Sub-30 fs Kerr-lens mode-locked Ytterbium-activated orthoaluminate laser

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Ytterbium (Yb^{3+})-doped yttrium orthoaluminate, $Yb:YAlO_3$ (abbreviated Yb:YAP), belonging to the orthorhombic class (sp. gr. *Pnma*, perovskite-type structure), is very promising for the development of high-power femtosecond lasers at ~1 μm due to a combination of excellent thermo-mechanical and spectroscopic properties [1, 2]. Yb:YAP is optically biaxial and its intrinsic birefringence provides polarization anisotropy leading to a linearly polarized laser emission, which suppresses the thermally induced depolarization losses inherent to isotropic laser gain media. The first demonstration of femtosecond passive mode-locking of a Yb:YAP laser was reported in 2008. A SEmiconductor Saturable Absorber Mirror (SESAM) mode-locked (ML) Yb:YAP laser delivered 225 fs pulses at 1041 nm with an average output power of 0.8 W [3]. Subsequently, power scaling of the SESAM mode-locked Yb:YAP laser was achieved by using a novel off-axis pumping scheme yielding 140 fs pulses at 1009.7 nm with an average output power of 4 W [4]. Here, we report on a sub-30 fs Yb:YAP laser delivering soliton pulses as short as 24 fs at 1085 nm with an average output power of 186 mW and a pulse repetition rate of 87.5 MHz via soft-aperture Kerr-lens mode-locking (KLM).

KLM operation was investigated in an X-folded astigmatically compensated standing-wave cavity with a 5 at.% Yb^{3+}-doped YAP crystal. The uncoated sample was cut along the ***a***-axis and mounted in a water-cooled copper holder placed at Brewster's angle between two concave dichroic folding mirrors with a radius of curvature (RoC) of -100 mm. The pump source was a spatially single-mode Yb-fiber laser emitting linearly polarized output at 979 nm. The intracavity group delay dispersion (GDD) was optimized by two flat dispersive mirrors (DMs) with a total round-trip negative GDD of -1200 fs^2. The physical cavity length was ~1.7 m corresponding to a pulse repetition rate of ~87.5 MHz. The laser polarization was along the ***b***-axis.

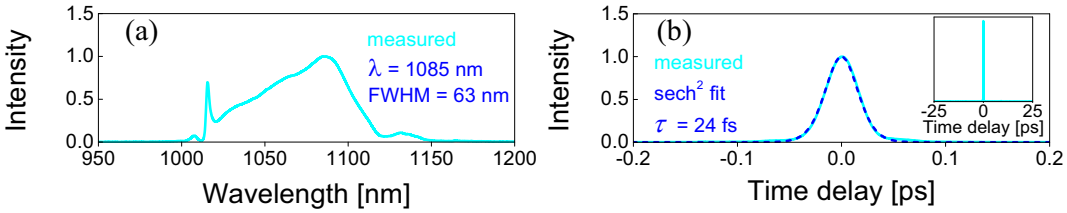

Fig. 1 KLM $Yb:YAlO_3$ laser with T_{OC} = 1%: (a) Optical spectrum and (b) SHG-based intensity autocorrelation trace. Inset in (b): simultaneously measured long-scale (50 ps) autocorrelation trace.

Soliton pulses as short as 24 fs were generated from the KLM Yb:YAP laser for 1% output coupler transmission. The maximum average output power amounted to 186 mW for an incident pump power of 2.5 W. The output spectrum was centered at 1085 nm and had a bandwidth of 63 nm (full width at half maximum, FWHM), which corresponded to a time-bandwidth product (TBP) of 0.385. The measured optical spectrum together with the corresponding second-harmonic generation (SHG) based intensity autocorrelation traces are shown in Fig. 1. The chirp could not be fully eliminated by the intracavity DMs, as can be deduced from the TBP which is larger than the Fourier-transform-limit for a $sech^2$-shaped pulse (0.315). Our result represents the shortest pulses ever achieved with any ytterbium-activated orthoaluminate crystal and highlights the potential for high-power few-optical-cycle pulse generation from a mode-locked Yb:YAP laser.

References

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