QED tests and fundamental constants from frequency comb spectroscopy on hydrogen and deuterium

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Current calculations and experiments on quantum electrodynamics (QED) both achieve twelve digits of accuracy [1] making it an excellent test ground of the fundamental physics and searches for new physics. Two fundamental constants are obtained from hydrogen spectroscopy with highest precision: the Rydberg constant and the (rms) proton charge radius.

While coherent sources in the deep UV are of great interest for both fundamental and applied physics, their usage has been so far limited by the difficulties to generate narrow line width laser sources in this region. Two-photon direct frequency comb spectroscopy [4] offers several unique features in this respect: efficient harmonics generation, low noise and narrow line widths, convenient absolute frequency referencing and a small interaction region, well suited for systematics characterization and trapped atoms and ions experiments.

We have performed a precision measurement of the 1S-3S transition in hydrogen [3] and deuterium, demonstrating the potential of this technique and investigating its limitations. Our result, combined with the 1S-2S transition in hydrogen [2], tests the bound state QED at the twelve decimal place and reduces the uncertainty of the Rydberg constant by a factor of two. It further gives the most precise determination of the rms proton charge radius besides the Lamb shift measurement in muonic hydrogen shedding light onto the so called "proton radius puzzle" [5].

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