Frontiers of spin-resolving momentum microscopy: towards an 'all-in-one' photoemission experiment

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Abstract

A fundamental concept in solid state physics describes the degrees of freedom of electrons in a solid by the relation of the energy E vs. the crystal momentum $\boldsymbol{k}$ in a band structure of independent quasi particles. The physical properties of modern condensed matter systems are largely determined by the details of this electronic structure. Phenomena such as magnetism and superconductivity are the result of a complex interplay of charge and spin-dependent interactions in a many-electron system on different length scales. The concepts of symmetry and topology govern the novel field of quantum materials [1]. Only recently, the comprehensive experimental access to the spin-resolved band structure at every point in the Brillouin zone became feasible by spin-resolved momentum microscopy [2]. This novel concept combines high resolution imaging of the spectral function in two-dimensional (k_x, k_y) planar sections through the valence electronic structure with an imaging spin filter [3].

This unique combination marks the long-awaited breakthrough in spin- and momentum resolving measurements of electronic states. The comprehensive information reveals intricate effects of electron interactions which directly affect our understanding of the complex interplay between magnetism, spin-orbit interaction, symmetry, and topology. For instance, our measurements give evidence that electron correlations in elemental ferromagnets like cobalt are of strongly nonlocal origin [4]. Moreover, combining strong spin-orbit interaction [5] and ferromagentism gives rise to complex spin-orbital textures, and topological phase transitions in the Fermi surface under broken fundamental symmetries [6].

The availability of spin resolving momentum microscopy opens a new avenue in photoelectron spectroscopy and paves the way towards an “All-in-One” photoemission experiment. With such an instrument, we are able to investigate spin-dependent electronic states and processes in real space ($\boldsymbol{r}$), reciprocal space ($\boldsymbol{k}$), as a function of binding energy E and time t. The accessible timescales range form several picoseconds down to a few femtoseconds, using pulsed synchrotron sources [7], free-electron laser [8], and laser-based UV-radiation facilities [9]. This unique combination provides a completely new tool set to investigate and disentangle the complex interplay of spin-dependent electronic interactions and correlations, and to image their respective dynamics in the time domain.

References

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