Soft X-ray Spectroscopy of Quantum Materials

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Without materials there is nothing. Without quantum materials there is nothing interesting. Quantum materials express our desire to find and explain new physical phenomena. In these materials, it is the complexity of the quantum mechanical interactions of the constituent electrons that gives rise to qualitatively new and unexpected behavior, offering a research field of inexhaustible depth while promising great technological potential.

To see how quantum materials work, we need to go beyond electrical transport measurements, which often provide the first clues to new electronic phenomena, and use spectroscopic tools that can provide direct snapshots of electron behavior in the machine room of materials. The most powerful toolbox in this regard is soft x-ray spectroscopy, and the single most powerful tool is angle-resolved photoelectron spectroscopy (ARPES), which has become a mainstay in imaging the momentum-dependent electronic structure of materials. Excitingly, ARPES has recently been transformed into a true *in operando* technique using nanofocused as well as ultrashort-pulsed soft x-rays to directly probe nonequilibrium electronic functions in materials and devices on relevant nanometer length and femtosecond time scales, respectively.

Here, I will give an introduction to electron behavior, quantum materials, and the novel possibilities of nanoscopic and femtostroboscopic imaging of electronic structures. The focus will be on results obtained with quasi-2D quantum materials from the transition-metal dichalcogenide family.