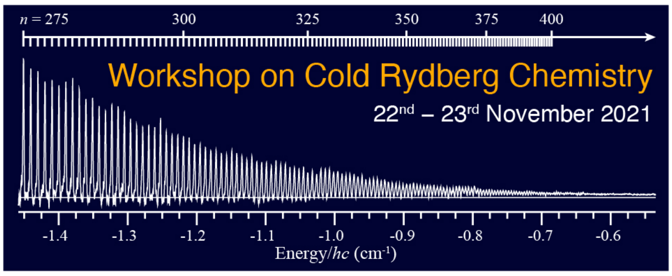

Contribution ID: **9**

Type: **Poster**

Ionization energy of the metastable 2 $^1\mathrm{S}_0$ state of ^{4}He from Rydberg-series extrapolation

Tuesday 23 November 2021 17:30 (45 minutes)

In a recent breakthrough in first-principles calculations of two-electron systems, Patkóš, Yerokhin and Pachucki [PRA **103**, 042809 (2021)] have performed the first complete calculation of the Lamb shift of the helium $2\,^3\mathrm{S}_1$ and $2\,^3\mathrm{P}_J$ triplet states up to the term in $\alpha^7 m$. Whereas their theoretical result of the frequency of the $2\,^3\mathrm{P} \leftarrow 2\,^3\mathrm{S}$ transition perfectly agrees with the experimental value, a more than 10σ discrepancy was identified for the $3\,^3\mathrm{D} \leftarrow 2\,^3\mathrm{S}$ and $3\,^3\mathrm{D} \leftarrow 2\,^3\mathrm{P}$ transitions, which hinders the determination of the He^{2+} charge radius from atomic spectroscopy that is necessary to complement the recent α-particle charge radius determination using muonic helium from J. Krauth *et al.* [Nature **589**, 527531 (2021)].
We report on the determination of the ionization energy of the metastable $2\,^1\mathrm{S}_0$ state of He ($960\,332\,040.491(32)$ MHz) by Rydberg-series extrapolation through the determination of the
frequencies of 21 transitions from the $2\,^1\mathrm{S}_0$ state to np Rydberg states with principal quantum number n in the range between 24 and 102, yielding a relative uncertainty of 3×10^{-11} [PRL **127**, 093001 (2021)]. A one-photon (∼312 nm) excitation scheme is used for Rydberg-state excitation of metastable He atoms in a doubly skimmed supersonic beam. The absolute frequency calibration is achieved using a frequency comb referenced to a GPS-disciplined Rb clock.
This absolute measurement is used in combination with the $2\,^3\mathrm{S}_1 \leftarrow 2\,^1\mathrm{S}_0$ interval measured by van Rengelink *et al.* [Nat. Phys. **14**, 1132 (2018)] and the $2\,^3\mathrm{P} \leftarrow 2\,^3\mathrm{S}_1$ interval measured by Zheng *et al.* [PRL **119**, 263002 (2017)] and Cancio Pastor *et al.* [PRL **92**, 023001 (2004)] to derive experimental ionization energies of the $2\,^3\mathrm{S}_1$ state ($1\,152\,842\,742.640(32)$ MHz) and the $2\,^3\mathrm{P}$ centroid energy ($876\,106\,247.025(39)$ MHz). These values reveal disagreements with the $\alpha^7 m$ Lamb shift prediction by 6.5σ and 10σ, respectively, and support the suggestion by Patkóš *et al.* of an unknown theoretical contribution to the Lamb shifts of the $2\,^3\mathrm{S}$ and $2\,^3\mathrm{P}$ states of He.

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Session Classification: Poster Session