Versatile Yb-Fiber-Amplifier-Based CEP-Stable Front-End for OPCPA

A. Fernandez[1], L. Zhu[1], A.J. Verhoef[1], D. Sidorov-Biryukov[1] C.-H. Liu[2], K.-H. Liao[2], A. Galvanauskas[2], S. Kane[3], A. Pugzlys[1], A. Baltuska[1]

1. Technische Universität Wien, Institut für Photonik, Gusshausstrasse 27-29/387, A-1040 Wien, Austria
2. Center for Ultrafast Optical Science, University of Michigan, Ann Arbor, MI 48109-2099, USA
3. HORIBA Jobin Yvon, Inc., 3880 Park Avenue, Edison, NJ 08820, USA

The rapidly rising technology of optical parametric chirped pulse amplification (OPCPA) [1] offers unique advantages, among others, such as high broadband gain, including frequency ranges inaccessible to direct laser amplification, and efficient energy conversion using narrowband picosecond pump pulses. The perennial problems of OPCPA, significantly slowing down its development into a mainstream amplifier technology, are pump–seed pulse synchronization and generation of a frequency-detuned compressible broadband seed pulse for the optical parametric amplifier (OPA). Demonstrated approaches to the synchronization of pump pulse sources include active locking of two master oscillators [2], nonlinear frequency shifting in a photonics crystal fiber (PCF) [3] and simultaneous seeding of the pump pulse laser and the OPA from an ultrabroadband Ti:sapphire oscillator [4]. IR OP(CP)A systems with passive carrier envelope phase (CEP) stabilization were realized using a broadband difference-frequency-generation (DFG) seed produced via spectral broadening of the output of full-fledged Ti:sapphire [5,6] and Yb [7] CPA systems. In this contribution we demonstrate a drastically simplified seeding/synchronization approach based on an environmentally stable µJ-energy 200-fs 100-kHz Yb-doped fiber amplifier (YDFA) that generates a white light continuum in bulk sapphire, pumps a DFG OPA and provides an optical seed compatible with most Nd and Yb ~1-µm pump pulse amplifiers (Fig. 1).

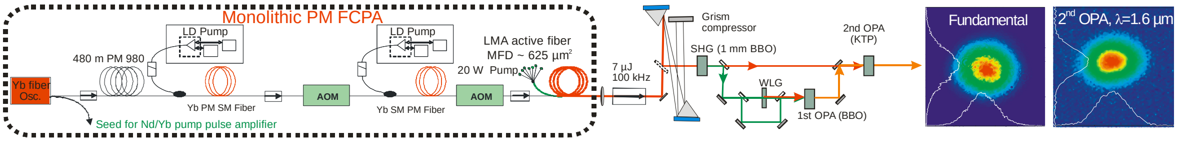

Fig. 1 Experimental layout and far-field modes of the fundamental and CEP-stable outputs.

Generation of temporally compressible white light in bulk media requires high-fidelity ≤200 fs pulses to minimize the impact of delayed (Raman) nonlinearities. Due to a large amount of higher-order linear and nonlinear dispersion, such pulses are difficult to obtain from YDFA, prompting the use of solid-state oscillators [8] or highly nonlinear fibers [9] for OPA seeding. Successful white-light seeding of an YDFA-driven OPA was demonstrated in [10], where the fidelity of the 1040-nm pulse was ensured by the use of free-space stretcher/compressor optics. In a bid for a robust turn-key alignment-free design, our YDFA system consists of a spliced chain of polarization maintaining (PM) fibers and pigtailed acousto-optic pulse pickers. This architecture allows us to completely dispense with free-space signal and pump coupling, although by deliberately avoiding pumping from the output fiber end the output pulse energy is restricted to 7 µJ before the ~50%-throughput grism compressor [11]. Generation of a tunable CEP-stable IR seed pulse follows the recipe in [7], using DFG in a 4-mm-long Type II BBO between a 1.2-µJ 520-nm pulse and the red wing of the white-light continuum pulse generated with a 0.9-µJ 520-nm pulse, and resulting in signal and idler pulse energies of up to 80 and 40 nJ, respectively. The IR pulse is then optionally ×4 amplified in a 2nd OPA (6 mm Type II KTP) using residual 1040-nm fundamental pump light. The tuning properties of the OPA stage are summarized in Fig. 2.

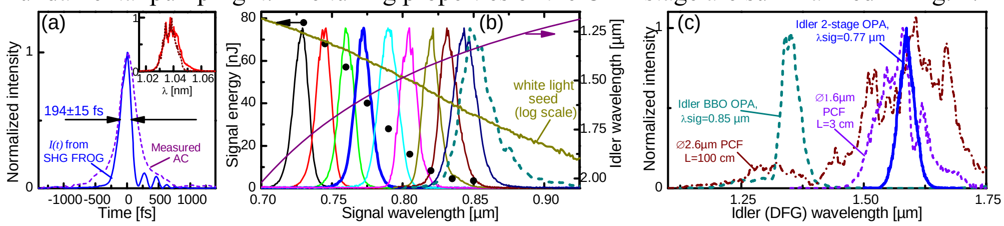

Fig. 2 (a) Fundamental pulse profile retrieved from FROG and amplified spectra before and after the grism compressor. (b) Tunability of 1st stage OPA (4-mm Type BBO seeded with 520-nm-generated white light from a 5-mm-thick sapphire plate. (c) CEP-stable idler spectra at selected wavelengths and results of spectral broadening of 1.6-µm pulse in negative-dispersion PCFs (zero dispersion point 750 nm.)

In conclusion, we present a robust directly-diode-pumped OPCPA front-end that provides straightforward optical synchronization with Nd/Yb pump lasers and emits tens of nJ of CEP-stable and pulse-pedestal-free DFG light, which is sufficient for overriding the superfluorescence background in multi-mJ OPCPA. The presented air-cooled system uses only ~20 W of optical diode power – significantly less than a CW-green-laser-pumped Ti:sapphire oscillator capable of delivering several nJ at 800 nm and merely several pJ in an IR DFG pulse.

References

[1] A.Dubietis, R.Butkus, and A.P. Piskarskas, IEEE J. Sel. Top. Quantum Electron. **12**, 163 (2006).
[2] S. Witte, et al., Opt. Express **14**, 8168 (2006).
[3] C.Y. Teisset, et al., Opt. Express **13**, 6550 (2005).
[4] N.Ishii, et al., IEEE J. Sel. Top. Quantum Electron. **12**, 173 (2006).
[5] C. Vozzi, et al, Opt. Lett. **32**, 2957 (2007).
[6] X. Gu et al., Opt. Express **17**, 62 (2009).
[7] O.D. Mücke, et al., Opt. Lett. **34**, 118 (2009).
[8] J. Rothhardt, S. Hädrich, D.N. Schimpf, J. Limpert, A. Tünnermann, Opt. Express **15**, 16729 (2007).
[9] A. Killi, A. Steinmann, G. Palmer, U. Morgner, H.Bartelt, and J. Kobelke, Opt. Lett. **31**, 125 (2006).
[10] C. Schriever, S. Lochbrunner, P. Krok, and E. Riedle, Opt. Lett. **33**, 192 (2008).
[11] L. Kuznetsova, F.W. Wise, S. Kane and J. Squier, Apl. Phys. B, **88**, 515 (2007).

978-1-4244-4080-1/09/$25.00