Ion clouds in radio-frequency linear traps: transport and phase transitions

M.R. Kamsap[1], J. Pedregosa-Gutierrez[1], C. Champenois[1], D. Guyomarc'h[1], M. Houssin[1], and M. Knoop[1]

[1] *Aix Marseille Université, CNRS, PIIM UMR 7345, 13397, Marseille, France*

Presenting Author: jofre.pedregosa@univ-amu.fr

An ion cloud confined in a linear RF-quadrupole trap is an example of a non-neutral plasma, a plasma consisting of particles with a single sign of charge. Its thermal equilibrium state has been widely studied by Dubin, O'Neil and co-workers in the context of large ion clouds in Penning traps and extrapolated to ions in RF-quadrupole traps (for a complete review, see [1]) and even to ions in multipole traps [2]. We are interested in the study of the dynamics of large ion clouds, in particular of out-of-equilibrium issues. For that purpose we have set-up a double linear RF-trap, being composed of three trapping zones of different potential geometries along a common z-axis [3].

One of the important issues in this configuration is the transport of an ion cloud by the translation of the trapping potential, with the objective of being as fast as possible without loosing ions. Among others, the transport duration is a critical parameter in order to increase the frequency stability of microwave ion clock like the NASA prototype dedicated to Deep Space Navigation and soon to be tested in a flight demonstration mission [4]. In our trap, the geometry induces a deformation of the trapping potential during translation, which is responsible for heating of the center of mass motion as well as of motion in the center of mass frame. Although the electric field along the ion path is not known precisely, we will show that it is possible to transport an ensemble of several tens of thousands of ions over distances of a few centimeters in times as short as 100 μs, loosing only few % of the ions. The observed dependence of the heating of the cloud with the duration of its transport will also be presented and compared to molecular dynamics simulations [5].

Moreover, we are interested in the phase transition that cold ions encounter when they are laser-cooled. The structural organization of cold ions depends on their density, temperature and storage potential. We will show recent results about large ion crystals made of calcium ions in quadrupole traps and preliminary results concerning cold ions in an octupole trap. If their density is high enough, cold ions in a linear octupole trap are expected to organize in a hollow structure, formed of concentric tubes [6].

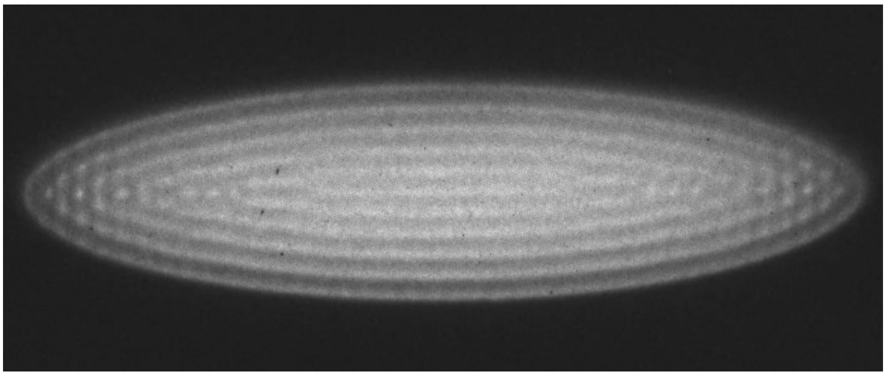

Figure 1: *Picture of a Coulomb crystal made of few thousands of calcium ions, laser cooled in a linear quadrupole trap*

References

[1] Daniel H. E. Dubin and T. M. O'Neil, Rev. Mod. Phys. **71** p. 87, (1999)
[2] C. Champenois, J. Phys. B, **42** 154002 (2009)
[3] C. Champenois, *et al.*, AIP Conference Proceedings , **1521** pp 210-219 (2013)
[4] `http://www.jpl.nasa.gov/news/news.php?release=2012-100`
[5] J. Pedregosa-Gutierrez *et al.*, submitted
[6] F. Calvo *et al.*, Phys. Rev. A 80, 063401 (2009)