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Microwave spectroscopy of antihydrogen in the ALPHA experiment

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The imbalance between matter and antimatter in the universe remains one of the biggest unanswered questions in physics. As the simplest purely antimatter atomic system, antihydrogen serves as an ideal platform for testing the fundamental symmetry between matter and antimatter (Charge-Parity-Time symmetry). Precise measurements of antihydrogen's transition frequencies, in direct comparison with their well-established hydrogen counterparts, provide a stringent test of CPT symmetry within the atomic sector. For example, microwave spectroscopy of the ground-state hyperfine splitting presents a promising avenue for exploration. In hydrogen, this transition has been measured with a precision of 1×10^{-12} and an absolute accuracy of 2 mHz, compared to 10 Hz for the 1S–2S transition potentially providing a probe for different physics.

The ALPHA collaboration at CERN has been leading the way in testing fundamental physics with magnetically trapped antihydrogen. Notable recent advances include high-precision spectroscopy of the 1S–2S transition, fine structure measurements, the first demonstration of laser cooling of antihydrogen, and the groundbreaking first observation of antihydrogen's gravitational free fall. Additionally, improvements in magnetic field control and significantly enhanced antihydrogen trapping rates, achieved through Be+ ion-assisted production, have opened new possibilities for microwave spectroscopy. In this talk, I will present ALPHA's latest microwave spectroscopy results and discuss prospects for achieving even higher precision measurements in the near future.

Keyword-1

Fundamental Symmetries

Keyword-2

Antimatter

Keyword-3

Hyperfine spectroscopy

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