

Spectroscopy of Andreev bound states using microwave resonators

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We will report on our current efforts to perform spectroscopy of Andreev bound states Josephson junctions formed in InAs nanowires coupled with a microwave cavity. We form coplanar waveguide microwave resonators from thin films of TiN and couple inductively a nanowire Josephson junction in an rf-SQUID geometry, Fig. 1 (b). Our nanowire junctions are formed using MBE grown InAs nanowires with an *in-situ* deposited Aluminium half shell ensuring high transparency superconducting contacts. For a suitable gate condition resulting in a low number of channels we are able to observe the dispersive shift of the cavity resonance due to interaction with Andreev bound states in the junction. The application of a second microwave tone then allows the probing of the possible photon mediated transitions in the system revealing the full phase dispersion of states within a frequency range <20GHz, Fig. 1 (a). Ultimately we aim to probe the dispersion of Andreev states in high magnetic fields to explore the crossover from the trivial to topological regime in which the signature of Majorana modes maybe detected through the observable trivial modes or possible single particle transitions. Toward this end we are developing microwave resonators which can operate in large in-plane magnetic fields up to several Tesla. Additionally we are interested in probing states in other systems such as Bismuth nanowires, Graphene or WTe₂ monolayers.

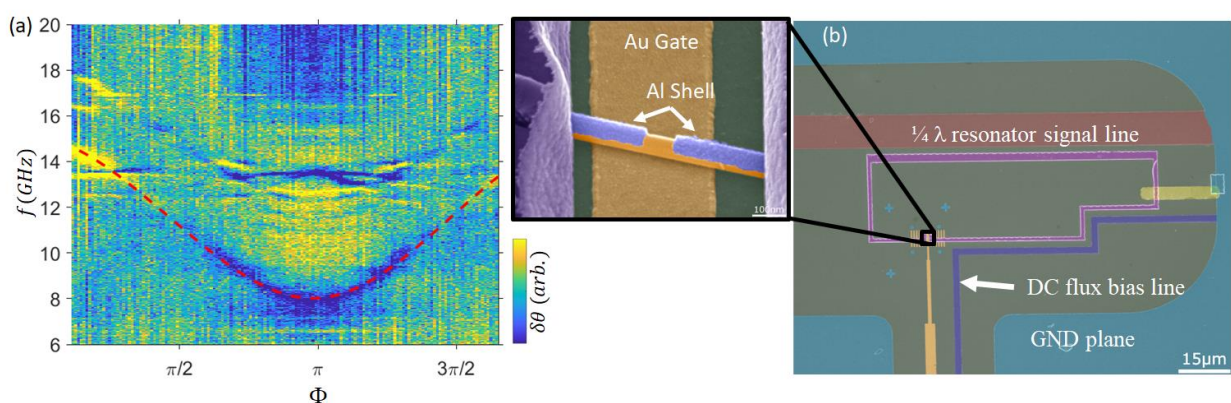


Fig. 1 (a) Example two tone spectroscopy measurement showing the phase shift measured at the bare resonance frequency of the cavity as a function of DC flux bias (Φ) and frequency of a second excitation tone. (b) Example device showing the rf-SQUID coupled to a 1/4 wavelength coplanar waveguide resonator fabricated from a TiN thin film. The rf-SQUID is formed from NbTi with a Josephson junction comprised of an InAs NW with epitaxial Aluminium contacts.