Hyperfine resonance of positronium using a static periodic magnetic field

Y. Nagata[1,*], K. Michishio[2], T. Iizuka[1], H. Kikutani[1], L. Chiari[3], F. Tanaka[1] and Y. Nagashima[1]

[1]*Department of Physics, Tokyo University of Science, 162-8601 Tokyo, Japan*
[2]*National Institute of Advanced Industrial Science and Technology (AIST), 305-8568 Ibaraki, Japan*
[3]*Department of Applied Chemistry and Biotechnology, Chiba University, 263-8522 Chiba, Japan*

[*]email: yugo.nagata@rs.tus.ac.jp

Usually atomic resonances are induced by electromagnetic waves like lasers and microwaves. An atomic resonance can also be induced by a static periodic field, when an atom passes through the field, because the atom feels a time-dependent oscillating field in the center of mass system. This method was vigorously applied to heavy ions using a crystalline periodic field in the transition energy higher than EUV. A periodically-placed magnet can also be used to manipulate Zeeman sub-levels of neutral atoms in a microwave region.

Positronium (Ps), composed of an electron and a positron, has a hyperfine structure in the ground state. The transition frequency is 203 GHz in the sub-THz region. So far, the frequency has been measured by a direct method using milliwaves and indirect methods with microwaves and a laser as a test of QED.

We demonstrated the observation of the hyperfine structure of Ps using a static periodic magnetic field generated by a multilayered magnetic grating, as shown in Fig. 1(a). *o*-Ps atoms pass through the grating and are counted by an MCP detector. When *o*-Ps atoms transition to *p*-Ps at the resonance frequency in the sub-THz region, they self-annihilate immediately due to the shorter lifetime and do not arrive at the detector.

The experiment was performed by using a high-quality and energy-tunable positronium beam [1]. Figure 1(b) shows the experimental result of the number of *o*-Ps atoms detected as a function of frequency [2]. The dip at around 210 GHz confirms the atomic resonance of the hyperfine structure of Ps.

This demonstration will be an important step towards the precise spectroscopy of the hyperfine structure of Ps using this method and will open the door to the application to other atoms and molecules.

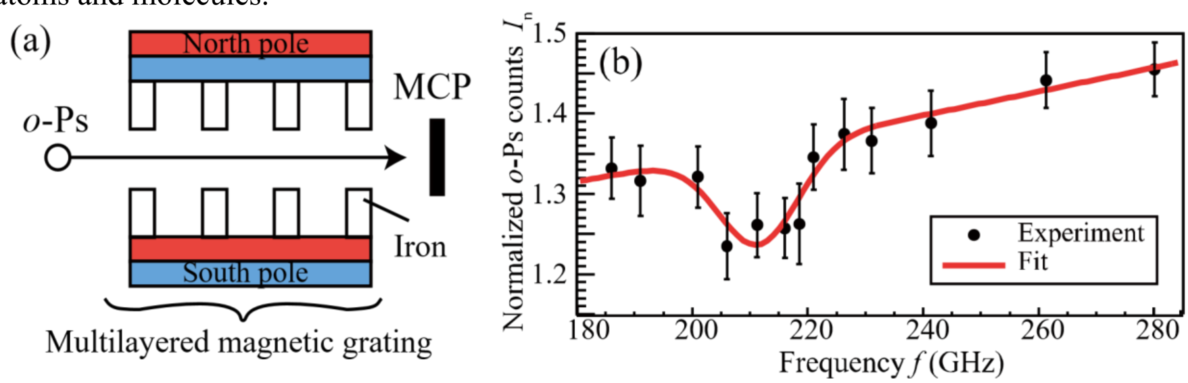

Fig.1. (a) Schematic figure of the experiment. (b) *o*-Ps counts as a function of the frequency.

[1] K. Michishio et al., *Rev. Sci. Instrum.* **90**, 023305 (2019).
[2] Y. Nagata et al., *Phys. Rev. Lett.* **124**, 173202 (2020).