Measurement of the forbidden $2\ ^3S_1 \rightarrow 2\ ^1P_1$ transition in quantum degenerate helium

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There is a longstanding 6.8 (3.0) MHz discrepancy between QED theory and the experimental value of the ionization energy of the $2\ ^1P_1$ state in helium. We present the first measurement of the forbidden 887-nm $2\ ^3S_1$ - $2\ ^1P_1$ transition in a quantum degenerate gas of ^{4}He* [1], using the experimental setup as used to measure the doubly forbidden $2\ ^3S \rightarrow 2\ ^1S$ transition by van Rooij *et al.* [2]. The low temperature of the gas ($\sim$1 μK) allows us to observe the transition at its natural linewidth of 287 MHz and control systematic frequency shifts with kHz accuracy.

From our measurements we obtain the transition frequency with a relative accuracy of 1.6×10^{-9} and determine the ionization energy of the $2\ ^1P_1$ state with 6.7×10^{-10} relative accuracy. Our result deviates $> 3\sigma$ from the currently most accurate QED theory for the $2\ ^1P_1$ ionization energy [3]. Recent measurements of the $2\ ^1S_0 \rightarrow 2\ ^1P_1$ [4] and $2\ ^1P_1 \rightarrow 3\ ^1D_2$ [5] transition frequencies by Luo *et al.*, which are performed in a RF discharge cell, allow an independent determination of the $2\ ^1P_1$ ionization energy and agree with our work. This discrepancy with theory is shown in Fig. 1 and indicates that a renewed effort on the QED calculations is required.

Furthermore, as the transition is observed at its natural linewidth, our measurement allows for the most accurate determination of the lifetime of the $2\ ^1P_1$ state to date. The determined lifetime of 0.551 $(0.004)_{\rm stat}$ $(^{+0.013}_{-0.000})_{\rm syst}$ ns is in agreement with theory and previous determinations that are based on completely different techniques.

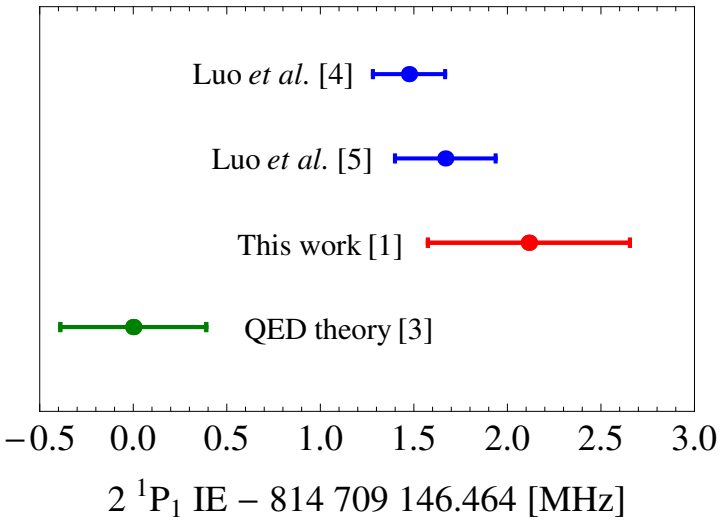

Figure 1: *Comparison of our experimental determination of the $2\ ^1P_1$ ionization energy [1] with other experiments by Luo et al. [4–5] and QED theory by Yerokhin and Pachucki [3].*

References

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