Experiments on temporally controllable dissipation in superconducting quantum circuits

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Quantum technology promises revolutionizing applications in information processing, communications, sensing, and modelling. However, efficient on-demand cooling of the functional quantum degrees of freedom remains a major challenge in many solid-state implementations, such as superconducting circuits. Here, we demonstrate direct cooling of a superconducting resonator mode using voltage-controllable photon-assisted tunneling of electrons [1]. The experimental results are in good quantitative agreement with our theoretical model which suggests that this kind of a quantum-circuit refrigerator is a very powerful tool in providing on-demand dissipation to a large class of quantum electric devices. For the superconducting quantum computer, for example, it may offer an efficient way of initializing the quantum bits.

At high bias voltages across the tunnel junctions of the quantum-circuit refrigerator, we observe direct heating of the resonator mode instead of cooling. Our experimental observations [2] of the power spectral density of the generated radiation reveal that the resonator mode can be at as high temperature as 2.5 K although the phonon and electron reservoirs are well below a kelvin. Consequently, the device may also be used as an incoherent photon source with voltage controllable output power exceeding those of the previous cryogenic sources based on single-charge tunneling. Finally, we measure the reflection co-efficient of the resonator as a function of the refrigerator operation voltage and observe that the voltage exponentially changes the dissipation rate inside the resonator. These experiments further support the validity of our theoretical model and our conclusions based on the first experiments in Ref. [1].

In summary, the quantum-circuit refrigerator is a promising component for initializing quantum electric devices and studying open quantum systems in general.

[1] K. Y. Tan, M. Partanen, R. E. Lake, J. Govenius, S. Masuda, and M. Möttönen, arXiv: 1606.04728 (2016)

[2] S. Masuda, K. Y. Tan, M. Partanen, R. E. Lake, J. Govenius, M. Silveri, H. Grabert, and M. Möttönen, arXiv:1612.06822 (2016)