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Development of a technique for sympathetically cooling positrons using laser-cooled Beryllium ions compatible with antihydrogen formation

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ALPHA works with trapped antihydrogen atoms to investigate some of its properties and compare it to its matter counterpart, hydrogen. These atoms are created by slowly mixing antiprotons and positrons in one of our Penning-Malmberg traps. There is strong evidence that positron temperature before mixing greatly influences the number of trappable antihydrogen atoms. [1]

Using laser ablation, a plasma of singly-charged Beryllium ions is formed. It is then trapped in the ALPHA-2 apparatus and laser-cooled. Mixing the laser-cooled $^{9}Be^{+}$ ions with a dense positron plasma sympathetically cools the positrons, having achieved a positron temperature of 6.8 ± 0.5K, as opposed to positrons cooling by cyclotron radiation which reach around 20K. [2] However, the work quoted in [2] does not explore the cooling of positrons under the inhomogenous magnetic field caused by the octupole, a necessary component for the trapping of antihydrogen. This inhomogeneity typically causes the expansion and heating of plasmas. [3]

We present the development of a technique that allows for sympathetic cooling of positrons using laser-cooled $^{9}Be^{+}$ compatible with antihydrogen formation. This includes installation of new hardware allowing for axial laser cooling of plasmas, novel implementation of Strong Drive Regime Evaporative Cooling (SDREVC) in ions allowing for enhanced reproducibility of number and size of $^{9}Be^{+}$ plasmas and e+/$^{9}Be^{+}$ mixing studies and optimization.

This will allow ALPHA to study the effect of lower positron temperatures in the formation of trappable antihydrogen, hopefully yielding a higher trapping rate.

[1] Ahmadi, M., Alves, B.X.R., Baker, C.J. et al. *Antihydrogen accumulation for fundamental symmetry tests.* Nat Commun **8**, 681 (2017).

[2] C. J. Baker *et al.*, Nat Commun **12**, 6139 (2021)

[3] Butler, E., *Antihydrogen Formation, Dynamics and Trapping*, Sec 3.5. PhD thesis, Swansea University (2011)

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