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Phase-sensitive measurements of exotic superconducting quantum materials and hybrid superconductor devices

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Many of the most interesting quantum materials are intrinsic superconductors or are induced by proximity to a superconductor. In these materials, unique information about their quantum state and excitations can be revealed by measuring their phase-dependent properties. The directionality and phase-sensitivity of the Josephson effect, the tunneling of Cooper pairs between two superconductors, provides a powerful probe of the phase anisotropy of unconventional superconductors and the nature of coherent states in hybrid devices incorporating superconductors and complex materials. In this talk, I will first review the technique and applications of Josephson interferometry. I will describe how this approach, originally developed to determine the order parameter symmetry of the high temperature cuprate superconductors, is now being used to probe many other exotic superconducting materials which exhibit multiple superconducting states, complex order parameters that break time-reversal symmetry, and topological properties. I will then describe related techniques for measuring the current-phase relation of Josephson devices. I will outline how these are being used to study supercurrent transport in hybrid devices that reveal phase-modulated electronic structure, explore the interplay of superconductivity and magnetism, and search for exotic excitations such as Majorana fermion states in topological superconductor devices that could enable topologically-protected quantum computing.