Spectroscopy at the Synchrotron, Microscopy of the Quantum World

Milan Radovic

PSI Center for Photon Science, Paul Scherrer Institut, Switzerland

ABSTRACT

Understanding the properties of quantum materials, such as strongly correlated electron systems, topological materials, and unconventional superconductors, requires advanced experimental techniques capable of probing their fundamental nature. Angle-Resolved Photoemission Spectroscopy (ARPES) [1] and Resonant Inelastic X-ray Scattering (RIXS) [2] are two powerful synchrotron-based techniques that provide complementary insights into the electronic structure and excitation spectra of these materials.

ARPES is an established method for directly mapping the electronic band structure of materials with momentum resolution, offering detailed insights into Fermi surface topology, electron correlations, spin-orbit coupling effects, and low-energy quasiparticle phenomena.
RIXS, on the other hand, is a highly sensitive probe of charge, orbital, spin, and lattice excitations, enabling a deeper understanding of the many-body interactions governing quantum materials. Additionally, by tuning the incident X-ray energy to a specific absorption edge, RIXS provides element- and orbital-specific information on collective excitations, including spin waves (magnons), phonons, and charge-ordering phenomena.
At modern synchrotron facilities, advancements in beamline instrumentation, high-resolution detectors, and improved sample environments have significantly enhanced both techniques, allowing for in situ studies of emergent quantum phases.

In my talk, I will present several examples demonstrating the capabilities of ARPES [3, 4] and RIXS [5] in understanding and uncovering novel phenomena in quantum materials.

1. J. A. Sobota, Y. He, and Z-X. Shen, Rev. Mod. Phys. 93, 025006 (2021).
2. M Mitrano, S. Johnston, Y.-J. Kim, and M. P. Dean, Phys. Rev. X 14, 040501 (2024).
3. M. Caputo, Z. Ristic, R. S. Dhaka, T. Das, Z. Wang, C. E. Matt, N. C. Plumb, E. B. Guedes, J. Jandke, M. Naamneh, A. Zakharova, M. Medarde, M. Shi, L. Patthey, J. Mesot, C. Piamonteze, M. Radović, Advanced Science 8 (19), 2101516 (2021).
4. H. Li, S. Yun, A. Chikina, V. Rosendal, T. Tran, E. Brand, C. H. Christoffersen, N. C. Plumb, M. Shi, N. Pryds, M. Radovic, Advanced Functional Materials 34, 2313236.
5. T. C. Asmara, R. J. Green, A. Suter, Y. Wei, W. Zhang, D. Knez, G. Harris, Y.Tseng, T. Yu, D. Betto, M. Garcia-Fernandez, S. Agrestini, Y. M. Klein, N. Kumar, C. W. Galdino, Z. Salman, T. Prokscha, M. Medarde, E. Müller, Y. Soh, N. B. Brookes, K.-J. Zhou, M. Radovic, T. Schmitt, Advanced Materials 36, 2310668 (2024).