Laser Spectroscopy at Extremes: Ultra-Stable and Ultra-Accurate Clock Transitions in Highly Charged Ions

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Highly charged ions (HCI) are less sensitive to external perturbations than neutral atoms and are therefore attractive for the development of ultra-stable clocks. However, only a few HCI candidates are known to provide clock transitions in the domain of optical lasers. We present a large family of HCI clocks, with more than 100 suitable optical clock transitions hidden in the fine-structure terms of open-shell ions over 70 elements [1, 2]. Their projected accuracies are $\delta\nu/\nu < 10^{-20}$, surpassing state-of-the-art optical clocks by several orders of magnitude. Furthermore, at given configurations, the clock transitions in heavy ions scale up to the XUV and soft-x-ray laser region, and thus enable the development of ultra-stable clocks based on shorter wavelengths. Research in this direction has recently been boosted by the new possibility of detecting metastable states via mass spectrometry [3,4]. The existence of multiple clock transitions in different charge states of a single element, as well as in a whole isoelectronic sequence would significantly enrich the search for beyond standard model-physics and the test of nuclear theory via high-precision laser spectroscopy.

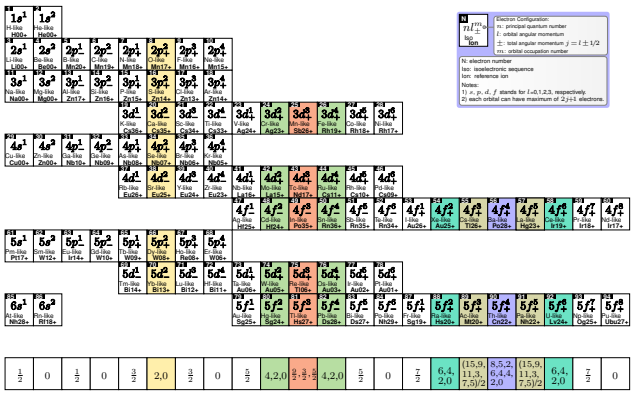

Figure 1: Periodic table for HCI, arranged according to the number of electrons N, with each cell representing an isoelectronic sequence with a given $nl^m_\pm$ configuration. The bottom row presents all allowed Js, ordered according to their increasing energies, of the ground-state j^m multiplet in each column

References

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[3] K Kromer, C Lyu, M Door, *et al.*, Phys. Rev. Lett. **131**, 223002 (2023)

[4] R X Schüssler, H Bekker, M Braß, *et al.*, Nature **581**, 42 (2020)