

Unitary model for the ionization of atoms of hydrogen by an intense laser pulse

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Synopsis A unitary model describing the electronic transitions in an atom subject to a laser pulse is proposed. The model include the initial state coupled with both the discrete and the continuum spectrum. Continuum-continuum transitions are neglected. The model lead to a single integro-differential equation for the initial state amplitude which is solved numerically. We compare our results with TDSE simulations for hydrogen atoms.

In recent years a variational method for describing laser-atom interactions has been proposed. The so called modified Coulomb-Volkov (MCV2⁻) theoretical approximation is based on this two front approach to provide the ionization amplitudes for atomic multiphoton ionization [1]. For the final state, the Coulomb-Volkov wave function is used. This wave function accounts for continuum-continuum coupling. For the initial state, previous options were either the simple unperturbed wave function or some expansions in terms of intermediate transient states [1]. For non-perturbative situations, the initial state decay should be considered. In this work we introduced a model accounting for full initial state coupling to the continuum while neglecting further continuum-continuum transitions. The model also consider transitions between initial state and other discrete states. Other discrete-discrete or discrete-continuum transitions are neglected. The present model leads to a single integro-differential equation for the initial state amplitude. This equation is easily solved (see [2]). We have analytically demonstrated that the sum of all transition probabilities is unity, *i.e.*, the model is unitary. As a test for the model goodness we show in Figure 1 transition probabilities of Hydrogen under a 20 cycles XUV laser pulse ($\omega=1$ a.u.). Two laser intensities are examined, $E_0=0.2$ a.u. (1.4×10^{14} W/cm²) and $E_0=0.4$ a.u. (5.6×10^{14} W/cm²). The model results for surviving probability as function of time is compared with full time dependent Schrödinger equation simulation performed with the Qprop code [3]. The comparison is rather good and it is meaningful for times t_i when the vector potential $\vec{A}(t_i)$ is null. For the larger intensity we observe a slight departure between both results.

We have been able to obtain a time-dependent ionization probability estimation from the mean energy provided by the Qprop code [3]. This ionization probability is also in good agreement with our model results, specially for the lower intensity here analyzed. In the same figure the sum of transition probabilities to the excited states is displayed. These probabilities while small are important to fulfill the unitary property.

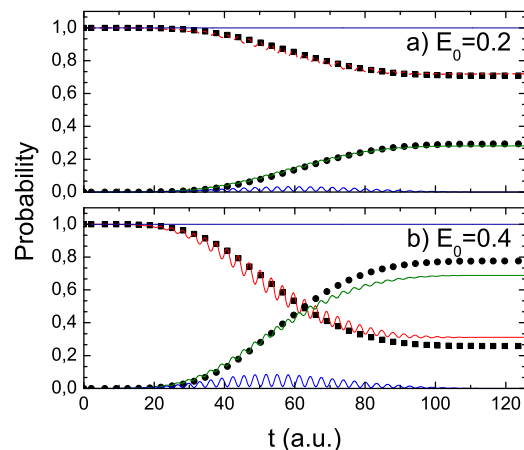


Fig. 1. Transition probabilities as a function of time. Symbols, Qprop: squares, survival probability; circles, ionization probability. Curves, model results. Lower curves, total excitation probability to bound states.

References

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