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Laser-induced electron diffraction with carrier-envelope phase-stabilized few-cycle pulses for extraction of elastic scattering cross sections

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The investigation of atomic and molecular structure is conventionally carried out with X-ray or electron diffraction spectroscopy, employing an external source for the projectiles probing the target. In recent years, an alternative method has been developed, building on the rescattering of tunnel-ionized electrons in a strong optical field. We carry out this kind of laser-induced electron diffraction with extremely short optical pulses, which enables us to employ the carrier-envelope phase (CEP) as a control parameter to spectrally resolve the rescattering process. This novel method allows to extract scattering properties of electron-ion collisions, which is demonstrated for the elastic scattering cross section of xenon.

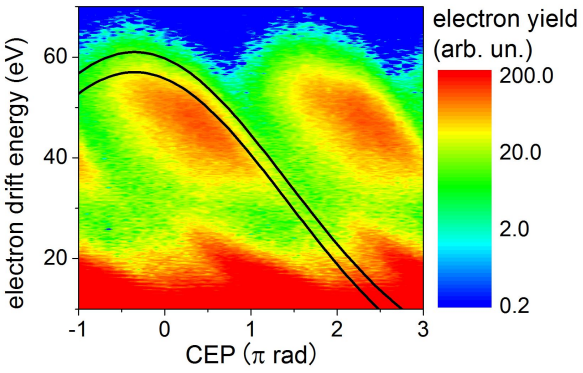

Fig.1: Electron spectra from ionization of xenon as a function of the CEP. The half-cycle cutoff region is indicated with black lines.

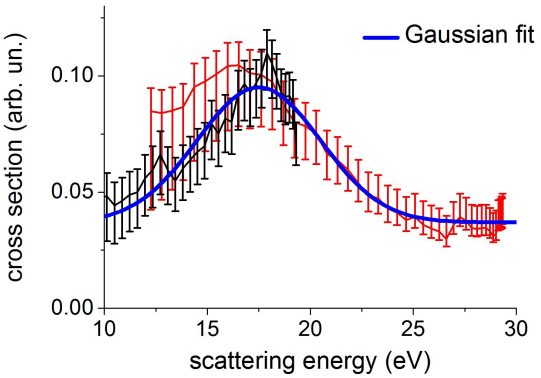

Fig.2: Extracted cross section for electron-ion scattering of xenon.

Our passively CEP-stabilized optical parametric chirped-pulse amplification system delivers sub-2-cycle pulses at 1.6 μm, enabling phase-resolved measurements, as exemplary shown in Fig. 1. The presented energy spectra of rescattered electrons from ionization of xenon exhibit a pronounced structure in the energy range between 30 and 60 eV, when plotted as a function of the CEP. This can be attributed to a resonance-like feature in the elastic backscattering cross section of the electron-ion collision. For the electrons with the highest energy originating from a single half-cycle of the optical pulse (half-cycle cutoff), a one-to-one correspondence between the scattering energy and the final energy can be established, and thus the scattering cross section can be extracted. The reconstruction of the responsible resonance is presented in Fig. 2.