Quantum Thermodynamics with Two Coupled Superconducting Qubits

MSc Thesis @ Quantum Technology Laboratory

In the past 20 years, **superconducting circuits** have emerged as a leading architecture for quantum information processing [1], with prospected applications in the areas of computation, simulation, and communication. At the same time, these systems constitute **an ideal platform to gain insight on fundamental aspects of quantum mechanics**, including, for instance, the meaning of measurement and the quantum-classical boundary.

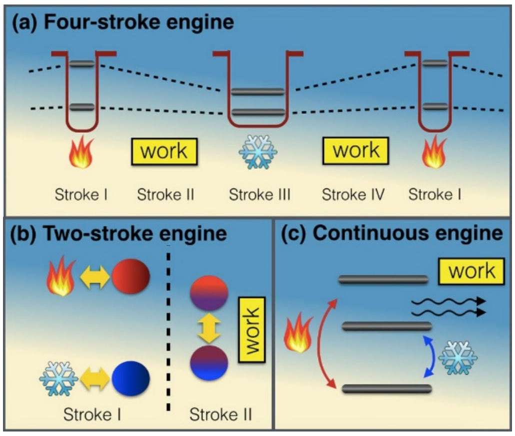
You will work with two superconducting quantum bits (qubits) such as those that we are currently developing to build a quantum computer. However, you will look at this composite system from a different perspective and explore its ability to **mediate the exchange of heat between thermal reservoirs**. In doing so, you will contribute to an ongoing debate in the scientific community: How are the laws of thermodynamics modified at the nanoscale? Does quantum mechanics play a *fundamental* role in it? And is there some form of ***quantum advantage*** that we can use to boost the performance of an engine [2], a refrigerator [3], a battery [4]?

You will: • Measure samples cooled down to below 20mK in a state-of-the-art dilution refrigerator, utilizing state-of-the-art microwave electronics operating in the 4-12GHz band • Interpret the results based on data analysis, fitting, and comparison to simulations.

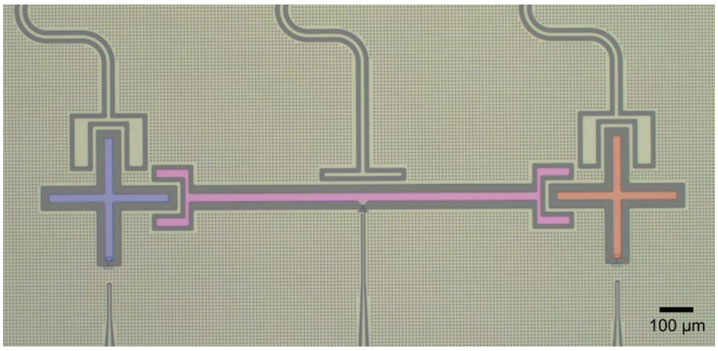
You will also: • Study the system dynamics by solving a master equation • Design a quantum circuit to implement the desired Hamiltonian with electromagnetic simulation software, with the help of experienced students and staff.

What's in for you: • Hands-on training on cutting-edge equipment and techniques relevant for a broad range of quantum technology applications • A unique mix of fundamental and applied science • Daily interactions with our team of quantum technologists • Possibility to continue as a PhD student

What we value: • Motivation, curiosity, independence, problem solving skills, ability to work in a team, creativity. • A good understanding of classical electrodynamics and basic quantum mechanics, and basic coding skills are required. • Previous lab experience, experience with numerical simulations and data analysis, are appreciated.



Different types of heat engines involving quantum systems or particles. Adapted from [2].



A system of two superconducting qubits (red, blue) can act as a heat engine. Micrograph courtesy of A. Bengtsson.

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Further reading

[1] M. Devoret and R. J. Schoelkopf, Science, **339**, 1169 (2013).
[2] R. Uzdin, A. Levy, and R. Kosloff, PRX, **5**, 31044 (2015).
[3] L. Buffoni, A. Solfanelli, P. Verrucchi, A. Cuccoli, and M. Campisi, PRL, **122**, 70603 (2019).
[4] F. Campaioli *et al.*, PRL, **118**, 150601 (2017)