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# Towards laser cooling of negative molecular ions

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The AEgIS experiment at CERN's Antiproton Decelerator aims at measuring the gravitational acceleration $\bar{g}$ of antihydrogen ($\bar{H}$) with high precision [1, 2]. A key limitation in these measurements is the $\bar{H}$ temperature: The thermal motion of the $\bar{H}$ atoms blurs their free-fall trajectories and thus limits the achievable $\bar{g}$ precision.

The temperature of antihydrogen, which is formed at AEgIS in a laser-induced charge transfer reaction between positronium and antiprotons ($\bar{p}$), is dominated by the temperature of the antiproton precursors. With the current passive cooling scheme, the achievable $\bar{p}$ temperature is limited to at best tens (but to date a few hundred) kelvin.

Sympathetic cooling of antiprotons through thermalization with co-trapped laser-cooled ions would enable achieving temperatures in the mK range. However, to avoid annihilation, the co-trapped coolant ions must be negatively charged.

The Borealis project at AEgIS aims at realizing Doppler laser cooling of a negative ion. In particular, the diatomic molecular $C_2^-$ ion, a well-suited anion species for laser cooling [3], has been produced, mass-selected and stored in a linear Paul trap [4]. Currently, the capture efficiency of the trap and the lifetime of trapped $C_2^-$ ions are improved and preparations for preliminary in-beam spectroscopic studies are underway.

[1] G. Drobychev et al., Proposal for the AEGIS experiment at the CERN antiproton decelerator, CERN-SPSC-2007-017, SPSC-P-334.
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[3] P. Yzombard et al., Laser Cooling of Molecular Anions, Phys. Rev. Lett. 114, 213001 (2015).
[4] A. Hinterberger et al., Trapping of $C_2^-$ in a digital ion trap, J. Phys. B: At. Mol. Opt. Phys. 52, 225003 (2019).

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