Non-perturbative semiclassical model for strong-field ionization

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Synopsis We present a non-perturbative semiclassical model for strong-field ionization that accounts for path interferences of tunnel-ionized electrons in the ionic potential within the framework of a classical trajectory Monte-Carlo representation of the phase-space dynamics.

Above-threshold ionization, high harmonic generation, and non-sequential double ionization are the most well-known examples of strong-field physics concerning with highly nonlinear phenomena originating from the interaction of strong laser radiation with atoms and molecules. In their original formulation, semiclassical models do not take into account the effect of the Coulomb potential of the parent ion on the electron motion after ionization. In turn, the Coulomb-corrected strong field approximation (CCSFA) and the quantum trajectory Monte Carlo method (QTMC) invoke first-order perturbation theory to include the Coulomb potential.

We formulate a semiclassical two-step (SCTS) model based on the theory of semiclassical time-dependent propagators [1] that accounts for the Coulomb potential beyond the perturbation theory. We derive a semiclassical expression for the transition amplitude for strong-field ionization that differs from the QTMC [2] and CCSFA [3] models improving the agreement with quantum simulations.

The figure 1 shows the photoelectron momentum distribution for H atom. Our SCTS result qualitatively resembles the results of the direct numerical solution of the time dependent Schrödinger equation (TDSE). However, we found that the low-energy spectrum shows marked deviations in the bouquet-shaped interference structure, where the number of radial nodal lines is controlled by the dominant partial-wave angular momentum [4]. Whereas the SCTS model closely matches the nodal pattern of the TDSE, the QTMC model yields fewer nodal lines, which is a direct consequence of the underestimate of the Coulomb interactions in the QTMC treatment of the interference phase.

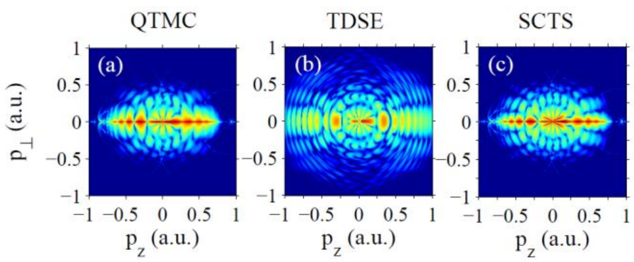

Figure 1. Vectorial momentum distributions for the H atom ionized by a laser pulse with a duration of $n = 8$ cycles, wavelength of $\lambda = 800$ nm, and peak intensity of $I = 9 \times 10^{13}$ W/cm^2 obtained from (a) the QTMC model, (b) solution of the TDSE, and (c) the present SCTS model. The laser field is linearly polarized along the z-axis.

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