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Coherent Quantum Phase Slip

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Abstract:

We are carrying out studies of coherent quantum phase slip (CQPS) effect which is the exact quantum mechanical conjugate to the Josephson effect. It is a phenomenon involving coherent tunneling of magnetic flux across a thin superconducting wire, just like tunneling of Cooper-pair across thin insulator in the Josephson tunnel junction. There are hopes of constructing various unique CQPS-based quantum devices conjugate to conventional structures relying on Josephson tunnel junctions. Examples include a current standard conjugate to the Josephson voltage standard for quantum metrology, and a superconducting quantum charge detector conjugate to the Superconducting QUantum Interference Device (SQUID) flux sensor.

Following our initial observation of CQPS in InOx nanowires [1], we are studying the behavior of the flux tunneling amplitude as a function of the wire width, typically between 10 and 50 nanometers, and its reproducibility in the disordered superconductors NbN and TiN [2]. The phenomenon is revealed as a superposition of flux states in a superconducting loop with the nanowire acting as an effective tunnel barrier for the magnetic flux. We couple the two-level systems to a coplanar waveguide resonator, and characterize them using microwave spectroscopy. As a result, we obtained an exponential dependence of the

CQPS energy on the wire width, as predicted by theory. In addition, coherent oscillations are revealed in time-domain measurements. Besides nanowires fabricated from these highly disordered superconductors with large kinetic inductance, we observe two-level system behavior also in purposely-made short and narrow constrictions in both NbN and TiN films.

[1] O. V. Astafiev et al., Nature 484, 355 (2012).
[2] J. T. Peltonen et al., Phys. Rev. B 88, 220506(R) (2013).