Electron Wavepacket Interferences pointing to Holographic Imaging with Few Cycle Laser Pulses

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Synopsis: Three-dimensional (3D) electron (and ion) momentum (**P**) spectra have been recorded for carrier-envelope-phase (CEP) stabilized few-cycle (~5 fs), intense (~0.4 PW/cm^2) laser pulses (740 nm) impinging on He using a reaction microscope. Preferential emission of low-energy electrons (E_e < 15 eV) to either hemisphere is observed as a function of the CEP. Clear interference patterns emerge in **P**-space at CEPs with maximum asymmetry, interpreted as holographic images of re-scattered electron wavepackets by means of a simple model and in line with previous theoretical predictions.

Interferometry with coherent electron wavepackets (EWPs), modulated through ultrafast processes (10^{-18}-10^{-15} s) in atoms and molecules, opens new possibilities to enhance our understanding of these dynamics. In recent experiments EWPs generated by attosecond pulse trains and steered by an infrared laser pulse have been demonstrated to image the coherent scattering of electrons from the parent ion [1]. In this contribution we present an alternative scheme for EWP interferences, manifested in the photoelectron spectra of single ionization in atoms with Carrier Envelope Phase (CEP)-stabilized few-cycle (~5 fs) laser pulses, investigated by a 'reaction microscope' [2].

In the experiment, linearly-polarized CEP stabilized 5 fs pulses at 740 nm (repetition rate: 3 kHz) were obtained at the attosecond beamline at Max-Planck-Institut für Quantenoptik, Garching. The laser beam, with intensities up to 0.4 PW/cm^2 at the focus was crossed with a supersonic, cold He jet (~10^{11} atoms/cm^2) in the ultra-high vacuum chamber (~10^{-10} mbar) of the reaction microscope.

2D electron momentum spectra (Fig. 1) at certain fixed CEP reveal in addition to enhanced emission into one **P**-hemisphere, regular interference stripes, parallel to the transverse momentum axis in the corresponding hemisphere and radial structures in the opposite hemisphere, in good qualitative agreement with theoretical predictions [3] and TDSE calculations. The spacing between the peaks, significantly smaller than the multi-photon peak structure previously observed for longer pulses, agrees with those calculated in a simple Strong Field Approximation (SFA)-based model. This model, invoking the interference of two

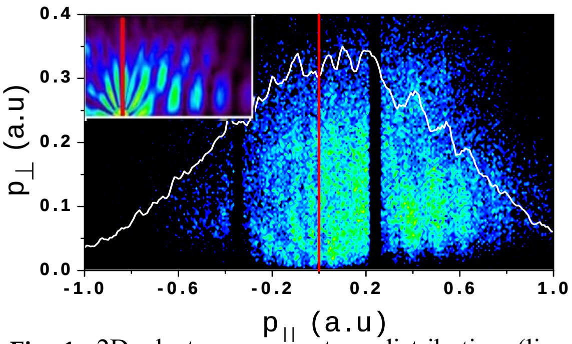

Fig. 1: 2D electron momentum distribution (linear scale) for a CEP with maximum asymmetry. The x-axis is the longitudinal momentum; the y-axis is the momentum transverse to the laser polarization axis. The red line indicates the position of $p_{\|}$ = 0. The projection onto the $p_{\|}$ -axis is indicated as a white line. Inset: TDSE calculations for a gaussian pulse (740 nm) with I_0 = 0.3 PW/cm^2, FWHM ~ 2.7 fs.

quantum paths leading to the same final drift momentum, captures the basic mechanism of holographic imaging via the superposition of a re-scattered, modulated EWP on an unaffected, directly launched 'reference' EWP (of the same electron!)[3].

We believe that holographic imaging through EWPs has the potential to obtain unprecedented information on ultra-fast correlated electron dynamics, for example, the details of the (time dependent) scattering potential in atoms and molecules

References

[1] Mauritsson J *et al.* 2008 *Phys. Rev. Lett.* **100** 073003.
[2] Ullrich J *et al.* 2003 *Rep. Prog. Phys.* **66** 1463.
[3] Arbó D *et al.* 2006 *Phys. Rev. A.* **74** 063407.

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