

Progress on Ni¹²⁺ based highly charged ion clock

Shaolong Chen¹, Zhiqiang Zhou^{1,2}, Jiguang Li³, Tingxian Zhang⁴, Chengbin Li¹, Tingyun Shi¹, Yao Huang¹, Kelin Gao^{1#}, Hua Guan^{1#}

¹State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences, Wuhan 430071, China.

²University of Chinese Academy of Sciences, Beijing 100049, China

³Institute of Applied Physics and Computational Mathematics, Beijing 100088, China

⁴School of Science, Lanzhou University of Technology, Lanzhou; 730050, China

Email: klgao@wipm.ac.cn; guanhua@wipm.ac.cn

Highly charged ions (HCIs) have promising clock transitions with potential accuracy below 10⁻¹⁹. Furthermore, they are sensitive to fine structure constant α and can be used to explore new physics beyond the standard physical model^{1,2,3}. we utilized the Shanghai-Wuhan Electron Beam Ion Trap (SW-EBIT)⁴ to perform a high-precision measurement of the M1 transition of Ni-HCI. Our approach involved an improved calibration scheme for the spectra, utilizing auxiliary Ar⁺ lines for calibration and correction. Our final measured result of the M1 transition wavelength demonstrate a four-fold improvement in accuracy compared to our previous findings⁵, reaching sub-picometer level accuracy⁶. In addition, High energy HCI bunches were slowed down⁷ to the ion trap and cooled in a room temperature ion trap by means sympathetic cooling through the laser-cooled Be⁺ ions. The Ni-HCIs temperature were decreased to hundred millikelvin level from megakelvin.

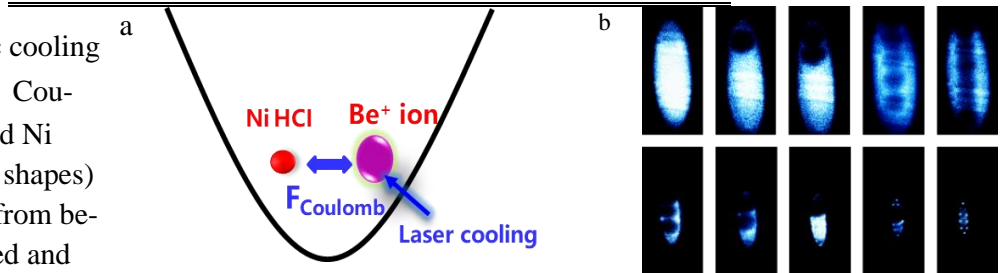
Table I. Error

budget: The final result and main error sources to the wavelength measurement

Source of error	Shift (pm)	Error
Line centroid determination	511582.05	0.21
Calibration system	/	0.42
Isotope shift	0.06	0.06
Stark shift	/	<0.01
2 nd -order Zeeman effect	/	<0.01
Total	511582.11	0.47

Fig. 1. The sympathetic cooling of

HCIs. a: Sympathetic cooling Schematic Image; b: Coulomb crystal of Be⁺ and Ni HCI (the dark circular shapes) --The process of HCI from being injected and trapped and subsequently lost one by one.



¹J. C. Berengut, *et al*, Phys. Rev. Lett. **105**, 120801 (2010).

²A. Derevianko, *et al*, Phys. Rev. Lett. **109**, 180801 (2012).

³M. G. Kozlov, *et al*, Rev. Mod. Phys. **90**, 045005(2018).

⁴S.Y. Liang, *et al*, Rev. Sci. Instrum. **90**, 093301 (2019).

⁵S.Y. Liang, *et al*, Phys. Rev. A **103**, 22804 (2021).

⁶S.L. Chen, *et al*, Phys. Rev. Res. **6**, 013030(2024).

⁷Z.Q. Zhou, *et al*, AIP Adv. **12**, 035220(2022).