Superconductings Nanocircuits for Topologically Protected Qubits

Sergey Gladchenko [1], David Olaya [1], Eva Dupont-Ferrier [1], Benoit Douçot [2], Lev Ioffe [1], and Michael Gershenson [1]

[1] Department of Physics and Astronomy, Rutgers University, 136 Frelinghuysen Rd., Piscataway, NJ 08854, USA
[2] Laboratoire de Physique Théorique et Hautes Energies, CNRS UMR 7589, Universités Paris 6 et 7,4, place Jussieu, 75005 Paris, France

For successful implementation of quantum computing, the logical elements of a quantum computer (qubits) should be simultaneously scalable and sufficiently decoupled ("protected") from environmental noise. In order to decouple the logical variable of a qubit from different local sources of noise, two approaches have been proposed. One of them is based on tuning the qubit control parameters in such a way that the qubit becomes less susceptible to noise. The existence of a "sweet spot" in the qubit parameters space, where the qubit is decoupled from noise in linear order, has been already established for superconducting qubits. At the same time, these experiments indicate that the linear-order decoupling is insufficient for practical realization of quantum computing. Our team pursues an alternative approach, which is based on the incorporation of error corrections at the "hardware" level, due to nontrivial symmetries which appear for properly engineered interactions between superconducting elements in qubits [1-3]. Realization of these fault-tolerant (topologically protected) superconducting qubits would offer suppression of coupling to noise well beyond linear order. Our proof-of-concept experiments show that even a relatively small prototype device is well protected against magnetic flux variations. These results provide an essential test for the proper strength of quantum fluctuations in the structure made of nanoscale Josephson junctions and demonstrate the viability of an idea of topologically protected superconducting qubits.

[1] B. Doucot et al., Phys. Rev. Lett. 90, 107003 (2003).
[2] B. Doucot et al., Phys. Rev. B 71, 024505 (2005).
[3] I.V. Protopopov and M.V. Feigelman, Phys. Rev. B 74, 064516 (2006).