Progress towards attaining an equidistant ion chain in an annular segmented surface ion trap

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Abstract

Scaling trapped ion quantum information processing to large numbers of qubits relies on micro-fabricated traps optimized for the applications in quantum computing and quantum simulation. For quantum simulations, long equidistant chains of ions, and ring-shaped crystals are of interest. Here, we demonstrate a chain of approximately 350 ions in a highly symmetric ring trap.

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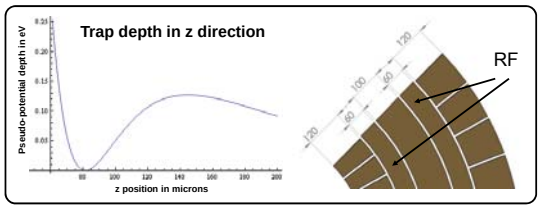
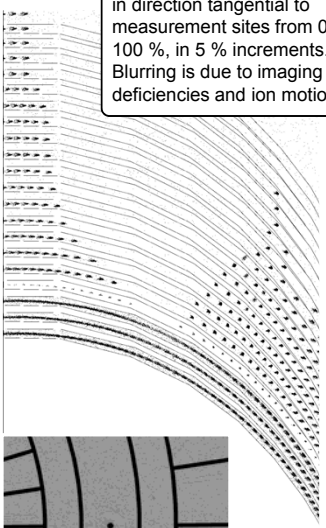
Motivation

- Large equidistant ion crystal
- RF potential is sufficient to trap ion chain
- Periodic boundary conditions
- Possible applications:
  - phase transitions (E. Shimshoni, G. Morigi, and S. Fishman, DOI: 10.1103/PhysRevLett.106.010401)
  - acoustic black holes (B. Horstmann, B. Reznik, S. Fagnocchi, and J. I. Cirac, DOI: 10.1103/PhysRevLett.104.250403)



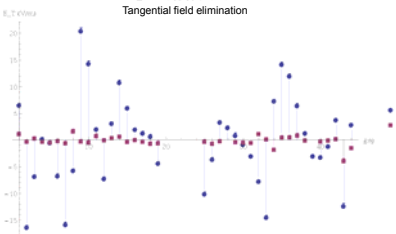
Design and implementation

- Relies on 4 metal level fabrication
- Numerical simulations for different species
- RF drive 53 MHz, 150 Vpp
- DC voltages < 10 V
- 624 micron ring radius
- 89 control electrodes
- 10μm loading hole
- For 200 Ca^+ ions ~125 kHz axial confinement (20 μm spacing) without DC
- In vacuum low pass filters
- PEEK ZIF socket



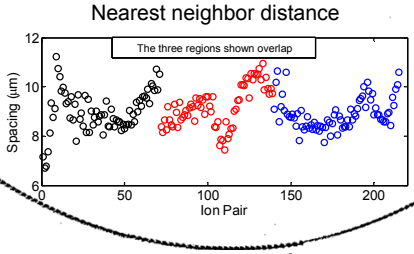
Scaling a correction for fields in direction tangential to measurement sites from 0 to 100 %, in 5 % increments. Blurring is due to imaging deficiencies and ion motion.

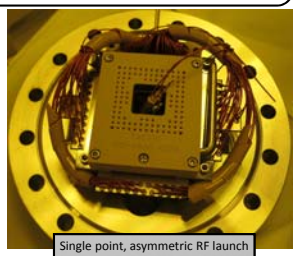
Realizing a long cyclic Ion crystal

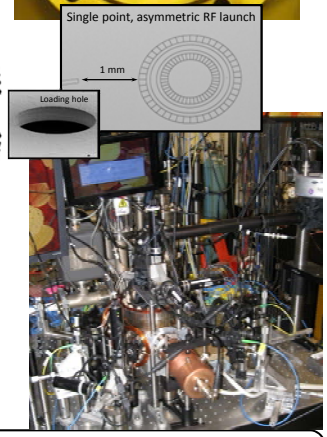


Stray field elimination procedure

- Tangential fields only are considered at 39 sites
- An electrode producing field in the relevant direction (as seen from simulation) is assigned to each site.
- That field, however, has effect over the full trapping volume and is accounted for at each site
- The electrodes are given weight so that the total field produced (as simulated) cancels the measured field in the tangential direction at each site
- Tangential fields are re-measured
- Ion spacing is inferred from images
- Procedure can be extended to all available 89 electrodes to tackle fields in arbitrary directions for a limited number of sites

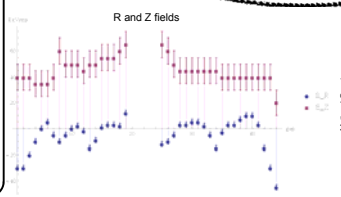


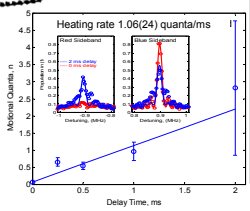




Stray field sources and measurement

- Major stray field sources can often be identified as particles contaminating the trap surface
- In addition, long range fields can be inferred
- Fields along 3 directions in the ion frame characterized at 39 locations
- Fields in radial (w.r.t. ion tangential motion) directions assessed with time of arrival and parametric heating techniques
- Fields in tangential directions inferred from ion displacement while scaling a DC trapping solution





Heating rate measurement

- Heating rate is assessed at a site at which stray fields are minimized
- Resolved sideband cooling techniques are used
- Heating rate of 1.06(24) quanta/ms comparable to that of other devices fabricated at SNL

Conclusion

- We demonstrate a proof of principle strategy aimed at producing an equidistant ion chain
- The results can be improved by using all available controls and different stray field compensation strategies