

Precision spectroscopy of transitions from the metastable 2^3S_1 state of ^4He to high np Rydberg states

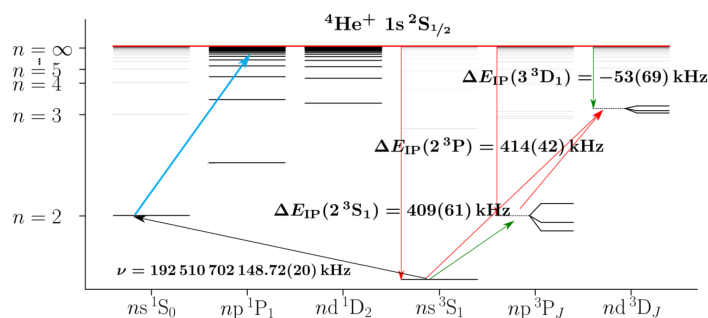
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The metastable He ($(1s)^1(2s)^1$) atom in its singlet (1S_0) or triplet (3S_1) states is an ideal system to perform tests of *ab-initio* calculations of two-electron systems that include quantum-electrodynamics and nuclear finite-size effects. The recent determination of the ionization energy of the metastable 2^1S_0 state of ^4He [1] confirmed a discrepancy between the latest theoretical values of the Lamb shifts in low-lying electronic states of triplet helium [2] and the measured $3^3D \leftarrow 2^3S_1$ [3] and $3^3D \leftarrow 2^3P$ [4] transition frequencies. This discrepancy could not be resolved in the latest calculations [5,6].

Currently, we focus on the development of a new experimental method for the determination of the ionization energy of the 2^3S_1 state of ^4He via the measurement of transitions from the 2^3S_1 state to np Rydberg states. Extrapolation of the np series yields the ionization energy with sub-MHz accuracy.

In this poster, we present the progress in the development of our experimental setup, which involves (i) the preparation of a cold, supersonic expansion of helium atoms in the 2^3S state, (ii) the development and characterization of a laser system for driving the transitions to the np Rydberg states and (iii) the implementation of a new sub-Doppler, background-free detection method. We present this new spectroscopic method, with which we cancel the 1st-order Doppler shift and illustrate its power with a new determination of the ionization energy of 2^3S_1 metastable He.



[1] Gloria Clausen, Paul Jansen, Simon Scheidegger, Josef A. Agner, Hansjürg Schmutz, and Frédéric Merkt, *Phys. Rev. Lett.* **127**, 093001 (2021).

[2] Vojtěch Patkóš, Vladimir A. Yerokhin, and Krzysztof Pachucki, *Phys. Rev. A.* **103**, 042809 (2021).

[3] Christophe Dorrer, François Nez, Béatrice de Beauvoir, Lucile Julien, and François Biraben, *Phys. Rev. Lett.* **78**, 3658 (1997).

[4] Pei-Ling Luo, Jin-Long Peng, Jinmeng Hu, Yan Feng, Li-Bang Wang, and Jow-Tsong Shy, *Phys. Rev. A.* **94**, 062507 (2016).

[5] Vladimir A. Yerokhin, Vojtěch Patkóš, and Krzysztof Pachucki, *Eur. Phys. J. D.* **76**, 142 (2022).

[6] Vladimir A. Yerokhin, Vojtěch Patkóš, and Krzysztof Pachucki, *Phys. Rev. A.* **107**, 012810 (2023).