PRECISION LASER SPECTROSCOPY OF ATOMIC HYDROGEN

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Abstract

Precision spectroscopy of atomic hydrogen permits unique confrontations between experiment and quantum electrodynamic theory. It has motivated advances in nonlinear laser spectroscopy and optical frequency metrology over more than three decades. Until a few years ago, the primary challenge in hydrogen spectroscopy has been the precise measurement of the frequency of laser light. Since the advent of the laser frequency comb technique, the challenge has moved to the understanding and control of systematic line shifts, which are particularly serious for very light atoms. Recent advances will be reported. A measurement of the frequency of the sharp 1S-2S two-photon resonance with the highest possible precision is of particular interest as a reference for future experiments with antihydrogen, in order to detect possible small differences between matter and antimatter.

The comparison of the 1S-2S frequency with quantum electrodynamic theory and the determination of the Rydberg constant is presently limited by the large 2% uncertainty of the rms charge radius of the proton, as determined from electron scattering experiments. To overcome this limit, we are working on a complementary experiment to measure the absolute frequency of the 1S-3S two-photon resonance, in order to take advantage of the different scaling of hadronic level shifts with the principal quantum number n.

An international collaboration at the Paul Scherrer Institute (PSI) in Switzerland is aiming for a tenfold improved value of the proton charge radius via infrared laser spectroscopy of the 2S-2P Lamb shift in muonic hydrogen. Together with the hydrogen 1S-2S frequency, this measurement could lead to an immediate 6-fold improvement in the accuracy of the Rydberg constant.

The development of laser frequency comb techniques in the extreme ultraviolet is openening intriguing prospects for precision spectroscopy of cold trapped hydrogen-like ions, such as He^+: