Updates from the Hydrogen 1S-3S Direct Frequency Comb Spectroscopy Experiment at MPQ

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Due to its simple structure, the Hydrogen atom is a powerful platform for precision tests of fundamental physics, more explicitly quantum electrodynamics. The energy levels in atomic Hydrogen can be calculated up to a high degree of precision and can be written as:

$$E_{n,l,j} = hc\mathbf{R_y}\left(-\frac{1}{n^2} + f_{n,l,j}(\alpha, \frac{m_e}{m_p}, ...) + \delta_{l,0}\frac{C_{NS}}{n^3}\mathbf{r_p}^2\right), \tag{1}$$

where $f_{n,l,j}$ is the QED series expansion in the fine structure constant α, containing various corrections to the leading Bohr-level term. The last term describes the contribution due to the finite size effect, i.e. the fact, that the proton in the atom core is not a point-like particle but has a charge distribution with the RMS charge radius r_p to which the s-states ($l = 0$) are sensitive to, due to their finite spatial overlap of the wave function with the atom core. As other required parameters, such as α or the electron to proton mass ratio m_e/m_p can be determined very accurately by other experiments in atom interferometers and Penning traps, R_y and r_p remain to be ascertained by spectroscopy [3]. Thus, two transition measurements in hydrogen are required to fix R_y and r_p and more to check for consistency. Contributing to that quest, the 1S-3S experiment at MPQ in Garching delivered its first result in 2020 with a fractional uncertainty of 10^{-13} [2]. The 1S-3S transition was also measured by colleagues at the Laboratoire Kastler Brossel in Paris [1], with a value different to the MPQ measurement by 2.1 standard deviation. Thus, this experiment is of particular importance as it provides the only transition measurement in Hydrogen that has been conducted redundantly by two groups with independent systematics and modern laser spectroscopy techniques. Strongly hinting to unknown experimental issues, this discrepancy motivates the further improvement of the experimental setup towards a lower uncertainty measurement. In this poster, an overview of the experimental setup is given, together with an outlook on the improvements expected from modifications currently underway.

References

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