Contribution ID: **26** Type: **not specified**

First Spectroscopy of the Hyperfine Interval of Positronium Using Millimeter Waves

Monday, 15 September 2014 12:00 (30 minutes)

We firstly performed the millimeter-wave spectroscopy of the ground-state positronium.
The energy difference between ortho-positronium (o-Ps) and para-positronium (p-Ps), the hyperfine structure, is in the millimeter-wave range (203 GHz).
Since the magnetic dipole transition from o-Ps to p-Ps is strongly suppressed due to their short lifetime, strong millimeter waves of over 20 kW are required to measure the Breit-Wigner resonance of the transition.
This experiment has not yet been performed because previously there were no high-power millimeter-wave devices.
We newly developed high-power and frequency-tunable millimeter-wave system composed of a gyrotron and a Fabry-Perot cavity, and directly measured the Breit-Wigner resonance of the transition from o-Ps to p-Ps.
This is a breakthrough to use millimeter waves in spectroscopic measurements.
Three parameters of this transition, the hyperfine structure, lifetime of p-Ps, and spontaneous transition rate are simultaneously determined through the measured Breit-Wigner resonance.

The hyperfine structure of positronium has been indirectly obtained via the Breit-Rabi formula and precise measurement of the Zeeman shifted levels in a static magnetic field of about 1 T.
The indirectly measured value differs from QED calculations by 15 ppm (3.9 standard deviations).
Some underestimated systematic uncertainties, such as a non-thermalized effect of positronium and non-uniformity of the magnetic field, are suspected.
The direct measurement is free from systematic problems due to the static magnetic field.
Although current accuracy of the direct measurement is about 700 ppm, it can be improved and used to examine the reported discrepancy in the indirect measurement.

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