Plasma Tools for Antimatter Physics

C. M. Surko
Department of Physics, University of California, San Diego, La Jolla CA 92067-0319

Techniques will be described to create, manipulate and store positron plasmas in Penning-Malmberg traps in new regimes of parameter space and to create finely focused positron beams [1]. Positron plasmas are compressed radially using rotating electric fields [the so-called "rotating wall" (RW) technique], in the case where the plasma is cooled by cyclotron radiation in a strong magnetic field (B = 5 tesla) [2-4]. A regime of RW operation will be described in which the application of a fixed RW frequency, f_{RW}, spins the plasma up until the plasma rotation frequency f_{E} (i.e., which is proportional to the plasma density, n) is approximately equal to f_{RW}. This provides the ability to create a rigidly rotating plasma with a known and constant high density, $n = f_{\mathrm{E}}B/\mathrm{ce}$ (e.g., 3 x 10^{10} cm^{-3} for $f_{\mathrm{E}} \approx f_{\mathrm{RW}}$ = 10 MHz). To access this regime, the plasma must be driven away from states localized near "zero-frequency modes" in which n is limited by drag torques due to trap imperfections. The criteria for accessing this regime, a model of the compression process, and possible limits of this technique will be discussed [3, 4].

Studies will also be described to extract beams of small spatial extent from the plasma center [5, 6]. For small-amplitude pulses, the radial beam profile is Gaussian with a beam radius of $2\lambda_{\mathrm{D}}$ (HW to 1/e), where λ_{D} is the Debye screening length. The fraction of the plasma that can be extracted in this manner is $N_{\mathrm{b}}/N \leq 0.1(2\,\lambda_{\mathrm{D}}/R_{\mathrm{p}})^2$, where R_{p} is the plasma radius, and N is the number of positrons [6]. A model of the radial beam profiles for larger beams will be presented.

Finally, a multicell trap will be described that is designed to store orders of magnitude more positrons than is currently possible (e.g., $N > 10^{12}$) [7, 8]. Plasmas will be stored in multiple Penning-Malmberg traps ("cells"), arranged both along and in parallel off the magnetic axis. An enabling technique to move plasmas across the magnetic field using autoresonant diocotron-mode excitation will be described as well as outstanding challenges in the next steps toward development of such a trap [8].

This work is supported by the U. S. National Science Foundation, grant PHY 07-13958, and is done in collaboration with J. R. Danielson and T. R. Weber.

References

1. C. M. Surko and R. G. Greaves, *Phys. Plasmas* **11**, 2333 (2004).
2. J. R. Danielson and C. M. Surko, *Phys. Rev. Lett.* **95**, 035001 (2005).
3. J. R. Danielson and C. M. Surko, *Phys. Plasmas* **13**, 055706 (2006).
4. J. R. Danielson, C. M. Surko, and T. M. O'Neil, *Phys. Rev. Lett.*, in press (2007).
5. J. R. Danielson, T. R. Weber, and C. M. Surko, *Appl. Phys. Lett.* **90**, 081503 (2007).
6. T. R. Weber, J. R. Danielson, and C. M. Surko, *Phys. Plasmas*, in press (2008).
7. C. M. Surko and R. G. Greaves, *Rad. Chem. and Phys.* **68**, 419 (2003).
8. J. R. Danielson, T. R. Weber, and C. M. Surko, *Phys. Plasmas* **13**, 123502 (2006).