A robust all-non-optical method for the complete characterization of single-shot few-cycle laser pulses

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Synopsis We analyse the "left" and "right" asymmetry of high-energy photoelectrons along the polarization axis generated by few-cycle infrared laser pulses from atomic targets. Based on the recently developed quantitative rescattering theory, we show that the carrier-envelope phase, the pulse duration and the peak intensity of each single-shot laser pulse can be accurately and efficiently retrieved, thus providing a robust all-non-optical method for the complete characterization of single-shot few-cycle laser pulses.

Observation of the interaction of laser pulses with matter requires the knowledge and control of the waveform of the laser field. The waveform is characterized by its pulse envelope, including the peak intensity and pulse duration, as well as the carrier-envelope phase (CEP) which measures the offset between the peak of the electric field and the peak of the envelope. Specifically, such a CEP-fixed waveform can be written as $E(t) = E_0(t)\cos(\omega t + \phi)$, where ω is the frequency of the carrier wave, ϕ is the CEP .

Recently, Wittmann *et al.* [1] reported that the left/right photoelectrons from individual laser shots can be measured. We propose a robust theoretical method to determine the CEP from each single shot data, the peak laser intensity at the laser focus and the pulse duration, thus providing a complete non-optical method for the full characterization of each few-cycle laser shot in the interaction region.

The present method of characterizing single-shot laser pulses is based on the recently developed quantitative rescattering (QRS) theory [2] for describing the momentum distributions of high-energy above-threshold-ionization (HATI) photoelectrons generated by infrared lasers from atoms . According to the QRS, the momentum distributions $D(p,\theta)$ of HATI electrons can be expressed as the product of a returning electron wave packet $W(p_r)$ with the elastic differential cross section (DCS), $\sigma(p_r,\theta_r)$, between the field-free electrons with the target ion, i.e., $D(p,\theta) = W(p_r)\sigma(p_r,\theta_r)$. The wave packets $W(p_r)$ are obtained from SFA2 [2] calculations and the DCS's are evaluated in partial wave expansions.

The peak intensity and the pulse duration can be determined by a single quantity called energy moment; The CEP of each single shot can be retrieved from the asymmetry of the left/right HATI electron yields, which is shown in Fig. 1.

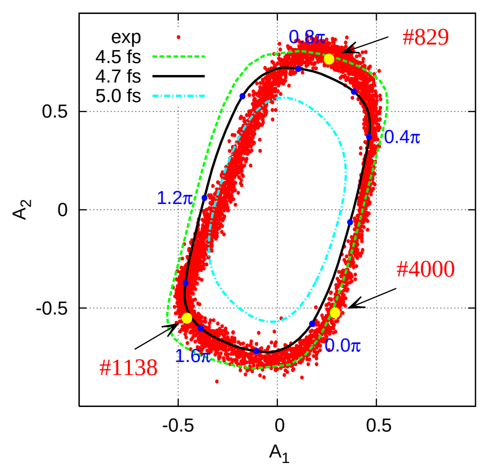

Fig. 1. Retrieval of CEP for each single shot: comparison of ellipse from experiment with theory.

References

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