

Coherent quantum phase slip in superconducting nanowire

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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 Inerference 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.

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 [3]. Quantum state control and coherent oscillations in the driven time evolution are achieved in such samples [3].

[1] O. V. Astafiev et al., *Nature* 484, 355 (2012).

[2] J. T. Peltonen et al., *Phys. Rev. B* 88, 220506(R) (2013)

[3] J. T. Peltonen et al., *Phys. Rev. B* 94, 180508(R) (2016)