Pico – Quantum Phenomena and Devices

Summer projects 2018

We offer summer projects related to the following topics. For more information on our research in general, check out the group website and recent publications. We offer topics that are suitable for both Bachelor’s and Master’s students, and the summer project can be summarized as a Bachelor’s thesis or a special assignment. Also topics for Master’s theses are available. The projects include design and nanofabrication of the devices in the Micronova cleanroom, measurements at low temperatures in our laboratory at Micronova, and modeling or numerical simulations. It is possible to focus more on experiments or modeling; we will fix the detailed job description according to your background and interests.

Single-electron counting

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Quantum heat engines and thermometry

a) Our superconducting qubit. Top left: the qubit, bottom left: chip with several qubits and microwave resonators, top and bottom right: characterization of the coherence time of the qubit.

b) The Otto cycle in a quantum heat engine, where the working gas is replaced by a superconducting qubit.

Understanding the heat transport in quantum systems is important for various applications of quantum technology, such as superconducting qubits or sensitive detectors. In a quantum heat engine, the performance (for example cooling power) is affected by the quantum coherence of the device. We are developing a quantum version of the Otto cycle commonly found in the combustion engines of cars, where a superconducting qubit plays the role of the expanding and contracting gas.

We have also been developing sensitive thermometers from superconducting and normal metal components to measure the temperatures of, for example, the hot and cold reservoirs in such a heat engine. One aim is to develop thermometers fast and sensitive enough to detect single microwave photons by measuring the temperature rise of a small volume where the photon is absorbed.
Maxwell’s demon is a famous thought experiment where a demon measuring the speeds of individual gas particles can make heat flow from cold to hot, in apparent violation of the second law of thermodynamics. We have implemented an electronic version of such a demon using single-electron structures at millikelvin temperatures. The demon is one example of stochastic thermodynamics: in small systems, the laws of thermodynamics hold only on average, and fluctuations from average quantities play an important role. For example, there is a non-zero probability for e.g. electrons moving in the ‘wrong’ direction towards a negative voltage (somewhat analogous to a ball rolling spontaneously uphill), producing negative entropy. Single-electron circuits allow measuring the distributions of fluctuating thermodynamic quantities and testing the predictions of stochastic thermodynamics experimentally, using charge detectors and/or nanoscale thermometers based on normal metal and superconducting components. A future challenge is implementing a quantum version of Maxwell’s demon.