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Laser spectroscopy of the hyperfine splitting energy in the ground state of muonic hydrogen

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We are planning to measure the ground-state hyperfine splitting energy of muonic hydrogen by laser spectroscopy techniques at the RIKEN-RAL Muon facility. The hyperfine splitting energy is about 0.182 eV, which corresponds to the laser wavelength of 6.7 μm. The experiment has become feasible by a narrow-bandwidth tunable mid-infrared laser recently developed in RIKEN [1]. The expected precision for the hyperfine splitting energy is around 2 ppm owing to the narrow bandwidth of the laser.

Through the theoretical calculation with the proton structure-dependent corrections [2], the hyperfine splitting energy is directly connected to the Zemach radius (the first moment of the convolution of the proton charge and the magnetic moment distributions). This experiment is the first precise measurement of the ground-state hyperfine splitting of muonic hydrogen and can provide new insights on "Proton radius puzzle", which has been issued by a recent measurement of the Lamb shift in muonic hydrogen at Paul Scherrer Institute [3].

When the laser is irradiated onto the ground-state muonic hydrogen with the resonance frequency of the hyperfine splitting energy, the spin-flip transition is induced from the spin-singlet to the spin-triplet hyperfine sub-levels. Since the muon spin in the triplet state can be polarized by a circularly-polarized laser, we can search for the resonance frequency by detecting the spatial asymmetry of the electrons from the polarized muon decay.

In this contribution, we present the physics motivation, the experimental principle and its feasibility.

[1] N. Saito et al., Proc. of SPIE, vol. 8526, 852605-1 (2012).

[2] A. Dupays et al., Phys. Rev. A68, 052503 (2003).

[3] R. Pohl et al., Nature 466, 213 (2010).

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