Beitrag ID: **14** Typ: **Talk**

Precision Spectroscopy of Highly-Charged Heavy Ions: Towards a Quantum Logic Clock Based on a Cryogenic Monolithic Paul Trap

Mittwoch, 17. September 2025 15:30 (20 Minuten)

Quantum logic spectroscopy (QLS) enables optical clocks based on atomic and molecular ions that lack direct laser cooling or state detection transitions [1]. QLS therefore serves as a key technique driving significant advances in optical frequency metrology [2-5]. Heavy hydrogen-like or lithium-like ions offer optical transitions that feature both strong suppression of systematic shifts and enhanced sensitivity to physics beyond the Standard Model [3,6,7]. While substantial progress has been demonstrated using medium-mass highly charged ions (HCIs) such as Ar^{13+} [4,5] or Ca^{14+} [8], extending QLS to the heaviest HCIs remains an open challenge while promising unprecedented tests of fundamental physics.

In this contribution, we present the current status of our experimental setup for QLS of heavy HCIs, specifically targeting the optical hyperfine-structure transition in $^{207}Pb^{81+}$ at 1019.7 nm [9], serving as a proof of principle. The experiment is set up downstream of the HITRAP decelerator at the GSI Helmholtz Center for Heavy Ion Research in Darmstadt. It will provide cryogenic trapping conditions for accelerator-produced heavy HCIs, enabling long storage times for high-resolution spectroscopy. Furthermore, it involves various laser systems for in-situ production of the logic ion Be^{+}, laser cooling to the quantum-mechanical ground state of motion, and coherent manipulation of qubit and HCI clock transitions. Based on these ingredients, quantum logic-assisted state preparation and clock state detection will be implemented. An advanced monolithic linear Paul trap is currently under development. Its design aims to minimize detrimental excess micromotion and thus plays a central role in the suppression of leading systematics.

References

[1] P. O. Schmidt et al., Science 309, 749–752 (2005)
[2] A. D. Ludlow et al., Rev. Mod. Phys. 87, 637–701 (2015)
[3] M. G. Kozlov et al., Rev. Mod. Phys. 90, 045005 (2018)
[4] P. Micke et al., Nature 578, 60–65 (2020)
[5] S. A. King et al., Nature 611, 43–47 (2022)
[6] S. Schiller et al., Phys. Rev. Lett. 98, 180801 (2007)
[7] N. S. Oreshkina et al., Phys. Rev. A 96, 030501(R) (2017)
[8] A. Wilzewski et al., Phys. Rev. Lett. 134, 233022 (2025)
[9] P. Seelig et al., Phys. Rev. Lett. 81 (1998)

Autor: HOMBURG, Nadine (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))

Co-Autoren: HAYAKAWA, Hiroshi; KAU, Lukas; Dr. MICKE, Peter (Helmholtz Institute Jena & GSI Helmholtz Center for Heavy Ion Research); STÖHLKER, Thomas (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)); Dr. ANDELKOVIC, Zoran

Vortragende(r): HOMBURG, Nadine (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))

Sitzung Einordnung: Session 8