Sub-80 fs pulses from a mode-locked Yb:NaGd$(WO_4)_2$ laser

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Recently we demonstrated for the first time laser operation of a disordered Yb-doped crystal [1], NaGd$(WO_4)_2$ or shortly NaGdW, belonging to the family of the tetragonal double tungstates previously studied only with Nd-doping. In such crystals the disorder and the inhomogeneous line broadening are rather due to occupation with some probability of two possible sites (each with multiple environments) than to lattice defects like in CaF_2. The interest in such double tungstates is motivated by their potential to ensure larger bandwidths in mode-locked lasers in comparison to the monoclinic double tungstates like KGd$(WO_4)_2$, KY$(WO_4)_2$ and KLu$(WO_4)_2$ which have exceptionally large cross sections. Tunability of the Yb:NaGdW laser from 1016 to 1049 nm could be achieved by a two-plate Lyot filter [1].

Here we demonstrate, for the first time to our knowledge, passive mode-locking of the disordered laser crystal Yb:NaGdW using a semiconductor saturable absorber mirror (SAM). The $NaGd_{0.92}Yb_{0.08}(WO_4)_2$ crystal was grown by the Czochralski method in air. The 3.273 mm thick Yb:NaGdW plate, oriented for the π-polarization, was positioned under Brewster angle between the two folding focusing mirrors (RC=-10 cm) of a Z-shaped astigmatically compensated cavity. The arm with the output coupler of transmission T_{OC} contained two SF10 Brewster prisms separated by 29 cm, and the other arm was terminated by a RC=-10 cm mirror providing an additional waist on the SAM. Longitudinal pumping through one of the folding mirrors was realized by an f=6.28 cm lens using a cw Ti:sapphire laser tuned to 974 nm and focused to a pump waist of about 30 µm. The cavity length corresponded to a repetition rate of 99 MHz.

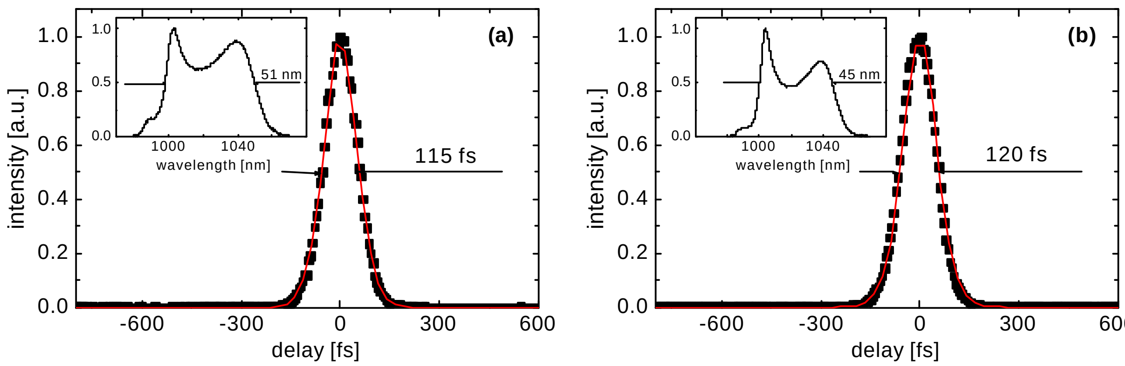

Fig. 1: Autocorrelation traces and spectra (insets) of the Yb:NaGdW laser for T_{OC}=1.2% (a) and T_{OC}=3.2% (b).

The autocorrelation trace in Fig.1a recorded for T_{OC}=1.2% corresponds to a pulse duration of 75 fs (FWHM) assuming a $sech^2$-pulse shape as shown by the fit. The output power in this case amounted to 23 mW. It could be increased to 61 mW using a T_{OC}=3.2% output coupler at only slightly lengthened (FWHM=78 fs) pulse duration (Fig. 1b). In both cases the output spectra are rather broad (see insets) corresponding to a time-bandwidth product of 1. Increasing the pump level, output powers of 112 mW could be obtained for T_{OC}=3% at a pulse duration of 146 fs. In this case the spectrum exhibited only a single peak centered at 1032 nm and the pulses were almost bandwidth limited (time-bandwidth product of 0.37). We believe that the optimisation of the cavity dispersion and the mirror reflectivity as well as the use of more appropriate SAM or direct Kerr-lens mode-locking will allow us in the near future to reduce the pulse duration from this laser to below 50 fs.

In conclusion pulse durations as short as 75 fs were achieved in an initial experiment on mode-locking of disordered Yb:NaGdW. Note that the shortest pulses reported so far with Yb:CaF_2, which exhibits otherwise much broader tunability, had a duration of 150 fs [2].

1. M. Rico, J. Liu, U. Griebner, V. Petrov, M. D. Serrano, F. Esteban-Betegón, C. Cascales, and C. Zaldo, Opt. Exp. **12** (2004) 5362.
2. A. Lucca, G. Debourg, M. Jacquemet, F. Druon, F. Balembois, P. Georges, P. Camy, J. L. Doualan, and R. Moncorge, Opt. Lett. **29** (2004) 2767.