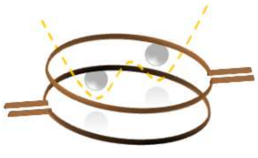
CHALMERS
UNIVERSITY OF TECHNOLOGY

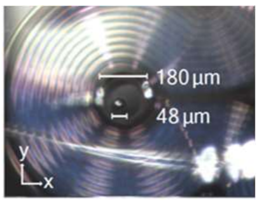
Department of Microtechnology and Nanoscience (MC2)
Quantum Technology Lab, Wieczorek Group
www.wieczorek-lab.com

Master Thesis Project

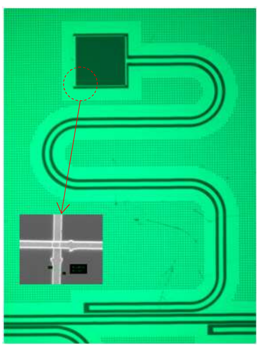
Superconducting resonators for macroscopic quantum experiments



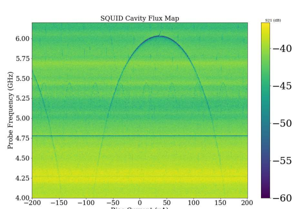
Cartoon of a levitated microparticle in the quantum regime exhibiting macroscopic quantum superposition



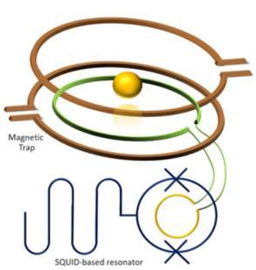
Optical image of an on-chip magnetic levitation trap with a 48 µm particle inside.



Optical image of a fabricated CPW resonator shunted with a DC-SQUID. The inset shows a Josephson junction.



Frequency tuning of a SQUID resonator via external magnetic flux.



Schematic of a magnetically levitated particle coupled to a SQUID resonator.

Background:

What are the limits of quantum mechanics? To explore this, we aim to bring a macroscopic particle into the quantum regime[1]. To do so, we magnetically levitate a micrometre-sized particle using on-chip coils[2,3].

For quantum control of this levitated particle, we need to cool the centre-of-mass of the particle to its motional ground state (~nK). This would need optomechanical techniques like feedback cooling[4].

For this, the particle's motion must be coupled to a flux-tunable resonator such as a superconducting coplanar waveguide (CPW) terminated with a DC-SQUID. A ground-state cooled levitated micro-particle can also be used for quantum sensing of force, acceleration and gravity[1,4,5].

Thesis Goals:

- Improve the quality factor of a SQUID resonator via design optimization and fabrication techniques
- Demonstrate flux-mediated coupling of a magnetically levitated microparticle to a superconducting resonator
- Maximize this coupling by designing an efficient flux transfer approach (flip-chip technique, in-plane coil etc.)

What we offer:

- The skills to design and analyze superconducting microwave circuits, SQUID-based CPW resonators, and flux transformers.
- A rich cleanroom experience in fabricating Josephson junctions and SQUID-based resonators using state-of-the-art tools at MC2.
- Training on electromagnetic simulation using ANSYS HFSS
- Experience with mK cryogenics on BlueFors dilution refrigerator
- Microwave spectroscopy and control of superconducting devices

Thesis expectations:

- The aim is to make the student independent such that they can drive the project on their own and formulate ideas and solutions

[1] O. Romero-Isart, et al., Physical Review Letters, 109, 147205, 2 (2012).
[2] M.G. Latorre, et al., IEEE Trans. on App. Supercond. 32, 1-5 (2022).
[3] M.G. Latorre, et al., Phy. Rev Applied, 19(5) (2023).
[4] M. T. Johnsson, et al., Scientific Reports, 6, 37495, 5-9 (2016).
[5] J. Prat-Camps, et al. Physical Review Applied, 8, (2017).

Witlef Wieczorek, Associate Professor, witlef.wieczorek@chalmers.se
Achintya Paradkar, PhD student, achintya@chalmers.se