Quantum circuits with multiterminal Josephson-Andreev junctions

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In quantum circuits, a conventional tunnel Josephson junction is described in terms of its macroscopic degrees of freedom: the number of tunneled Cooper pairs and its conjugate variable, the phase difference. But this approximation is only valid when the fermionic excitations of the junction itself are far from the lowest circuit levels. In fact, these junctions are just a particular case of a weak link between superconductors, where their internal structure combines with the superconducting leads to form Andreev bound states, typically examined at a fixed phase difference. Here [1], we explore the intermediate regime, i.e., a weak link where the phase fluctuations are important, which is now becoming experimentally accessible [2]. We consider a multiterminal junction embedded in different kinds of circuits and discuss, on the one hand, its application to the design of protected qubits [3] and, on the other hand, more fundamental questions about its topological properties and the proper quantization rules [4].

References

[1] Cf. arXiv:2312.17305 (2023)
[2] A. Bargerbos et al., Phys. Rev. Lett., 124, 246802 (2020); M. Coraiola et al., arXiv:2307.06715; T. Vakhtel et al., Phys. Rev. B 107, 195405 (2023), arXiv:2310.03102 (2023)
[3] A. Gyenis et al., PRX Quantum 2, 030101 (2021)
[4] R. P. Riwar et al, Nat. Comm., 7, 11167 (2016), npj Q. Inf. 8, 36 (2022); X. You et al., Phys. Rev. B, 99 174512 (2019)

Figures

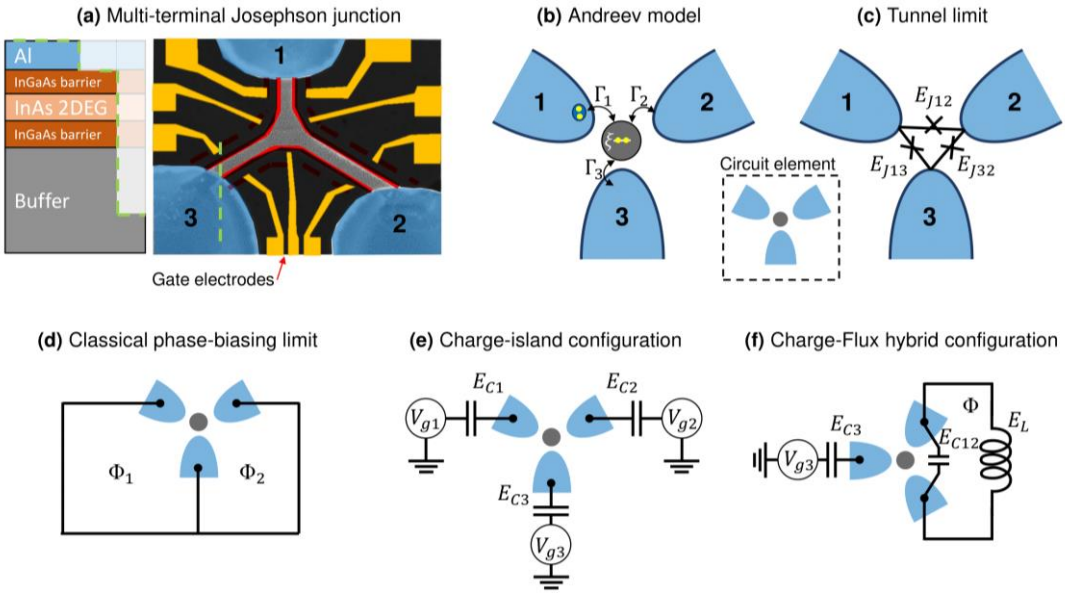

Figure 1: (a) Possible realization of the trijunction with 3 superconducting leads (blue) and a central region confined by tunable barrier gates (yellow). (b) Model accounting for the central region by a single level. (c) Effective model with 3 tunnel Josephson junctions. (d-f) Three circuits we analyse: in (d), the phases are fixed by external fluxes; in (e), the leads are islands with finite charging energy; in (f), two leads form a loop with finite inductance – this configuration can implement analogues of the bifluxon and the 0-π qubits, protected against decoherence induced by charge and flux noise.