Spectroscopy of Andreev bound states in a hybrid semiconductor-superconductor Josephson junction

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Planar Josephson junctions realized on proximitized semiconductors are a platform to study topological superconductivity that has been intensively studied within the last few years. In those devices, a spin-orbit coupled semiconducting region connected to two superconducting contacts can be engineered into a topological state that is controlled by the phase difference between the superconductors [1]. Tunneling spectroscopy of the semiconductor is used to probe the Andreev bound states spectrum and ultimately the formation of Majorana bound states [2, 3]. We explain that the magnetic flux penetrating the inductive superconducting loop embedding the Josephson junction induces superconducting phase evolution in the system, and allows to recover the Andreev bound states structure from the experimental measurements. Based on recent experimental results, we show that in fact the Andreev bound states spectroscopy is sensitive mostly to the states located on the edges of the junction, e.g., close to the tunneling barriers. This effect becomes visible in the transverse magnetic field that induces crosswise phase shifts of Andreev bound states located on the edges [4], as found in the experiment and confirmed in our numerical simulations. Moreover, we show how the finite electron mean free path and superconducting coherence length impact the results of tunneling spectroscopy and the visibility of the edge and bulk Andreev bound states.

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