Quantum Nanomechanics

(Prof. Mika Sillanpää)

Nanomechanical systems in the quantum limit, superconducting qubits, magneto-acoustic hybrid systems. Experimental work done in the premises of Low Temperature Laboratory.

The projects are designed to be suitable as a special assignment or bachelor's thesis work. In many cases they can also be extended as a diploma work. The experimental projects involve design and simulations, and hands-on work in the laboratory either with device fabrication or measurements. The projects give an excellent overview of cutting-edge experimental research on an exciting topic with a strong relevance to quantum technologies.

Superconducting – mechanical hybrid quantum systems

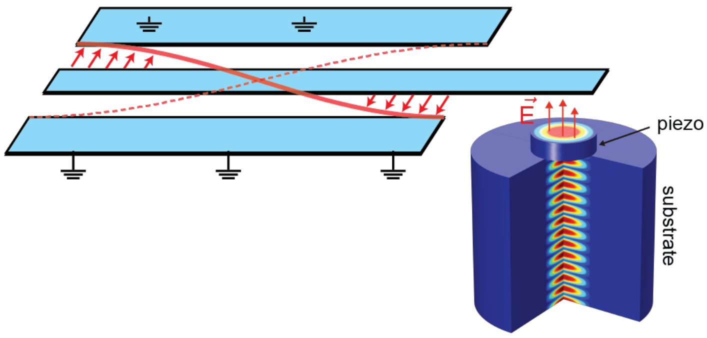

Figure 1: GHz acoustic resonances in a substrate are coupled to electromagnetic fields via piezoelectricity.

1. Dynamical Casimir effect

The Casimir effect is an attractive force between conducting plates. It is due to vacuum fluctuations of the electromagnetic field, and thus one of the rare direct manifestations of non-zero energy density of vacuum. A more elaborated version of the Casimir effect is the dynamical Casimir effect, where photons are created out of vacuum by moving boundary conditions. The dynamical effect is much weaker, but can possibly be studied with cold electromechanical systems. In this project you will take the first step towards such an experiment. You will design an electromagnetic waveguide interacting with acoustic High-Overtone Bulk Acoustic (HBAR) resonator (Figure 1) such that the latter has subharmonic resonances with the electromagnetic mode. Subsequently, you will realize such a sample in the cleanroom, and make initial characterizations.

2. GHz phononic waveguides

Quantum bits made with Josephson junctions are considered the most promising platform for realization of quantum computer. Superconducting qubits can also be useful for exploring hybrid quantum systems, and testing quantum mechanics in nearly macroscopic systems. A longer-term goal of qubit-acoustic hybrids is to couple these systems to propagating acoustic waves. To this end, in this work you will explore a basic scheme where surface waves are generated electrically, and detected as after travelling a waveguide. You will design, realize and measure this type of device.

Magneto-acoustics

Magnetic nanostructures are a key enabling technology in modern society. We are working on integrating magnonics with coherent micromechanical and acoustic modes, with the eventual goal to experimentally push it into the quantum-mechanical regime.

3. Coupling of spin waves to acoustic resonances

In this project, you will implement a setup where breathing modes of a ferrimagnetic sphere couple to magnon resonance in the sphere. The measurement is carried out via a microwave cavity resonator. You will familiarize yourself with the literature, carry out acoustic and electromagnetic simulations, realize the device, and make initial characterizations.