A Josephson phase battery

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A classical battery converts chemical energy into a persistent voltage bias that can power electronic circuits. Similarly, a phase battery is a quantum device that provides a persistent phase bias to the wave function of a quantum circuit. It represents a key element for quantum technologies based on phase coherence. Starting from the Josephson effect, we discuss the realization of a phase battery in a hybrid superconducting circuit. It consists of an n-doped InAs nanowire with unpaired-spin surface states, that is proximitized by Al superconducting leads. It has been found that the ferromagnetic polarization of the unpaired-spin states is efficiently converted into a persistent phase bias φ_0 across the wire, leading to the anomalous Josephson effect. By applying an external in-plane magnetic field one can achieve continuous tuning of φ_0, hence charging and discharging the quantum phase battery. A theoretical model consistent with the observed symmetries of the anomalous Josephson effect in the vectorial magnetic field is also presented. Our results demonstrate how the combined action of spin-orbit coupling and exchange interaction induces a strong coupling between charge, spin, and superconducting phase, which is able to break the phase rigidity of the system and produce a phase battery [1].

[1] E. Strambini, A. Iorio, O. Durante, R. Citro, C. Sanz-Fernández, C. Guarcello, I. V. Tokatly, A. Braggio, M. Rocci, N. Ligato, V. Zannier, L. Sorba, F.S. Bergeret, F. Giazotto, ***A Josephson quantum phase battery***, Nat. Nanotechnol. 15, 656–660 (2020).