Streaking of shake-up ionization in helium

Johannes Feist*,[1], Andreas Kaltenbäck*, Stefan Nagele*, Renate Pazourek*, Emil Persson*, Barry I. Schneider†,§, Lee A. Collins¶, Joachim Burgdörfer*

*Institute for Theoretical Physics, Vienna University of Technology, 1040 Vienna, Austria, EU
†Physics Division, National Science Foundation, Arlington, Virginia 22230, USA
§Electron and Atomic Physics Division, National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA
¶Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Synopsis We investigate whether an apparent "time delay" between electrons ionized by an attosecond XUV pulse with and without shake-up excitation of the remaining ion can be extracted using XUV-IR streaking setups. To do so, we solve the full Schrödinger equation for the helium atom including all correlation effects. We discuss whether a time delay extracted from the streaking spectra corresponds to a "real" time delay or is induced by other effects, such as the influence of the IR field on the ionization process.

The question whether there is a time delay between electrons liberated from an atom with or without shake-up excitation of the remaining ion has recently become a topic of interest. Such time delays can be measured in streaking experiments, which for example have shown an apparent time delay between electrons ionized from the conduction band and from core states in condensed matter systems [1].

In a streaking setup, an attosecond XUV pulse is used to free electrons from the target, which then acquire additional momentum from the IR pulse. This allows one to map the release time of the electron to the final momentum. A physical time delay between electrons produced in different processes results in a shift between the streaking curves (Fig. 1) with respect to each other.

One fundamental problem is the time delay between the electrons liberated from an atom with or without excitation (shake-up) of the remaining ion. An XUV pulse of high enough energy can either leave the ion in its ground state or promote it to an excited state through electron-electron interaction. We investigate this problem for the helium atom, for which it is possible to solve the full six-dimensional time-dependent Schrödinger equation ab initio [2].

The interpretation of any *apparent* "delay" extracted from simulations requires great care. In particular, the ionization and shake-up process itself can be influenced by the IR field, leading to additional momentum shifts on the electron which are not related to any time delay. In our contribution, we will address these questions and investigate whether a time delay between electrons ejected with and without shake-up can be unambiguously extracted.

Work supported by the FWF-Austria, grant SFB016, and NSF, TeraGrid grant TG-PHY090031.

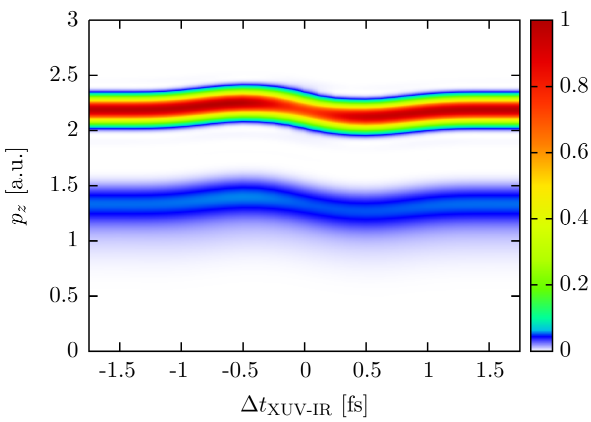

Fig. 1. Streaking image (electron spectrum in polarization direction vs. time delay) for ionization of a He atom by an 90 eV XUV pulse, synchronized with a single-cycle IR pulse. The upper line ($p_z \approx 2.2$ au) corresponds to ionization leaving the He^+ ion in the ground state, while the lower line corresponds to ionization leaving the ion in an excited state (primarily $2s$ and $2p$).

References

[1] A. L. Cavalieri et al., Nature **449**, 1029 (2007).

[2] J. Feist et al., Phys. Rev. A **77**, 043420 (2008).

[1]E-mail: johannes.feist@tuwien.ac.at