Contribution ID: **62** Type: **Poster**

Industrially microfabricated ion traps with low loss materials

Tuesday 28 June 2022 18:12 (3 minutes)

Quantum computers have the potential to revolutionize computation by making certain types of classically intractable problems solvable. There are several platforms, that might host a future quantum computer. Trapped ions enable quantum gate operations on quantum bits (qubits) by manipulating single or multiple ions. Trapped ion quantum computing offers advantages over other platforms like low error rates and long storage times [1]. The path towards a universal quantum computer unavoidably requires scaling up the number of qubits, which today poses a considerable engineering challenge. Pogorelov et al. [2] have recently managed to fully entangle 24 optical qubits in a 1-dimensional ion crystal by means of a linear Paul trap. To enable scalability, we employ an industrially microfabricated surface ion trap which features the ability to scale up to higher qubit numbers. However, by scaling up to higher qubit numbers the energy dissipation in the trap becomes an increasingly important obstacle. To address this problem, we promote the usage of wide bandgap dielectric materials as substrate and electrode materials with a high electrical conductivity.

We will present a surface ion trap capable of trapping 18 ions in two adjacent 1D crystals, arranged in an architecture suitable for further upscaling. In an ongoing research project, we investigate the usage of different electrode and substrate materials. In contrast to silicon, wide-bandgap (>6 eV) dielectric substrate, such as fused silica or sapphire, exhibits low radiofrequency (RF) absorption and is transparent to most lasers used in quantum computing with optical ions. These properties additionally opens up the possibility to remove a large metal layer, which shields the silicon from the RF fields and laser light. By restructuring our trap design, we are able to cut our trap capacitance nearly in half (Simulated old design: 38pF; new design: 22pF). To reduce the dissipated power resulting of Ohmic losses caused by capacitive charging currents, we investigate the usage of highly conductive materials. By using copper instead of aluminum together with the reduced overall trap capacitance, we will be able to reduce the power dissipation by at least one order of magnitude.

[1] C. Bruzewicz, Trapped-ion quantum computing: Progress and challenges, arXiv:1904.04178

[2] I. Pogorelov, A compact ion-trap quantum computing demonstrator, arXiv:2101.11390

[3] P. Holz, Two-dimensional linear trap array for quantum information processing, arXiv:2003.08085

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Session Classification: Posters