Toward High-Precision XUV Spectroscopy of the 1S-2S Transition in He^+

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Bound-state quantum electrodynamics (QED) accurately describes the energy levels of hydrogen-like atoms and ions. High-precision laser spectroscopy experiments provide one of the best tests of the theory. The frequency of the narrow 1S-2S transition of atomic hydrogen has been measured with a relative uncertainty of less than 10^{-14}. By combining two spectroscopic measurements of a hydrogen-like system, the Rydberg constant and the nuclear charge radius can be determined. The comparison of physical constants obtained from different measurement combinations serves as a consistency check for the theory [1]. It is valuable to study different hydrogen-like systems, as they exhibit varying sensitivities to different contributions of the theory. The measurement of the Lamb shift in muonic hydrogen, for instance, has enhanced sensitivity to the proton radius and led to the proton radius puzzle [2].

Another interesting spectroscopic target is the hydrogen-like He^+ ion. Higher-order QED corrections scale with high powers of the nuclear charge, making He^+ significantly more sensitive to these effects than hydrogen. We are preparing an experiment to measure the 1S-2S two-photon transition in He^+ [3]. Ideal conditions for high-precision measurements are achieved by holding a small number of He^+ ions nearly motionless in the field-free environment of a Paul trap, where they are sympathetically cooled by co-trapped Be^+ ions. The 1S-2S transition will be excited by an extreme-ultraviolet (XUV) frequency comb at 60.8 nm, generated via high-harmonic generation from a high-power infrared frequency comb. After successful excitation to the 2S state, a significant fraction of the He^+ ions will be further ionized to He^{2+} and remain in the Paul trap. Sensitive in-situ mass spectrometry using secular excitation will detect the number of trapped He^{2+} ions, serving as a single-event-sensitive spectroscopy signal.

To perform Doppler-free spectroscopy of the He^+ transition, two counterpropagating pulses of the frequency comb must overlap spatially and temporally at the ion position. Achieving this overlap before the spectroscopy experiment is crucial to find the spectroscopy signal within a reasonable measurement time, making it a critical preparatory milestone. Another key milestone is the installation of a custom XUV spectrometer to fine-tune the spectral envelope of the frequency comb to match the expected He^+ transition.

This poster provides an update on the progress toward He^+ spectroscopy in our experiment and offers an opportunity to further discuss the details presented in the accompanying talk.

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References

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