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Complete waveform characterization of mid-infrared ultrashort pulses

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Development of ultrafast mid-infrared (MIR) pulse lasers has been in rapid progress over the past decade. Since a number of molecular vibrations have resonance in the MIR region, the ultrafast MIR pulse lasers are very useful for advanced molecular spectroscopies, such as frequency comb spectroscopy for the molecular fingerprint region, pump-probe spectroscopy to trace ultrafast structural dynamics, and control of photodissociation by selective excitation of vibrational states. The development of such a light source is also attracting more attention in the high field laser physics. The cutoff extension of high harmonic generation (HHG) driven by a long wavelength few-cycle pulse has been carried out, and generation of shorter attosecond pulses is predicted. Since it is a process within the single optical cycle of the driver electric field, it is very important to have a few-, single-, or sub-cycle pulse with a precisely controlled field oscillation, namely the phase control of the laser field within at least a few tenth of the oscillation period. In such an experiment, field-revolved detection of the ultrashort MIR pulses is essential since the cutoff of high harmonic generation is sensitive to the field strength of the driver laser pulse.

Recently, we have proposed a new scheme of waveform characterization, frequency-resolved optical gating capable of carrier-envelope phase determination (FROG-CEP) [1], which is based on a combination of frequency-resolved optical gating (FROG) [2] and electro-optic sampling (EOS) [3]. In this invited talk, we plan to introduce our studies of waveform characterization using the FROG-CEP. It has been demonstrated that a waveform of a sub-cycle ($\sim$7 fs) MIR pulse [4] is measured with a reference pulse which has longer duration than the period of the target wave [1, 5]. HHG in Si membrane driven by the well-characterized sub-cycle MIR pulses has been realized. The waveform (carrier-envelope phase) dependence of the high harmonic spectra has been clearly observed and well-reproduced by the numerical simulations based on the optical Bloch equations with the experimentally measured sub-cycle waveforms. We have also succeeded in characterizing the waveform of a few-cycle ($\sim$20 fs) MIR pulse without any reference pulses by using the FROG-CEP method [6].

References

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