Ponderomotive Energy Scaling with a 0.1-TW Peak Power Mid-IR Few-Cycle Source

G. Andriukaitis, T. Balčiūnas, I. Diomín, A. Pugžlys, A. Baltuška
Photonics Institute, Vienna University of Technology, Gusshausstrasse 27-387, A-1040, Vienna, Austria
E-mail: baltuska@tuwien.ac.at

Abstract: We demonstrate a compact versatile high-field parametric source operating at 1.5 and 3.9 μm and delivering 600-nm-wide >6 mJ compressed mid-IR pulses that are compressed to 75±10 fs (< 6 optical cycles).

Recent discoveries in theoretical and experimental strong field physics have stimulated the quest for intense long-wavelength few-cycle driver sources which promise distinct advantages with respect to traditional Ti:sapphire-based amplified ultrashort pulse systems at 800 nm [1]. The increase of the optical cycle duration plays a crucial role in many areas: the development of secondary sources of radiation, in particular coherent sources of extreme UV and X-ray pulses, laser-driven elementary particle acceleration, femtosecond mass spectroscopy, etc. The key advantages for such applications are the \( \lambda^2 \) scaling of the ponderomotive energy in a strong-field interaction and the ability to suppress multiphoton ionization in favor of the tunneling ionization mechanism. Phase-matched generation of high-flux coherent keV-photon-energy X-ray pulses in atomic gas targets via the mechanism higher-order harmonic generation (HHG) was recently made possible by the use of OPAs operating in the near-IR range of 1.3–2.1 μm [2] and is predicted to be further enhanced when intense longer-wavelength sources become available.

We demonstrate the first multi-mJ mid-IR few-cycle source based on a hybrid of CPA and OPCPA technologies. The achieved ponderomotive energy equals that of a large 1.6-TW-peak-power Ti:sapphire system as the result of the \( \lambda^2 \) scaling. The collinear OPCPA is pumped at the wavelength of 1.064 μm and emits a tunable signal wave around 1.5 μm (about 20 mJ, uncompressed) and an idler wave around 3.9 μm (~9 mJ before the grating compressor, >6 mJ compressed) at the repetition rate of 20 Hz. The wavelength configuration resembles a traditional KTA-based nanosecond OPA used for countermeasures, since both the signal and the idler waves correspond to transparency windows of the atmosphere. Because of the ability to generate femtosecond filaments [3] in air, the developed source holds significant promise for defense and remote sensing applications. The talks will explain the design and performance of the novel parametric system and present the results of several test applications. Ongoing efforts to upgrade the repetition rate to 1 kHz and to implement a carrier-envelope stabilization lock to the superposition of 1.5 and 3.9-μm will also be presented.

Fig.1: Characterization of MIR OPCPA (a) measured and retrieved idler wave spectra; (b) temporal envelope measured with two different FROG techniques; (c) measured and (d) reconstructed 3rd harmonic FROG traces; (e) photograph showing the onset of filamentation with 3.9-μm pulses focused in air with an f=30 cm optic. The resultant white-light continuum stretches into the visible along with prominent perturbative odd-order harmonics.

References: