Physics Institute – Solid State Physics – Prof. R. Kleiner, Prof. D. Kölle

Bachelor/Master thesis available!

Development of niobium-based superconducting mechanical oscillators for microwave optomechanics

The implementation of microwave optomechanical circuits using superconducting LC oscillators and suspended Aluminum structures as high quality-factor mechanical oscillators has enabled groundbreaking experiments with mechanical objects in the recent decade. Ground-state cooling [1], quantum squeezing [2] or quantum entanglement of vibrating, massive objects [3] have been realized and quantum-limited microwave signal processing has been implemented. An example for an Aluminum drum capacitor is shown in Figure 1.

One disadvantage of many existing technologies, however, is that the structures are made of Aluminum, which means that they have to be cooled to mK temperatures and can only be operated in small magnetic fields.

The goal of this thesis is the development of similar, but enhanced mechanical resonators based on niobium, a superconducting material with larger critical temperature and larger critical field than the so far used aluminum. The succesful development of these niobium-based mechanical resonators and their implementation in microwave optomechanical circuits will allow for the next generation of experiments and technologies with mechanical oscillators in so far unaccessible parameter regimes of temperature and magnetic fields.

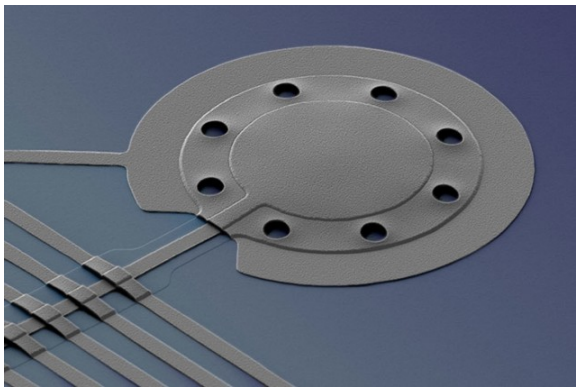

Figure 1: *Scanning electron microscope image of a superconducting vacuum parallel plate capacitor, which is a mechanical drum oscillator and at the same time forms part of a microwave LC resonator. From the physicsworld.com article "Squeezed light plays a quantum drum".*

The main tasks and challenges will be:

- Fabrication and optimiziation of niobium mechanical resonators
- Design, simulation and fabrication of superconducting microwave LC circuits
- Combination of mechanical resonators and LC circuits in electromechanical devices
- Characterization by vector network analysis and microwave spectroscopy
- Data analysis and measurement scripting using python

This thesis is integrated into a bigger team effort within the PIT II and if you are interested in the topic and motivated to contribute to the next generation of advanced superconducting microwave experiments in Tübingen within your thesis don't hesitate to contact us.

References:

[1] J. D. Teufel *et al.*, Nature **475**, 359-363 (2011)
[2] E. E. Wollman *et al.*, Science **349**, 952-955 (2015)
[3] C. Ockeloen-Korppi *et al.*, Nature **556**, 478-482 (2018)

Supervisors/contact: Daniel Bothner daniel.bothner@uni-tuebingen.de
Benedikt Wilde benedikt.wilde@uni-tuebingen.de
Dieter Koelle koelle@uni-tuebingen.de