Confining the double ionization dynamics of argon to half of a laser cycle

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Synopsis: The sub-cycle dynamics in non-sequential double ionization of argon are studied by combining a reaction microscope with a single-shot carrier-envelope phase measurement technique.

Non-sequential double ionization (NSDI) of atoms in strong laser fields has become a paradigm for the study of correlated electron dynamics. Although NSDI has been the subject of numerous experimental and theoretical studies, the mechanisms governing it are not yet fully understood. Two scenarios have been proposed to describe the NSDI process: (i) the (e,2e)-mechanism, in which the re-colliding electron directly promotes a second electron into a continuum state via electron impact ionization [1] and (ii) the re-collision induced excitation with subsequent ionization (RESI) [2], where the re-colliding electron excites the parent ion, which is later ionized by the laser field. Taking advantage of recent advances in the generation of ultra-short light pulses [3], we investigate the dynamics of NSDI in argon atoms exposed to near single cycle laser pulses.

Combining a reaction microscope (REMI) with the recently developed single-shot carrier-envelope phase (CEP) measurement technique [4], allows us to confine the dynamics of NSDI to less than a laser cycle. Pulses with a central wavelength of 750 nm and 4 fs duration are generated at a repetition rate of 3 kHz in an amplified few-cycle laser system and focused into a cold atomic jet in the center of the REMI. The REMI consists of two time-of-flight spectrometers for electrons and ions combined with position sensitive detectors, enabling measurement of the particles' three-dimensional momentum vectors. The peak intensity used in the present experiment is on the order of 10^{14} W/cm^2. A small fraction of the beam is focused into a Stereo-ATI phase meter providing a measurement of the relative carrier envelope phase for every single laser shot [4].

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Our approach [5] facilitates measuring CEP dependencies over the long acquisition times needed for low rate experiments. We observe a pronounced CEP-dependent asymmetry in the longitudinal recoil momentum spectra of the Ar^{2+} ions. Experimental results are analyzed and discussed in terms of a semi-classical model.

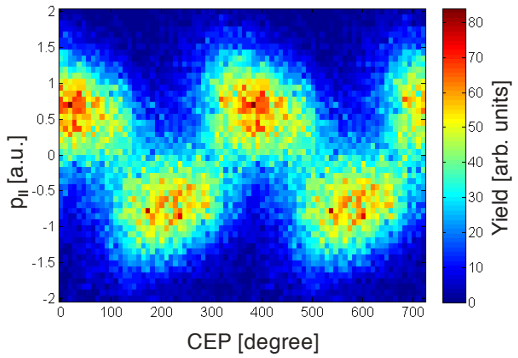

Figure 1. Experimental results showing the dependence of the Ar^{2+} longitudinal recoil momentum spectra (along the laser polarization axis) on the relative CEP.

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