A fermion-parity qubit in a double quantum dot

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Quantum dots (QDs) allow to control and manipulate the quantum mechanical properties of individual electrons using external potentials and electromagnetic fields. Their exquisite tunability as well as their long coherence times give them a central role in the development of quantum technologies, being the base for charge and spin qubits. However, QD states decohere due to charge fluctuations and random magnetic fields coming from the environment, limiting their use for applications. On the other hand, superconductors have played a central role in the development of quantum technologies, thanks to their macroscopic quantum properties.

In this presentation, I will introduce a new qubit type based on the combination of quantum dots and superconductors, exploiting some of the advantages of both platforms. Bound states that appear in quantum dots coupled to superconductors can be in a coherent superposition of states with different electron number but with the same number parity. Electrostatic gating can tune this superposition to a sweet spot, where the quantum dot has the same mean electric charge independent of its electron-number parity [1]. Here, we propose to encode quantum information in the local fermion parity of two tunnel-coupled quantum dots embedded in a Josephson junction [2]. At the sweet spot, the qubit states have zero charge dipole moment. This protects the qubit from dephasing due to electric field fluctuations. Depending on the strength of the tunnel coupling between the dots, the system is further protected towards either relaxation (weak tunneling) or dephasing (strong tunneling) from noise coupling separately to each quantum dot. We describe initialization and readout as well as single-qubit and two-qubit gates by pulsing gate voltages.

References

[1] E. J. H. Lee, X. Jiang, M. Houzet, R. Aguado, C. M. Lieber, and S. De Franceschi, Nat. Nanotechnol. **9**, 79 (2014).
[2] M. Geier, R. Seoane Souto, J. Schulenborg, S. Asaad, M. Leijnse, and K. Flensberg, arXiv: 2307.05678 (2024)

Figures

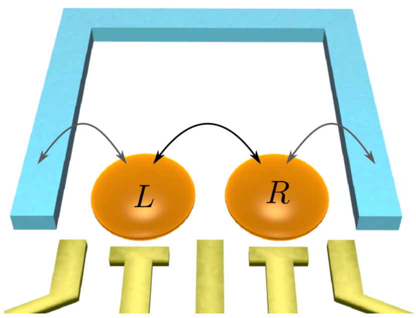

Figure 1: Sketch of the proposed parity qubit, where two QDs (orange) couple to a superconductor (blue). The loop allows for phase control.