. Zaldo

Instituto de Ciencia de Materiales de Madrid, Consejo Superior de Investigaciones Científicas,  
Calle Sor Juana Inés de la Cruz 3, Cantoblanco, E-28049 Madrid, Spain

Recently crystals of NaLa(WO<sub>4</sub>)<sub>2</sub> (NaLaW) could be successfully grown with Yb<sup>3+</sup> doping [1,2]. The fluorescence lifetime of Yb:NaLaW is 220 μs [2]. Having a congruent melting character NaLaW is attractive because it can be pulled directly from melt by the Czochralski method. NaLaW is a disordered uniaxial crystal with tetragonal structure where an almost random distribution of Na<sup>+</sup> and La<sup>3+</sup> (or Yb<sup>3+</sup>) ions over same lattice sites occurs leading to inhomogeneous broadening of the dopant spectral lines. Pulsed laser operation of Nd:NaLaW at 1063.5 and 1335.5 nm was demonstrated more than 30 years ago. It is the first time that we report continuous-wave (cw) lasing of uncooled Yb:NaLaW, the second disordered crystal of that type after the isostructural Yb:NaGd(WO<sub>4</sub>)<sub>2</sub> or Yb:NaGdW whose laser performance was described in [3]. The interest in such Yb-doped tetragonal sodium double tungstates is due to their potential to ensure larger bandwidths (supporting sub-100 fs pulses) in mode-locked lasers in comparison to the monoclinic potassium double tungstates Yb:KGd(WO<sub>4</sub>)<sub>2</sub>, Yb:KY(WO<sub>4</sub>)<sub>2</sub>, and Yb:KLu(WO<sub>4</sub>)<sub>2</sub>.

The sample used in the present experiment was grown in air by the Czochralski method. The Yb content in the melt was 5 mol % but the amount incorporated into the crystal was  $1.09 \times 10^{20} \text{ cm}^{-3}$  (segregation coefficient  $K \approx 0.6$ ). The main absorption line of Yb<sup>3+</sup> near 977 nm is stronger for the  $\pi$ -polarization [1,2] and the 3.4 mm thick sample had a small signal absorption of about 50% at that wavelength under Brewster angle. The three-mirror astigmatically compensated cavity (total length: 65 cm) consisted of a RC=5 cm end mirror, a RC=10 cm folding mirror through which the Ti:sapphire laser pump beam was focused by an  $f=6.28$  cm lens, and a plane output coupler of transmission  $T_{OC}$ .

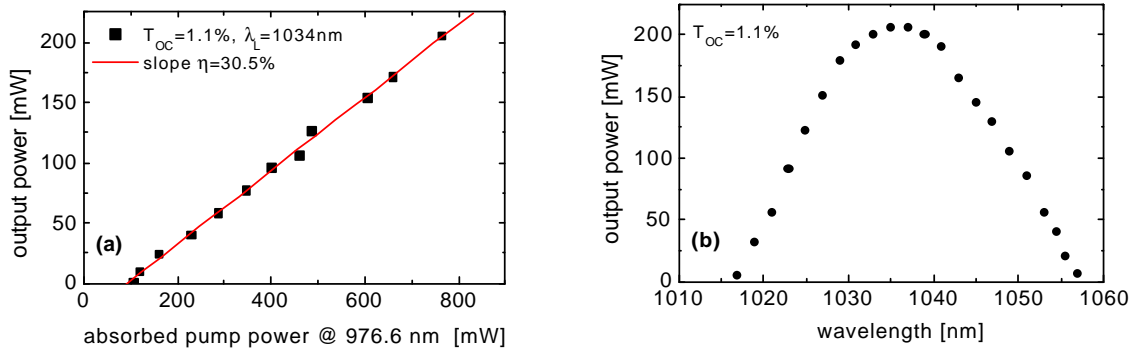


Fig. 1: Output power versus absorbed power (a) and wavelength tunability (b) of the Yb:NaLaW laser.

The optimum pump wavelength corresponded to the main absorption peak. At the maximum pump power incident on the crystal (1.9 W) the absorption was bleached down to 20%. Lasing had a recycling effect and in the case of  $T_{OC} = 1.1\%$  (Fig. 1a) the latter value increased to 39.4%. Using other output couplers with  $T_{OC} = 3\%$  and  $5.4\%$ , the intracavity power decreased and the absorption for the maximum applied pump power was 32.3% and 26.4%, respectively. Hence, these output couplers did not yield higher output powers although the slope efficiency slightly increased to  $\approx 35\%$ . The maximum output power with  $T_{OC} = 1.1\%$  exceeded 200 mW and the maximum pump efficiency was  $\approx 27\%$  (Fig. 1a). The threshold absorbed pump power was 100 mW for  $T_{OC} = 1.1\%$ , 110 mW for  $T_{OC} = 3\%$ , and 200 mW for  $T_{OC} = 5.4\%$ . The maximum output power achieved for  $T_{OC} = 3\%$  and  $5.4\%$  was 181 mW ( $I_L = 1029$  nm) and 132 mW ( $I_L = 1027$  nm), respectively. The insertion of a two-plate Lyot filter did not affect the maximum output power but allowed tuning between 1017 and 1057 nm (Fig. 1b). Note that the reduction of the recycling effect additionally confines the achievable tunability in the cw regime while in a mode-locked laser this effect will be absent.

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