Coulomb crystallization of highly charged ions

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In highly charged ions (HCIs), the electronic wavefunction is much reduced in size. Subsequent advantages for precision spectroscopy are: higher sensitivity to electron-nucleus interactions and QED terms in general, and an extremely suppressed sensitivity to external field perturbations. Further, electric dipole forbidden optical transitions found near level crossings in HCIs are extremely sensitive to possible drifts in the fine structure constant α [1]. Thus, cold, strongly localized HCIs are of particular interest for bound-state QED studies (g-factor measurements), metrology (development of novel optical clocks) and the search for α variation. We report on Coulomb crystallization of highly-charged $^{40}Ar^{13+}$ ions through sympathetic cooling with co-trapped, laser-cooled $^{9}Be^{+}$ ions to final translational temperatures of about 200 mK or less [2]. The Ar^{13+} ions are produced in, and extracted from an electron beam ion trap (EBIT). They are decelerated and precooled by means of two serrated interlaced pulsed drift tubes before they are injected into the cryogenic Paul trap CryPTEx [3]. Subsequently, they are forced to interact multiple times with a Coulomb crystal of laser-cooled Be^{+} ions, thereby losing enough energy to end up implanted as dark structures of spherical shape in the bright fluorescing Be^{+} crystal. The combination of an EBIT with a linear Paul trap operating at ~7 K facilitates not only the formation of mixed-species 3D Coulomb crystals, but also of 1D Coulomb crystals down to a single HCI cooled by a single Be^{+} ion (Fig.1). This is a necessary step for future quantum logic spectroscopy at a potential 10^{-19} level accuracy. Our preparation technique of cold Ar^{13+} is readily applicable to a broad range of other highly charged elements and is thus a significant step forward for precision spectroscopy of HCIs.

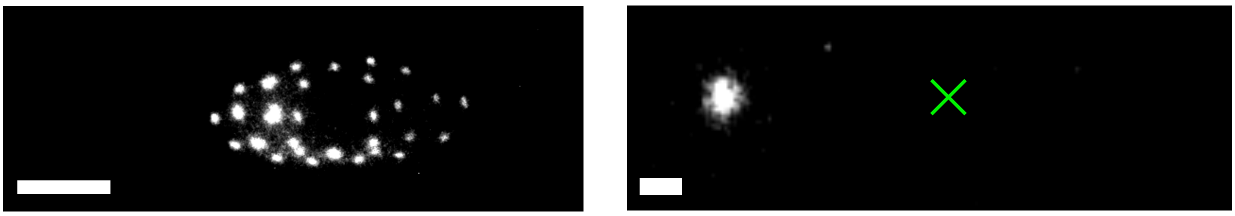

Figure 1: *Left: A single Ar^{13+} ion sympathetically cooled by several Be^{+} ions. White scale bar denotes 100 μm.Right : AsingleAr^{13+} ion (position marked by cross) sympathetically cooled by a single laser-cooled Be^{+} ion. White scale bar denotes 20 μm.*

References

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