Monolithic-YDFA Based CEP-Stable OPA with Broad Tunability

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Abstract We demonstrate an efficient broadband difference-frequency converter emitting carrier-envelope-offset-free seed pulses for chirped-pulse parametric amplification and pumped by a monolithic femtosecond Yb-doped fiber amplifier that simultaneously provides passive optical synchronization for an OPCPA pump pulse source.

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 OPCPA systems with passive carrier envelope phase (CEP) stabilization were realized using a broadband difference-frequency-generation (DFG) seed produced from a spectrally broadened output of full-fledged Ti:sapphire [5, 6] and Yb [7] CPA systems. In this letter 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.

The experimental layout, consisting of the YDFA, grism pulse compressor, and a Type II collinear CEP stable OPA is shown in Fig. 1. The front end of the system is an all polarization maintaining (PM) monolithic fiber chirped pulse amplifier (MFCPA). It consists of a fiber oscillator, two PM single mode fiber (SMF) preamplifiers and a PM large mode area (LMA) fiber amplifier. The oscillator delivers 150 fs pulses at a repetition rate of 76 MHz. Before being amplified to 1.6 nJ at the full repetition rate in the first preamplifier, the pulses are stretched to ~350 ps in 480 m of PM SMF. A second AOM is used after the second preamplifier for suppression of amplified spontaneous emission (ASE). The grism compressor consists of a single 400 grooves/mm grism and a 1000 groove/mm gratings. The CEP stability of the OPA output is shown in Fig. 2. The CEP stability is verified by a widely linear frequency shift resulting in a broadband spectrum with a peak at the frequency doubled wavelength.

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

Fig. 2 Fundamental pulse profile retrieved from FROG and amplified spectra before and after grism compressor.
emission. Both preamplifier stages use highly Yb-doped PM-SMF as active medium. Pre-amplified pulses are launched into the final LMA fiber amplifier via a mode field adaptor. The last amplifier is based on 3 m of Yb-doped LMA double clad fiber (Nufern PASA-YDF-30/250-7x1, 30 µm core, ~625 µm² mode field diameter). It is fully monolithic and is pumped by 7 laser diodes capable of delivering up to 6 W pump power each. After the final stage, >9 µJ pulses are generated at total pump power of ~20 W. Generated pulses are compressed to 200 fs in a negative dispersion compressor based on a pair of grisms designed from F2 glass prisms and 1480 lines/mm reflection gratings. Compressed pulses were characterized with SHG FROG (the results are presented in Fig. 2). Far field beam profile of the MFCPA output is given in the left inset of Fig. 1.

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