Centre des Lasers Intenses et Applications

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PROPOSITION DE THESE/Ph.D PROPOSAL

Titre/*Title***: Etude des effets relativistes en régime non-linéaire d'interaction entre les molécules et les impulsions lasers xuv/soft-x brèves** */Study of relativistic effect in non-linear interaction between molecules and xuv/soft x-ray short laser pulses*

Context. The Ph.D is organized as a co-tutelle. In Bordeaux, the future Ph.D. student will be guided by H. Bachau (Directeur de Recherches au CNRS) and F. Catoire (Chargé de Recherches au CNRS), while at UAM Madrid this task will be fulfilled by Prof. F. Martín and Dr. A. Palacios (Associate Professor).

The co-directors of the Ph. D. will be H. Bachau and F. Martín

Support. Campagne de doctorat international 2016 de l'Initiative d'excellence de l'université de Bordeaux and the project "XUV/X-ray lasers for ultrafast electronic control in chemistry (XChem)", funded by the European Research Council (Universidad Autónoma de Madrid).

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Ph.D. Objectives. The work is fully theoretical, its aim is to explore non-dipole effects in laser-molecule interaction by including the non-dipole effect in the Hamiltonian at the lower order in 1/c (c being the velocity of the light) [1]. Therefore relativistic effects are treated at the lower order in 1/c. The laser-atom (or laser-molecule) interaction is usually treated in the so-called "dipole approximation" (DA). This approximation consists in replacing the term exp(i**k.r**) (where the vectors **k** and **r** refer to the wave vector and electron position, respectively) by unity. DA is valid provided that the distance |**r**| between the electron and the nucleus is much smaller than the laser wavelength. Therefore, it breaks down for short wavelengths or very high laser intensities. In the context of two-color ionization of hydrogen atom, we have recently shown that DA is not valid for photons energies ranging from few hundreds of eV to keV in stimulated Compton scattering [1,2,3]. This result was unexpected since it is generally considered that the breakdown of DA occurs at much smaller wavelengths. We have investigated the situation where the electron energy distributions in the ionization of ground state hydrogen atom, due to the interaction with the superposition of two pulses of electromagnetic radiation, reveal a peak corresponding to an ionization process where the bound electron absorbs the photon energy difference. We identify this contribution as due to stimulated Compton scattering (SCS). Comparing the resolution of the time-dependent Schrödinger equation within DA and non-DA (i.e., including the correction terms to DA, called retardation terms), the energy and angular distributions of the emitted electron reveals that the non-dipole (or retardation) terms play a crucial role in SCS. Our objective is now to investigate complex systems, like molecules. The study of non-dipole effects in molecular systems has received little attention from the theoretical side until now, while the experimental activity is rapidly growing around the FEL and HGG sources. It is therefore of high interest to theoretically investigate the molecular case. The purpose of the Ph.D. is to study the case of molecules. We shall consider first the case of the molecular ion H_2^+ in xuv fields and then the H_2 molecule [4].

[1] H. Bachau, M. Dondera and V. Florescu, Journal of Modern Optics **63** (2016) 402
[2] H. Bachau, M. Dondera and V. Florescu, Phys. Rev. Lett. **112** (2014) 073001
[3] M. Dondera, V. Florescu and H. Bachau, Phys. Rev. A **90** (2014) 033423
[4] A. Palacios, J.L. Sanz-Vicario and F. Martín, Topical Review, *Theoretical methods for attosecond electron and nuclear dynamics: applications to the H_2 molecule*, J. Phys. B **48** (2015) 242001