Hybrid Qubits in Kitaev Chains

Tobias Kuhn
Raffael Klees
Monica Benito

University of Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

tobias.kuhn@uni-a.de

The goal of this project is to investigate superconducting quantum dot arrays integrated with superconducting circuits as possible platforms for hybrid qubits. Under the appropriate magnetic fields, the effective mechanism of superconducting pairing along such arrays was predicted to be a spinless *p*-wave type, leading to the realization of a Kitaev chain with Majorana zero modes [1]. When two such chains are embedded in a transmon circuit, hybrid qubits are formed [2] that could harness the controllability of transmon qubits and the topological protection of Majorana modes. In particular, we derive an effective low-energy Hamiltonian of the minimal Kitaev model [3], study extensions to longer chains as well as embeddings into circuit QED architectures [4]. As a future goal, the ability to perform single-qubit operations will be a first step towards quantum computing in such hybrid devices [5,6].

References

[1] A. Y. Kitaev, Phys.-Usp. **44,** 10S (2001) 131
[2] D. M. Pino, R. Seoane Souto, and R. Aguado, Phys Rev. B **109,** 7 (2024) 075101
[3] M. Leijnse and K. Flensberg, Phys. Rev. B **86**, 13 (2012) 134528
[4] A. Blais, A. L. Grimsmo, S. M. Girvin, and A. Wallraff, Rev. Mod. Phys. **93**, 2 (2021) 025005
[5] A. Bargerbos et al., Phys. Rev. Lett. **131**, 9 (2023) 097001
[6] M. Geier et al., arXiv:2307.05678 (2023)

Figures

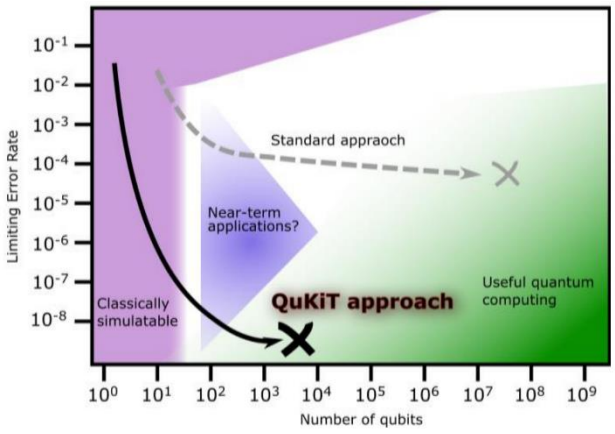

Figure 1: Roadmap for the QuKiT project to fabricate high fidelity qubits. The Kitmon qubit is expected to reduce the limiting error rate harnessing topological protection of Majorana modes while sacrificing some scalability.

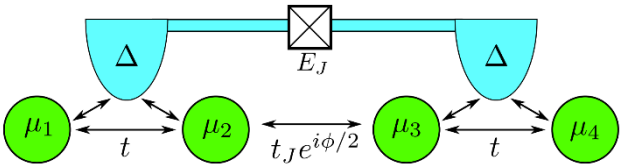

Figure 2: Proposed minimal realization of the Kitmon qubit. Two minimal Kitaev chains (green) with onsite energy μ_{1-4} coupled by a superconducting transmon circuit (cyan) with Josephson energy E_J form a local parity qubit. This device supports elastic cotunneling t, crossed Andreev reflection Δ and Josephson coupling t_J with superconducting phase difference ϕ.