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

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We propose a new measurement of the ground-state hyperfine splitting of muonic hydrogen by laser spectroscopy techniques with the accuracy of ~2 ppm. The hyperfine splitting energy is directly connected to the Zemach radius, which is a convolution of the spatial distribution of the charge and the magnetic moment within the proton, through the theoretical calculation with the proton structure-dependent corrections [1]. This is the first precise measurement of the ground-state hyperfine splitting of the 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 [2].

Muonic hydrogen atoms are formed when negative muons are stopped in the hydrogen. They immediately reach the ground state and muons in the ground state decay with the lifetime of 2.2 μs. When the laser with the resonance frequency of the hyperfine splitting energy is irradiated, the spin-flip transition is induced from the spin-singlet ($^1S_0$) to the spin-triplet ($^3S_1$) hyperfine sub-levels. Since the muon spin in the $^3S_1$ state can be polarized by a circularly-polarized laser, we can search for the resonance frequency with the muon decay asymmetry by the decay-electron detection.

The hyperfine splitting energy of the ground-state muonic hydrogen is about 0.182 eV, which corresponds to the laser wavelength of 6.7 μm. The experiment becomes feasible by a narrow-bandwidth tunable mid-infrared laser recently developed in RIKEN [3].

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

References

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