MICROWAVE PHOTON SOURCE BASED ON SINIS JUNCTIONS

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Microwave photons in a superconducting resonator have been used as information carriers and for controlled qubit operations in various superconducting quantum computing architectures [1]. For superconducting qubits, microwave photons may also provide interactions between the qubits and coupling to a dissipative environment [2]. Thus accurate and rapid control of photonic states of microwave resonators is important in the development of quantum information technology. However, an active control of the photonic quantum state using single-electron tunneling across superconducting–insulator–normal–metal (SIN) junctions has not been harnessed to date.

We propose and demonstrate a new method to control the quantum state of a microwave resonator in a mesoscopic device utilizing controlled single–electron tunneling across SIN junctions. We study a device, in which a superconducting coplanar resonator is coupled to SIN junctions (see the figure below). When an electron tunnels across a SIN junction, it absorbs a photon from or emits it to the resonator. Using the bias voltage applied to the SIN junctions, this mechanism allows us to electrically control the output power from the device which works as a microwave photon source.

In our theoretical model, we calculate the power between the resonator and tunneling electrons using $P(E)$ theory [3] and obtain the power between the resonator and the transmission line using the method developed in Ref. [4]. Numerical results show agreements with the experimental results in low voltage regime. The model can also be used to examine the time evolution of the resonator state.

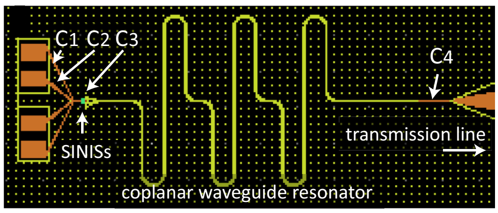

Figure: Schematics of the device design. Two pairs of SIN junctions and a transmission line are capacitively coupled to coplanar superconducting resonator. $\mathrm{C}_{1,2,3,4}$ denote parallel–plate capacitors.

[1] J. Kelly et al., Nature **519**, 66 (2015).

[2] M. Partanen, K. Y. Tan, J. Govenius, R. E. Lake, M. K. Mäkelä, T. Tanttu, M. Möttönen, appears in Nature Physics, arXiv:1510.0398 (2015).

[3] G. -L. Ingold and Yu. V. Nazarov, *Single Charge Tunneling*, NATO ASI Series B, Vol. 294, Chap. 2 (Plenum Press, New York, 1992).

[4] P. J. Jones, J. Salmilehto and M. Möttönen, J Low Temp. Phys. **173**, 152 (2013).