Time-resolved photoemission: From bandstructure to orbital movies

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Time-resolved photoemission combines femtosecond pump-probe techniques with angle-resolved photoelectron spectroscopy (ARPES). While the target of many early investigations was the dynamics of surface electronic states, recent developments enable the method to basically track electron motion in momentum space on ultrafast time scales. This capability allows to explore ultrafast electronic processes of a variety of novel materials by clear-cut experiments.

In this talk, I will briefly introduce the state-of-the-art of the method and discuss a couple of examples from our recent work. These include bandstructure movies of the intraband acceleration of electrons in topologically protected Dirac surface states [1,2], of the birth and collapse of Floquet-Bloch states [3], and of the formation of momentum-forbidden and spin-forbidden dark excitons in TMDC monolayers [4]. Finally, I will outline the perspectives of photoemission orbital tomography [5] to take slow-motion movies of molecular orbitals while they are driven by lightwaves.

[1] J. Reimann *et al.*, "*Subcycle observation of lightwave-driven Dirac currents"*, Nature **562**, 396 (2018)
[2] C. P. Schmid *et al.*, "*Tunable non-integer high-harmonic generation in a topological insulator"*, Nature **593**, 385 (2021)
[3] S. Ito *et al.*, "*Ultrafast birth, rise, and collapse of a Floquet-Bloch band structure*", Nature **616**, 696 (2023)
[4] R. Wallauer *et al.*, "*Momentum-resolved exciton formation dynamics in monolayer WS_2"*, Nano. Lett. **21**, 5867 (2021)
[5] R. Wallauer *et al.*, "*Tracing orbital images on ultrafast time scales*", *Science* **371**, 1056 (2021)

Short Biography:

Ulrich Höfer received his doctoral degree in physics in 1989 from the Technical University of Munich, Germany. After spending two years as a visiting scientist at the IBM Watson Research Center in Yorktown Heights, New York, he joined the Max-Planck-Institute for Quantum Optics in Garching/Munich, as a group leader. In 1999, he became a full professor for experimental physics at the Philipps University of Marburg. Since 2022, he is also an adjunct professor of the University of Regensburg. Höfer's main research interests are ultrafast processes at surfaces and interfaces. He is a pioneer of time-resolved ARPES (angle-resolved photoemission spectroscopy) and coherent light-matter interaction at surfaces. His awards include the Arnold Sommerfeld prize of the Bavarian Academy of Sciences and a Synergy Research Grant from the European Research Council (ERC).