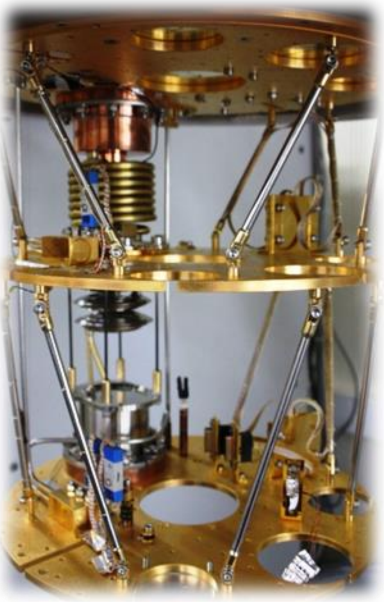
Quantum Measurement and Control Laboratory



A dilution refrigerator capable of cooling to a temperature of 10 mK

Welcome to QuMaC lab

The Quantum Measurement and Control Laboratory (QuMaC) at TIFR primarily investigates quantum phenomena in superconducting circuits. These nanofabricated electrical circuits are engineered to behave as "artificial atoms" with quantized energy levels. Two of those levels can form a quantum bit (qubit) and used to store and process information. With such qubits, one can build powerful computing machines capable of providing exponential speed up for certain mathematical problems. Our lab aims to tackle the basic challenges in building and controlling such quantum systems.

Tools & Techniques

Our experiments are carried out at cryogenic temperatures of around 10 mK, achieved using a dilution refrigerator. The superconducting circuits are made out of aluminium on silicon or sapphire wafers using nano-lithography in a cleanroom. We use microwave frequency (4 – 8 GHz) signals to manipulate and measure our devices. We use high speed digitizers and FPGAs to record and process the measurement signals at GHz rates. We also design and build custom microwave frequency amplifiers, filters, attenuators and circuit boards.

CURRENT MEMBERS:

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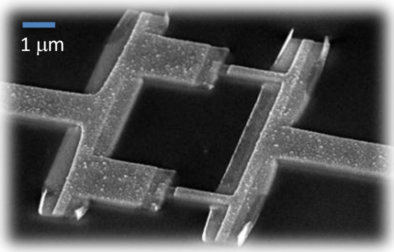
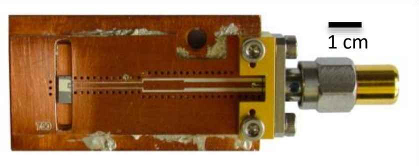
Quantum Feedback Control

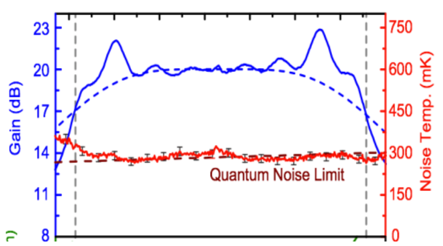
One of the central challenges in building a quantum computer is that the qubits do not maintain their quantum nature for a very long time. This phenomena is called decoherence and happens primarily due to environmental noise. However, it is possible to use multiple imperfect qubits to build a near-perfect qubit using a process called quantum error correction. This involves encoding the single qubit state among multiple physical qubits, making the right kind of measurements to detect any errors and then use feedback to correct those errors. We are investigating techniques to implement quantum error correction using weak continuous measurements and feedback. This will involve ultra-fast signal processing using Field Programmable Gate Arrays (FPGA).

Quantum Simulations

The computational resources required to simulate quantum mechanics on a classical computer grows exponentially with the size of the simulated system. Feynman had originally suggested that one should use quantum systems to simulate quantum mechanics. The basic idea is to have a well characterized and controllable quantum system to mimic the behaviour of other systems of interest. Our lab is interested in studying collective behaviour in superconducting qubits and developing the necessary architecture for performing quantum simulations.







Top: Scanning Electron Microscope image of a superconducting qubit. **Right:** Impedance engineered parametric amplifier and its gain and noise data. Our new designed allowed nearly a 10X performance improvement (arXiv:1510.03065)