Optical fiber integrated point Paul trap

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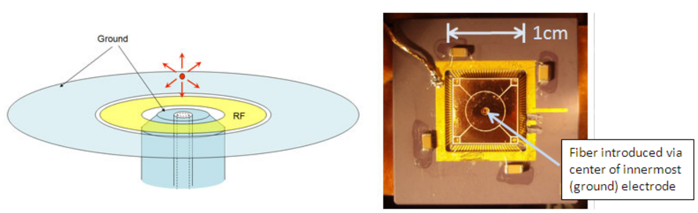
Surface-electrode ion traps represent a distinct advance in quantum information processing, in that the trap manufacturing process inherits the inherent scalability associated with conventional microfabrication. However, the construction of large-scale ion processors will require not only a sensibly scalable electrode architecture for trapping many ions simultaneously, but also additional infastructure for optical readout and control of the many ion qubits.

We report on progress towards an optical fiber-integrated planar trap for the purpose of ion control. The design (see Figure 1) is based on a novel type of surface trap with cylindrically symmetric arrangement of the electrodes, known as the "point Paul" trap. This particular layout lends itself well to integration with optical fibers and other optical structures, many of which possess symmetry about an axis. In addition, the point Paul design allows dynamic control of ion height (typical variations of $\pm 40\%$) by applying a second RF to the innermost electrode, thereby varying the fiber-ion coupling. The current implementation is based on a 3um-core fiber that is single-mode for both the doppler cooling (422nm) and the qubit (674nm) transitions of strontium. The ion is held 1mm away from the trap plane, at which the laser spot sizes are 45um and 72um for the 422nm and 674nm transitions, respectively. We have deployed the trap in a 4K closed-cycle cryostat and have stably trapped ions with the fiber-integrated structure. Furthermore, both axial and radial trap frequencies were measured that agree with simulation, and ion overlap with the fiber-introduced 674nm light was demonstrated by observing shelving (during $5S_{1/2} \leftrightarrow 5P_{1/2}$ doppler cooling) into the dark $4D_{5/2}$ state.



(a) (b)

Figure 1: *(a) Schematic of the fiber-integrated point Paul trap. The ground electrode is fabricated on an off-the-shelf optical ferrule. (b) Photograph of the actual assembly.*

The point Paul design represents a trap primitive with optical integration in mind, which is a necessity in the construction of large-scale ion trap processors. Furthermore, with its capability for *in situ* ion height adjustment, the trap be may immediately useful in investigation of surface effects, such as anomalous ion heating which currently impedes progress in quantum computation with trapped ions.