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Towards Quantum Logic Spectroscopy of Highly Charged Ions

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Highly charged ions (HCIs) offer forbidden optical transitions near level crossings due to reordering of the electronic level structure as the charge state grows. Some of these transitions have an enhanced sensitivity to a possible variation of the fine-structure constant [1]. Furthermore, HCIs are insensitive to external fields because of their strong internal Coulomb field. This can be exploited for building optical clocks with small systematic shifts.

Generally, HCIs do not have transitions appropriate for direct laser cooling. However, they can be sympathetically cooled with another ion species –in our case Be^+. Then, spectroscopic measurements can be carried out by using quantum logic: A single HCI (spectroscopy ion) is co-trapped together with a Be^+ logic ion, which provides not only cooling, but also both state preparation and readout.

For this purpose an electron beam ion trap (EBIT) breeds HCIs. Next, the HCIs are extracted, decelerated and injected into a cryogenic linear Paul trap. The cryogenic environment provides extremely high vacuum for preventing HCIs from capturing electrons from residual atoms. Thereby, long storage times can be achieved.

Recently, the collaborative experiment CryPTEx (Cryogenic Paul Trap Experiment [2]) at the Max-Planck-Insitut für Kernphysik has already proven the successful deceleration, injection and subsequent trapping of HCIs within a Coulomb crystal of trapped Be^+ ions.

We are currently setting up an experiment for the Physikalisch-Technische Bundesanstalt aiming at quantum logic spectroscopy of HCIs. For this experiment we combine a novel compact EBIT based on permanent magnets and an ultra-low-vibration cryogenic Paul trap.

References

[1] M. S. Safronova et al., PRL, 113, 030801 (2014).

[2] M. Schwarz et al., Rev. Sci. Instrum., 83, 083115 (2012).

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