Title: Electronic transport and topological superconductivity in nanoscopic Josephson junctions

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Abstract:

Majorana zero modes, arising in topological superconductors, are promising building blocks for fault-tolerant quantum computation due to their non-Abelian exchange statistics and intrinsic robustness against decoherence. Planar Josephson junctions have emerged as a versatile platform for engineering Majorana zero modes and studying topological superconductivity. This thesis investigates the underlying physics of Andreev bound states, Majorana zero modes, and transport properties of Josephson junctions. First, Andreev bound state spectra of junctions in a perpendicular magnetic field are investigated. It is shown how the vector potential produces the relative phase shifts in the spectra, providing a transparent explanation of experimental tunneling spectroscopy measurements. Building on this, the interplay between spin–orbit coupling and magnetic field in Josephson junctions is studied with the demonstration of how nonlocal conductance can serve as a reliable probe of topological superconductivity. Realistic device limitations, such as phase slips in junctions embedded in superconducting loops, are shown to hinder the emergence of Majorana zero modes at low magnetic fields. To address this issue, it is proposed to elongate the junction, which widens the accessible phase interval and reduces the magnetic field required for the topological transition. This work contributes to the study of Josephson junctions as a promising platform for realizing Majorana zero modes, by exploring their transport properties, and by guiding experimental implementations.

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