Time-resolved photoemission: From bandstructure to orbital movies

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Time-resolved photoemission can track electron motion in 2d momentum space. This unique capability is the key to clear-cut experiments of ultrafast electron dynamics at surfaces, interfaces, and 2d materials.

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 (accepted, 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)