Observation of the 1S - 2S transition in trapped antihydrogen

Stefan Eriksson* [1] **from the ALPHA-collaboration**†

* Department of Physics, College of Science, Swansea University, Swansea SA2 8PP, UK
† CERN, CH-1211 Geneve 23, Switzerland

Synopsis The two-photon transition to the first excited state of antihydrogen has been observed in the ALPHA experiment at CERN. This first observations of the optical spectrum of neutral antimatter is the most precise measurement on an antiatom. Our result is consistent with CPT invariance to a relative precision of around 2×10^{-10}.

Antihydrogen offers a unique way to test matter/antimatter symmetry. Antihydrogen can reproducibly be synthesized and trapped in the laboratory for extended periods of time [1, 2] offering an opportunity to study the properties of antimatter with high precision. New techniques to study antihydrogen have emerged; the ALPHA-collaboration at CERN can now interrogate the bound state energy structure with resonant microwaves [3], determine the gravitational mass to inertial mass ratio [4] and measure charge neutrality [5.6]. Here, the first observation of the two-photon transition to the first excited state in antihydrogen is presented [7].

Antihydrogen is synthesized by mixing antiproton plasmas originating from the Antiproton Decelerator at CERN and positrons from a Surko-type accumulator. Mixing 90,000 antiprotons and 1.6 million positrons results in about 25,000 antihydrogen atoms per attempt. Atoms with kinetic energy less than the 0.5 K (in units of the Boltzmann constant) can be trapped in the superconducting magnetic minimum trap. In this work, about 14 anti-atoms were trapped per trial. Antihydrogen is detected by releasing the anti-atoms from the trap and collecting the annihilation byproducts on as silicon vertex detector. The topology of the events is used to distinguish antiproton annihilation from cosmic rays.

Whilst trapped, the anti-atoms are illuminated with 243 nm light from a frequency stabilized laser system. A cryogenic ultrahigh-vacuum enhancement cavity ensures sufficient power to both drive the two-photon transition and subsequently ionize the atom. The ionized atoms leave the trap. The atoms are exposed to light at the two possible hydrogenic resonance frequencies in trapped atoms (Figure 1) during 300 s each. Control experiments are performed with the laser detuned by 200 kHz (at 243 nm) off resonance and with no laser light present under otherwise identical conditions. In eleven runs of each type, 159±13 antihydrogen detector counts were observed off resonance, 67±8.2 counts on resonance, i.e. 58%±6% of the trapped atoms are removed by the resonant 1S-2S excitation. Counts during the hold time are in good agreement.

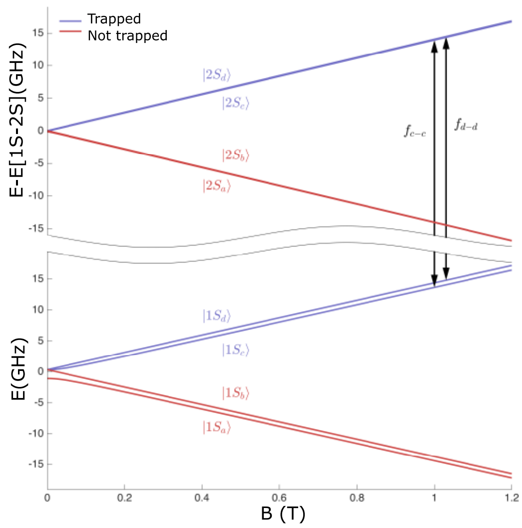

Figure 1 Energy levels of (anti)hydrogen in a magnetic field. The magnetic trap field minimum is about 1T. Possible two-photon transitions of trapped atoms are indicated by black arrows.

Assuming no asymmetries in the antihydrogen spectrum, together with a simulated spectrum which takes into account the motion of the atoms in the trap, the result can be interpreted as a test of CPT symmetry at a precision of 200 parts per trillion.

References

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[1] E-mail: s.j.eriksson@swansea.ac.uk