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Quantum and closed-orbit theory Calculations for the photodetachment cross sections of H^- near two perpendicular elastic planes

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Abstract. The photodetachment cross section of H^- near two perpendicular elastic planes is investigated in this paper. Both the traditional quantum approach and closed orbit theory are applied to explicitly derive the formulas of the cross section for different laser polarization direction. We first compared the quantum formulas with closed orbit theory formulas, and then found that the quantum results are shown to be in good agreement with the semiclassical results. Further more, we also found that the cross section depends strongly on the direction of the laser polarization. When the polarization is parallel to the closed orbit, the corresponding oscillation in the cross section is very obvious. However, When the polarization is perpendicular to the closed orbit, the corresponding oscillation is too small for closed-orbit theory formula to describe.

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Key words: photodetachment, closed-orbits theory, elastic planes

1 Introduction

In 1987, Bryant *et al.* found some oscillations occurring among the photodetachment cross section of hydrogen ion in electrostatic field [1]. Rau [2] and Du [3] calculated the photodetachment cross section of hydrogen ion in electrostatic field by using quantum methods in coordinate representation and momentum representation respectively, which is consistent with the experimental results. Another method to calculate photodetachment cross section is closed orbit theory [4,5] which not only can get the results consistent with

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the experiment but also give the clear physical illustration intuitively for the oscillation structure of photodetachment cross section [6].

For decades, the environment around hydrogen ion is more and more complex in recent studies. At first, the researchers pay their main attention to photodetachment in the external field, including uniform field and non-uniform field, such as, the photodetachment in the magnetic field [7,8], in the parallel electromagnetic field and vertical electromagnetic field [9–14], in the electric and magnetic field with any orientation [15–17], in gradient field [18], in non-uniform electric field [19,20], near a repulsive potential [21], near two repulsive potential [22]and near a repulsive potential in the electric field [23]. Later, the photodetachment near the different interfaces aroused the research interests of all either,including near a single elastic interface [24–26], near a inelastic interface [27], near metal nanometer spherical [28], near a metal surface [29–31] and near a deformation spherical [32] and etc. Additionally, the photodetachment in different cavities which are composed by elastic interfaces have also been extensively concerned recently, such as in a parallel plate cavity [33,34], in an open cavity [35], inside a circular microcavity [36] and inside a square microcavity [37], and etc. Some of the above researches use quantum method, some others employ the closed orbit theory method or both.

While in this paper, we will further study the effects of two perpendicular elastic planes on photodetachment of hydrogen anion nearby. The system can be explicitly derived by the quantum approach and has three closed orbit. So we can consider the quantum influence from each one of the closed orbits .

2 Quantum formulas

The hydrogen negative ion is located between two infinitely extending planes which intersect vertically. It is at a distance a in front of one plane and a distance b in front of the other plane. The position of the coordinate system and the dimensions are given in Fig.1.

Then the Hamiltonian describing the detached electron motion of H^- can be given by

$$H=\frac{1}{2}\mathbf{p}^2+V_b(r)+V(\mathbf{r}). \tag{1}$$

where $V_b(r)$ is a short-range potential, and it binds the active electron to the atom. When the electron is far away from the nucleus, the binding potential V_b can be neglected.

The photodetachment cross section is given in terms of the dipole matrix elements by the following expression in atomic units [3]

$$\sigma^{\mathbf{q}}_{quant}=\frac{2\pi^2}{c}\int df 2E_p\left|\langle\Psi_f|\mathbf{q}|\Psi_i\rangle\right|^2\delta(E_f-E), \tag{2}$$

where $\mathbf{q}$ represents either x, y or z for corresponding laser polarizations directions; the speed of light c is approximately 137; the photon energy E_p is equal to the sum of the