Precision spectroscopy of atomic helium and molecular hydrogen at Hefei

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Atomic helium and molecular hydrogen are the simplest neutral systems after atomic hydrogen. Their energy levels and properties can be calculated precisely based on the quantum electrodynamics (QED) theory and several fundamental constants. In this talk, we present our recent progress on precision measurements of these two systems.

The post-selection (PS) effect was investigated in high-precision spectroscopy of the $2^3S - 2^3P$ transition of ^{4}He using an atomic beam. This effect induces a shift in the measured transition frequency of up to –55 kHz. After correcting for the PS shift, we obtain a transition frequency of $276,764,094,712.45 \pm 0.86$ kHz for the $2^3S_1 - 2^3P_0$ transition [1]. This result, combined with the existing data for ^{3}He, was used to extract the difference in the squared nuclear charge radii between the ^{3}He and ^{4}He nuclei. A new precision measurement of the $2^3S_1 - 2^3P$ transition of ^{3}He is currently underway.

In the past decade, the precision of transition frequencies for molecular hydrogen, including H_2 and HD, has been significantly improved to the 10–100 kHz level. Beyond transition frequencies, other molecular properties can also serve as valuable tests for theoretical models and computational methods. Recently, we measured the electric polarizability of the H_2 molecule with an uncertainty at the 10^{-5} level [2], which agrees well with the theoretical predictions. Additionally, we measured [3] the line intensity of the Q(1) line in the (2–0) vibrational band of H_2 near 1.24 μm with an uncertainty of less than 0.1%, and compared the results with theoretical calculations [4, 5]. These measurements provide a solid foundation for further improvements in the near future, and the techniques used are applicable to other molecular systems as well [6, 7].

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