Strong field dynamics with ultrashort electron wave packet replicas

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Synopsis We investigate theoretically electron dynamics under a VUV attosecond pulse train which has a controlled phase delay with respect to an additional strong infrared laser field. We analyze the dynamics in terms of electron wave packet replicas created by the attosecond pulses. The absorption probability shows strong modulations as a function of the phase delay for VUV photons of energy comparable to the binding energy of the electron, while for higher photon energies the absorption probability does not depend on the delay, in line with the experimental observations for helium and argon, respectively.

Technological advance has made it possible to expose atoms and molecules to a combination of attosecond pulse trains (APT) and infrared (IR) laser pulses with an accurate control of their phase delay [1]. The photo electron spectrum of atoms, as well as above threshold ionization or photoassociation have been studied in this combined light field [2].

A dynamically very interesting regime emerges when the energy of the VUV photon from the APT is comparable to the ionization potential but the IR pulse alone (typically 780 nm wavelength) is not intense enough to ionize the atom. The combined action of both fields leads to a time-dependent wave packet dynamics which is very sensitive to the phase delay, equivalent to the carrier-envelope phase (CEP) of the IR field. It has been recently shown that the phase delay modulates the total ionization and absorption probability [3]. A solution of the one-electron time-dependent Schrödinger equation (TDSE) yields excellent agreement with this experiment [3], but the exact reason and systematics of these oscillations are difficult to identify in a fully numerical solution.

Here, we formulate a minimal analytical approach [4]. It elucidates the mechanism behind the pronounced structures in the electron observables as a function of phase delay in the spirit of the "simple man's approach" [5].

Using the strong field approximation, we arrive at a minimal analytical model for the kinetic energy distribution of the electron and photoabsorption probability, as a function of the phase delay between the fields. We analyze the dynamics in terms of EWP replicas created by the attosecond pulses.

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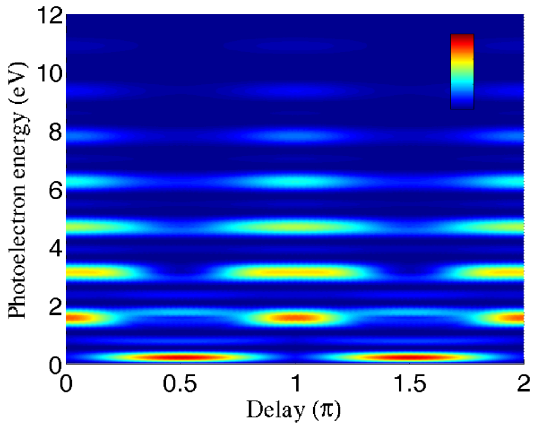

Fig. 1. Photoelectron energy spectrum for $I = 1.3 \times 10^{13}$ W/cm^2, 6 IR cycles and 2 atto pulses per cycle [4].

The absorption probability is the product of two terms: a *comb* function which filters particular values of the momentum and depends on the number of pulses in the APT, and a wave packet that suffers streaking in the IR field. It shows strong modulations as a function of the phase delay for VUV photons of energy comparable to the binding energy of the electron, while for higher photon energies it does not depend on the delay, in line with the experimental observations for helium and argon, respectively [3].

References

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