The PALLAS ring trap - towards crystalline ion beams

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For heavy ion storage rings like TSR [1] or ASTRID [2] molecular dynamics simulations revealed that, mainly due to the too low symmetry and periodicity of their lattices, the formation of crystalline ion beams is restricted to lowest order structures [3]. To experimentally elucidate fundamental issues of crystalline ion beams [4] at low velocities, we set up PALLAS, a table top circular RF-quadrupole storage ring [5]. It principally resembles a linear Paul-trap bent to a circle [6], but equipped with additional drift tubes, uniformly distributed along the ring circumference [5]. These provide static axial electric fields, which can be ramped in time to provide acceleration of an ion cloud stored and prepared in advance. Two counter-propagating laser beams are used for Doppler-cooling and probing of the ion ensemble.

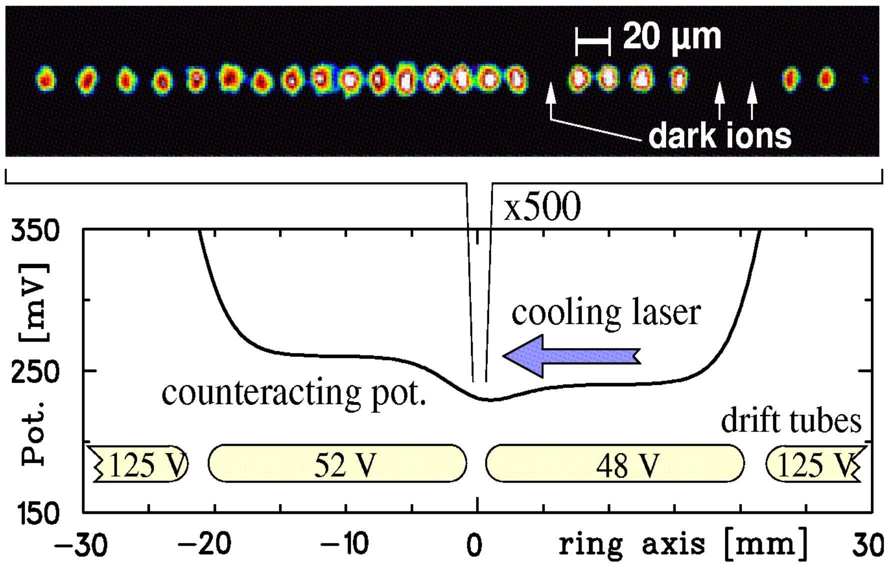

Figure 1: CCD-camera image of the fluorescence of the lowest order ion crystal, the linear chain (25 ions). The $^{24}Mg^{+}$-ions are axially confined in a part of the ring trap PALLAS by the static potential (biased drift-tubes) sketched below, also locally counter-acting the laser force.

To gain experience in operating PALLAS, we first investigated the cooling dynamics of a $^{24}Mg^{+}$-ion ensemble at rest in a well-defined region of the ring-trap. The axial confinement is provided by DC-voltages on four (see fig. 1) of the 16 drift tubes, mentioned above. One tunable UV laser beam was used for Doppler-cooling the ion distribution, counter-acted by an adjustable potential wall. As the laser was repeatedly tuned slowly over the resonance, ion ensembles of up to several 100 $^{24}Mg^{+}$-ions were cooled close to the Doppler-limit, undergoing the well-known phase transition to form an ion crystal, as observed by the fluorescence signal.

With the laser detuning kept slightly below resonance, the crystalline structure was observed by an image intensified CCD camera, fig. 1 showing the image of a linear ion chain built up from 25 ions. The inter-particle distance amounts to about $10\,\mu$m, varying with the position of the ions in the unharmonic axial potential shown. Those positions where no light is detected are occupied by dark ions beeing cooled sympathetically by the Mg^{+} ions and preferentially shifted against the laser in the direction of the electrostatic potential.

Having systematically studied the behaviour of ion crystals *at rest* in our trap so far, we presently investigate the acceleration of ions to form a low energy ion beam, then subject to further laser cooling . Up to now, we observed first evidence for ion acceleration to a *beam* having a velocity of 5000 m/s.

Once the goal of a crystalline ion beam is reached in PALLAS, we plan to continuously introduce disturbances to investigate the influence of lattice effects. Comparing and scaling anticipated results from PALLAS (≈ 0.4 m circumference) with simulations will allow the detailed study of the properties of beam crystallization in typical ion storage rings (≈ 50 m circumference). Furthermore the ultimate brilliance of such a beam should allow a wide variety of high precision experiments.

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