Postdoc project
European fellowship

Timing photoionization in small molecules

Scientific background

This project will build on some earlier studies carried out jointly by two of the Attofel European Network partners, namely Lund Laser Center and CEA, and two external partners, the CELIA lab in Bordeaux and the LCPMR in Paris as for the theoretical part. It is aimed at unraveling the temporal aspects of electron ejection during photoionization in a XUV+IR field. Using a RABBIT setup with a magnetic bottle electron spectrometer as a detector, it was discovered experimentally in 2009 by the Saclay and Bordeaux groups that the photoionization of N_2 shows uncommon features on the low energy side of the photoelectrons spectrum [1]. More precisely, vibrational levels could be resolved and the phases of the photoelectron dipoles transition elements leading to each of these lines could be measured. A tentative interpretation was proposed in the first publication and a more thorough theoretical background was later provided by members of the consortium in ref. [2]. In brief, when using a 792 nm laser, H11 falls right on a complex resonance and depending on which energy part of the harmonic one considers within its width, the measured dipole may or not show a π phase shift. In ref. [2], this phase shift was directly linked to a photoionization time and a wavelength scan was proposed to access it experimentally.

The LLC group reported on the observation of such an effect in He [3]. In order to pass by a resonance, either the frequency of the laser was tuned or the intensity dependence of the stark shift was used. In particular unusual dependence of the Stark-shift with the ponderomotive potential of the dressing beam was identified. This work was further pursued studying phases of the photoionization of Ar out of resonance in [4], revealing the need for a precise interpretation of the photoionization time. In particular the Wigner delay was thoroughly discussed. Such a discussion arose again lately in [5]. This scientific landscape clearly shows the timeliness of further studies, especially on the experimental side where angularly resolved measurements of 2-photons ionization of aligned molecules for tuned XUV wavelengths, could directly give access to photoionization times. It could help provide a more complete picture of photoionization in the time domain for both atoms and molecules and stimulate theoretical studies.

Details

Institute	IRAMIS, CEA-Saclay
Laboratory	Service des Photons Atomes et Molécules, Attophysics-group
Supervision	Thierry Ruchon
Dates	1 year already funded, starting fall 2012

CEA-Saclay, SPAM, Bâtiment 522, – 91191 Gif-sur-Yvette, France
☎ *+33 1 69 08 70 10* • FAX *+33 1 69 08 12 13* • ✉ *thierry.ruchon@cea.fr*

Website	www.attophysique-saclay.fr
email	thierry.ruchon@cea.fr
Funding	Provided by the Marie Curie Initial Training Network (ITN) "Attofel" (EU grant)
Eligibility	Doctor in Physics at the date of recruitment, not having spend more than 12 months in France within the past 3 years.

Funding details

As part of a European Marie Curie Network, the allowance will be determined by European rules. As indicative information, an equivalent position within FP7 is paid approx. 2500 € per month after taxes. This is complemented by a bonuses which depend . As a worker in France health insurance is included.

Objectives

We propose to further demonstrate the capabilities of the RABBIT technique to get a full spectrum of both the imaginary and real parts of a two photon transition matrix element passing by an intermediate resonance. Initially, a so-called complex resonance at 17 eV in N2 will be targeted. This is chosen for i) the mechanism underlying it is not perfectly elucidated and ii) it falls close to an available line in Ti:sapph based lasers. We expect the measurements to give a clearer picture of the states coming into play in this resonance and possibly to propose a temporal sketch of the mechanism thanks to the phase information obtained.

Besides, it may be noted that 2-photons transitions are considered (XUV+IR) which have the capability to complement 1-photon spectroscopy by opening new channels as exemplified in multiphoton spectroscopy techniques. While N2 provides a suitable model system for the proposed studies, the project will aim to identify other systems with resonance features of interest for future studies.

