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Sympathetic cooling of 9Be+ by laser-cooled 88Sr+ in an ion trap: an experimental simulation of the trapping and cooling of antimatter ions (GBAR experiment).

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We develop an experiment to study the energy exchange during the *sympathetic cooling* of a light ion, 9Be+, by a set of laser-cooled heavy ions, 88Sr+. The objective is to simulate an important step of the GBAR (Gravitational Behavior of Antihydrogen at Rest) experiment installed at CERN which aims at studying the effect of the Earth's gravity on anti-matter by analyzing the free fall of anti-hydrogen atoms at rest [1]. In this experiment a Hbar+ ion (an anti-proton with two positrons) is produced and then slowed down before entering an ion trap with an energy of the order of 1eV. This ion is then cooled to about 10µK and then a laser beam photo-detach a positron. The antihydrogen atom, is only subjected to gravity and free falls on one of the detectors. The time between the photo-detachment of the positron and the detection allows to calculate the fundamental constant gbar which is the equivalent of g but between matter and antimatter. One of the essential steps of this experiment is the cooling of the Hbar+ ion. One of the crucial step of this experiment is the sympathetic cooling of the Hbar+ ion (light ions) by a reservoir of cold laser-cooled Be+ ions (heavy ions).

Modeling the cooling of the Hbar+ ion is a process that involves an N-body problem, which makes numerical simulations very cumbersome and does not allow modeling the cooling dynamics over times longer than a few milliseconds. To understand the cooling dynamics over long times it is necessary to implement an experimental approach. We developed a setup to study sympathetic cooling of a light and hot 9Be+ ion (the equivalent of Hbar+) by a heavy laser-cooled 88Sr+ ion (the equivalent of 9Be+ in the GBAR experiment). Using the 88Sr+/9Be+ ion pair offers two advantages: (i) its mass ratio (88/9≈9,78) is very close to the one in GBAR (9/1), (ii) and both species are laser addressable. This allows for optical diagnosis and thus provide insight into the cooling dynamics of the light ion.

I will present our experiment for which we have designed a surface-trap with two trapping zones, a Be+ ion will be trapped in one zone and a set of Sr+ ions in the other. Both species will be cooled by laser. Then, by varying the voltages of our segmented trap, the light ion will be transferred to the second trapping zone with a well-controlled energy up to 1eV. The analysis of the light ion fluorescence will allow us to know its velocity distribution and thus to determine its temperature. It will then be possible to follow the cooling dynamics of the ion and determine the optimal cooling parameters and protocols for the GBAR experiment.

Preliminary experiments have already been performed in a volume trap. The cooling of 9Be+ by a coulomb crystal of 88Sr+ has been demonstrated with a cooling time of several seconds.

[1] P Pérez et al. The GBAR antimatter gravity experiment. Hyperfine interactions, 233 :21–27, 2015.

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