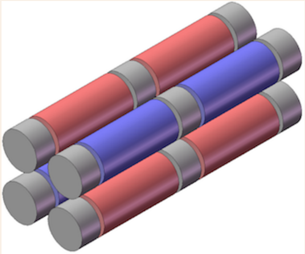
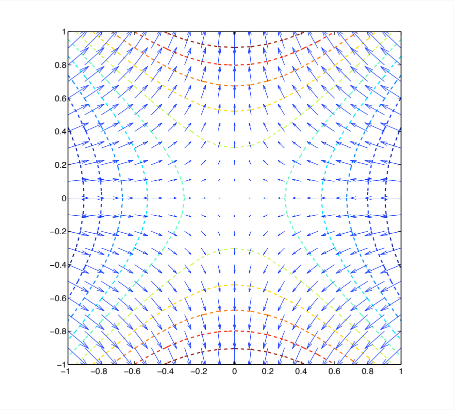
oscillating electric fields to confine in 2D

When an oscillating voltage is applied between two pairs of opposite electrodes the potential inside the trap is

$$\Phi_{rf} \propto (x^2 - y^2)\cos(\Omega t)$$





radio-frequency linear trap : the concept II

a potential that can trap only on average

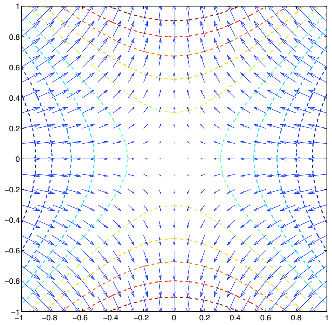
- equivalent to the pseudo-potential :

$$V^*(\mathbf{r}) = \frac{q^2 E_0^2(\mathbf{r})}{4m\Omega^2}$$

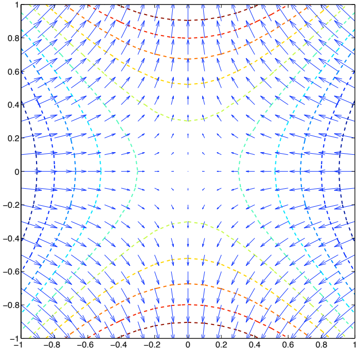
- plus the RF -driven motion

$$\mathbf{R_1}(t) = -\frac{q\mathbf{E_0}(\mathbf{R_0})}{m\Omega^2}\cos(\Omega t)$$

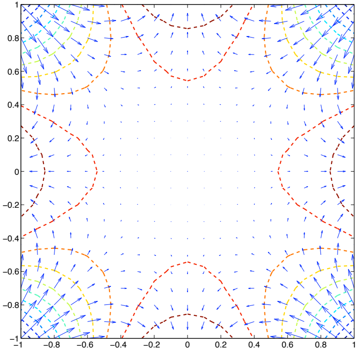
- requires DC voltage at both end of the trap axis



Different RF-electric field gradient



quadrupole trap



octupole trap, a multipole trap

Laser cooled ions in multipole traps

Already in Tokyo, in a linear octupole trap

- Okada *et. al.* PRA **75** (2007) 033409
- Okada *et. al.* PRA **80** (2009) 043405

some Coulomb crystals demonstrated

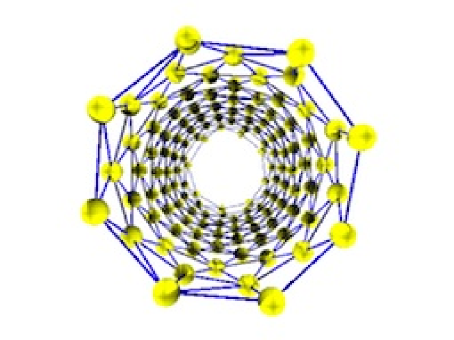
- up to 10^4 Ca^+ ions,
- for temperature estimated under 10 mK.

within the same group in Tokyo, in a hexapole trap

- observation of small stable structures
- demonstration of hollow structures

In a linear octupole trap,

a Coulomb crystal should look like that :



126 $^{40}Ca^{+}$ ions in the pseudo-potential of an octupole trap at 6 mK

(molecular dynamics simulation, credit M. Marciante)