Methodology

The ER will have to coordinate the work of the two Attofel partners in close collaboration with the two other members of the consortium in order to design the experimental setup. The theoretical team based in Paris, next to Saclay, will be of considerable help to orient the experiment and will be available every day. The experiment itself will probably be based on the existing setup in Lund where the best tunable laser is available. It will be the work of the ER to precisely define the schedule, but one may anticipate that three steps will be taken, of increasing novelty:

1. Based on the Saclay/Bordeaux experience on the one hand, and the Lund experience on the other hand, RABBIT phase measurements will be acquired in N_2 injected in the sensitive region of a MBES spectrometer while scanning the wavelength of the laser.

2. A more ambitious step, aiming at doing the same experiment but aligning the molecules and recording angularly resolved spectra will be subsequently taken in a VMIS.

3. As a bonus, if everything goes fine, we propose to measure phase differences against the revival time. Doing so, it might be possible to identify some dynamics among the different rotational levels populated by the alignment beam.

Environment

A large part of this work will be performed in collaboration with other members of the consortium, providing a great deal of experience to the successful applicant. The PostDoc will join the group working on high harmonic generation and attophysics, composed of five permanent senior researchers, three doctorates and two postdocs. Saclay provides an excellent scientific environment: it has a long tradition and expertise in intense laser-matter interactions, and especially, in high harmonics and attosecond pulses generation, both in theory and experiments.

The Saclay Laser-matter Interaction Center has been agreed as a European Facility and welcomes European researchers willing to use its state-of-the-art laser systems. The geographical location (Paris'suburbs) close to Orsay University, École Polytechnique, LOA-ENSTA, SOLEIL synchrotron... allows frequent and fruitful exchanges.

Applications

Candidates should send a CV, letter of interest in research, and the name and address of a potential reference to Thierry Ruchon. In the frame of the ATTOFEL Equal Opportunity policy, female candidates are especially encouraged to apply.

Publications

[1] S. Haessler, B. Fabre, J. Higuet, J. Caillat, T. Ruchon, P. Breger, B. Carre, E. Constant, A. Maquet, E. Mevel, P. Salieres, R. Taieb, and Y. Mairesse, "Phase-resolved attosecond near-threshold photoionization of molecular nitrogen," *Physical Review A*, vol. 80, p. 011404, JUL 2009.

[2] J. Caillat, A. Maquet, S. Haessler, B. Fabre, T. Ruchon, P. Salieres, Y. Mairesse, and R. Taieb, "Attosecond resolved electron release in two-color near-threshold photoionization of n-2," *PHYSICAL REVIEW LETTERS*, vol. 106, p. 093002, MAR 1 2011.

[3] M. Swoboda, T. Fordell, K. Klünder, J. M. Dahlström, M. Miranda, C. Buth, K. J. Schafer, J. Mauritsson, A. L'Huillier, and M. Gisselbrecht, "Phase measurement of resonant two-photon ionization in helium," *Phys. Rev. Lett.*, vol. 104, p. 103003, Mar 2010.

[4] K. Klünder, J. M. Dahlström, M. Gisselbrecht, T. Fordell, M. Swoboda, D. Guénot, P. Johnsson, J. Caillat, J. Mauritsson, A. Maquet, R. Taïeb, and A. L'Huillier, "Probing Single-Photon Ionization on the Attosecond Time Scale," *Physical Review Letters*, vol. 106, p. 143002, Apr. 2011.

[5] M. Schultze, M. Fiess, N. Karpowicz, J. Gagnon, M. Korbman, M. Hofstetter, S. Neppl, A. L. Cavalieri, Y. Komninos, T. Mercouris, C. A. Nicolaides, R. Pazourek, S. Nagele, J. Feist, J. Burgdorfer, A. M. Azzeer, R. Ernstorfer, R. Kienberger, U. Kleineberg, E. Goulielmakis, F. Krausz, and V. S. Yakovlev, "Delay in photoemission," *Science*, vol. 328, no. 5986, pp. 1658–1662, 2010.

CEA-Saclay, SPAM, Bâtiment 522, – 91191 Gif-sur-Yvette, France

☎ *+33 1 69 08 70 10* • FAX *+33 1 69 08 12 13* • ✉ *thierry.ruchon@cea.fr*