Direct sampling of electric-field waveforms emitted by an optical parametric oscillator

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Electro-optic sampling (EOS) with ultrashort laser pulses provides direct access to the waveforms of phase-locked electric field transients and was originally introduced for the THz frequency range [1]. So far, these waveforms were generated by single-pass optical rectification of femtosecond near-infrared (NIR) pulses. Here, we exploit EOS to characterize the output generated by a resonant system – an optical parametric oscillator (OPO) operating in the subharmonic (frequency-divide-by-2) regime.

Our setup (Fig. 1) starts from a passively phase-stable (carrier-envelope offset (CEO) frequency $f_{ceo} = 0$) Er:fiber laser system (DFG-comb, blue panel in Fig. 1(a)) centered at 193 THz (wavelength of 1.55 µm) [2]. Part of its output is used to synthesize a few-femtosecond NIR probe (green) adequate for sampling mid-infrared frequencies. In the second output, pulses centered at 155 THz (wavelength of 1.935 µm, orange in Fig. 1(a)) are generated as pump for the OPO.

In the OPO (purple panel in Fig. 1(b)), the subharmonic of the pump is generated in an orientation-patterned (OP) GaAs crystal. We highlight that the emitted frequency comb of the OPO is phase-locked to the pump source in the degenerate regime [3]. In particular, the CEO frequency of the subharmonic can be chosen to be half that of the pump, corresponding to $f_{ceo} = 0$ and thus enabling direct detection by EOS.

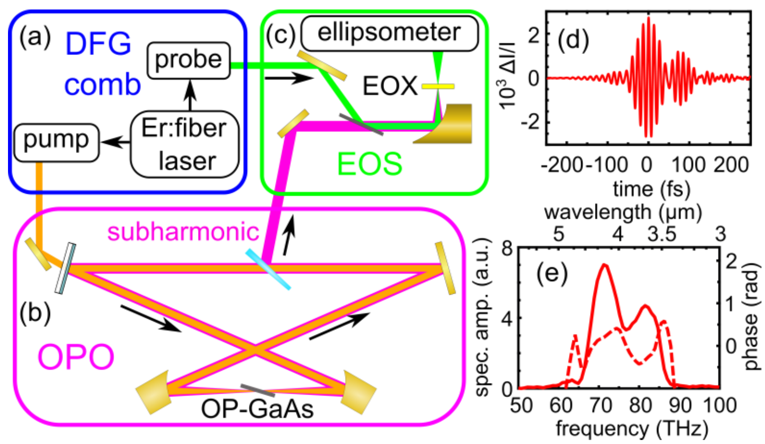

Fig. 1: *Scheme of the setup (a) – (c) and experimental results (d), (e). (a) Passively phase-stable frequency comb, (b) mid-infrared optical parametric oscillator (OPO), (c) electro-optic sampling (EOS), (d) electro-optic signal, (e) Fourier transform of (d)*

To this end, the NIR probe and OPO output beams are focused into the electro-optic crystal (EOX, green panel in Fig. 1(c)). The field of the subharmonic OPO induces a polarization change on the probe that is evaluated with an ellipsometer. The resulting electro-optic signal indicates a full-width-at half maximum (FWHM) of the intensity of 43 fs limited by third-order dispersion only (Fig. 1(d)). The spectral amplitude (solid line) and phase (dashed line) obtained via Fourier transform are depicted in Fig. 1(e) with a center frequency of 77 THz and a FWHM bandwidth of 17 THz.

In summary, exploiting a passively phase-stable Er:fiber comb as an OPO pump, we generate a phase-locked subharmonic output with $f_{ceo} = 0$ that supports field-resolved detection with electro-optic sampling. Compared to conventional optical rectification, this approach provides an increase of electric field amplitudes by an order of magnitude. Our next goal is to exploit this setup for generation of nonclassical states of mid-infrared radiation as a key resource for time-domain quantum electrodynamics.

References:

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