Cooper pair entanglement manipulation in hybrid topological Josephson junctions

Gianmichele Blasi, Fabio Taddei, Vittorio Giovannetti, and Alessandro Braggio

Istituto Nanoscienze CNR, NEST, Scuola Normale Superiore, Piazza San Silvestro 12, Pisa 56127, Italy

We investigate the supercurrent of hybrid topological Josephson junction done by two superposed layer of 2D topological insulator which allows local (LAR) and crossed (CAR) Andreev reflections with the s-wave leads [1]. We show that by simply applying gate potentials or magnetic flux to the junction one can uniquely affect the dissipationless current. We demonstrated that the gating, thanks to its symmetry with respect to time-reversal and its differential action between upper an lower layer, is capable to change the spin symmetry of non-local Cooper pairs from singlet to triplet. We establish both analytically and numerically the connection between the Josephson current-phase relationship and the manipulation of external potentials to local and nonlocal components. We discuss notable limits, such as the single-shot regime, which clearly demonstrate that entanglement symmetry is manipulated and that can be identified in the critical current. We examine the universal behavior of the critical current, how it depends on the amplitude ratio between the CAR and LAR processes and on the external potential manipulations. Finally we clarify the role of the multiple Andreev reflection in the presented phenomenology.

The proposed setup and the simple signature in the dependence from external potentials are expected to be experimental accessible with the measurement of the critical currents which one the most basic characterization of a Josephson junctions.

[1] G. Blasi, F. Taddei, V. Giovannetti and A. Braggio, Phys. Rev. B 99 (2019) 064514.