Supercurrent noise in short ballistic graphene Josephson junctions

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Short ballistic graphene Josephson junctions sustain superconducting current with a non-sinusoidal current-phase relation up to a critical current threshold. The current-phase relation, arising from proximitized superconductivity, is gate-voltage tunable and exhibits peculiar skewness observed in high quality graphene super-conductors heterostructures with clean interfaces. These properties make graphene Josephson junctions promising sensitive quantum probes of microscopic fluctuations underlying transport in two-dimensions. Understanding material-inherent microscopic noise sources possibly limiting the phase-coherent behavior of GJJ-based quantum circuits represents an essential, still unexplored, prerequisite. In this presentation we first demonstrate that fluctuations with 1/f power spectrum of the critical current of a short ballistic GJJ directly probe carrier density fluctuations of the graphene channel induced by the presence of charge traps in the nearby substrate, modeled by a spatially uniform distribution of independent generation–recombination centers. Secondly, we study the effect of a dilute homogeneous spatial distribution of non-magnetic impurities on the equilibrium supercurrent within the Dirac-Bogoliubov-de Gennes approach and modeling impurities by the Anderson model. The potentialities of the supercurrent power spectrum for accurate spectroscopy of the hybridized Andreev bound states-impurities spectrum are highlighted. In the low temperature limit, the supercurrent zero frequency thermal noise directly probes the spectral function at the Fermi energy. Our results suggest a roadmap for the analysis of decoherence sources in the implementation of coherent devices by hybrid nanostructures.

[1] F. M. D. Pellegrino, G. Falci, E. Paladino arXiv:2203.04017

[2] F. M. D. Pellegrino, G. Falci, E. Paladino Comm. Phys. 3:6 (2020)