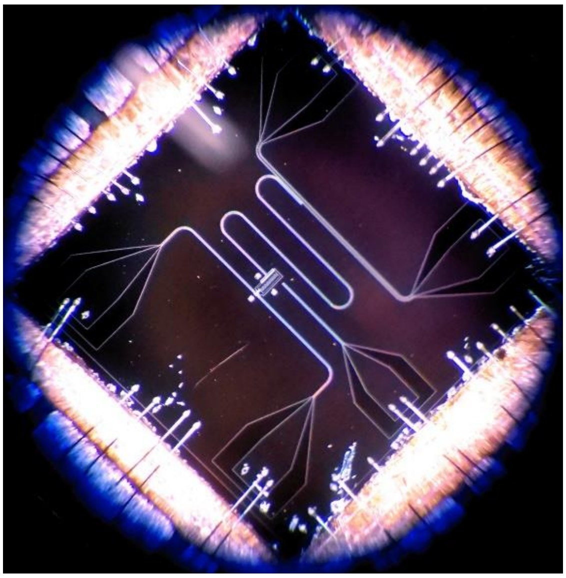
Kvantti group – summer students projects 2024



Supervisor:

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Superconducting circuits are one of the most promising experimental platforms for the realization of quantum computers and simulators. A superconducting qubit behaves as an artificial two-level system, with transitions between the ground state and the first excited state being driven by resonant microwave fields. In the Kvantti group we design, fabricate and measure these amazing devices. We have several research projects for the summer of 2024. Note that they might look "advanced" (and they are!) but all of them can be tailored to adjust your level (B.Sc. thesis, M.Sc. thesis, etc.) and your interests.

1. Efficient gates and readout protocols for superconducting processors

Present designs for quantum gates, either single- or two-qubit ones, involve typically simple assumptions about how the pulses interact with the device. However, leakage outside the computational subspace is a real detrimental effect that has to be mitigated. The goal of this project is to design an optimized pulse scheme that leads potentially to higher fidelities, by taking into account that typical devices such as transmons, in reality, are multilevel systems. In particular, we are interested in exploring two-qubit coupling schemes, since improving their fidelity is essential for the scalability of superconducting quantum processors. Advanced optimization methods based on machine learning may also be used. You will join a team of researchers performing experiments on superconducting qubits to learn how to do qubit characterization and to further optimize the gates using superadiabatic and numerical methods.

2. Entanglement in parametric devices

In this project the goal is to characterize the entanglement properties of parametric Josephson devices fabricated by our collaborators at VTT. Entanglement is a characteristic of the state of two (or in general multiple) quantum systems that – if it exists – results in measured correlations stronger than for classical systems. Einstein himself famously struggled with the concept. The devices you will measure are expected to generate microwave photons, and your task will be to show that these photons are entangled by measuring the quadratures and calculating the covariance matrix. You will explore detection schemes aiming at achieving single-photon sensitivities.

3. Quantum heat engines

You have most likely studied classical cycles like Carnot, Otto, Stirling, Diesel, that are used in heat engines and refrigerators, which typically consists of pistons that compress or expand a gas, called "working fluid". But what happens if your working fluid consists of just one atom with say two energy levels? Can you still make the engine work and what is the role of quantum effects in this case? In this project you will study what happens when a qubit is in contact with two thermal reservoirs (a hot bath and a cold bath) and the spacing of the energy levels is modified to simulate compression and expansion.

4. Precision measurements of magnetic fields

Our group has a long-standing interest in quantum metrology – an emerging research direction where one studies what are the fundamental limits in the precision of estimating the values of physical observables. In this project you will consider a qubit driven by a time-dependent magnetic flux. By using a sequence of Ramsey measurements, the goal in this project is to characterize the relation between bandwidth and sensitivity under realistic conditions (qubits subjected to experimental noise).