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Micrometer-scale ion traps from micro-mass spectrometry to quantum information processing - why instrumentation still matters

Matthew G. Blain†

Sandia National Laboratories
Albuquerque, NM 87185USA

Microfabricated ion traps offer important advantages for both micro-mass-spectrometry and quantum information science. If properly engineered for the experimental objectives, these micro-devices offer the ability to extend the performance of their macroscopic equivalents, and can even allow new concepts to be explored in both classical and quantum ion physics and chemistry. Some technical aspects of the realization of micrometer-scale traps will be presented. One early example to be described is the design, simulation, and construction of a large array of micrometer-sized cyclindrical ion traps for application as a micro-mass-analyzer. As a second example, the ability to fabricate complex and arbitrarily arranged two-dimensional (2-D) trap electrode geometries and arrays has been recognized to be critical for a number of trapped ion quantum information experiments (both proposed and realized). In particular, surface electrode ion traps have enabled the Kielpinski ion trap CCD (charge coupled device) architecture [1], whereby individual ions can be moved between different trapping regions optimized for ion loading and qubit initialization, entanglement, storage, and read-out. The ability to design and fabricate surface electrode trap junctions for the spatial re-ordering of single ions [2], precision through-chip holes for ion loading and photon collection/delivery, and arbitrarily shaped trap chips for increased optical access to the ions, are critical for constructing the required trap features and ultimately rendering a highly evolved ion trap chip technology. Additionally, if engineered appropriately micro-ion trap chip technologies may be interfaced to micro-optic devices, for example diffractive optical elements (DOEs) or cavity mirrors, to allow for state read-out or coherent information transfer. This "micro-systems" approach to the instrumentation of micrometer-scale ion traps relies on microfabrication techniques to render devices optimized for the experimental application.

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†*email: blainmg@sandia.gov*

[1] D. Kielpinski, *et al.*, Nature, 709, 417 (2002).
[2] D L Moehring, *et al.*, New Journal of Physics 13 (2011) 075018.