Theoretical study of multi-photon double electron excitation of He by intense ultrashort EUV pulses

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Synopsis We use the time-dependent hypersperhical close-coupling method to study the double excitation of helium atoms by intense ultrashort XUV pulses. In addition to showing the photoelectron yield spectra, we demonstrate that free electron lasers can be used to efficiently create doubly excited electron wave packets, opening up the possibility of visualizing the correlated motion of electrons in atoms.

Recent advent of ultra-short intense free electron lasers (FEL) with durations of the order of femto- or atto-seconds provides new opportunities in studying ultra-fast nonlinear optical processes [1]. Here we present a theoretical study on the non-linear excitation of the strongly correlated electrons in a helium atom by ultra-short intense extreme ultraviolet (EUV) pulses. We accurately solve the time-dependent Schrödinger equation for the two-electron atom under a laser field, while the electron correlations are fully taken into account by using the hyperspherical wave functions.

We focus on the photon energies in resonant with the transition from the ground state to the singly excited 1snp $^1P^o$ states. Three-photon absorption from the ground state can thus be greatly enhanced by the intermediate bound states, leading to efficient excitation to the doubly excited states of He(3lnl′ $^1P^o$, $^1F^o$) (cf. Fig. 1) and the creation of doubly-excited electron wave packets. The resonance features in the photoelectron spectra such as the relative yields of excitation to different doubly excited states and the resonance profiles are found to be strongly dependent on the laser intensity. Convoluted spectra will also be presented to simulate real experimental conditions, such as frequency jittering and detection resolution. We also analyze the time evolution of a coherent doubly-excited electron wave packet created by an intense femtosecond EUV pulse [2] (cf. Fig 2). Our results imply that currently available FEL could be implemented for ultrafast coherent control of transient correlated electrons, opening up the possibility of visualizing the correlated motion of electrons in atoms.

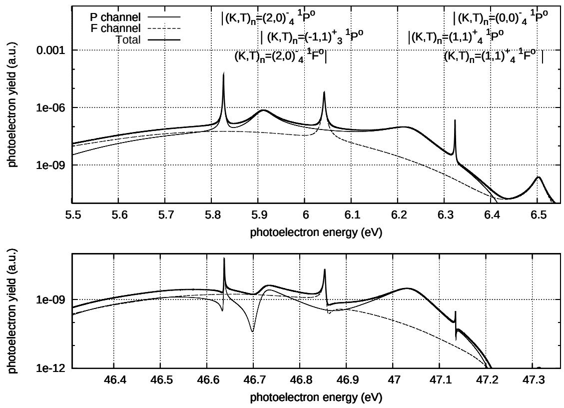

Figure 1. Total and partial photoelectron yield spectra for a XUV pulse with a photon energy of 23.74 eV, FWFM=12 fs and an intensity of 3.5×10^{12} W/cm^2 in different energy regions corresponding to different He+ ion states: (a) He$^+$(2s,2p), (b) He$^+$(1s).

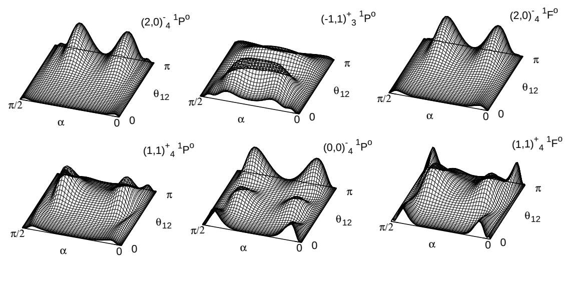

Figure 1. Probability densities of the channel functions for all doubly excited states in the energy range.

References

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