Topological Quantum Computing and Planar Josephson Junctions: Anisotropy, Finite-Size Effects, Superconducting Diodes, and Microwave Manipulation and Detection

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Abstract:

Planar Josephson junctions provide a platform to host topological superconductivity which, through manipulating Majorana bound states, could enable fault-tolerant quantum computing. A standard model of these Josephson junctions, which can be fabricated to have a nearly perfect interfacial transparency, predicts a simple universal behavior: At a single critical value of Zeeman field, the system undergoes a topological transition with a π phase jump and a minimum in the critical superconducting current I_c, while applying a controllable phase difference yields a diamond-shaped topological region as a function of ϕ and a Zeeman field. In contrast, even for a perfect interfacial transparency, we find a much richer and nonuniversal behavior for a finite-sized system with possible anisotropies, where the topological phase diagram is shifted and distorted, the phase jump is smooth and I_c dips aren't absolute. These Josephson junctions show a striking example of a nonreciprocal transport and superconducting diode effect. Guided by the advances in microwave spectroscopy, we consider Al/InAs-based planar Josephson junctions embedded in an RF-SQUID to identify possible microwave signatures of topological superconductivity. Remarkably, we show that even in a wide planar Josephson junction with many Andreev bound states, such a topological signature is distinguishable in the resonance frequency shift of a microwave drive. Our findings provide guidance for future superconducting spintronics and an important step towards experimental detection of non-Abelian statistics and implementing scalable topological quantum computing.

Biography:

Dr. Barış Pekerten received his M.Sc. from IZTECH under the supervision of Doğan Abukay and his Ph.D. from Sabancı University under the supervision of İnanç Adagideli. He subsequently held postdoctoral positions with Alex Matos-Abiague at Wayne State University and with Igor Žutić at the University at Buffalo, SUNY. His research focuses on topological superconductivity, planar Josephson junctions, and their applications in quantum computing.