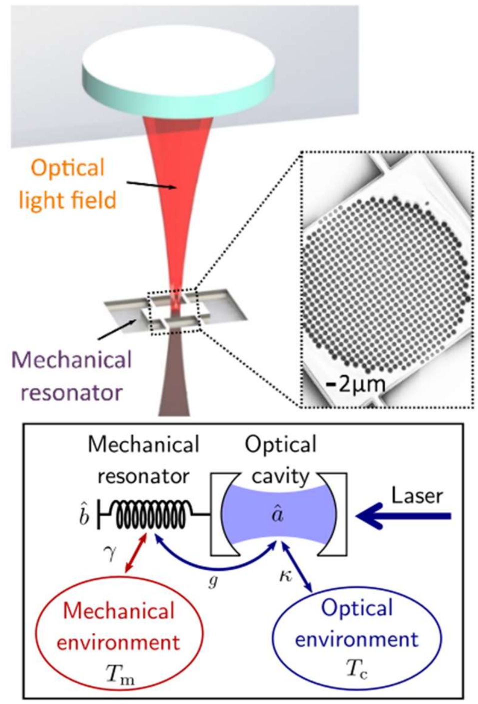
Energy harvesting with a nano-optomechanical heat engine

Background



With the rise of nanotechnologies and quantum computing, understanding and controlling energy exchanges at the nanoscale has become crucial. The sustainability of these technologies can be improved by finding ways to re-use waste heat to produce work, that is ”useful” energy. Therefore, researchers investigate how to harvest heat and how to make heat engines at the nanoscale. Optomechanical devices, such as the one shown in the figure, are promising for this purpose. Indeed, one expects that heat can be absorbed from an optical bath and used to produce mechanical or electrical work. Thermodynamics was developed in the 19th century to describe macroscopic machines such as steam engines. This theory is currently being adapted to the nanoscale where a completely new picture arises: instead of macroscopic statistics, quantum fluctuations play a decisive role and quantum effects are expected to lead to new functionalities.

Problem description

Optomechanical devices consist of an optical cavity coupled to a nano-mechanical resonator and provide a unique possibility to study heat engines at the micro- and nanoscale. This project investigates how the quantum properties of such devices can be exploited for heat-to-work conversion. A typical heat engine has three key elements: a working medium and two heat baths at different temperatures. In this setup, the mechanical resonator is the working medium whose energy can be harvested by coupling to electronic degrees of freedom. The environment of the mechanical resonator is the hot bath while the optical cavity acts as an engineered cold bath. We will calculate the heat flow between the device’s elements and find optimal conditions for an efficient heat-to-work conversion.

Activities

During this project, you will become familiar with the concept and theoretical description of heat engines in nanoscopic systems. The main goal of the project is the proposal and the analysis of a theoretical model for a nano-mechanical heat engine based on an optomechanical system. This model shall be based on experimental parameters, which correspond to experiments performed at MC2.

Group size: Ca. 3-4 students.

Target group: F, GU-Fysik

Literature tips

https://www.quantamagazine.org/the-quantum-thermodynamics-revolution-20170502/
https://www.nature.com/news/battle-between-quantum-and-thermodynamic-laws-heats-up-1.21720

Supervisors

Juliette Monsel, monsel@chalmers.se
Matteo Acciai, acciai@chalmers.se
Janine Splettstoesser, janines@chalmers.se
Witlef Wieczorek witlef.wieczorek@chalmers.se