1 Abstract

Progress in experiments [3] leads to increasing interest in understanding interaction of atoms with an electromagnetic field in the high intensity regime. Well known effects are the generation of higher harmonics and the above threshold ionization which leads to a generation of high energetic electrons. We solve the multidimensional time dependent Schrödinger equation in the Kramers-Henneberger frame in dipole approximation and present numerical calculations of ionization processes for bound state electrons and electron wave packet scattering processes in strong laser fields for model systems. Recent calculations for electron scattering on a single 1D screened Coulomb potential [3] are extended to multidimensional systems as well as potential chains. The fast electron spectrum is analyzed.

2 Method

Consider the time dependent Schrödinger equation in dipole approximation for one particle in a time dependent external field (laser field) and a screened Coulomb potential \( V(x) = -1/|x| + \alpha x^2 \) representing the ion on which scattering processes will take place:

\[
\frac{\partial}{\partial t} \Psi(x,t) + i \frac{\nabla}{\nabla} \Psi(x,t) = \left( V(x) + \frac{\alpha x^2}{2} \right) \Psi(x,t) + \epsilon \sin(\omega t) \Psi(x,t) \tag{1}
\]

Atomic units (\( \hbar = m = \epsilon = 1 \)) are used. All results are presented in units of \( E_0 = 27.214 V \) (Barret) and \( \alpha_0 \) (Bohr).

Equation 1 can be transformed into the Kramers-Henneberger frame [2] (1D case is shown):

\[
\frac{\partial}{\partial r} \bar{\Psi}(r,t) + \frac{\alpha}{2} \frac{\partial^2}{\partial r^2} \bar{\Psi}(r,t) = \left( \frac{1}{2} V(r,t) + \frac{\alpha}{2} r^2 \right) \bar{\Psi}(r,t) + \epsilon \sin(\omega t) \bar{\Psi}(r,t) \tag{2}
\]

The argument of the potential \( V \) is shifted by the quiver motion of the electron in the laser field. For \( \omega = 0.2 \) and \( \epsilon = 0.2 \) results an intensity of \( 1.4 \times 10^{14} \) W/cm

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The energy distribution of scattered electrons is obtained by Fourier transformation of the wave function where only parts far away from the scattering region are taken into account. Therefore no inverse transformation from the Kramers-Henneberger state to the laboratory state is necessary which is approved by test calculations.

3 The Model System

3.1 Bound States

Electron Ion Scattering (3.2)

Electron-Ion Scattering (3.3)

Electron scattering on an ion pair with varying \( D \) (cf. Fig. 3) for \( k = 1 \) (4 in the left (right) figure) and \( \epsilon = 0.2 \), \( \omega = 0.2 \) leads to a distribution of fast electrons in the forward scattered waves. The main peak in the spectrum of forward scattered electrons is due to the incident wave packet. A resonance behavior with maximum energy gain for the electrons is found (\( k = 1 \), \( D = 50.0 \), \( k = 4 \), \( D = 100.0 \)).

5.3 Potential Chain Scattering

5.4 1D Scattering

6 2D Scattering

7 Outlook

In further calculations we plan to increase the number of scattering centers and extend the model of wave packet scattering on ions to the two dimensional case. In the next step our goal is to implement more realistic potentials like pseudopotentials in order to simulate surface scattering in a one particle approximation. It is expected to see altered distributions of fast electrons in these systems.

References


