Autonomous Quantum Heat Engine

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Quantum heat engines provide appealing means in quantum thermodynamics for studying the flow of heat and work in open quantum systems. Experimental implementations of heat engines operating at the level of a few excitation quanta require external driving, which has made the observation of produced work challenging. Conversely, autonomous quantum heat engines only require a flow of heat to operate and generate usable work. However, autonomous quantum heat engines have not yet been experimentally demonstrated in any system despite numerous theoretical investigations. Here, we experimentally realize an autonomous quantum heat engine based on superconducting circuits. We construct the engine circuit implementing an approximate Otto cycle by coupling two superconducting resonators with a superconducting quantum interference device, and coupling this system to spectrally filtered hot and cold reservoirs. For varying the initial conditions, we observe coherent microwave power generation arising from the internal dynamics of the system driven only by the thermal reservoirs. Our results validate previous theoretical predictions for this quantum circuit [1], enable experimental studies of autonomous heat engines, and in general, provide means to enable the conversion of excess heat into coherent microwave radiation.

[1] M. Rasola, V. Vadimov, T. Uusnäkki, and M. Möttönen, SciPost Phys. 19 (2025) 101.