

Capture of highly charged ions in a hyperbolic Paul trap

J.N. Tan¹, A.S. Naing^{1,2}, J.M. Dreiling¹, J.M. Hanson³,
S.F. Hoogerheide¹, and S.M. Brewer^{1,4}

¹National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899, USA

²University of Delaware, Newark, Delaware 19716, USA

³Clemson University, Clemson, South Carolina 29634, USA

⁴University of Maryland, College Park, Maryland 20742, USA

Confinement of ions in a trap have interesting applications, including precision spectroscopy, quantum metrology, as well as collective behaviors in strongly-coupled one-component plasmas. In most cases, singly-charged ions or few-times-ionized species are created *in situ* within the trap. However, certain applications require a dedicated, external ion source. For instance, ion beams are injected into linear radio-frequency (RF) traps to form space-charge dominated nonneutral plasmas for experiments designed to simulate the propagation of intense charged particle beams, such as found in heavy ion fusion reactors, spallation neutron sources, and high energy physics.

The isolation of highly charged ions (HCIs) is made more involved by the stronger space-charge effects, which are proportional to the square of the charge state. In this work, we report the capture of ~ 500 Ne^{10+} ions in a hyperbolic RF trap. Highly charged ions are extracted from an electron beam ion source/trap (EBIS/T) at NIST, and subsequently guided by a 7 m long beamline to an ion trap apparatus; a charge-to-mass analyzer nested within the electrostatic beamline optics is used to select a single charge state (Ne^{10+}) to be recaptured in the RF trap. We discuss the experimental optimization and compare the results with computational simulations. An experimental capture efficiency of $\sim 20\%$ was attained, capturing ~ 500 Ne^{10+} ions in the hyperbolic RF trap, comparable to that attained in a unitary Penning trap [1]. The larger optical access available in an RF trap is advantageous for improving spectroscopic experiments. Due to heating by the RF-driven micromotion and the absence of any cooling mechanism, the observed storage lifetime of 69 ms for the Ne^{10+} ions stored in the RF trap is shorter than the corresponding storage lifetime in the unitary Penning trap. Nevertheless, this can be useful for a variety of spectroscopic experiments, including atomic state lifetime measurements for many charge states. Possible improvements for increasing the number of captured ions and storage lifetime are explored.

References

[1] J.N. Tan, S.M. Brewer, and N.D. Guise, Rev. Sci. Instrum. **83**, 023103 (2012).