Precision spectroscopy of the 2S-4P transition in atomic hydrogen

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The comparison between experimental and theoretical values of transition frequencies in atomic hydrogen, the most simple atomic system, provides stringent tests of bound state quantum electro dynamic (QED) calculations. For more than one decade, this comparison has been limited by insufficient knowledge about the size of the proton, strictly speaking its r.m.s. charge radius r_p. In 2010, a value for r_p ten times more accurate than any previous measurement has been determined by laser spectroscopy of muonic hydrogen [1]. However, this value deviates from the one extracted from regular hydrogen spectroscopy by four combined standard deviations. The muonic hydrogen value has been confirmed and improved in a recent publication [2] while the source of the discrepancy remains unclear and suggested solutions to this 'proton size puzzle' range from experimental shortcomings to physics beyond the Standard Model [3].

In this talk, we will report on an experiment aiming to contribute to a more precise determination of the Rydberg constant and the proton charge radius from regular atomic hydrogen spectroscopy: Our measurement of the 2S-4P transition is the first precision experiment of its kind utilizing a cryogenic source of hydrogen atoms [4]. Optical excitation to the meta-stable 2S state preserves the atoms' low thermal velocity and allows for preparation of 2S atoms in only one hyperfine state. In our apparatus, systematic effects such as the Doppler effect, ac Stark effect and different line pulling effects present in previous work are significantly reduced. Preliminary results of our latest measurements of the 2S-4$P_{1/2}$ and 2S-4$P_{3/2}$ transitions will be discussed and a reproducibility of the line center extraction of a few parts in 10^{12} is demonstrated. The study of different systematic effects is underway and will be discussed as well.

[1] R. Pohl *et al.*, Nature **466** (7303), 213-216, 2010.

[2] A. Antognini *et al.*, Science **339**, 417-420, 2013.

[3] R. Pohl *et al.*, arXiv:1301.0905 [physics.atom-ph], 2013.

[4] A. Beyer *et al.*, accepted in Ann. Phys. (Berlin), 2013.