Attosecond Interference Induced by Coulomb-Field-Driven Transverse Backward-Scattering Electron Wave-Packets

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Synopsis A novel and universal interference structure is found in the photoelectron momentum distribution of atoms in intense infrared laser field. Theoretical analysis shows that this structure can be attributed to a new form of Coulomb-field-driven backward-scattering of photoelectrons in the direction perpendicular to the laser field, in contrast to the conventional rescattering along the laser polarization direction. This transverse backward-scattering process is closely related to a family of photoelectrons initially ionized within a time interval of less than 200 attosecond around the crest of the laser electric field. Those electrons, acquiring near-zero return energy in the laser field, will be pulled back solely by the ionic Coulomb field and backscattered in the transverse direction. Moreover, this rescattering process mainly occurs at the first or the second return times, giving rise to different phases of the photoelectrons. The interference between these photoelectrons leads to unique curved interference fringes which are observable for most current intense field experiments, opening a new way to record the electron dynamics in atoms and molecules on a time scale much shorter than an optical cycle.

In the ionization process of atoms in intense laser field, the electron wave packet (EWP) may follow different paths from its bound state to the continuum in the combined laser and Coulomb fields. The interference between the EWPs might create richly structured patterns in the final photoelectron distribution, which inherently encode the temporal and spatial information of the ions and electrons.

In this work, we show that the ionic Coulomb potential can leave a significant imprint on the interference structure in the photoelectron momentum spectrum of atoms, which is demonstrated experimentally by a novel and universal curved interference pattern in the PMD. Using a recently developed generalized quantum-trajectory Monte Carlo (GQTMC) method, we clarify that this new structure can be attributed to a Coulomb-field-driven transverse backward-scattering process. In contrast to conventional rescattering which happens in the laser polarization direction, when electrons emitted around the peaks of the laser electric field come back to the core with near-zero drift energy in the laser polarization direction, they will be pulled back solely by the Coulomb potential and backward scattered upon the core in the direction of perpendicular to laser polarization axis. The interference among the Coulomb-field-driven transverse backward-scattering electrons, initially emitted near the crest of the oscillating electric field, can induce a distinct interference structure, which can be well distinguished from other interference structures, e.g., the well-documented holographic interference structure.

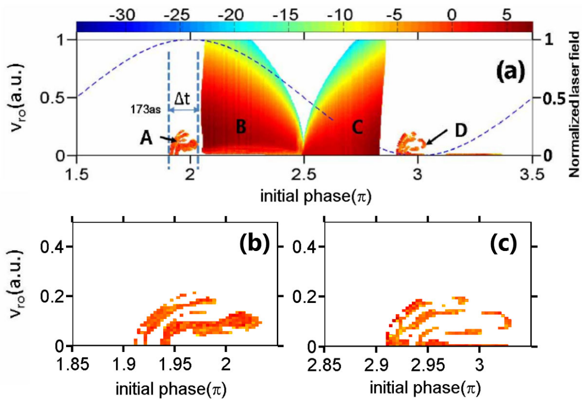

Figure 1. (Color online) (a) Distributions of the initial transverse velocities and the initial ionization phases for $0.3a.u. \leq \mathbf{p}_z$ in Fig. 1(c). The color code denotes the weights of the electrons in area A-D. A zoom in of A and D in (a) is shown in (b) and (c), respectively.

References

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