J. At. Mol. Sci.
doi: 10.4208/jams.042912.052012a

Vol. **4** , No. 2 , pp. 95-104
May 2013

Spin effects in laser-assisted semirelativistic excitation of atomic hydrogen by electronic impact

M. El Idrissi[a], S. Taj[a], B. Manaut[a,*], Y. Attaourti[b], and L. Oufni[c]

[a] *Université Sultan Moulay Slimane, Faculté polydisciplinaire, Laboratoire Interdisciplinaire de Recherche en Sciences et Techniques (LIRST), Boite Postale 2390, Morocco*
[b] *Université Cadi Ayyad, Faculté des Sciences Semlalia Département de Physique, Boite Postale 2390, Morocco*
[c] *Université Sultan Moulay Slimane, Faculté des Sciences et Techniques, Département de Physique, LPMM-ERM, Boite Postale 523, Morocco*

Received 29 April 2012; Accepted (in revised version) 20 May 2012
Published Online 28 March 2013

Abstract. New insights into our understanding of the semirelativistic excitation of atomic hydrogen by electronic impact have been made possible by combining the use of polarized electron beams and intense laser field. The paper reviews relativistic theoretical treatment in laser-assisted electron scattering with particular emphasis upon spin effects. Different spin configurations for inelastic electron-atom collisions is also discussed. The role of laser field in such collision is of major importance and reveals new information on the dynamics of the collision process. The examined modern theoretical investigations of such relativistic laser-assisted collisions have shown that the need for experimental data is of a paramount importance in order to asses the accuracy of our calculations.

PACS: 34.80.Dp, 12.20.Ds

Key words: spin effects, laser assisted, QED calculation

1 Introduction

The spin is not only an indispensable ingredient in atomic physics but also responsible for many phenomena observed in solid-state physics. In addition to the uses of polarized electrons in studies of atomic physics, there have been numerous studies of polarized electron scattering and polarized electron emission from ferromagnetic solids over the past decade. In 1975, the purpose of the Spin-Polarized Electron Source was to describe

*Corresponding author. *Email address:* `b.manaut@usms.ma` (B. Manaut)

how this effect, which had been discovered in spin-polarized photoemission experiments by Pierce *et al.* at the ETH-Zurich [1], could be used to provide a compact spin-polarized electron gun. Later on, an experimental work has been done to produce electron beams in which the spin has a preferential orientation. They are called polarized electron beams [2] in analogy to polarized light, in which the field vectors have a preferred orientation. Extensive theoretical works have been performed by introducing relativistic and spin effects in the collision between incident particles and atoms [3-6]. There are many reasons for the interest in polarized electrons. One important reason is that in physical experiments one endeavors to define as exactly as possible the initial and/or final states of the systems being considered.

Since the 1960s when lasers became a worldwide-used laboratory equipment and also large polarization effects in low-energy electron scattering were ascertained, experimental and theoretical studies of laser-matter interaction have witnessed continuous progress. By virtue of the increasing progress in the availability of more powerful and tunable lasers, such processes are nowadays being observed in laboratories [7-10]. Most experimental and theoretical studies of laser-assisted electron-atom collisions were restricted to the nonrelativistic regime and low-frequency fields, where it has been already recognized that, as a general consequence of the infrared divergence of QED, large numbers of photons can be exchanged between the field and the projectile-target system. An extension of the first-Born nonrelativistic treatment [11] to the relativistic domain was formally derived for unpolarized electrons [12]. There have been also theoretical investigations of relativistic scattering in multimode fields [13].

In the present paper we have to extended our previous results [14] to the case of laser assisted inelastic excitation $1s$ to $2s$ of the atomic hydrogen by polarized electrons. Therefore, we have begun with the most basic results of our work using atomic units (a.u) in which one has ($\hbar = m_e = e = 1$), where m_e is the electron mass at rest. We have used the metric tensor $g^{\mu\nu} = diag(1,-1,-1,-1)$ and the Lorentz scalar product defined by $(a.b) = a^{\mu} b_{\mu}$. The organization of this paper is as follows: the presentation of the necessary formalism of this work in Section 2, the result and discussion in Section 3 and at last a brief conclusion in Section 4.

2 Theory

The transition matrix element corresponding to the laser assisted inelastic excitation of atomic hydrogen by electronic impact from the initial state i to the final state f is given by

$$S_{fi} = -i \int dt \, \langle \psi_{q_f}(\mathbf{r}_1)\phi_f(\mathbf{r}_2) | V_d | \psi_{q_i}(\mathbf{r}_1)\phi_i(\mathbf{r}_2) \rangle \tag{1}$$

where $V_d = 1/r_{12} - Z/r_1$ is the interaction potential, $\mathbf{r}_1$ are the coordinates of the incident and scattered electron, $\mathbf{r}_2$ the atomic electron coordinates, $r_{12} = |\mathbf{r}_1 - \mathbf{r}_2|$ and $r_1 = |\mathbf{r}_1|$. Before we present the most interesting results of our investigation regarding laser-assisted