A Multicell Trap for Storage of Large Numbers of Positrons*

J. R. Danielson, T. R. Weber, C. M. Surko
University of California, San Diego

Penning-Malmberg traps have proven useful, and sometimes critical for the accumulation, storage and manipulation of positron plasmas [1]. Scientific applications of these plasmas include creating cold, trap-based beams for atomic physics studies and tailored sources of positrons for the formation of antihydrogen atoms and positronium molecules ($\text{Ps}_2$). Technological applications include forming state-of-the-art positron beams for materials analysis. Generally, the capacity of such traps is expected to be limited by the space charge of the plasma which, is proportional to the total particle number per unit length of the plasma. For example a plasma of $10^{11}$ particles, 10 cm in length, requires a confinement potential of $\sim 7\, \text{kV}$. In order to circumvent this limitation, we proposed a multicell architecture for an antimatter trap, in which multiple traps are arranged in parallel and series (shielded from one another by electrodes) in a common solenoidal magnet and vacuum system [2].

We describe here techniques that will aid in the practical implementation of this multicell trap [2, 3]. It is designed to increase positron storage by orders of magnitude (e.g., to particle numbers $N > 10^{13}$). The experiments are done using test electron plasmas with the required cooling provided by cyclotron radiation in a 5 tesla magnetic field. A technique is described to move plasmas rapidly across the magnetic field and dump them at specific radial and azimuthal locations (i.e., to fill off-axis cells). Techniques are demonstrated to operate two in-line plasma cells simultaneously and the use of 1 kV confinement potentials to trap in excess of $3 \times 10^{10}$ particles. These experiments establish the capability to create, confine, and manipulate plasmas with the parameters required for a multicell trap, namely $N > 10^{10}$ in a single cell with temperatures $< 0.2\, \text{eV}$, plasma lengths $\sim 10\, \text{cm}$, and radii $\sim 0.2\, \text{cm}$. The design of a new electrode structure to test the confinement of plasmas in off-axis cells will be described, as well as a further-improved design of a multicell positron trap for $10^{12}$ particles. Potential applications, including prospects for a portable positron trap (e.g., to replace conventional isotope and accelerator-based sources), will be discussed.

* This work is supported by the National Science Foundation, grant PHY 07-13958.