Thin Disk Lasers enable High-Power Frequency Combs

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Stabilized frequency combs with high average power become increasingly attractive for applications such as intra-cavity high harmonic generation for XUV frequency combs. SESAM-modelocked thin disk lasers (TDLs) are very attractive as they achieve nowadays average powers (275 W) and pulse energies (80 µJ) orders of magnitude higher than any other laser oscillator technology [1]. Compared to standard carrier-envelope phase-stabilized oscillators, TDLs operate in a very different regime, as they require optical pumping with very high powers, only achievable with very strongly multi-transverse mode laser diodes. For a long time, it remained unclear whether carrier-envelope offset (CEO) frequency stabilization of this laser technology is possible as achieved for conventional ultrafast lasers, such as Ti:Sapphire.

We recently demonstrated the first CEO-stabilized SESAM-modelocked TDL [2]. Our oscillator is based on the broadband gain material Yb:CALGO and delivers sub-100 fs pulses with 2.1 W of average output power. Using a common *f*-to-2*f* interferometer, the CEO beat-note frequency f_{ceo} was reliably detected and locked to an external reference using simple current feedback to the multimode pump laser diode (Fig. 1). A residual in-loop CEO integrated phase noise of 120 mrad (1 Hz - 1 MHz) was achieved [2], with a contribution of amplitude-to-phase noise conversion in the generated CEO beat assessed to be < 3 mrad. A fractional frequency stability of 10^{-10} at 1 s was measured for the 26.18-MHz CEO frequency (Fig. 2). In addition to proving that multimode-pumped TDL oscillators can be stabilized with straightforward current feedback, these results show that the intrinsic high-Q factor of such TDL oscillator is beneficial for self-referencable frequency combs with high average power. We have also investigated the noise of the pump laser and its propagation through the system showing its impact on the laser output power and CEO noise. This understanding is a crucial step for the design and the stabilization of laser systems with higher average power in the near future.

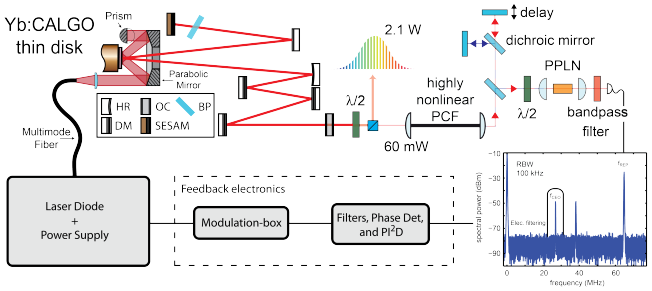

Fig. 1: Experimental set-up. Only 2% of the thin disk laser output power is launched into an *f*-to-2*f* interferometer to detect f_{ceo}, which is stabilized using a feedback current to the pump diode.

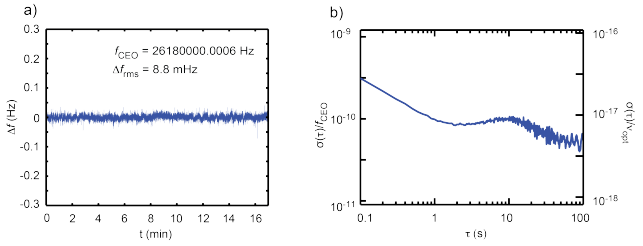

Fig. 2: 1000-s time series of the stabilized f_{ceo} (a) showing an Allan deviation of 10^{-10} at 1 s (b).

[1] C. J. Saraceno, et al., "Cutting-edge high-power ultrafast thin disk oscillators," Appl. Sciences **3**, 355-395 (2013).

[2] A. Klenner, et al., "Phase-stabilization of the carrier-envelope-offset frequency of a SESAM modelocked thin disk laser," Opt. Exp. **21**, 11 (213).