New technique for antihydrogen synthesis promises answers to mysteries of antimatter

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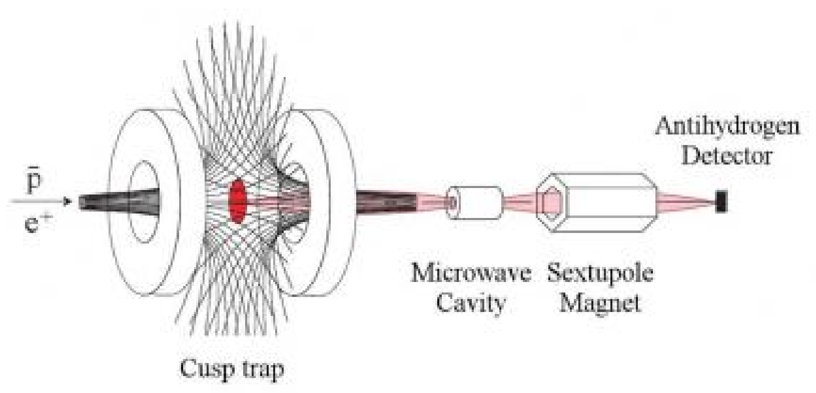
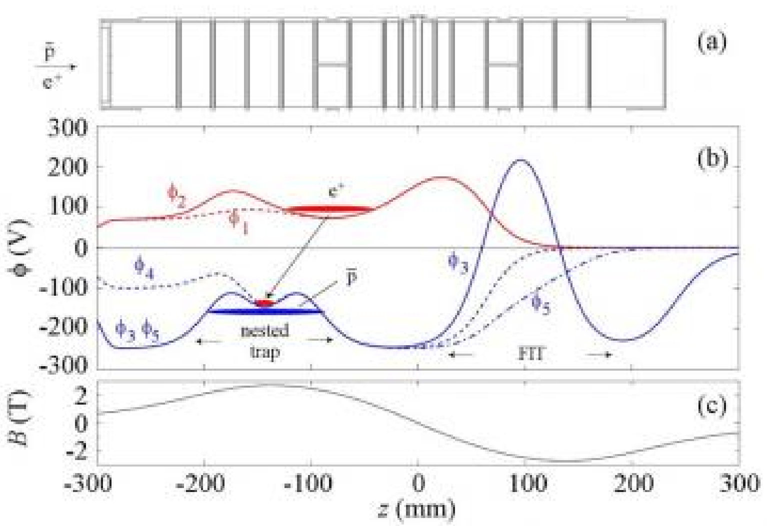


Conceptual experimental setup for ground-state hyperfine transition measurements of antihydrogen atoms with the cusp trap.

(PhysOrg.com) -- Researchers at RIKEN, Japan's flagship research institution, have successfully devised the world's first experimental technique for measuring ground-state hyperfine transitions of antihydrogen. By enabling scientists to test fundamental theories of symmetry and gravity, the new technique promises to shed light on some of the most profound mysteries of our universe.

One of the most puzzling findings to emerge from modern physics, the existence of antimatter is at the heart of some of the most challenging unsolved problems in science. Why is it that the universe today is made up almost exclusively of matter, and not antimatter? The standard model of particle physics, currently our best theory on the subatomic world, fails to provide an answer to this question.

Instead, scientists believe the answer may lie in tiny differences between the properties of matter and antimatter, manifested in violations of a principle known as CPT (charge, parity, time) symmetry. Antihydrogen, made up of an antiproton and a positron, is attractive for testing CPT symmetry given its simple structure. First produced in large quantities at CERN in 2002, antihydrogen was recently trapped for the first time in a widely-reported study by the international ALPHA collaboration, published last month in Nature.



(a) Stack of multiple ring electrodes of the cusp trap. (b) The electrical potential along the beam axis. The potential Φ1 for injection of positrons, Φ2 for accumulation and compression of positrons. and Φ3 for mixing of antiprotons and positrons. (The mixing region in the upstream part is called the nested trap, and the harmonic part in the downstream is called the field-ionization trap (FIT)). Φ4 for antiproton injection from the upstream side. Φ5 for extraction of antiprotons accumulated in the FIT originating from the field-ionized antihydrogen atoms. (c) The magnetic field B(T) along the beam axis.

The new experimental technique, also developed at CERN in a project called ASACUSA, adopts a novel approach for testing CPT in antihydrogen. Whereas ALPHA focused on high-precision laser spectroscopy measurement of 1S-2S electron transitions, ASACUSA uses high-precision microwave spectroscopy to study much smaller hyperfine transitions. The latter approach does not require that atoms be trapped for their properties to be measured, thus making it possible to study an actual beam of antihydrogen.

The new experimental setup, which produces antihydrogen by colliding positrons and antiprotons in a novel “cusp” trap, is an essential precursor to creating such a beam. Initial findings reported in the journal *Physical Review Letters* indicate that more than 7% of all antiprotons injected into the trap successfully combine to form antihydrogen, suggesting that tests of CPT symmetry are not far away. Together with the studies on trapped antihydrogen, new experiments promise groundbreaking insights into the nature of antimatter, revolutionizing our understanding of matter and the universe.

More information: Y. Enomoto, N. Kuroda, K. Michishio, C.H. Kim, H. Higaki, Y. Nagata, Y. Kanai, H.A. Torii, M. Corradini, M. Leali, E. Lodi-Rizzini, V. Mascagna, L. Venturelli, N. Zurlo, K. Fujii, M. Ohtsuka, K. Tanaka, H. Imao, Y. Nagashima, Y. Matsuda, B. Juhasz, A. Mohri, and Y. Yamazaki. Synthesis of Cold Antihydrogen in a Cusp Trap. *Physical Review Letters* (2010).

Provided by RIKEN