Challenging QED with atomic hydrogen

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Precise determination of transition frequencies of simple atomic systems are required for a number of fundamental applications such as tests of quantum electrodynamics (QED), the determination of fundamental constants and nuclear charge radii. The sharpest transition in atomic hydrogen occurs between the metastable 2S state and the 1S ground state with a natural line width of only 1.3 Hz. Its transition frequency has been measured with almost 15 digits accuracy using an optical frequency comb and a cesium atomic clock as a reference [1]. A measurement of the Lamb shift in muonic hydrogen is in significant contradiction to the hydrogen data if QED calculations are assumed to be correct [2]. In order to shed light on this discrepancy the transition frequency of one of the broader lines in atomic hydrogen has to be measured with very good accuracy. For this purpose we have employed our previous 1S-2S apparatus as a cold source of laser excited 2S atoms in order to perform spectroscopy on the 2S-4P transitions. With a natural line width of 12.7 MHz, large Doppler effects, quantum interference etc. a good line shape analysis is mandatory to identify the true transition frequency. Our result on this transition yields a value for the proton radius that is compatible with the value obtained from muonic hydrogen with an uncertainty that is comparable to the previous hydrogen world data [3]. Meanwhile H. Fleurbaey and her team at the Laboratoire Kastler Brossel, Paris have re-measured the 1S-3S transition frequency with a significantly improved accuracy and find the previous "regular hydrogen charge radius" [4]. At our lab we have also been working on this transition with a different method. We hope to be ready to report a result soon. This will provide a unique opportunity to compare two highly accurate measurements obtained at different labs.

[1] C.G. Parthey et al., Phys. Rev. Lett. 107, 203001 (2011).

[2] A. Antognini et al., Science 339, 417, (2013).

[3] A. Beyer et al., Science 358, 79 (2017).

[4] H. Fleurbaey et al., PRL 120, 183001 (2018).