Real-time imaging of single trapped Mg^+ ions at 280 nm

F. Hakelberg, P. Kiefer, L. Nitzsche, V. Vierhub-Lorenz, M. Wittemer, H. Kalis, M. Mielenz, U. Warring and T. Schaetz, Institute of Physics, University of Freiburg, Germany (December 2016)

Application Note

Introduction

Trapped ions are promising candidates to control increasingly large systems of particles at the quantum level. In our experiment we use magnesium ions confined in radiofrequency traps. Applications include quantum simulations [1,2] and the investigation of structural defects in Coulomb crystals [3]. The latter allows the investigation of the properties of discrete solitons and requires spatial resolution and sensitivity in the UV at 280 nm.

The use of surface electrode traps allows improved control of electric potentials in comparison to conventional Paul traps.

Experiment

We trap different Mg^+ isotopes in a surface electrode trap, provided by Sandia National Labs. Magnesium atoms are ionized from an atomic beam by a two-photon process at 285 nm. Trapped in the radiofrequency potential, they are Doppler cooled on the $S_{1/2} - P_{3/2}$ transition near 280 nm with laser beams provided by a frequency quadrupled fiber laser. The ions scatter photons on this cycling transition that can be detected by our imaging system (figure 1).

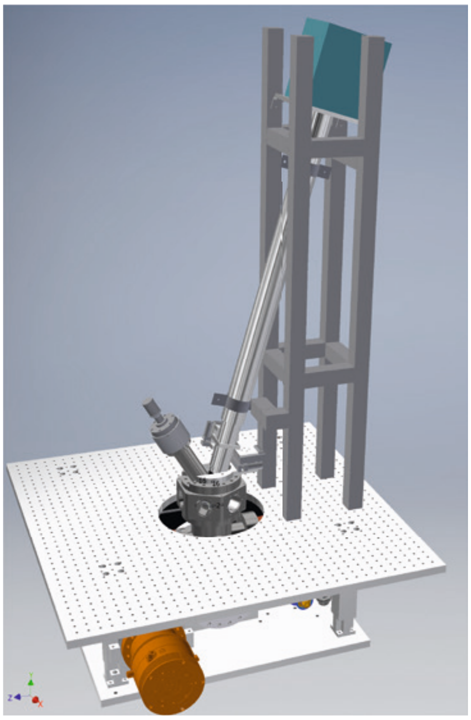

Figure 1 a) Sketch of the experimental setup. At the center is the vacuum apparatus containing the surface-electrode ion trap. The imaging optics is mounted under an angle of 16 deg to the surface normal of the trap. The three condenser lenses can be adjusted via three linear stages. The iXon Ultra camera (cyan box) is mounted 1 m above the ion's position. To reduce stray light, the optical path is enclosed by black anodized aluminum tubes. Further, there is a short-pass filter in front of the camera aperture.

The fluorescence light is collected by an objective lens with focal length f=57 mm and relayed by the UV sensitive Andor iXon Ultra DU888 UCS-UVB EMCCD camera. Background light is reduced using a short-pass filter. Our setup offers a magnification of 16.

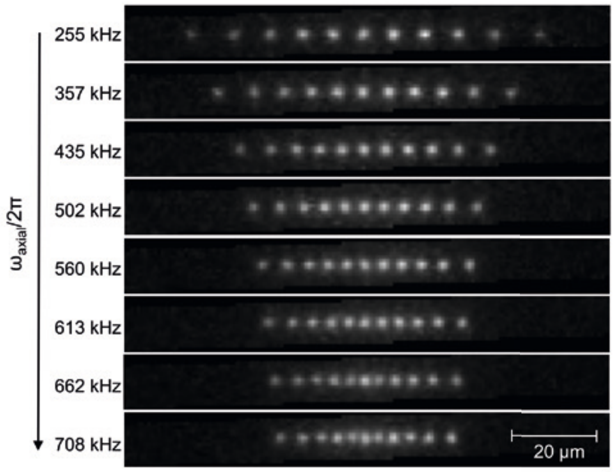

Figure 2) Linear chain of fluorescing Mg+ ions observed by the iXon Ultra 888 EMCCD camera.

During the configuration of the experiment, a live feed from the camera assists the adjustment of the different laser beams. Light scattered from the trap surface is used to focus, overlap, and position the beams. These parameters are essential for reliable trapping of ions.

Real-time imaging of the fluorescence of a single ion selected by a region of interest in the Solis software provides the possibility to further refine the positioning of the cooling and detection laser.

An exemplary fluorescence image of a linear ion chain is shown in figure 2. The positions of the ions are determined by the trapping potential, characterized by three secular frequencies. To achieve the linear trapping geometry, the axial frequency ω_{axial} is small compared to the radial frequencies, which results in a linear arrangement of the ions. Exploiting the well-known magnification, calibrated via the surface-electrode structure, we can directly calculate the axial trapping frequencies from the fluorescence images. This enables a fast examination of the trapping conditions, essential for calibration and verification of electrical control potentials.

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Furthermore, we are able to compensate electrical stray fields via ion position detection in the image stream.

Additionally, two-dimensional Coulomb crystals can be imaged which allows the investigation of topological defects therein.

References

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Contact

Prof. T. Schaetz
Physikalisches Institut
Albert-Ludwigs-Universität Freiburg
Hermann-Herder-Str. 3
79104 Freiburg

phone +49 (761) 203 5880
fax +49 (761) 203 5881
E-mail tobias.schaetz@physik.uni-freiburg.de
Web www.qsim.uni-freiburg.de