Dynamics of Superconductor-Semiconductor Josephson junctions

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In 1937, Ettore Majorana, predicted the existence of a particle that is its own anti-particle, the Majorana fermion [1]. After extensive search in high energy physics no positive results are reported up to today. After first ideas of engineering a Majorana state of Alexei Kitaev in 2001 [2]. In 2010, two independent groups of condensed matter theorist proposed to engineer a Majorana state in a one dimensional semiconductor channel proximity coupled to a superconductor in an external applied magnetic field [3,4]. Two years later, the group of Leo Kouwenhoven found in such a system strong signatures of the existence of the Majorana state[5]. In addition to the fundamental interest in Majorana physics, there is also the interest to build a robust topological qubit where the qubit state could be changed by braiding Majorana states around each other. The qubit state relies on the parity state of the superconducting circuit, and to this end we showed parity control in the host superconductor of the Majorana's (NbTiN) and timescales up to 1 minute [6].
To further investigate the nanowire/superconductor structure we embed the nanowire in a Josephson junction geometry. Here we perform Andreev bound state (ABS) spectroscopy utilizing an on/chip coupling of photons emitted by inelastic Cooper pair tunneling by a SIS junction. We demonstrate electrostatic gate control of the transmission and the number of ABS in the semiconductor channel. The magnetic field dependence shows hints of strong spin-orbit interaction and time reversal symmetry breaking in the nanowire.
In a final round of experiments, we voltage bias a nanowire Josephson junction to investigate the periodicity of the AC Josephson relation. We show our recent results exhibiting a pronounced gate tenability of the AC Josephson effect measured by both inelastic Cooper-pair tunneling of the nanowire junction and photon-assisted quasiparticle tunnel current in an AC-coupled SIS tunnel junction.

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