Contribution ID: **40** Type: **Poster**

Fabrication of ion trap microchips with advanced features for trapped ion quantum coumputing

Tuesday 9 July 2024 17:32 (2 minutes)

We present the fabrication of trapped ion microchips integrated with the key features required to realise a scalable architecture for a modular microwave trapped-ion quantum computer. In our approach for ion trap quantum computing [1], high currents of up to 15 A generate large local magnetic field gradients at the ion position which, together with global microwave and RF fields, enable the implementation of high-fidelity quantum gates [2]. In order to enable such high currents within the quantum computing microchip, we fabricated surface ion trap microchips with current-carrying wires (CCWs) integrated into the silicon substrate. With the developed chips, currents up to 13 A can be applied continuously, resulting in a simulated magnetic field gradient of 144 T/m at the ion position, which is 125 µm from the trap surface. The low resistivity of the CCWs allows for a power dissipation of 1 W for 10A and 3 W for 13 A at a base temperature of 38 K for the CCWs including the compensation coils [3]. Our ion trap architecture is also modular, which means that arbitrary numbers of modules can be connected via electric fields to allow ion transport between individual modules. The key technique for this approach is aligning modules with respect to each other, requiring protruding electrodes at the edge of each module. For this purpose, silicon undercuts have also been fabricated at the edges of the developed chips. We have successfully fabricated such a chip, which has been used for coherent ion transport between two quantum computing modules [4]. We are currently working on integrating vias for inner segmented electrodes and atomic ovens.

[1] Lekitsch, Bjoern, et al. "Blueprint for a microwave trapped ion quantum

computer."Science Advances 3.2 (2017): e1601540.

[2] Weidt, S., et al. "Trapped-ion quantum logic

[3] Siegele-Brown, Martin, et al. "Fabrication of surface ion traps with

integrated current carrying wires enabling high magnetic field gradients."

Quantum Science and Technology 7.3 (2022): 034003.

[4] Akhtar, M., et al. "A high-fidelity quantum matter-link between ion-trap

microchip modules."Nature Communications 14.1 (2023): 531.

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Session Classification: Poster session

Track Classification: Quantum Information & Computing