Density profile calculated in the pseudo-potential,

a cold charged fluid model : the *non-neutral plasma*

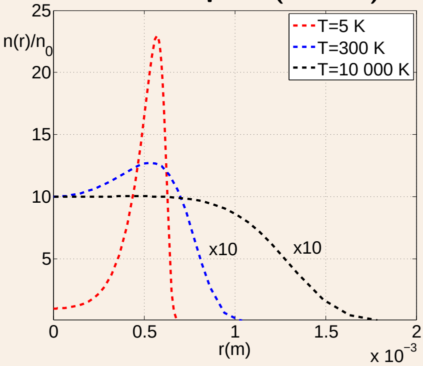
- based on a mean field method :

$$n(\mathbf{r}) = \mathcal{N} \exp\left[-\frac{\mathcal{E}(\mathbf{r})}{k_B T}\right]$$

- the charge equilibrium at low temperature leads to :

$$\lim_{T \to 0} n(\mathbf{r}) \propto \Delta V^*(\mathbf{r}) \sim r^{2k-4}$$

in an octupole ($2k = 8$)



Champenois J. Phys. B **42** (2009) 154002.

Scaling law at low temperature for a long prolate cloud

- for a N ion cloud of length L, the radius behaves like ($2k$ is the number of RF-electrodes)

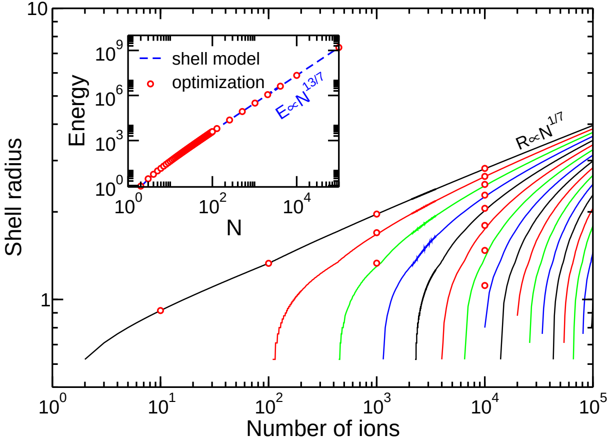
$$R \propto \left(\frac{N}{L}\right)^{1/(2k-2)}$$

- the potential energy **per ion** due to the **rf** confinement behaves like

$$E_{rf} \propto \frac{N}{L}\frac{1}{(k-1)}.$$

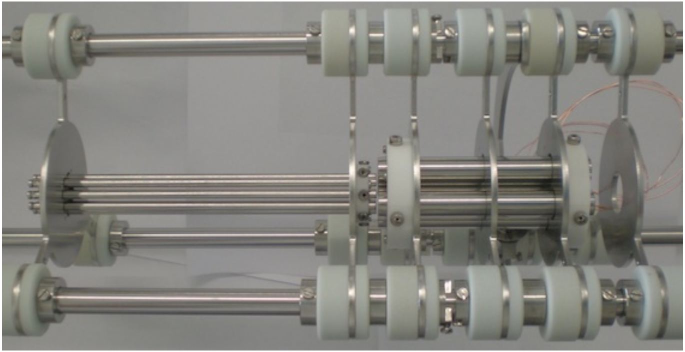
Scaling law in a 3D octupole trap

- comparaison between the non-neutral plasma and Monte-Carlo simulations : size scaling laws agree as soon as N is few hundreds.



(F. Calvo *et. al.* PRA **80** (2009) 063401)

A setup to study large ion cloud in quadru/multi-polar trap



designed by Jofre Pedregosa and Vincent Long
notice that the quadrupole part is split in two sub-zones,
the right one is devoted to ion creation

Transport of a large ion cloud within the quadrupolar trap

Preliminary results of june 2013

- a gate is defined by the temporal variation of the DC voltage applied to the electrodes confining along the trap axis.
- we transport ion cloud in their gaseous phase (work better than when they are in the liquid phase!) and we hit 95% transfer efficiency one-way.
- for the same gate, we observe a rate transfer that depends on the size of the cloud and on trapping parameters
- the gates are designed by Jofre Pedregosa and since december 2012, the experiments are mostly run by Marius Kamsap
- we expect to publish results soon!