Physikalisches Kolloquium

Universität Konstanz

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Di, 19.07.22
15:15 Uhr
R513
Kaffee/Tee im Anschluss

Measuring the timing of the photoelectric effect

The generation of single isolated attosecond pulses in the extreme ultraviolet (XUV) together with fully synchronized few-cycle infrared (IR) laser pulses allowed to trace electronic processes on the attosecond timescale. A pump/probe technique, “attosecond streaking”, was used to investigate electron dynamics on surfaces and layered systems with unprecedented resolution.

The attosecond streaking method [1] is among the most established techniques in attosecond science. Photoelectrons generated by laser based attosecond extreme ultraviolet pulses (XUV), are exposed to a dressing electric field from well synchronized laser pulses. The energy shift experienced by the photoelectrons by the dressing field is dependent on the delay between the XUV pulse and the dressing field and makes it possible to measure the respective delay in photoemission between electrons of different type (core electrons vs. conduction band electrons). The information gained in such experiments on tungsten [2] triggered many theoretical activities leading to different explanations on the physical reason of the delay. Attosecond streaking experiments have been performed on different solids [3,4], layered structures and liquids, resulting in different delays – also depending on the excitation photon energy. These measurements lead to a stepwise increase of the understanding of different physical effects contributing to the timing of photoemission.

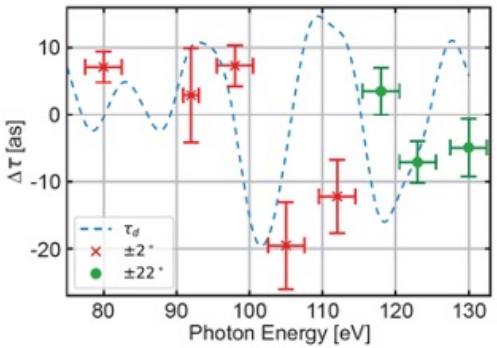

Fig. 1: Experimental data (dots/crosses with error bars) and simulation for the relative time delay between p-electrons and s-electrons of the HOPG valence band as a function of excitation energy

In the presentation, an overview on the different physical contributions to attosecond time delays in photoemission will be given. The “absolute” time delay, i.e. the delay between the instant of ionization and the emission of a photoelectron will be discussed and new measurements will be presented, e.g. the first investigation of the photoemission time delay of a single-element layered system (Highly Ordered Pyrolytic Graphite, HOPG) by attosecond chronoscopy. We present the fundamental influence of an energetic band gap on the time delay of the photoelectric effect. The reported measurements prove that the timing of the photoelectric effect exhibits a significant energy dependence if the final energy of the photoelectrons lies in the bandgap region of the investigated solid (Fig 1). Thereby, we can unambiguously attribute the identified energy-dependent phase shifts to the scattering of the photoelectrons at the periodic potential of the crystal, which we explain as the Eisenbud-Wigner-Smith (EWS) time delay. We thus disentangle an important contribution to the complex interplay between electronic structure and the attosecond dynamics of the fundamental light-matter interactions underlying the photoelectric effect.

[1] R. Kienberger et al., Nature 427, 817 (2004)
[2] A. Cavalieri et al., Nature 449, 1029 (2009)
[3] S. Neppl et al., Nature 517, 342 (2015)
[4] Ossiander et al., Nature 561, pages374 (2018)