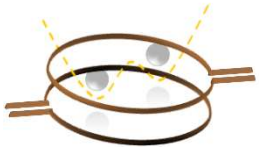
CHALMERS UNIVERSITY OF TECHNOLOGY
Department of Microtechnology and Nanoscience (MC2)
Quantum Technology Lab, Wieczorek Group
www.wieczorek-lab.com

Master Thesis Project

Vibration Isolation Stage for Quantum Experiments at mK Temperature



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

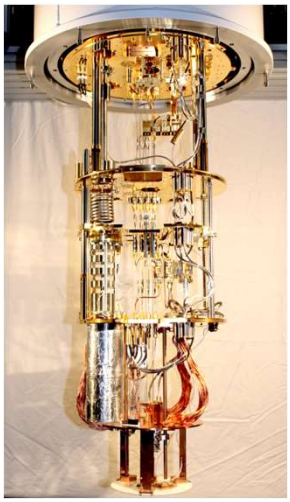
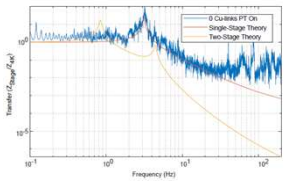


Photo of a BlueFors dilution refrigerator with the current single-stage isolation system

CAD model of the single-stage isolation with the experiment sitting on the bottom (blue). The springs are attached to the nylon wires at the top (white)



Transmissibility of a two-stage system

Background:

A levitated microparticle is a promising platform for quantum sensing as it is maximally isolated from the environment. This makes it highly sensitive to forces on the order of zeptonewton and thus can be used to detect, for example, weak gravitational signals. We levitate superconducting particles using magnetic fields. Inside this magnetic field, the particle oscillates at a frequency of a few hundred Hz.

The entire experimental setup (see image) is placed inside a high vacuum (10^{-6} mbar) dilution refrigerator that cools the system down to 20 mK. However, external mechanical vibrations excite the particle and increase its effective temperature.

To dampen these vibrations, we have built a single-stage passive spring-mass system that gives a 20 dB attenuation in the amplitude of particle motion. However, for reaching the ground state, we need the noise to be below 60 dB. For this, we need a multi-stage vibration isolation setup.

Thesis Goals:

- Design, analyze and simulate a multi-stage vibration isolation system
- The stage must be mechanically isolated but well-thermalized to the fridge
- Noise damping from the fridge and surrounding must be at least 60 dB at all frequencies above 100 Hz.
- Experimentally test the damping characteristics of the stage.

What you will learn:

- Vibration dynamics in cryogenic environment for quantum applications
- Design and thermalization of passive components for given constraints
- Working in experimental physics with an interdisciplinary team

Desired skills:

- Structure Dynamics, Control Systems, dynamic simulation (e.g., ANSYS Mechanical), CAD (Creo, Solidworks), basic coding (Python, MATLAB)

[1] Leng, Y., et al. (2021). Mechanical dissipation below 1 μHz with a cryogenic diamagnetic-levitated micro-oscillator. Physical Review Applied, 15(2), 024061 10.1103/PhysRevApplied.15.024061
[2] de Wit, M., et al. (2019). Vibration isolation with high thermal conductance for a cryogen-free dilution refrigerator. Review of Scientific Instruments, 90(1), 015112 10.1063/1.5066618

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