Research project in NANO group:
“Fast measurement system for resonance response in mechanical nanodevices”

Description of the project:
Aim of this research project is development of fast measurement setup for fundamental problems in nanoelectromechanical systems (NEMS). The key element of the setup is ultra-high frequency Lock-in Amplifier (https://www.zhinst.com/products/uhfli) with 1.8 GSa/s sampling rate. The device has eight internal oscillators which allows a free choice of frequency for each of its 8 demodulators. This facilitates simultaneous testing of the system response for excitations with eight different frequencies, which results in a reduction of the measurement time to 1/8 of regular lock-in measurements.

The Lock-in Amplifier is operated via a computer, and ready-made software exists for its control. Operation of the setup in the multi-frequency lock-in mode will be realized and tested on a mechanical quartz tuning fork resonator. Such tuning forks can be employed in low temperature physics as thermometers or pressure sensors owing to the dependence of the resonance line shape on environmental conditions. Final testing of the setup will be performed on a carbon nanotube resonator in Bluefors dilution refrigerator (https://www.bluefors.com/) down to 10 mK temperature. The task also includes development of a simple feedback scheme, which facilitates tracking of the resonance frequency as a function of temperature.

Together with basic theory of mechanical NEMS resonators, this project forms a BSc thesis work.


Software: MatLab, LabOne

More information:
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Research project in NANO group: "Relativistic correlations between quantum objects"

Description of the project:
Aim of this research project is to simulate a measurement setup for fundamental issues in relativistic nanophysics. The recently developed quantum limited amplifiers in our group (https://arxiv.org/abs/1812.07621) provide wide ranging possibilities for studies of correlated microwave quanta that are generated via dynamical Casimir effect from the quantum vacuum. It has even been suggested that such vacuum-induced correlations could lead to space-like correlations between quantum objects, for example between qubits.

In this project, quantum systems with vacuum induced correlations will be analyzed using circuit simulation programs. The simulations are performed with experimentally relevant parameters, which facilitates evaluation of chances for the experimental observation of these effects. The simulation can be done either in Microwave Office (Aplac) or by performing integration of the underlying equations of motion for the electromagnetic mode equations. The results will be employed to improve the experimental setting that is being constructed presently in the LTL by the NANO group (https://www.aalto.fi/otanano/low-temperature-laboratory)

The final report of the project can be a BSc thesis work. This project can also be performed at more advanced level and extended to a MSc work.


Software: Microwave Office, Aplac

More information:
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Summer student position:

We have opening for summer students interested in **theoretical condensed matter physics**. For more details contact Alexander Zyuzin (alexander.zyuzin@aalto.fi). Possible summer project is

**Transmission of Light through Disordered Amplifying Medium**

There is a growing interest in non-Hermitian topological phases of matter, specifically in edge states appearing on lattices represented by a non-Hermitian Hamiltonian. Typical examples are the electromagnetic field amplifying or absorbing medium and interacting electronic Dirac materials. We will investigate the statistical properties of such non-Hermitian systems with a particular focus on light propagation in disordered amplifying medium. This project will be interesting for students willing to have introduction to topological phases of matter, quantum field theory, and Feynman diagrams. The tasks are:

Calculate the correlations in intensity of light transmitted through a disordered non-Hermitian system. Analyze the transmission of monochromatic light through such medium. Evaluate the surface states dispersion in systems with high-order non-Hermitian degeneracies.

Bulk Fermi arc arising from paired exceptional points split from a single Dirac point. (A, B ) Illustration of photonic crystal structures, isofrequency contours, and band structures. (C ) A few examples of the isofrequency contours in this system, including the open bulk Fermi arc at the EP frequency (middle panel), and closed contours at higher (upper panel) or lower (lower panel) frequencies. From: H. Zhou et al., Observation of bulk Fermi arc and polarization half charge from paired exceptional points. Science 10.1126/science.aap9859 (2018).