MAX PLANCK INSTITUTE
OF QUANTUM OPTICS

PhD thesis: precision spectroscopy of the 2S-9P transition in atomic hydrogen and deuterium

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Precision laser spectroscopy of atomic hydrogen and deuterium has long been used to determine physical constants and to test fundamental theories, owing to the simple structure of atoms allowing comparison with precise calculations. We are continuously improving constraints on these tests and shine light on possible discrepancies, such as the proton radius puzzle [1]. At the moment, we are measuring the 2S-6P transition in deuterium which allows for determination of the deuteron radius and further tests of quantum electrodynamics. To reach the required fractional uncertainty of a few parts in 10^{12} of the transition frequency, a sophisticated control over systematic effects such as quantum interference is required [2]. The 2S-9P transitions in hydrogen and deuterium bear the potential for an even higher precision and an improved determination of the Rydberg constant and the proton or deuteron radii due to the narrower natural linewidth. Furthermore, an experiment involving higher *n*P states can be more sensitive for certain constraints on new physics. To this end, we have the laser system for measuring the 2S-9P transitions ready to be integrated into the apparatus for future measurements.

We are **looking for a doctoral student for the hydrogen and deuterium spectroscopy experiment** who is interested in working with a typical atomic physics toolkit. More specifically, the student would participate in the current and future measurements of the 2S-*n*P transitions in atomic hydrogen and deuterium. This project includes mostly hands-on experimental work with ultra-stable lasers, the frequency comb, electronics, a high vacuum system, a liquid helium cryostat, as well as our recently published improved active fiber-based retroreflector [3]. Apart from experimental work, not only data analysis, but also high performance computing simulations are important in order to investigate effects like quantum interference or the light force shift.

If you are interested in joining our team and want to learn more about the project, do not hesitate to contact Vitaly Wirthl (vitaly.wirthl@mpq.mpg.de). Please send your application along with your CV to Prof. Thomas Udem (thu@mpq.mpg.de) with CC to Vitaly.

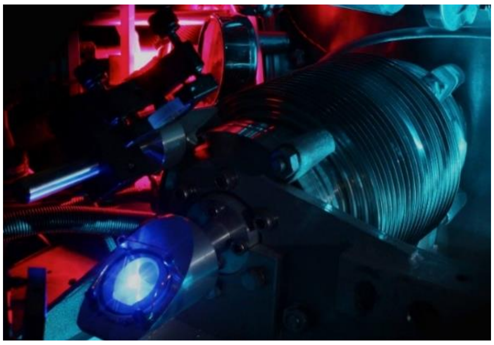

Photo showing the vacuum chamber used to measure the 2S-4P transition frequency in atomic hydrogen. The purple glow in the back stems from the microwave discharge that dissociates hydrogen molecules into hydrogen atoms. The blue light in the front is fluorescence of the vacuum viewport from the ultraviolet laser that excites the atoms to the 2S state. The turquoise blue glow is stray light from the laser system used to measure the frequency of the 2S-4P transition. (Credit: Axel Beyer / MPQ)

Key references

[1] A. Beyer *et al.* The Rydberg constant and proton size from atomic hydrogen. *Science* **358**, 79–85 (2017).

[2] Th. Udem *et al.* Quantum Interference Line Shifts of Broad Dipole-Allowed Transitions. *Annalen der Physik* **531**, 1900044 (2019).

[3] V. Wirthl *et al.* Improved active fiber-based retroreflector with intensity stabilization and a polarization monitor for the near UV. *Opt. Express* **29**(5), 7024-7048 (2021).