Passively mode-locked Yb:Lu_2O_3 laser

U. Griebner and V. Petrov
Max-Born-Institute for Nonlinear Optics and Ultrafast Spectroscopy, Max-Born-Str. 2A, D-12489 Berlin, Germany,

K. Petermann and V. Peters
Institute for Laser Physics, University of Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany

Abstract: A mode locked Yb-laser with host material of Lu_2O_3 is demonstrated for the first time. Using a saturable absorber mirror ps-pulses and with dispersion compensation pulses as short as 220 fs were obtained at 1033.5 nm.

OCIS codes: (140.4050) Mode-locked lasers; (160.5690) Rare earth doped materials

Ytterbium doped materials are attractive for compact high-power femtosecond laser sources in the 1 µm spectral range due to their small quantum defect, lack of excited state absorption and upconversion processes and the possibility for efficient pumping with InGaAs diodes. The isotropic sesquioxides Sc_2O_3, Y_2O_3 and Lu_2O_3, doped with Yb exhibit a potential alternative to Yb:YAG for high power applications because of their excellent thermal properties. The splitting of the ground state is larger and the thermal conductivity of the undoped sesquioxides is better than of YAG. Among them Lu_2O_3 is the only material where the thermal conductivity doesn't drop after doping with ytterbium [1]. The advantages of the sesquioxides have already been evidenced in terms of the slope efficiency in continuous wave (cw) laser experiments [1,2]. Very recently, the first mode-locked laser operation based on sesquioxide hosts has been reported for crystalline Yb:Sc_2O_3 [3] and Yb:Y_2O_3 ceramic [4].

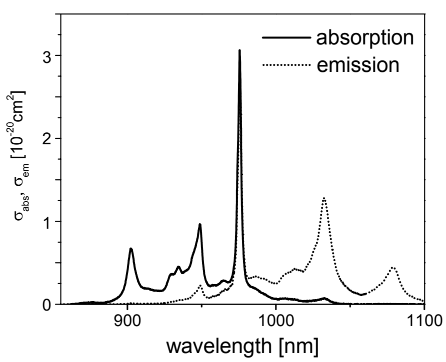

Fig. 1: Absorption σ_{abs} and emission cross section σ_{em} of Yb:Lu_2O_3.

Here we demonstrate for the first time to our knowledge mode-locked operation of the Yb^{3+}:Lu_2O_3 and present results obtained both in the picosecond and the femtosecond regime. We studied a Z-shaped astigmatically compensated resonator with two folding mirrors in the middle to form a cavity waist at the position of the Yb:Lu_2O_3 crystal. One arm contained an additional focusing mirror to increase the intensity on the semiconductor saturable absorber mirror (SESAM) which terminated the resonator. The other arm contained a plane output coupler and in this arm two dispersion compensating prisms could be included. 70% of the incident pump power (2 W at 975 nm from a home made Ti:sapphire laser) were absorbed by the 2.7% Yb-doped sample of Lu_2O_3 (thickness: 1.3 mm) which was used under Brewster angle. The absorption and emission cross sections of Yb:Lu_2O_3 are shown in Fig. 1. The SESAM (BATOP GmbH) reflection band was from 995 to 1095 nm with 2% of saturable absorption, 70 $\mu J/cm^2$ saturation fluence, and 20 ps carrier lifetime.

With a 5% output coupler and without intracavity prisms the passively mode-locked laser operated in the picosecond regime at a pulse repetition rate of 109 MHz. The threshold measured (cw) amounted to 380 mW of absorbed power and the mode-locked slope efficiency to 44%. The maximum optical to optical pump efficiency reached 32%. Fig. 2 shows the temporal and spectral characteristics at the maximum output power of 470 mW. Both the experimental data (squares) and the fit assuming $sech^2$-pulse shapes (line) are plotted. The deconvolved FWHM of the pulse is 1.16 ps. The spectrum centered at 1033.5 nm (Fig. 2) leads to a time-bandwidth-product exceeding about 6 times the Fourier limit.

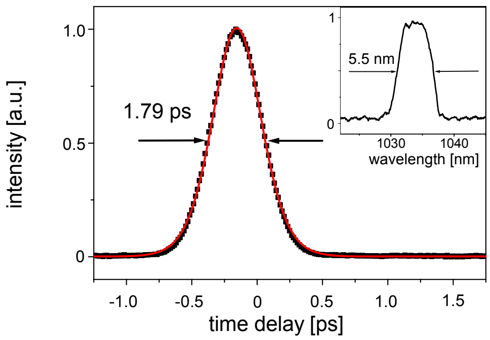

Fig. 2: Autocorrelation trace and spectrum (inset) in the picosecond regime.

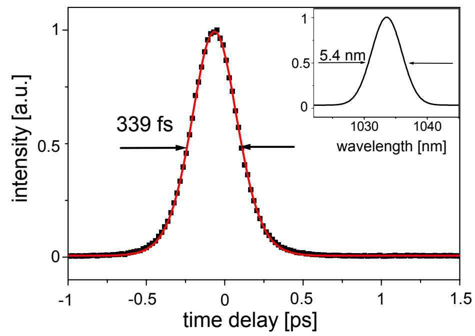

Fig. 3: Autocorrelation trace and spectrum (inset) in the femtosecond regime.

The femtosecond regime was achieved by adding two 60° SF6-prisms with a separation of 41 cm into the arm containing a 3% output coupler, which resulted in a pulse repetition rate of 97 MHz. Pulses as short as 220 fs (Fig. 3) at 1033.5 nm could be generated. The time-bandwidth-product amounted to 0.334 which is very close to the Fourier limit (0.315). The output power of 266 mW corresponded to a pump efficiency of 18%.

In conclusion, we have generated the shortest pulses for a sesquioxide laser and demonstrated experimentally that Yb:Lu_2O_3 is a very promising material for compact mode-locked lasers in the 1 µm range which possesses larger gain bandwidth and thermal conductivity than Yb:YAG.

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