Compact Frequency Combs from Ytterbium-Doped Diode-Pumped Solid-State Lasers

Alexander Klenner[1], Stéphane Schilt[2], Thomas Südmeyer[2], Ursula Keller[1],

[1]Department of Physics, Institute for Quantum Electronics, ETH Zurich, Zurich, Switzerland
[2]Laboratoire Temps-Fréquence, Université de Neuchâtel, Neuchâtel, Switzerland

Email: klenner@phys.ethz.ch

Optical frequency combs (OFC) from modelocked lasers find many applications in high-speed communications, precision spectroscopy and particularly in metrology. All of these applications benefit from robust, low-noise and high-power systems. OFCs are typically built from green singlemode-pumped Ti:sapphire oscillators or fiber lasers, which often require pulse compression and amplification, making the overall system complex and expensive. Many applications favor more compact frequency combs using Yb-doped diode-pumped solid-state lasers (DPSSLs). For high-power operation these systems need to be pumped with strongly multimode laser diodes and for a long time pump-induced instabilities did not allow full frequency comb stabilization. Recently we demonstrated carrier-envelope-offset (CEO) phase-stabilization of a SESAM-modelocked thin disk laser (TDL) [1]. However, the TDL pumping scheme benefits from a multipass geometry that may average down the multimode spatial noise and it remained unclear whether conventional DPSSLs pumped with a multimode diode could be stabilized as well.

We present here the first phase-stabilized CEO frequency (f_{CEO}) from a conventional solid-state laser pumped by a multi-transversal-mode laser diode. The laser is based on a Yb-doped Potassium-Gadolinium Tungstate crystal (Yb:KGW) and delivers ~300-mW average output power with ~110-fs pulses at a 133-MHz repetition rate. A coherent peak is obtained in the CEO beat using feedback applied to the multimode pump (see Fig. 1). The tight lock is confirmed by the measured in-loop f_{CEO} frequency noise lying integrally below the β-separation line [2]. The residual integrated phase noise is only 407 mrad (1 Hz - 5 MHz). Our study revealed essential requirements for multimode pumped frequency combs, such as the required loop-bandwidth, loop-architecture and characteristics of the multimode pump. Furthermore, we show the impact of f_{CEO} stabilization on the amplitude noise and timing jitter of our oscillator. This work is an essential step towards stabilized high-power GHz-OFCs from Yb-based DPSSLs.

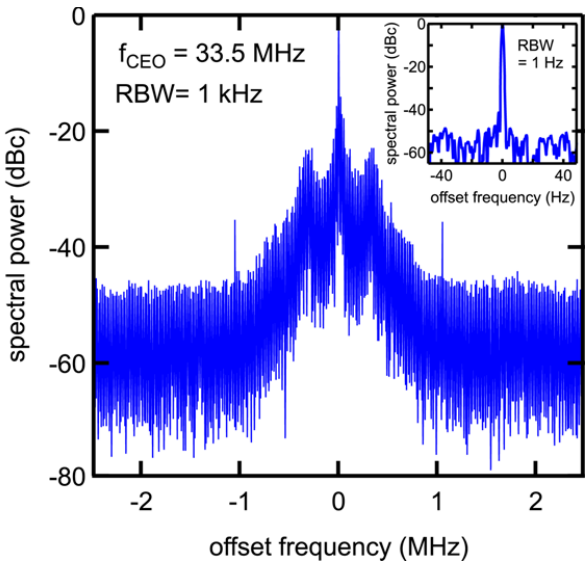

Fig. 1: Tightly locked f_{CEO} of a 133-MHz Yb:KGW oscillator directly pumped with a multi-transversal-mode laser-diode. Inset: coherent peak with 50-dB single-to-noise ratio in a 1-Hz RBW.

[1]A. Klenner, F. Emaury, C. Schriber, A. Diebold, C. J. Saraceno, S. Schilt, U. Keller, and T. Südmeyer, "Phase-stabilization of the carrier-envelope-offset frequency of a SESAM modelocked thin disk laser," Opt. Exp. **21**, 11 (2013).
[2]G. Di Domenico, S. Schilt, and P. Thomann, "Simple approach to the relation between laser frequency noise and laser line shape," Appl. Opt. **49**, 4801-4807 (2010).