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Microfabricated 2D array of ion traps

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Quantum computers need to fulfill five criteria as stated by DiVincenzo [1]. Trapped-ion quantum computers excel in all but one criterion: scalability remains hindered by challenges on system- and device-level. To that end, the quantum CCD architecture (QCCD) [2,3] has been introduced for scalable quantum computation and simulation. As a first step in this direction we demonstrate the microfabrication of 2D ion trap arrays and present first experimental results.

Fabrication of the ion trap is carried out in a state-of-the-art industrial facility to guarantee high process reproducibility and therefore identical ion traps. A three-metal-layer structure provides high performance and flexibility of the ion trap. A screening metal layer both screens the ion from charge carriers in the silicon substrate while also shielding the substrate from the RF field. Therefore, micromotion [4] and RF losses [5] are minimized. An interconnect metal layer connects the DC island electrodes to the bonding pads for electrical contact and thereby facilitates complex layouts like the QCCD architecture. The top metal layer is optimized for high currents to guarantee low Ohmic losses during RF operation. All metal layers are connected through vertical interconnect access (via).

Careful electrical characterization is conducted before device shipping: the Ohmic resistance of metal layers and vias as well as the capacitance between metal layers is determined. Additionally, DC dielectric breakdown voltages of the inter-metal oxide are measured at both room temperature and cryogenic temperature. Typical DC breakdown voltages show values of around 800 V at cryogenic temperatures. This exceeds the operating RF voltage of around 200 V and demonstrates reliable trap fabrication.

The presented geometry allows for ion shuttling in each of the two 1D arrays and adjusting the inter-ion distance inside each 1D array. Furthermore, lowering the RF voltage in between the two 1D arrays enables tuning of the inter-ion distance in between the two ion chains. This allows Coulomb coupling of ions inside one 1D array as well as in between the 1D arrays [6]. Therefore, in future experiments a rectangular or triangular lattice of coupled ions might be realized.

As a first experimental result the heating rate of the ion trap is measured to be 60 phonons per second. This value already allows for various fundamental investigations. Up to six ions located in both chains are trapped simultaneously. Finally, simultaneous shuttling of ions throughout both chains reveals the feasibility of implementing a QCCD architecture.

In summary, our work demonstrates that industrial fabrication of ion traps is an important step towards quantum computing by offering highly reproducible ion traps with unprecedented performance and flexibility.

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