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Microfabricated 3D Ion Traps and Integrated Optics

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A future quantum computer will potentially outperform a classical computer in certain tasks, such as factorizing large numbers [1]. A promising platform to implement a quantum computer are trapped ions, as long coherence time, high fidelity quantum logic gates and the implementation of quantum algorithms, such as the shore algorithm, have been demonstrated [2], [3]. To evolve trapped ion quantum computers from laboratory setups to devices able to solve real world problems, the amount of controllable qubits must be increased.
In recent trapped ion quantum computers, ions are often trapped in macroscopic linear ion traps which are not capable of hosting large numbers of ions. Moreover, trapped ions are addressed with free space optics, making it difficult to scale qubit numbers, because vibrations of the trap relative to the beam introduce beam-pointing errors, and the access for free space optics to address arrays of > 100 ions is geometrically limited. Additionally, small distances between neighbouring ions lead to crosstalk errors.
Microfabricated surface ion traps produced on a wafer level, are promising devices for scalable quantum computers, since they can host and control many ions. These traps are not limited to linear trapping potentials; they can be designed to generate individual trapping sites for each ion, leading to increased ion-ion distance and thus reduced crosstalk [4]. However, surface traps suffer from weak confining potential, limiting the lifetime of the ions and gate fidelity, and making ion shuttling unstable. To overcome the limit of small trapping potentials, we developed a microfabricated 3D ion trap, produced and assembled on wafer level by waferbond techniques. This trap contains structured electrodes on two opposing wafers, separated by a glass wafer as a spacer. In the diced trap, the electric field generated by the electrodes on the top and the bottom wafer define trapping sites in between the two wafers of 1 eV, exceeding the confinement of conventional surface traps. Furthermore, the glass spacer between top and bottom of the trap offers the opportunity to tackle problems introduced by free space optics:
We are working on the integration of optics into the spacer wafer of the microfabricated 3D ion traps, using waveguides imprinted in the spacer wafer to route the light to trapping sites [5], [6]. Integrating optics in quantum processors eliminates vibrations between optics and the ion trap and obviates a precise alignment of lasers. In the future, integrated waveguides are expected to realize complex light routing to multiple trapping sites and to make quantum information processors more robust and parallelizable.

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