Quantum refrigeration powered by noise in a superconducting circuit

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While dephasing noise frequently presents obstacles for quantum devices, it can become an asset in the context of a Brownian-type quantum refrigerator. Here we demonstrate a novel quantum thermal machine that leverages noise-assisted quantum transport to enable a cooling engine in steady state. The device exploits symmetry-selective couplings between a superconducting artificial molecule and two physical heat baths. Each bath is realized with a microwave waveguide populated with synthesized quasithermal radiation. Energy transport is enabled by injecting dephasing noise through a third channel that is longitudinally coupled to one of the two artificial atoms of the molecule. By varying the relative effective temperatures of the reservoirs and measuring photonic heat currents with a resolution below 1 attowatt, we demonstrate that the device can be operated as a quantum heat engine, thermal accelerator and refrigerator. Our work is the first demonstration of a Brownian refrigerator and opens new avenues for experiments in quantum thermodynamics using superconducting circuits coupled to physical heat baths.

Figures

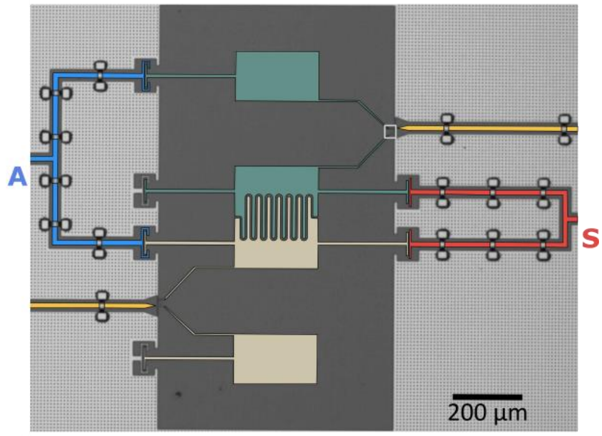

Figure 1: False-color micrograph of the device comprised of two frequency-tunable transmons, colored in green and beige, coupled to microwave waveguides labeled S (red) and A (blue). Flux lines coupling longitudinally to the system are colored in yellow.

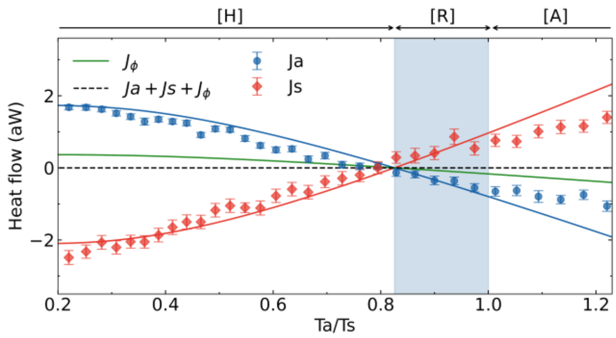

Figure 2: Heat flows from averaged power measurements through the antisymmetric (blue) and symmetric (red) waveguides as a function of their temperature ratio Ta/T. Whilst Ts remains fixed at 177 mK, Ta is increased from base temperature to 217 mK. The first region [H] marks the operational regime of a heat engine, [R] that of a refrigerator (shaded blue region) and [A] a thermal accelerator.

References

[1] S. Sundelin, M. A. Aamir, V. M. Kulkarni, C. Castillo-Moreno, and S. Gasparinetti. Quantum refrigeration powered by noise in a superconducting circuit. arXiv:2403.03373 (2024)