Theory of three-terminal Andreev spin qubits

Kiryl Piasotski,
A. Svetogorov, W. Belzig, and M. Pletyukhov

Institut für Theorie der Kondensierten Materie (TKM), Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany

Institut für Quanten Materialien und Technologien (IQMT), Karlsruher Institut für Technologie, 76021 Karlsruhe, Germany

kiryl.piasotski@kit.edu

Abstract

In this work, we introduce a concise theoretical framework for the equilibrium three-terminal Josephson effect in spin-orbit-interacting systems, inspired by recent experiments on an InAs/Al heterostructure [1]. We develop an analytical model to capture the essential low-energy physics of the system and examine its potential as an Andreev spin qubit, while also reconciling some findings of Ref. [2]. Our analysis of the transitions between the Andreev levels in the junction shows that, in an idealized scenario, the transition between the lowest pair of pseudo-spin-split Andreev levels is blocked by pseudo-spin conservation. We demonstrate that to operate the system as an Andreev spin qubit, leveraging the significant spin splitting observed experimentally, additional ingredients such as external magnetic filed or magnetic impurities are required. Finally, we apply our model to investigate the coupling between two such qubits, mediated by supercurrent.

References

1. Phys. Rev. X **14**, 031024 (2024).
2. Phys. Rev. B **90**, 155450 (2014).