

## Coulomb crystallization of highly charged ions

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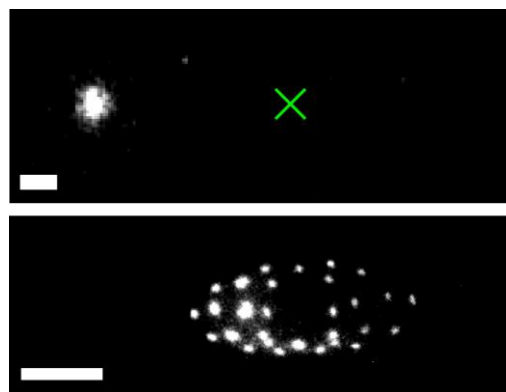
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**Synopsis** Sympathetic Coulomb crystallization of highly charged ions, re trapped in a cryogenic radiofrequency trap, is demonstrated by an over seven orders-of-magnitude decrease in motional temperature.

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  $\alpha$  [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  $\alpha$  variation. We report on Coulomb crystallization of highly-charged  $^{40}\text{Ar}^{13+}$  ions through sympathetic cooling with co-trapped, laser-cooled  $^9\text{Be}^+$  ions to final translational temperatures of about 200 mK or less [2]. The  $\text{Ar}^{13+}$  ions are produced in, and extracted from an electron beam ion trap (EBIT). They are decelerated and pre-cooled 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  $\text{Be}^+$  ions, thereby losing enough energy to end up implanted as dark structures of spherical shape in the bright fluorescing  $\text{Be}^+$  crystal. The combination of an EBIT with a linear Paul trap operating at  $\sim 7$  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  $\text{Be}^+$  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  $\text{Ar}^{13+}$  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.** Top: A single  $\text{Ar}^{13+}$  ion (position marked by cross) sympathetically cooled by a single laser-cooled  $\text{Be}^+$  ion. White scale bar denotes 20  $\mu\text{m}$ . Bottom: A single  $\text{Ar}^{13+}$  ion sympathetically cooled by several  $\text{Be}^+$  ions. White scale bar denotes 100  $\mu\text{m}$ .

## References

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