DPP11-2011-000055

Abstract for an Invited Paper
for the DPP11 Meeting of
the American Physical Society

Review of Plasma Techniques Used to Trap Antihydrogen[1]

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Recently, the ALPHA collaboration at CERN trapped antihydrogen atoms.[2] To date,[3] over three hundred antiatoms have been confined, some for as long as 1000s. This was the first time that antiatoms had ever been trapped. The ultimate goal of the ALPHA collaboration is to test CPT invariance by comparing the spectra of hydrogen and antihydrogen, and to measure the gravitational attraction between matter and antimatter. Such studies might resolve the baryogenesis problem: why is there very little antimatter in the Universe? The ALPHA experiment brought together techniques from many different fields of physics, but the crucial breakthroughs were in plasma physics. The essential problem is this: How does one combine two Malmberg-Penning trapped plasmas, one made from antiprotons, and the other positrons, which have opposite electrostatic potentials of nearly one volt, in such a manner that the antiprotons traverse the positrons with kinetic energies of less than 40μeV, this latter being the depth of the superimposed neutral antihydrogen trap? The plasma techniques ALPHA developed to accomplish this include:

- Minimizing the effects of the neutral trap multipole fields on the positron and antiproton plasma confinement.
- Compressing antiprotons down to less than 0.5mm.
- Using autoresonance to inject antiprotons into the positrons with very little excess energy.
- Evaporative cooling of the electrons and antiprotons to record low temperatures.
- Development of charge, radial profile, temperature, and antiproton loss location diagnostics.
- Careful and lengthy manipulations to finesse the plasmas into the best states for optimal antihydrogen production and trapping.

The plasma techniques necessary to trap antihydrogen will be reviewed in this talk.

[1]This work was supported by DOE and NSF, and is reported on behalf of the ALPHA collaboration.
[2]*Trapped antihydrogen*, Nature, **468**, 673, 2010.
[3]*Confinement of antihydrogen for 1,000 seconds*, Nature Physics, **7**, 558, 2011.