Contribution ID: **60**　　Type: **not specified**

Positronium Doppler laser cooling: results and perspectives

Tuesday 27 August 2024 15:15 (25 minutes)

Positronium is the bound state of an electron and its antimatter counterpart, a positron. With just two times the mass of the electron and no nucleus, this exotic compound is the lightest of all known atoms with no gluon contribution to its mass. Its electronic structure resembles the one of hydrogen with a factor two lower reduced mass. Positronium is therefore a system of particular interest for testing fundamental properties of antimatter such as the gravitational acceleration of antimatter in the Earth's gravitational field and bound state quantum electrodynamics. Positronium can also be used to form antihydrogen by collision with antiprotons [1]. All these experiments benefit from cold sources of positronium for example to remove the second order Doppler shift and transit time broadening in $1^3S \longrightarrow 2^3S$ spectroscopy or to increase the production rate of antihydrogen. However, laser cooling positronium poses a unique combination of challenges. First, the initial velocity distribution of thermalized positronium induces Doppler broadening of several hundreds of GHz. Being composed of two fundamental particles which can annihilate together, the lifetime of positronium is limited. In the ground ortho-state configuration, the annihilation lifetime of positronium is 142 ns setting the timescale available for laser cooling. The $1^3S \longrightarrow 2^3P$ transition used for laser cooling lies in the ultraviolet range (243 nm).

Here we report on the first experimental positronium laser cooling with broadband 70 ns long pulses [2]. We will report on the alexandrite laser system developed to overcome the challenges posed by positronium laser cooling as well as on the experimental results showing a reduction of temperature from 380(20)K to 170(20)K within 70 ns measured by two-photon resonant ionization on the Doppler sensitive $1^3S \longrightarrow 3^3P$ transition monitored by Positron Annihilation Lifetime Spectroscopy. Our results demonstrate that we realized the maximum of cooling efficiency allowed by classical Doppler cooling and that the transient excitation of positronium in the long-lived 2^3P state allows to extend the overall lifetime of the atoms. Finally, we will present future perspectives opened by this work and discuss the possibility to perform coherent laser cooling on positronium to reach even lower temperatures.

[1] C. Amsler, et al. (AEḡIS Collaboration), "Pulse production of antihydrogen,"Comm. Phys. 4:19 (2021).
[2] L. T. Glöggler, et al. (AEḡIS Collaboration), "Positronium Laser Cooling via the 13S-23P Transition with a Broadband Laser Pulse,"Phys. Rev. Lett. 132, 083402 (2024).

Author: CAMPER, Antoine (University of Oslo (NO))

Presenter: CAMPER, Antoine (University of Oslo (NO))

Session Classification: Parallel I