Two-Dimensional Control of Trapped Ions in a T-junction Array of Ion Traps*

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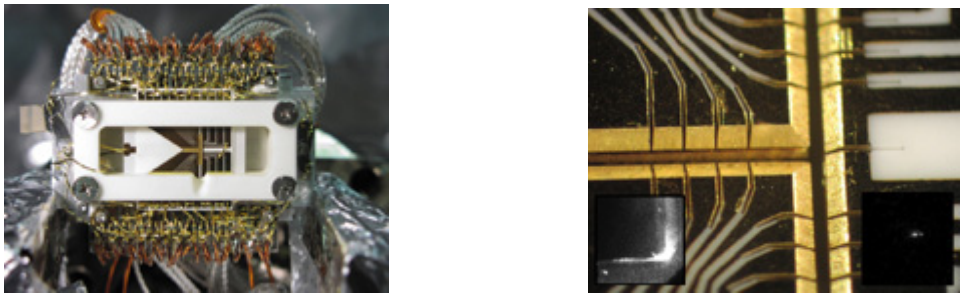
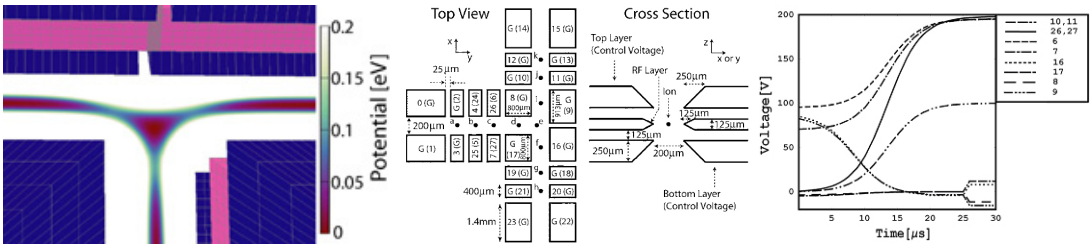
One proposal for a scalable quantum computer involves shuttling trapped atomic ions between interaction zones where ions can be entangled and storage zones where ions can be sent to store quantum information[1, 2]. We have performed a proof-of-principle experiment where ions were shuttled throughout an array of linear traps arranged to make a T-junction with 11 trapping zones.



(a) (b)

Fig. 1: (a). T-junction ion trap array outside of vacuum. (b). Close-up of T-junction ion trap electrodes. The lower left picture is a CCD image of a trapped ion near the junction region. The CCD image in the lower right is two different isotopes of trapped Cd ions.

In order to arbitrarily control trapped ions in two-dimensions, it may be necessary to implement four key shuttling protocols that have all been experimentally demonstrated in the T-junction array[3]: linearly shuttling ions along channels and through junctions, shuttling ions around corners, and separating and recombining two ions that are in the same trapping zone. By combining these protocols, we demonstrated the controllable swapping of the positions of two ions in the same trapping zone by executing a "three-point-turn" around the junction. These experiments were guided by simulations of the electric potential in the ion trap array, where time-varying potentials are efficiently modeled with electrode "basis" functions that exploit the potential of each individual electrode. Of particular importance are the traversals of the rf ponderomotive "humps" that appear near the junction.



(a) (b) (c)

Fig. 2: (a). Simulation of the rf pseudo-potential near the junction region showing three rf humps that are approximately 200µm in extent. (b). Top view and cross section view of T-junction ion trap array. Dots indicate trapping zones. The numbered control electrodes are used for shuttling ions throughout the ion trap array. The parentheses denote the bottom electrode and "G" indicates a grounded electrode. (c). Voltage profile used to shuttle an ion from zone d to zone i.

*Work supported by the Disruptive Technology Office and National Security Agency under Army Research Office contract W911NF-04-1-0234 and the National Science Foundation ITR Program.

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