Dynamic Stark effect and the Coulomb-Volkov approximation

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Synopsis A modified Coulomb-Volkov theory is used to study the interaction of intense laser pulses with atomic Hydrogen. Photon energy greater than the ionization potential and non-perturbative conditions are considered. The dynamical Stark effect is accounted by introducing the initial state coupling to the remaining discrete and continuum atomic spectrum. Both the Stark shift and the decay of the initial state are studied. The ionization spectra, the Stark shift and the total ionization probability are compared with results obtained from numerical solution of the time dependent Schrödinger equation. Both results agree well.

The above threshold ionization of atomic Hydrogen by ultrashort laser pulses is studied. We consider the case in which the photon energy is greater than the ionization potential. Under perturbative conditions, the Coulomb-Volkov ($CV2^-$) theory provides a good description of the multiphoton ionization spectrum [1]. Continuum-continuum coupling is already included in the $CV2^-$ theory by using the Coulomb-Volkov wave function for the final state. However, non-perturbative conditions require introducing the coupling of the initial state with the discrete and continuous part of the atomic spectrum. Thus, the trial initial state wave function here proposed accounts for both the decay of the initial state and the Stark shift of its energy level. The ionization spectra, the initial state Stark shift and the total ionization probability are analyzed.

In the Schrödinger picture the transition amplitude from the initial state i at time $t = 0$ to the final state f at time $t = \tau$ may be approximated by the Demkov variational expression for the transition amplitude. The final state is represented by the Coulomb-Volkov wave function while the initial is approximated by

$$\chi_i^+(\overrightarrow{r}, t) = a_{1s}^{DC}(t)\varphi_{1s}(\overrightarrow{r}) \exp(-i\epsilon_{1s}t), \qquad (1)$$

where the amplitude of the state is obtained from the solution of the model's integro-differential equation. Figure 1 shows in a) the Stark shift of the first ATI peak of the spectrum and in b) the total probability of ionization, both as a function of the laser electric field intensity. It can be noticed that the present model (CV2-DC) is in good agreement with the results of the TDSE obtained using the Qprop code [3]. Results using reference [2] are shown as upper triangles. The model introduced in [2] has been improved in this work. First, the integro-differential equation arising from the coupling to the continuum is solved exactly. Second, the coupling to the discrete spectrum is accounted for. This is essential to the correct ATI peaks description. It is not necessary to suppress the ponderomotive potential to explain the ATI peaks position.

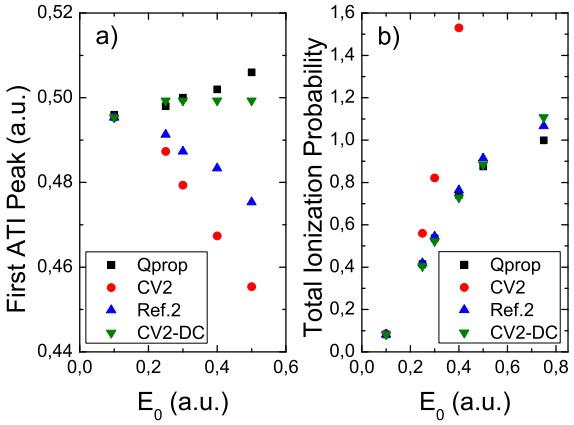

Fig. 1. a) First ATI peak energy position, and b) Total ionization probability as a function of the laser electric field amplitude. Laser pulse duration and frequency are 20 cycles and 1 a.u., respectively.

References

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