**Quantum Computing Laboratory Course**

**Superconducting Qubit lab**

**Main objective and learning outcomes**

The main objective of this lab will be to expose the students to basic physics that go into superconducting qubit devices, including Josephson Junctions, SQUID magnetometers, and superconducting resonators. Fully functional superconducting qubits require dilution

refrigerator temperatures, multi-step nanofabrication, and RF electronics well beyond the scope of an educational lab. However, many of the essential concepts and physics can be performed at “warm” cryogenic temperatures of about 4K, and this is what we will aim for. We also envision that the students will get exposed to various RF electronics and measurements.

**Main apparatus**

The experimental system will use a closed-loop cryocooler with a compressor, capable of cooling down the set-up to a liquid-helium temperature of about 4K. The cold-head area of the cryostat will be reasonably large, at least many square centimeters, to enable operation with a range of superconducting devices. We envision using niobium-based junctions, squid magnetometers, and resonators.

**Brief outline of measurements**

When fully operational the students will perform the following measurements:

* Measure the critical temperature, Tc, of niobium and the Residual Resistivity Ratio (RRR).
* Measure I-V curve of a Josephson Junction, measure critical current, Ic.
* Observe Shapiro steps.
* Measure I-V curve of a SQUID, explore the dependence of these curves on temperature.
* Operate the SQUID in closed and open loop conﬁguration.
* Measure the ﬂux noise of the SQUID.
* Measure the quality factor of a superconducting resonator.

7) Measure the quality-factor (Q) of a superconduc3ng resonator.