Improved Weisskopf-Wigner approximation for atomic ionization by short laser pulses

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Synopsis An improved Weisskopf-Wigner approximation allows to obtain a closed form for the survival amplitude and the ionization amplitudes of atoms subject to laser pulses. The improvement avoids the numerical solution of a Volterra integro-differential equation obtained by modeling full initial state coupling to the continuum as well as transitions between initial state and other discrete states. The calculations are made in the velocity gauge. The improved approximation compares well with a full TDSE numerical solution for Hydrogen.

In a recent work we have introduced a model to deal with atomic ionization by short laser pulses [1]. The model accounts for full initial state coupling to the continuum and discrete spectrum, while discrete-discrete, discrete-continuum and continuum-continuum transitions are neglected. We have obtained a single Volterra integro-differential equation for the initial state amplitude. This equation is easily solved using the Goldfine prescription [2]. We have analytically shown that the sum of all transition probabilities is unity, i.e., the model is unitary.

In this communication we consider the model in the velocity gauge and report two analytical approximations (closed-forms) to the integro-differential equation: one, closely related to the Weisskopf-Wigner approximation, and the second one, an improved version of it.

To test the model and its approximations we show in figure 1 the ionization spectra of Hydrogen under a 20 cycles XUV laser pulse ($\omega = 0.6$ a.u.). Two laser intensities are examined, $E_0 = 0.2$ a.u. (1.4×10^{14} W/cm^2) and $E_0 = 0.4$ a.u. (5.6×10^{14} W/cm^2). The results obtained with the model and its approximations for the electron spectrum, are compared with full time dependent Schrödinger equation simulation performed with the Qprop [3]. The comparison is rather good for the entire electron energy interval, at the smaller intensity. The full model and both Weisskopf-Wigner approximations are close each other and follow the TDSE results quite well. For the larger electric field amplitude, the improved Weisskopf-Wigner approximation remains close to the full model calculation, which in turn keeps near Qprop simulations within 15 percent. The simplest Weisskopf-Wigner approach depart considerably from TDSE results.

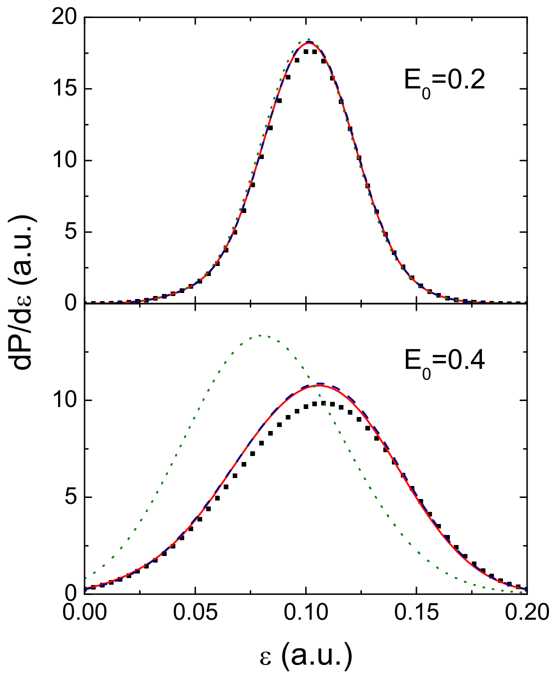

Figure 1. Hydrogen ionization spectra (first peak) for a 20 cycles laser pulse with $\omega = 0.6$ a.u. The laser field amplitudes are $E_0 = 0.2$ a.u. and $E_0 = 0.4$ a.u. Colors online. Full line (red), unitary model; dashed line (blue), improved Weisskopf-Wigner approximation; dotted line (green), Weisskopf-Wigner approximation; squares: exact calculations with Qprop code [3].

References

[1] M. G. Bustamante and V. D. Rodríguez, unpublished.

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