Identifying optical transitions in highly charged ions with applications for metrology and searches of variation of the fine-structure constant

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Many highly charged ions (HCI) have been proposed for use in next generation optical clocks for metrology purposes, see for example [1, 2]. Due to the compact size of their electronic cloud, HCI are less sensitive to external perturbations than the neutral and singly charged systems that are currently widely employed in metrology. Furthermore, increased relativistic effects in HCI lead to a strong sensitivity to variation of the fine-structure constant α. However, for these HCI, theory is not capable of predicting the energy level structures to the precision required for precision laser spectroscopy.

To address this issue, we investigated several of the proposed HCI, which we produced, trapped, and collisionally excited in the Heidelberg electron beam ion trap (HD-EBIT). The wavelengths of subsequent fluorescence light were determined at the ppm-level using a grating spectrometer. We present our latest results for Ir^{17+}, which features transitions with an extremely high sensitivity to variation of the fine-structure constant [1,3]. Identifying these transitions is cumbersome due to the uncertainties of the predictions, the large amount of observed transitions, and their low intensities. However, by observing their Zeeman splitting in the strong magnetic field of the HD-EBIT, many important lines could be identified, c.f. Fig. 1.

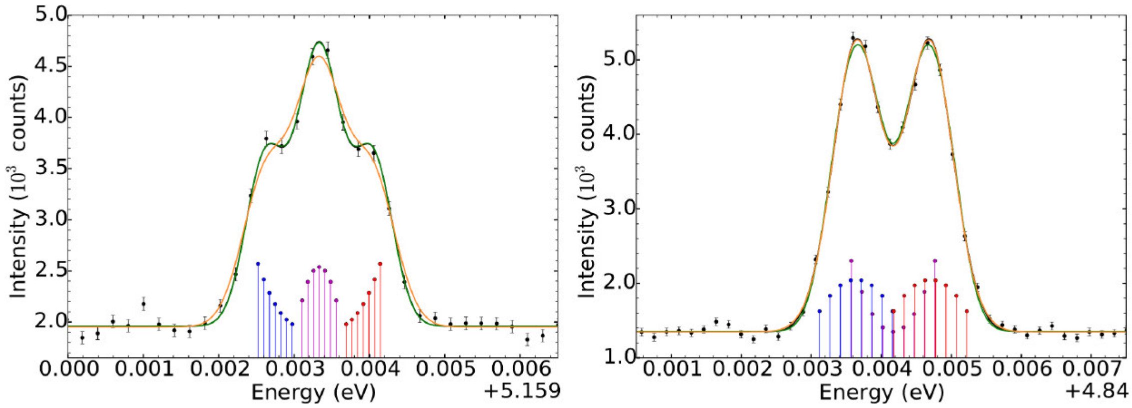

Fig. 1: Observed Zeeman splitting of two Ir^{17+} lines (black points), and fits to the data based on predicted line shapes (solid lines). The individual Zeeman components as determined by the fit, are shown by vertical lines.

Furthermore, our latest results for Pr^{9+} and Pr^{10+} are discussed. In addition to the previously mentioned advantageous properties of HCI, Pr^{9+} is predicted to have a metastable state with an extremely long lifetime of 21 megayears, which potentially makes it suitable as a quantum memory [2].

All the presented results are used to benchmark state-of-the-art atomic theory calculations. Our investigations aim to provide a deeper insight into the suitability of the proposed HCI for metrology purposes, and to pave the way for future laser spectroscopy.

References

[1] J. C. Berengut *et al.*, Phys. Rev. Lett. **106**, 210803 (2011)
[2] M. S. Safronova *et al.*, Phys. Rev. Lett. **113**, 030801 (2014)
[3] A. Windberger *et al.*, Phys. Rev. Lett. **114**, 150801 (2015)

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