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Theoretical study of the two-dimensional momentum spectra of H^- ion in the intense laser fields

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Abstract. By using two model potentials chosen, the second outermost back rescattered ridges (BRR) of the two-dimensional (2D) momentum spectra of H^- ion in the linear polarization laser fields are studied under the strong-field approximation (SFA). The results show that the polarization potentials in the two model potentials have little effect on the 2D momentum spectra, the number of BRR increases and the fluctuation of angular distributions along the second BRR decreases with the increase of the laser intensity, but the accurate electron-atom elastic scattering cross sections can be retrieved directly along the second outermost BRR by the polynomial fitting method.

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Key words: strong field approximation method, time-dependent Schrödinger equation, momentum spectra

1 Introduction

Strong field physics is an important frontier field in the present physics research [1, 2]. The above-threshold ionization (ATI) of atoms and molecules is the one of the most fundamental processes of the interaction between intense laser fields and atoms and molecules, which can provide urgently needed data and theoretical support for the new particle accelerator [3, 4], attosecond physics [5, 6] and atomic structure measurements [7, 8], etc. The study of ATI of atoms and molecules in the intense laser fields can not only further understand the laser properties, but also has important significance for understanding the interaction mechanism between atoms and molecules and intense laser

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fields. In recent decades, the momentum and energy spectra of the negative ions in intense laser fields had been extensively studied [9], where H^- ion was reported in experiments [10-12] and in theories [13-18].

Theoretically, the principal theoretical methods have the strong-field approximation (SFA) method and the numerical solution of time-dependent Schrödinger equation (TDSE) method. The TDSE method can obtain accurate results, but the defects of TDSE are large amount of calculation and limited to computer hardware and software. Since SFA method treats the continuum states with the Volkov states, and neglects that the nucleus has influence of Coulomb field on the ionization electrons, thus SFA method can be used to study the photodetachment of negative ions in intense laser fields quiet well [17, 18].

In recent years, the most back rescattered ridges (BRR) of the two-dimensional (2D) momentum spectra of neutral atoms [19-22] and negative ions [18] have been studied theoretically, but the study on the second outermost BRR of the 2D momentum spectra has not been reported. The recent study results show that the 2D photoelectron momentum spectra of H^- ion in the intense laser fields obtained using SFA method are in good agreement with the ones obtained using TDSE method [18]. To further study the second outermost BRR of the 2D photoelectron momentum spectra of H^- ion and the influence of static potential and polarization potential included model potentials on the 2D photoelectron momentum spectra in the different laser fields, the 2D photoelectron momentum spectra of H^- ion in the linear polarization laser fields are calculated using the SFA method by choosing two model potentials. Atomic units are used throughout the paper unless otherwise indicated.

2 Theoretical method

The detachment amplitude of H^- ion with momentum p is expressed as [23]

$$f(p)=f^{(1)}+f^{(2)}. \tag{1}$$

The first and second terms are, respectively, the first-order and second-order amplitude, and they can be expressed as

$$f^{(1)}=-i\int_{-\infty}^{+\infty}dt\langle\chi_p(t)|H_i(t)|\Psi_0(t)\rangle \tag{2}$$

$$f^{(2)}=-\int_{-infty}^{+\infty}dt\int_{-\infty}^{t}dt'\int dk\langle\chi_p(t)|V|\chi_k(t)\rangle\times\langle\chi_p(t')|H'(t')|\Psi_0(t')\rangle \tag{3}$$

where V, $\Psi_0(t)$ and $\chi_p(t)$ are model potential, initial wavefunction and Volkov state wavefunction with the momentum p, respectively.

In the linear polarization laser field, the 2D photoelectron momentum spectra can be expressed as

$$\frac{\partial^2 P}{\partial E\partial\theta}=|f(P)|^2 2\pi p\sin\theta. \tag{4}$$