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Developments in antihydrogen laser cooling and future high-precision studies

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One of the most enduring mysteries in contemporary physics is the disparity in matter and antimatter within the observable universe. The Standard Model of particle physics posits that the Big Bang generated an equal quantity of matter and antimatter. However, cosmological observations reveal that the antimatter-to-matter ratio is approximately 10-8. Any discrepancies in the properties of matter-antimatter pair particles could potentially indicate a violation of CPT symmetry, potentially providing an explanation for the universe's apparent preference for matter. The ALPHA (Antihydrogen Laser PHysics Apparatus) collaboration, at CERN (European Organisation for Nuclear Research), conducts research on antihydrogen's atomic spectrum and interactions within Earth's gravitational field.

Recent publications by the ALPHA collaboration have demonstrated the operational functionality of all the apparatus's components. Measurements have been conducted on the hyperfine transition, 1S-2S, 1S-2P, laser cooling, and gravitational interaction involving trapped antihydrogen within the ALHPA2 and ALPHAg apparatus. Notably, we have recently published a detailed analysis of the 1S-2S line-shape of laser-cooled antihydrogen samples. Future high-precision studies of antihydrogen at ALPHA will necessitate enhanced laser cooling techniques for the trapped antihydrogen samples and precise diagnostics of their energy levels to achieve comparable results with equivalent studies conducted on hydrogen.

In this presentation, I will give an overview of the research done by ALPHA. The focus will be on the ALPHA2 and ALPHAg experimental apparatuses. I will describe the laser cooling techniques employed, particularly the 121 nm pulsed laser system. Furthermore, I will discuss the temperature diagnostics of these trapped samples. Cold and well-diagnosed antihydrogen samples are indispensable for high-precision measurements, directly influencing the accuracy of ALPHA's endeavours. Finally, I will address the significance of direct hydrogen-antihydrogen comparisons, which provide pivotal tests of fundamental physics, such as CPT symmetry, and enhance our comprehension of matter-antimatter interactions.

Keyword-1

Antimatter

Keyword-2

Fundamental symmetry

Keyword-3

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