Circular dichroism in hydrogen multiphoton ionization by a bichromatic field of frequencies ω and 3ω

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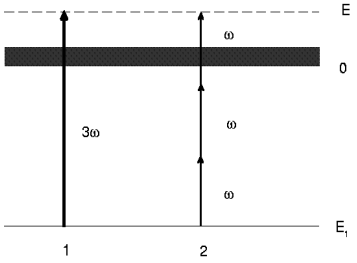
Recent measurements of circular dichroism (CD) in double photoionization of He [1] and the experiments in progress on CD in two-photon ionization of noble gases [2] pose an increasing interest in the study of laser-assisted processes in circular polarization (CP). The goal is to determine under what conditions the helicity of the photons might be a relevant parameter.

The aim of this work is to study the ionization of the ground state hydrogen atom by the electric field :

$$\vec{A}(t) = A_L \vec{s}_L \cos \omega t + A_H \vec{s}_H \cos 3\omega t \; . \tag{1}$$

The laser, of frequency ω, is linearly polarized ($\vec{s}_L$) while its second harmonic, of frequency 3ω, is circularly polarized ($\vec{s}_H$). A_L and A_H denote the vector potentials of the laser and harmonic, respectively. We investigate the angular distributions of the photoelectrons of energy $E = E_1 + 3\hbar\omega$ (E_1 the ground state energy). In the domain of moderate field intensities, this continuum state can be reached by two main interfering paths: the single-photon absorption of the harmonic and the three-photon absorption from the laser.



According to the time-dependent perturbation theory, the amplitude of the process in this figure is given by

$$M = -2\pi i \, \frac{eA_L}{2m_e} \left\{ \frac{A_H}{A_L} \mathcal{T}_H + \left(\frac{eA_L}{2m_e} \right)^2 \mathcal{T}_L \right\} , \tag{2}$$

with e the electron charge and m_e its mass. $\mathcal{T}_H$ and $\mathcal{T}_L$ are the transition amplitudes of the

two individual processes:

$$\mathcal{T}_H = \mathcal{F}\left(\vec{n}\cdot\vec{s}_H\right) \ , \qquad \mathcal{T}_L = \vec{n}\cdot\vec{s}_L\left[\left(A+2B\right)\left(\vec{s}_L\right)^2 + C\left(\vec{n}\cdot\vec{s}_L\right)^2\right] \ . \tag{3}$$

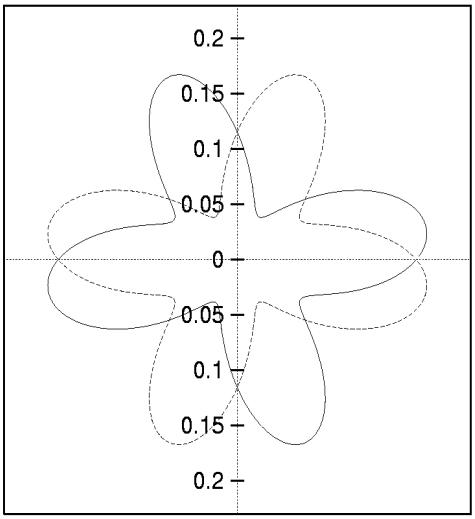
The amplitudes A, B, C (evaluated in Ref.[3]) and $\mathcal{F}$ are scalars, depending only on the two frequencies and on the electron energy.

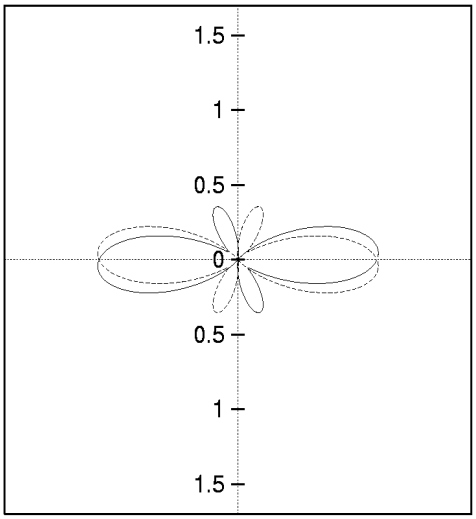
The differential rate of the ionization corresponding to the process depicted in the previous figure has the expression

$$\frac{d\Gamma}{d\Omega} = \frac{d\Gamma_H}{d\Omega} + \frac{d\Gamma_L}{d\Omega} + 2\sqrt{\frac{d\Gamma_H}{d\Omega}\,\frac{d\Gamma_L}{d\Omega}}\cos\left[\arg\mathcal{T}_L - \arg\mathcal{T}_H\right] \ , \tag{4}$$

where the last term is the interference term depending on the helicity of the harmonic. Its contribution is modulated by the magnitude of the relative intensity of the harmonic I_H with respect to that of the laser I_L. Strong interferences are necessary in order to observe dichroism effects. The helicity of the harmonic photon is not a relevant parameter in the absence of the liniarly polarized laser field.

We illustrate our numerical results for the differential rate of ionization considering the relative intensity $I_H/I_L = 10^{-2}$, the laser field is rather strong $I_L = 3.51 \times 10^{13}$ W/cm^2. We choose two values for the wavelength of the fundamental; they are close to the resonances related to two-photon virtual excitation of $3s-$, $3d-$states ($\lambda = 203.5$ nm in the left panel) and $4s-$, $4d-$states ($\lambda = 194$ nm in the right panel). The quantization axis (Oz) is defined by the common direction of propagation of the two laser beams and the polarization vector of the laser determines the Ox axis. The graphs show the differential rate of ionization as a function of the azimuthal angle of the ejected electron, for the polar angle $\theta = \pi/2$. Each panel contains two curves: full lines correspond to left hand CP and dotted lines to right hand CP.





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[2] P. Agostini, at Ultraintense Laser Interactions and Applications-1, Crete (1999) .

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