Coherent quantum phase slip

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***Abstract*—Coherent quantum phase slip (CQPS) experiment is described, 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.**

Keywords—superconductivity, coherent quantum phase slip, Josephson effect

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.

Direct observation of the CQPS in was made in a flux qubit with narrow superconducting segment, as shown in Fig 1. As in the figure, flux qubit was positioned in a coplanar waveguide microwave resonator. In this circuit, quantum coherence due to CQPS effect was observed as gap energy in the spectroscopic analysis, as shown in Fig. 2. [1].

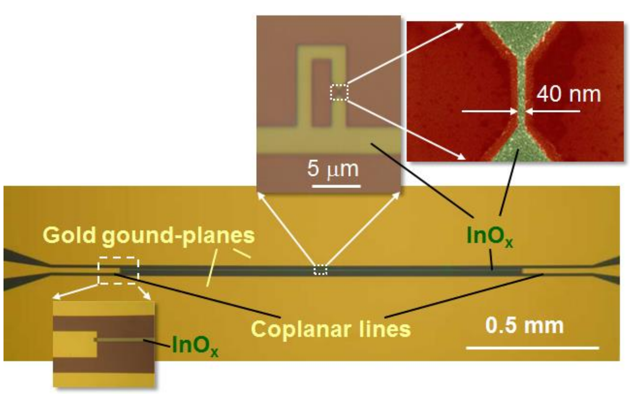

Fig. 3. CQPS qubit in resonator

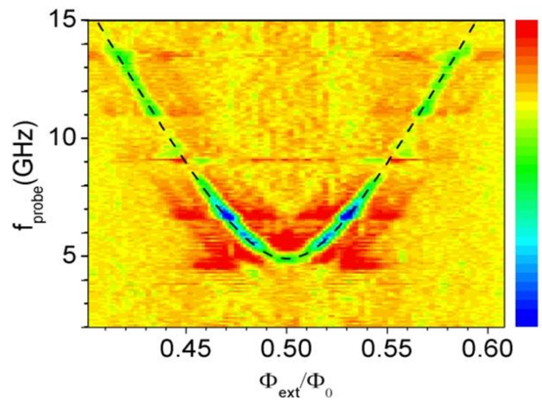

Fig. 1. Spectroscopy of the CQPS qubit showing energy gap

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 as shown in Fig. 3. [2]. 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.

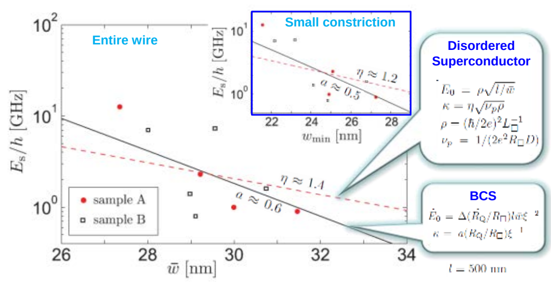

Fig. 3. Width dependence of the CQPS energy

Acknowledgment

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References

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