Ionization of atoms by few-cycle laser pulses: spatial and temporal interference effects

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Synopsis The intra-pulse interference effects appearing during the ionization of atoms by few-cycle laser pulses is studied. These are the result of coherent superposition of electronic wave packets, which follow different spatio-temporal paths. With the help of a wave function analysis tool, the spatial and temporal interference patterns are disentangled and studied separately.

The momentum distribution of continuum electrons created during the ionization of atoms by few-cycle laser pulses is modulated by interference effects, which are the results of superposition between electronic wave packets following different spatial and temporal paths [1]. The spatial interference, is one from the numerous possible interference scenarios [1], and occurs when wave packets emitted at the same time (i.e., during the same quarter-pulse cycle), but following different spatial paths are coherently added in the continuum (spatial interference). The formed radial interference pattern (see Fig. 1) is the result of the interference between the direct (i.e., unscattered) and the scattered wave packets [2, 3]. By considering the direct wave packet as reference, while the scattered wave packet as a signal wave, the spatial interference pattern can be interpreted as the holographic mapping (HM) of the target atom's state [2].

In our previous theoretical studies [3, 4, 5] we have used specially tailored two-cycle laser pulses, where the large portion of ionization occurred during a single half-cycle. As a result of this, in the ionization spectrum, the dominant interference pattern was the HM, which allowed us the systematic study of it's properties. The high photon energy and high pulse intensity (see the example in Fig. 1) used in our theoretical studies is not feasible in experiments, thus in the present work we have modified our laser pulse parameters (lowering the photon energy and field intensity, adding more optical cycles) in order to converge towards experimentally available laser pulses.

As a result of these modifications the interference pattern became more complicated, composed by the superposition of both spatial (HM) and temporal interference patterns. In order to perform a systematic study on these interference patterns, we have developed a wave function analysis tool, which allows the disentanglement of the different interference patterns based on the numerical solution of the time-dependent Schrödinger equation (TDSE).

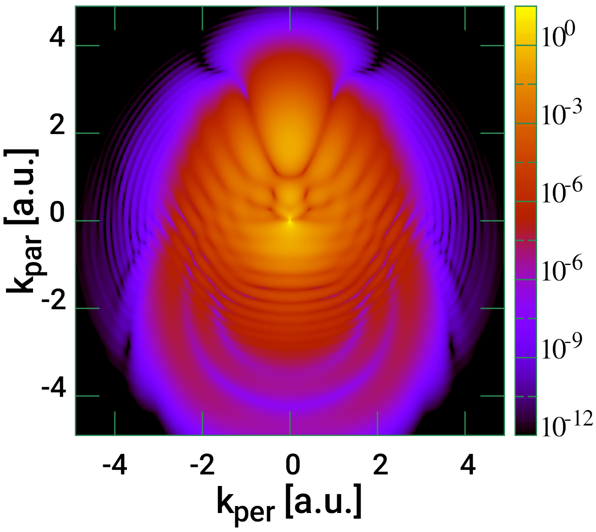

Figure 1. The distribution of the continuum electrons as a function momentum components parallel and perpendicular to the laser polarization vector obtained for H target. The parameters of the driving laser pulse are: $\omega = 0.4445$ a.u. (photon energy), $\tau = 28.27$ a.u. (pulse duration), $E_0 = 1$ a.u.(pulse strength).

During the numerical solution of the TDSE, we have separated and stored in partial wave functions the electronic continuum wave packets created during each half-cycle of the laser pulse. By calculating the ionization spectrum separately for each partial wave function we have obtained the pure HM pattern created by each half-cycle of the driving laser field. The final electron spectrum is obtained by adding coherently the partial ionization amplitudes. During this coherent summing the temporal interference effects emerge.

References

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