31-fs OPCPA front-end at 1.55 µm

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Abstract

We present an OPCPAe front-end at 1.55 µm pumped by an Yb CPA at kHz repetition rates. The front-end delivers 40 µJ and pulse duration of 31 fs.

Attophysics has been driving the development of new high-peak-power, few-cycle sources in the near and middle infrared. Optical parametric amplification (OPA) has been accepted as a key technology able to offer few-cycle sources with high-peak-power and high-average-power infrared sources with repetition rates ranging from a few Hz to hundreds of kHz [1-2]. Recent development of CPA Ytterbium laser delivering picosecond pulses at a repetition rate of 1-100 kHz and average power in the range of ~1 kW [3] (10-100 mJ per pulse) opens the path to OPA sources generating few-cycle pulses in the 1.4-4.0 µm wavelength range up to the mJ energy level.

In this abstract, we present a chirped-pulse OPA (OPCPA) front-end delivering pulses of 40 µJ, 31 fs at 1.55 µm with a repetition rate of 2 kHz. This OPCPA features an all-bulk dispersion scheme with, a heart of the setup, a conjugation of the spectral phase and collinear OPAs based on large aperture MgO-doped periodically-poled Lithium Niobate crystals.

The parametric amplifiers are pumped by a commercial Yb-doped pump laser from Amplitude Systèmes (S-Pulse HP2). This pump laser delivers pulses of 500 fs pulses FWHM at 1028 nm. The energy varies from 2 mJ at 1 kHz (2W) to 40 µJ at 200 kHz (8W). Here we run the pump laser at 2 kHz with an available pump energy of 2 mJ (4W average power). A fraction of the pump energy (4.5 µJ), is sampled to generate a continuum in a 10 mm undoped YAG rod. The continuum spectrum spans up to 2.4 µm (Fig. 1). The wavelengths below 1.1 µm are blocked by a 2 mm AR-coated Silicon (Si) window. This window adds a strong dispersion to the transmitted part of the continuum spectrum and the 1.4-1.8 µm bandwidth is chirped to match the pump pulse duration. About 7 nJ is contained in the 1.4-1.8 µm bandwidth after the Si window.

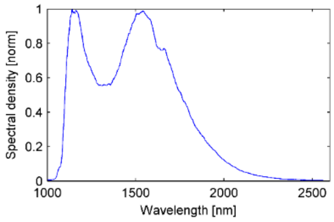
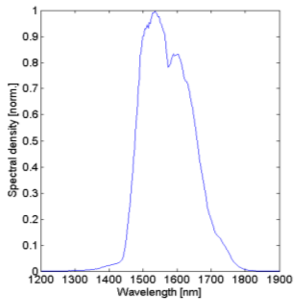


Fig. 1: continuum spectrum after the 2 mm Si window.

This bandwidth is amplified in a first collinear OPA stage consisting in a 1 mm fan-out MgO:PPLN crystal from HC Photonics. This OPA is pumped with 22 µJ and the 1.4-1.8 µm bandwidth is amplified to 3 µJ (gain of ~500, quantum yield of ~20%). The spectral phase of the amplified signal is then conjugated (sign reversal) by a TeO_2 acousto-optic programmable dispersive filter (AOPDF). Because the phase conjugation preserves the pulse duration the pulses can be further amplified in similar OPAs. A second and third collinear OPA stages, both made of a large aperture MgO:PPLN crystal (3 mm x 3 mm x 1mm) amplify the pulse energy up to 40 µJ. The total pump energy for both stages is 500 µJ (quantum yield of 12%). Finally the pulses are compressed in a 2-mm Silicon windows. Because of the symmetric properties of the dispersion scheme (positive dispersion, spectral phase conjugation, and positive dispersion) the pulses are compressed at the output of the Silicon window. The output pulses exhibit a broadband Gaussian-like spectrum supporting pulse duration shorter than 6 optical cycles (29 fs FTL, 31 fs measured by SH-FROG).



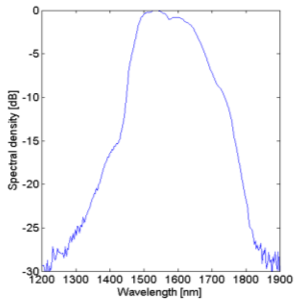


Fig. 2: Amplified spectrum after compression in linear (left) and logarithmic (right) scale.

Future work will be dedicated to add a difference-generation (DFG) stage pumped by the residual pump energy (1 mJ). Thanks to the properties of DFG, idler pulses at 3.2 µm with passive carrier-envelope phase stability, pulse energy of 100 µJ and pulse duration of 30 fs are expected.

References

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