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Cold highly charged ions in a Paul trap with superconducting magnetic shielding

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Highly charged ions (HCI) offer promising candidate species for searches of physics beyond the Standard Model and next-generation optical atomic clocks. In the CryPTEx-SC experiment, we store HCIs in a cryogenic linear Paul trap that simultaneously functions as a superconducting radio-frequency resonator filtering the trap drive [1].

The HCIs are produced in a compact electron beam ion trap and then injected into and sympathetically cooled by a Coulomb crystal of Be^+ ions. Subsequently removing ions until a single Be^+ cooling ion and a single HCI are left enables quantum logic spectroscopy towards frequency metrology and qubit operations with a great variety of species.

We present Be^+ microwave spectroscopy measurements characterizing the magnetic shielding properties of the resonator trap built from superconducting niobium that almost fully encloses the stored ions [2]. While cooling the resonator trap down through its transition temperature into the superconducting state, a quantization magnetic field applied at this time becomes persistent and the trap becomes shielded from subsequent external electromagnetic fluctuations.

Using a magnetically-sensitive hyperfine transition of Be^+ as probe, we measure the fractional decay rate of the stored magnetic field to be at the 10^{-10} s^{-1} level. Ramsey interferometry and spin-echo measurements yield coherence times of over 400 ms without active field stabilization, demonstrating excellent passive shielding of magnetic field noise at frequencies down to DC, producing a suitable environment for precision ion spectroscopy.

[1] Stark et al., Rev. Sci. Instrum. **92**, 083203 (2021)

[2] Dijck et al., arXiv:2306.01670, to appear in Rev. Sci. Instrum. (2023)

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