1P102 Ionization of hydrogen atom in the presence of intense chirped laser pulse.

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Abstract

Ionization of atoms, molecules and surfaces with high intensities and frequencies has become an area of wide interest. High intensities lead us to a new region of study, one where conventional description of atom field interaction breaks down and where previously unobserved phenomena are expected to occur. In this article we present the field of high intensity chirped laser pulse interaction with a hydrogen atom. The evolution is dynamic and needs an alternative approach to the earlier used non-perturbative techniques which become non-reliable at high intensities. The most used method is the direct integration of the time dependent Schrödinger equation as it does not place any restriction on the type of the laser pulse used[1]. We have used this method to study the ionization of the hydrogen atom in the presence of chirped laser pulse. The target wave functions are expanded in terms of discrete L^2 basis and expand the target wave functions in terms of basis functions. We choose a Laguerre basis of size N. On diagonalizing the target Hamiltonian in terms of above basis we get N energy eigenvalues, spanning both negative and positive energies[2]. The lowest lying negative eigenfunctions are excellent approximations to the exact bound states. The positive energies represent the continuum of the target.

Let us consider the problem of interaction of a high power short optical pulse with an atom. The electron behaviour is described by the Schrodinger equation (in atomic units)

$$i\frac{\partial \psi(\vec{r},t)}{\partial t} = H(\vec{r},t)\psi(\vec{r},t) \qquad (1)$$

where $H(\vec{r},t) = H_0(\vec{r}) + H_I(\vec{r},t)$ with H_0 being the unperturbed Hamiltonain and $H_I(\vec{r},t) = \vec{r} \cdot \vec{E}(t)$ is the perturbation part. $\vec{E}(t)$ is the applied electric field. Let us seek the electron wavefunction in the form

$$\psi(\vec{r},t) = \sum_{n=0}^{N} \sum_{l=0}^{L} a_{nl}(t) \psi_{nl}^{(0)}(\vec{r}) e^{-iE_{nl}^{(0)}t} \qquad (2)$$

$\psi_{nl}^{(0)}(\vec{r})$ are the eigenfunctions of the unperturbed Hamiltonian.

Substituting equation (2) into equation (1) and using orthogonality property of the wavefunctions, we get a set of coupled differential equations for $a_{nl}(t)$, which we solved numerically using the Runge-Kutta method.

We evaluated the probability of ionization as

$$P_{ion}(t) = \sum_{E>0 states} |a_{nl}(t)|^2 \qquad (3)$$

The determination of the coefficients $a_{nl}(t)$ allows us to calculate the probability of ionization for various laser intensities for various values of frequency chirp. The dependence of ionization on the frequency chirp is investigated and it is found that the ionization is enhanced when the applied pulse is blue to red chirped (i.e.negatively chirped). We have also found that the use of the pulse with continuously varying frequency is certainly more appropriate, as the exact knowledge of the transition frequency for   bound-free transition is not imperative. For the present case we have taken a Gaussian pulse with FWHM ≈ 34 a.u. and studied the variation of transition probability at different intensities as the pulse progresses.

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