【Grant-in-Aid for Specially Promoted】

Science and Engineering (Mathematics/Physics)

Title of Project： Hyperfine splitting of antihydrogen and magnetic moment of antiproton

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Research Area：Physics (atoms, molecules, quantum electronics)
Keyword：CPT symmetry, antihydrogen, antiproton, magnetic moment

【Purpose and Background of the Research】

CPT symmetry is considered to be the most fundamental symmetry under simultaneous inversion of charge (C), parity (P), and time (T). Till now, P and CP symmetries were believed to be conserved, but later both were found to be false. CPT is the last one still escaping from our chase. Further, it is also believed that the Big Bang taken place 13.7 billion years ago produced exactly the same number of matter and antimatter although the present universe is filled solely with matter. The fundamental question how to develop such unbalanced universe is not known. In the present project, we are going to synthesize antihydrogen atom (consisting of an antiproton (antiparticle of proton) and positron (antiparticle of electron)), the representative of stable antimatter, and to compare its physical property with that of hydrogen. By this way, the most fundamental symmetry of nature, CPT symmetry, will be stringently tested.

【Research Methods】

The CPT symmetry guarantees that the mass, the absolute values of charge, magnetic moment, lifetime, etc. are all exactly the same between the paired matter and antimatter. We are particularly interested in the magnetic moment of antiprotons, because (1) it is known only with the precision of 3 digits, which is million-fold worse than the mass and charge, and (2) a theoretical discussion called SME (standard model extension) predicts that the magnetic moment is extremely sensitive to the CPT violation as compared with e.g. 1S-2S transition.

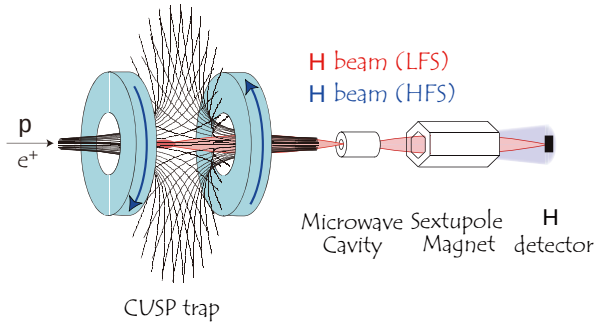

Fig.1: Synthesizer of Spin-polarized antihydrogen and microwave spectroscopy

We decided to develop a spin-polarized cold antihydrogen beam, and then apply microwave spectroscopy to determine the hyperfine transition frequencies with a precision of six digits. At the same time, we will start measuring spinflip frequency of an isolated antiproton in a penning trap, which allow the antiproton magnetic moment with a precision of six digits or better. The combination of these two quantities provides us with the magnetic moment as well as the magnetization distribution inside of antiproton for the first time.

【Expected Research Achievements and Scientific Significance】

The synthesis of spin-polarized cold antihydrogen beam the first step of this project is already one of the most important mile-stone achievements in the field of antimatter science. Any measurements proposed, microwave spectroscopy of antihydrogen, high precision measurements of hyperfine transitions and spin-flip frequencies of isolated antiproton have not been realized till now, and should give high impact not only to the related fields but also to general society.

【Publications Relevant to the Project】

Y. Enomoto, et al., “Synthesis of Cold Anti-hydrogen in a Cusp Trap”, Phys. Rev. Lett. **105** (2010) 243401(1-4).
S. Ulmer, et al., ”Direct Measurement of the Free Cyclotron Frequency of a Single Particle in a Penning Trap”, Phys. Rev. Lett. **107**, 103002 (2011)

【Term of Project】 FY2012-2016

【Budget Allocation】 269,000 Thousand Yen

【Homepage Address and Other Contact Information】

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