Probing autoionizing decay in He atom with ultrashort laser pulses

2012 J. Phys.: Conf. Ser. 388 032039

(http://iopscience.iop.org/1742-6596/388/3/032039)

XXVII International Conference on Photonic, Electronic and Atomic Collisions (ICPEAC 2011) IOP Publishing
Journal of Physics: Conference Series **388** (2012) 032039 doi:10.1088/1742-6596/388/3/032039

Probing autoionizing decay in He atom with ultrashort laser pulses.

C.M. Granados and J.L. Sanz-Vicario[1]

Grupo de Física Atómica y Molecular. Instituto de Física, Universidad de Antioquia, Medellín, Colombia.

Synopsis A time dependent Feshbach method is implemented to study the correlated electron dynamics of He doubly excited states below the He^+ (N=2) ionization threshold, using ultrashort laser pulses in XUV-pump IR-probe delay schemes.

Recent progress in the generation of XUV and IR ultrashort laser pulses in the femto-(fs) and attosecond (as) time domain has opened up the opportunity to trace the correlated dynamics of electronic wave packets of atomic transient states (see [1]). The He atom subject to an XUV ultrashort laser pulse (fs or as) may lose electrons through a direct photoionization process or by means of autoionization from doubly excited states (DES), leading to quantum interferences that generate Fano profiles in the frequency domain photoionization spectrum. The time resolved observation of the formation of Fano profiles may be feasible with attosecond streak cameras [2] and it has been a recent focus of theoretical attention [3]. A numerical time-dependent study of photoinduced autoionization decay of $^1P^o$ resonances in He was already reported for longer fs pulses in [4].

In this work, the time dependent Schrödinger equation is solved with a close-coupling method in which the total wave packet $\Phi(t)$ is expanded in terms of the Feshbach $\mathcal{QHQ}$ (resonant space) and $\mathcal{PHP}$ (continuum space) eigenfunctions of the field-free Hamiltonian. Considering a XUV-pump plus τ-delayed IR-probe scheme, the laser-atom $\mathbf{p}\cdot[\mathbf{A}_{pump}(t)+\mathbf{A}_{probe}(t-\tau)]$ and the $\mathcal{QHP}$ (responsible of resonance decay) matrix elements are both included in the dynamical interaction potential. $\mathcal{QHQ}$ DES below the He^+ (N=3) limit and $\mathcal{PHP}$ continuum states for $He^+(N=1)$ and $He^+(N=2)$ ionization channels are calculated for all $^1L^\pi$ symmetries with L up to 5-6 (high enough to produce IR sidebands) by using CI wave functions in terms of orbitals expanded in a B-splines basis within a large box. For continuum states above $He^+(N=2)$ threshold the multichannel problem is addressed by solving a Lipmann-Schwinger equation. An analogous method has already been used to study the dissociative photoionization of molecular hydrogen [5].

In recent works using XUV-pump IR-probe schemes on He, the decay mechanism of a manifold of $^1P^o$ DES is shown to be in the form of electron ejection through isolated bursts [6] and collected streaked photoelectron spectra allows for measuring DES lifetimes as a function of the XUV-IR time delay τ [7]. By appropriate selection of frequencies and duration of the pumping laser, initial wave packets may contain either an isolated DES or a coherent superposition of DES. Whereas the creation of wave packets of $^1P^o$ DES (mainly a superposition of ${}_2(0,1)_2^+$ and ${}_2(0,1)_3^+$ states with lifetimes ∼18 and ∼81 fs, respectively) can be accessed by one-photon absorption of XUV as pulses, to monitor the time evolution of $^1S^e$ and $^1D^e$ DES (with even faster decay down to ∼5 fs for the $^1S^e$ ${}_2(1,0)_2^+$ state) two-photon absorption with a ∼30 eV highly intense XUV-pump (or two-color ∼ 21+39 eV absorption) is firstly required.

References

[1] F. Krausz and M. Ivanov (2009) *Rev. Mod. Phys.* **81**, 163

[2] M. Wickenhauser, J. Burgdörfer, F. Krausz and M. Drescher (2005) *Phys. Rev. Lett.* **94**, 023002

[3] W.-C. Chu and C.D. Lin, (2010) *Phys. Rev. A* **82**, 053415; Th. Mercouris, Y. Komninos, and C.A. Nicolaides, (2011) *Phys. Rev. A* **83**, 015403;

[4] S.X. Hu and L.A. Collins, (2005) *Phys. Rev. A* **71**, 062707

[5] J.L. Sanz-Vicario, H. Bachau and F. Martín (2006) *Phys. Rev. A* **73**, 033410

[6] L. Argenti and E. Lindroth, (2010) *Phys. Rev. Lett.* **105**, 053002

[7] S. Gilbertson *et al* (2010) *Phys. Rev. Lett.* **105**, 263003

[1]E-mail: sanjose@fisica.udea.edu.co