Towards High-Precision Spectroscopy of the 1S–2S Transition in He^+

Akira Ozawa[a], Fabian Schmid[a], Jorge Moreno[a], Johannes Weitenberg[a,b], Theodor W. Hänsch[a,b], Thomas Udem[a,b]

[a] *Max-Planck-Institut für Quantenoptik,Hans-Kopfermann-Straße 1, 85748 Garching, Germany*
[b] *Fraunhofer-Institut für Lasertechnik ILT, Steinbachstraße 15, 52074 Aachen, Germany*
[c] *Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany*

The energy levels of hydrogen-like atoms and ions are accurately described by bound-state quantum electrodynamics (QED). The frequency of the narrow 1s-2s transition of atomic hydrogen has been measured with a relative uncertainty of less than 10^{-14}. In combination with other spectroscopic measurements of hydrogen and hydrogen-like atoms, the Rydberg constant and the proton charge radius can be determined. The comparison of the physical constants obtained from different combinations of measurements serves as a consistency check for the theory [1]. The hydrogen-like He^+ ion is another interesting spectroscopic target for QED tests. Due to their charge, He^+ ions can be held nearly motionless in the field-free environment of a Paul trap, providing ideal conditions for high-precision measurements. Interesting higher-order QED corrections scale with large exponents of the nuclear charge, making this measurement much more sensitive to these corrections compared to the hydrogen case. The measurement of a transition in He^+ will extend the test of QED beyond the long-studied hydrogen. In this talk, we describe our progress towards precision spectroscopy of the 1S-2S two-photon transition in He^+ [2]. The transition can be directly excited by an extreme-ultraviolet frequency comb at 60.8 nm generated by a high-power infrared frequency comb using high-order harmonic generation (HHG). A femtosecond enhancement resonator with non-collinear geometry is used for this purpose. The spectroscopic target is a small number of He^+ ions trapped in a linear Paul trap and sympathetically cooled by co-trapped Be^+ ions. After successful excitation to the 2S state, a significant fraction of the He^+ ions are further ionized to He^{2+} that remain in the Paul trap. Sensitive mass spectrometry using secular excitation will reveal the number of trapped He^{2+} ions and will serve as a single-event sensitive spectroscopy signal.

---

[1] Th. Udem. Nat. Phys. **14**, 632 (2018).
[2] M. Herrmann *et al.*, Phys. Rev. A **79**, 052505 (2009).