Recent Trends in Ultrafast Diode-Pumped Solid-State Lasers and Frequency Combs

Thomas Südmeyer
Laboratoire Temps-Fréquence, Université de Neuchâtel,
Avenue de Bellevaux 51, CH-2000 Neuchâtel, Switzerland
Thomas.Sudmeyer@unine.ch

In the last decade, ultrafast diode-pumped solid-state lasers (DPSSLs) have been revolutionizing numerous areas in science and technology. However, there is still a strong need for further improvements in terms of cost efficiency, performance, compactness, and reliability. In this presentation, we will review latest developments in the area of ultrafast solid-state laser oscillators and frequency comb generation.

The highest average power levels and pulse energies of ultrafast laser oscillators are achieved in the thin disk laser geometry. In the first part of this talk, the latest milestones in terms of duration, power and pulse energy will be reviewed and the performance of carrier-envelope-offset (CEO) stabilized SESAM-modelocked thin disk lasers will be discussed [1].

In the second part, frequency comb stabilization methods for DPSSLs will be discussed. Optical feedback to the SESAM is a recent method for CEO-stabilization. It overcomes bandwidth limitations of the standard pump current control in DPSSLs. In case of a CEO-locked 1.5-µm Er-based DPSSL, it enabled ten times lower residual phase noise [2].

Although large research efforts target to improve the gain bandwidth of new laser materials, the shortest achievable pulse duration directly from an oscillator is still achieved from Ti:Sapphire lasers. However, Ti:sapphire requires a pump wavelength in the blue-green spectral region, which until recently required the use of complex and expensive pump lasers. Frequency-doubled green DPSSLs are typically used, and an additional modulator is often required for fast control of the pump power in applications like CEP-stabilization. With the advent of gallium nitride diodes, a major breakthrough was achieved in 2009, when Roth et al. demonstrated the first directly diode-pumped Ti:Sapphire laser [3]. However, the so far achieved power levels are too low for many applications, and it remained unclear if there is a limiting issue for the efficiency of ultrafast Ti:Sapphire DPSSLs. In the third part of the presentation, I discuss a green-pumped ultrafast Ti:Sapphire DPSSL generating 200 mW and which has a 4-times higher efficiency than the previous diode-pumped power record. It uses two 520-nm pump diodes with a total pump power of 2 W incident onto the laser crystal and achieves self-starting SESAM-modelocked operation with 68 fs pulses. The cavity is compact due to its high repetition rate of 378 MHz. No complex cooling system is required: neither the SESAM nor the Ti:Sapphire crystal are actively cooled, only the diodes are cooled by a small fan [4]. We expect that cheap, compact, air-cooled Ti:Sapphire lasers will soon be available for numerous applications, and that CEO stabilization can be achieved in a simple way by direct pump diode current modulation.

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[3] P. W. Roth, A. J. Maclean, D. Burns, and A. J. Kemp, "Directly diode-laser-pumped Ti:sapphire laser," Opt. Lett. **34**, 3334-3336 (2009).
[4] Kutan Gürel, Martin Hoffmann, Clara Saraceno, Valentin J. Wittwer, Sargis Hakobyan, Bojan Resan, Andreas Rohrbacher, Kurt Weingarten, Stéphane Schilt, and Thomas Südmeyer, "Ultrafast Ti:Sapphire diode-pumped solid-state laser (DPSSL) generating 200 mW average power in 68 fs pulses", submitted to CLEO 2015