Developing Antimatter Containment Technology: Modeling Charged Particle Oscillations in a Penning-Malmberg Trap

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The NASA MSFC Propulsion Research Center (PRC) is conducting a research activity examining the storage of low energy antiprotons. The High Performance Antiproton Trap (HiPAT) is an electromagnetic system (Penning-Malmberg design) consisting of a 4 Tesla superconductor, a high voltage confinement electrode system, and an ultra high vacuum test section; designed with an ultimate goal of maintaining^{12} charged particles with a half-life of 18 days. Currently, this system is being experimentally evaluated using normal matter ions which are cheap to produce and relatively easy to handle and provide a good indication of overall trap behavior, with the exception of assessing annihilation losses. Computational particle-in-cell plasma modeling using the XOOPIC code is supplementing the experiments.

Differing electrode voltage configurations are employed to contain charged particles, typically using flat, modified flat and harmonic potential wells. Ion cloud oscillation frequencies are obtained experimentally by amplification of signals induced on the electrodes by the particle motions. XOOPIC simulations show that for given electrode voltage configurations, the calculated charged particle oscillation frequencies are close to experimental measurements. As a two-dimensional axisymmetric code, XOOPIC cannot model azimuthal plasma variations, such as those induced by radio-frequency (RF) modulation of the central quadrupole electrode in experiments designed to enhance ion cloud containment. However, XOOPIC can model analytically varying electric potential boundary conditions and particle velocity initial conditions. Application of these conditions produces ion cloud axial and radial oscillation frequency modes of interest in achieving the goal of optimizing HiPAT for reliable containment of antiprotons.