Generation of high energy self-phase-stabilized near-IR pulses by difference frequency generation and optical parametric amplification

C. Vozzi, C. Manzoni, E. Benedetti, F. Calegari, G. Cirmi, G. Sansone, S. Stagira, O. Svelto, S. De Silvestri, M. Nisoli and G. Cerullo

CNR-INFM – ULTRAS Dipartimento di Fisica, Politecnico, Piazza L. da Vinci 32, 20133 Milano, Italy

Control of the carrier-envelope phase (CEP) of light pulses is one of the most advanced frontiers of ultrafast optics. The generation of optical waveforms with reproducible electric field profile is important in the case of few-optical-cycle pulses for which a CEP variation produces a strong change in the waveform. CEP-dependent phenomena are observable in high-intensity interactions, such as above-threshold ionization [1] and high-order harmonic generation (HHG) [2,3], moreover CEP stabilization is a fundamental prerequisite for the production of isolated attosecond pulses through HHG [4].

In this work we propose a novel scheme for the generation of high energy ultrabroadband near-IR pulses with passive CEP stabilization [5,6], starting from an amplified Ti:sapphire laser system. A phase stable seed is generated by difference frequency generation (DFG) between the frequency components of a hollow-fiber-broadened supercontinuum. This configuration intrinsically provides a high CEP stability due to the absence of mechanical delays between the frequency components undergoing the DFG process. The seed is then boosted in energy through a multistage near-IR optical parametric amplifier (OPA), exploiting the broad gain bandwidths available around degeneracy. We generated ~300-μJ phase-stable pulses at 1.6 μm and, after compensation of the negative dispersion by propagation through bulk media, we have obtained nearly transform-limited sub-25 fs pulse duration, which corresponds to less than 4 optical cycles at the considered carrier frequency. To verify that CEP-stabilization is preserved after the OPA stages and that amplified parametric superfluorescence is negligible, we used an f-to-2f interferometer. The appearance of a stable, high-contrast fringe pattern upon averaging is a clear proof of the shot-to-shot stability of the CEP due to the self-phase-stabilization mechanism.

Once compressed, these pulses could be ideal drivers for HHG experiments; indeed taking into account that the ponderomotive energy of the recolliding electron scales as the square of the laser carrier wavelength, the use of near-IR pulses will enable the generation of higher order harmonics. Even more interesting is the possibility of using this system as a front-end for high energy OPA pumped by a 100-mJ, 10 Hz Ti:sapphire laser system, enabling multi-mJ-level self-phase-stabilized pulses.

References

1. G. G. Paulus *et al.*, Nature **414**, 182 (2001).
2. A. Baltuska *et al.*, Nature **421**, 611 (2003).
3. M. Nisoli *et al.*, Phys. Rev. Lett. **91**, 213905 (2003).
4. R. Kienberger *et al.*, Nature 427, 817 (2004).
5. A. Baltuska *et al.*, Phys. Rev. Lett. 88, 133901 (2002).
6. C. Manzoni *et al.*, Opt. Lett. 31, 963 (2006).

Corresponding author: Caterina Vozzi, e-mail: caterina.vozzi@polimi.it; phone: +39 0223996085