Physics Institute – Solid State Physics – Microwave Team Tübingen

Bachelor/Master thesis available!

Development of niobium-based gradiometric SQUID optomechanics

Superconducting quantum interference devices (SQUIDs) are fascinating and extremely useful electronic components. They are amongst the world's most sensitive sensors for magnetic flux, they are used in nowdays quantum information processors and they allow for high-resolution imaging techniques. When they are integrated into a superconducting LC circuit, one obtains a quantum interference microwave circuit. If in addition a part of the SQUID loop is suspended from the substrate and free to oscillate mechanically, cf. Fig. 1, the result is a SQUID optomechanical device, that allows to detect and control the micromechanical oscillator using microwave photons.

SQUID optomechanics has attracted a lot of attention in recent years, since the interaction rate between photons and phonons in the system is directly proportional to an externally applied magnetic field and therefore can in principle be scaled up to values orders of magnitude larger than what can be achieved in other optomechanical platforms. Once the interaction rate is large enough, it will be possible to directly prepare and investigate large quantum states of motion such as Schrödinger cat states and use these states to test quantum physics with massive macroscopic objects.

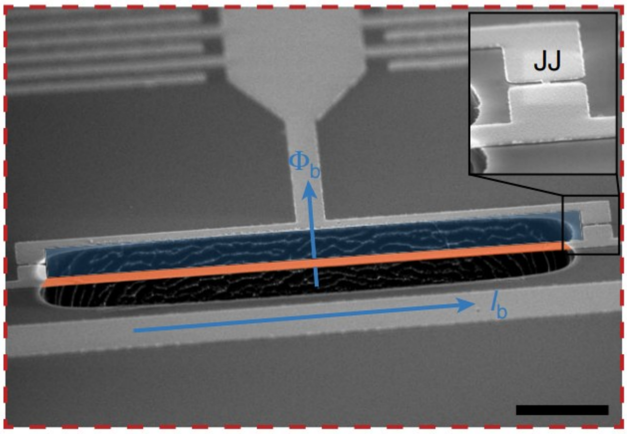

***Figure 1**: Scanning electron microscope image of a superconducting quantum interference resonator with integrated mechanical beam oscillator. Visible is the rectangular SQUID in the center (part of the loop is suspended here as mechanical resonator, shown in orange) and a finger capacitor in the background. The magnetic flux through the SQUID loop Φ_b can be changed with a current I_b through the bias line in the front. Scale bar is 1 μm. Inset shows zoom into the constriction-type Josephson junction (JJ). From [1].*

So far, several factors are limiting the achievable interaction rates though. One of the most important factors currently is external magnetic noise coupling into the SQUID loop with contributions from different origins. To mitigate the harmful impact of homogeneous-field noise and to reach the next level of SQUID optomechanics, a highly promising idea is to develop and a corresponding device with a so-called gradiometric SQUID (loop chaped like an "8").

This is where you and your bachelor and/or master project could come into play! Contact us if you are excited to contribute or to just learn more about our experiments and plans.

The main tasks and challenges during the thesis project will be:

- Design and simulation of superconducting microwave circuits
- Advanced nano-fabrication using lithography and ion beam patterning
- Characterization of circuits in cryogenic experiments using microwave spectroscopy
- Data analysis and measurement scripting using python

References:
[1] I.C. Rodrigues*, D. Bothner*, and G. A. Steele, Nature Communications **10**, 5359 (2019)

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