CFEL SCIENCE

Colloquium

January 11th, 2013 – 2:00 pm
Bld. 99 - Seminar Room I-III

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Time-delays in ionization: real, imaginary, and imagined

I will present our recent work on trying to understand how much time it takes to liberate an electron from an atom or a molecule, via either one-photon ionization or via optical tunnelling.

Attosecond experiments are now taking the challenge of resolving attosecond dynamics of ionization in laser fields, both in the one-photon [1,2] and strong-field multi-photon [3] regimes. The goal of this talk is to address several questions: (i) what physical mechanisms can be responsible for delays in one-photon ionization, (ii) what do we really measure when trying to time-resolve one-photon ionization, and (iii) how long does it take an electron to tunnel from an atom or a molecule.

Interaction of intense infrared laser light with atoms and molecules leads to rich dynamics which presents unique combination of quantum and classical physics, combined with unusual opportunities for imaging dynamics at the time-scale from few 10-s of attoseconds to a few femtoseconds.

In one-photon ionization in the presence of an infrared laser field, the moment the liberated electron shows up in the continuum is mapped onto its final momentum. In this case, the time-delays can be both real and imagined. In simple terms, the real ones are associated with the time it takes an electron to recognize where and what it is. In rigorous terms, these are delays associated with core rearrangement driven by the ionization and the creation of a hole – the time it takes the hole to figure out which ionic state, or a superposition of states, it is going to occupy. As for imagined delays, they are associated with the artefacts of the measurement – the inaccuracies of mapping between the final momentum and the instant of time the electron is transferred to the continuum. I will show calculations which demonstrate the simple physical picture underlying real time-delays, and I will also present an analytical formula that does excellent job calibrating out the imagined time-delays.

If time permits, I will also describe our recent results on using high harmonic generation spectroscopy to time-resolve optical tunnelling, that is, multi-photon ionization driven by strong low-frequency laser field. Theory predicts that one-electron tunnelling happens in imaginary time, and experimental results [2,3] confirmed this conclusion for circularly polarized laser fields. I will describe theoretical and experimental results for linear polarization, where the laser field changes from maximum to zero in a fraction of femtosecond. While we find that for single active electron time-delays are purely imaginary, there are indications that for multi-electron systems they turn out real.

Host: Valentyn Prohorenko MPSD/CFEL