Michihisa Yamamoto[1]
Ivan V. Borzenets[1], Chung-Ting Ke[2], Francois Amet[2], Yuya Shimazaki[1], Gleb Finkelstein[2], Seigo Tarucha[1, 3]
[1]Department of Applied Physics, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan
[2]Department of Physics, Duke Univeristy, Durham, NC, USA
[3]Center for Emergent Matter Science (CEMS), RIKEN, Saitama, Japan

yamamoto@meso.t.u-tokyo.ac.jp

Graphene-based Cooper pair splitters

Graphene-superconductor junctions allow us to create variety of gate-tunable superconductor devices. One of the examples is the graphene-based Cooper pair splitter. Two electrons of a Cooper pair are scattered into opposite valley and spin in graphene. The spatial splitting of a Cooper pair in graphene therefore generates a non-local spin entangled state.
In this talk, we present demonstration of graphene-based Cooper pair splitters. We first present a Cooper pair splitter utilizing charging energy of two closely separated graphene quantum dots contacted with a proximity induced graphene superconductor [1]. High efficiency is achieved owing to the large coherence length of the graphene superconductor compared to the distance between the two quantum dots. We also find in clean graphene-based Josephson junctions that the supercurrent can flow through a quantum Hall state [2]. This supercurrent is carried by an Andreev bound state at which an electron incident on the superconductor from one of the graphene edges is reflected as a hole in the other edge, mediated by a charge-neutral electron-hole hybrid mode at the interface. It is thus realization of the perfect Cooper pair splitter. We also briefly present systematic analysis of the critical current in such Josephson junctions. The temperature dependence of the critical current allows us to identify and observe the crossover from the short ballistic to the long ballistic junction regimes, characterized by the ratio of the superconducting coherence length ξ to the junction length L [3]. At low temperatures, we show that the critical current saturates at a level determined by the product of the governing energy ($\Delta \propto 1/\xi$ or $\delta E \propto 1/L$) and the number of the junction's transversal modes. The analysis also allows us to evaluate the graphene-superconductor junction transparency, showing that almost ideal junctions are realized.
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References

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