Unitary model for atomic ionization by an intense laser pulse

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Synopsis　A unitary model describing the electronic transitions in an atom interacting with a laser pulse is proposed. The model includes the initial state coupling with the continuum spectrum. Continuum-continuum transitions are neglected although transitions from the initial state to other discrete states within the first Born approximation are considered. The model leads to a single integro-differential equation for the initial state amplitude which is numerically solved. The results are compared 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 approach to provide the 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 have been 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 a model accounting for initial state full coupling to the continuum while neglecting further continuum-continuum transitions is introduced. This model also considers transitions from initial state to other discrete states, within the first Born approximation. 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 using the Goldfine prescription [2]. It is analytically demonstrated that the sum of all transition probabilities is unity, *i.e.*, the model is unitary. As a test for the model goodness transition probabilities of Hydrogen under a 20 cycles XUV laser pulse (ω=1 a.u.) are shown in Figure 1 . Two laser intensities are examined, E$_0$=0.2 a.u. $(1.4\times10^{14}$ W/cm$^2)$ and E$_0$=0.4 a.u. $(5.6\times10^{14}$ W/cm$^2)$. The model results for the surviving probability as function of time is compared with full time dependent Schrdinger equation (TDSE) simulation performed using the Qprop code [3]. The comparison is fairly good at the times t$_i$, when the vector potential $\overrightarrow{A}$(t$_i$) is null. For the larger intensity, a slight discrepancy is observed. A time-dependent ionization probability estimation from

the mean energy provided by the Qprop code [3] has been able to be obtained. This ionization probability is also in good agreement with the 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 in spite of being small are important to fulfill the unitary property.
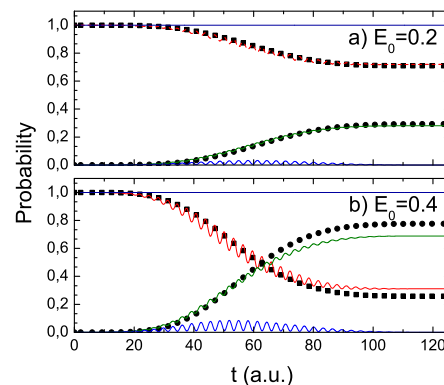
Fig. 1. Transition probabilities as a function of time. Symbols, Qprop results: squares, survival probability; circles, ionization probability. Curves, corresponding model results. Lower curves, total excitation probability to bound states. Horizontal upper curves, sum of all the transition probabilities.

References

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