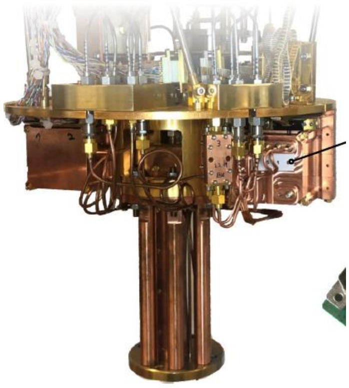
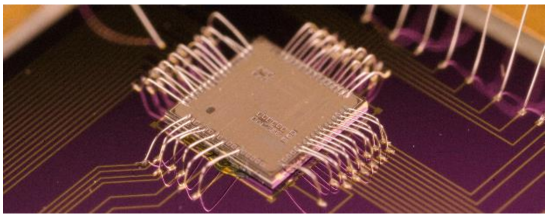
Bachelor's Project

Thermal Solutions for Large Scale Quantum Computing

(a)



(b)



(c)

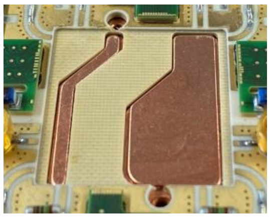


Fig. 1: ***(a)*** *Mixing chamber stage of a dilution refrigerator with a nominal base temperature of about 8 mK.* ***(b)*** *Cryogenic voltage source for qubit operation. This kind of electronics essential for scaling with be a main contributor to heat production.* ***(c)*** *Novel Sample mount with cooling surfaces in direct contact to the silicon chips.*

Background

Recent successes in the development of two-qubit gates for spin qubits in silicon have given the field of semiconductor-based quantum computing new momentum [1]. The enormous requirements on qubit numbers dictated by quantum error correction will most likely require very tight integration of the qubits with their corresponding control circuitry. Even with specialized ultra-low-power electronics, this will lead to a significant power output of the quantum processor given the current operating temperature of qubits at a few mK [2]. At these temperatures reached in commercially available dilution refrigerators, the available cooling power is only a few hundred microwatts, limiting the per qubit power budget. Additionally, temperature gradients across materials and interfaces can be significant at these low powers. Subsequently, careful design of cryostats, sample mounting, and qubit chips and a good knowledge of all materials and their behavior will be essential for the future of quantum computing.

Your Task

Your task will consist of two main parts. The first will be evaluating different simulation options in their capabilities to handle ultra-low temperature thermal simulation. The best-fitting solution will be tailored to our needs and used to simulate the thermal behavior of our cryostats and qubit samples. Second, you will conceptualize an experiment to measure low-temperature thermal conductivities of different materials and interfaces. The setup will then be constructed by our mechanical workshop and tested by you. This experiment will be the first step in creating a database of thermal properties for more accurate theoretical predictions. We will try to work in conjunction with the Cryolab at FZJ.This project will allow you to extend your knowledge of these topics, among other things:

- Theory of electron spin qubits and quantum computation
- Theory of heat conduction at very low temperatures and across interfaces
- Depending of Focus: Finite Element Simulation and CAD construction and experimental design

Furthermore, you will participate in group seminars and Journal Clubs to discuss cutting-edge developments in this area of research.

References

[1] https://www.nature.com/nature/volumes/601/issues/7893

[2] https://www.nature.com/articles/s41534-017-0038-y

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