lecture 19.11.2010

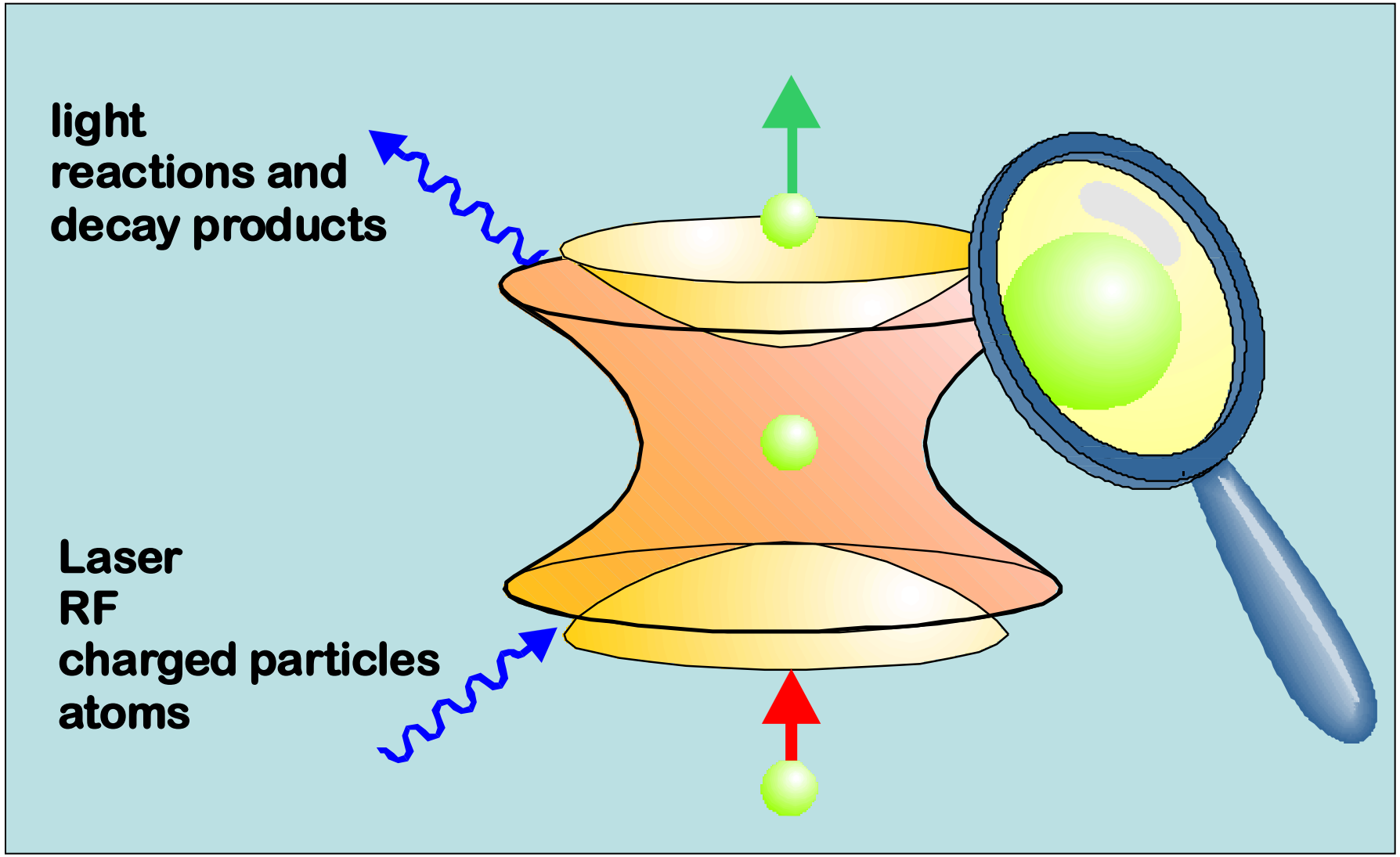
we had so far:

- cooling schemes
- optical molasses
- Bose Einstein condensation

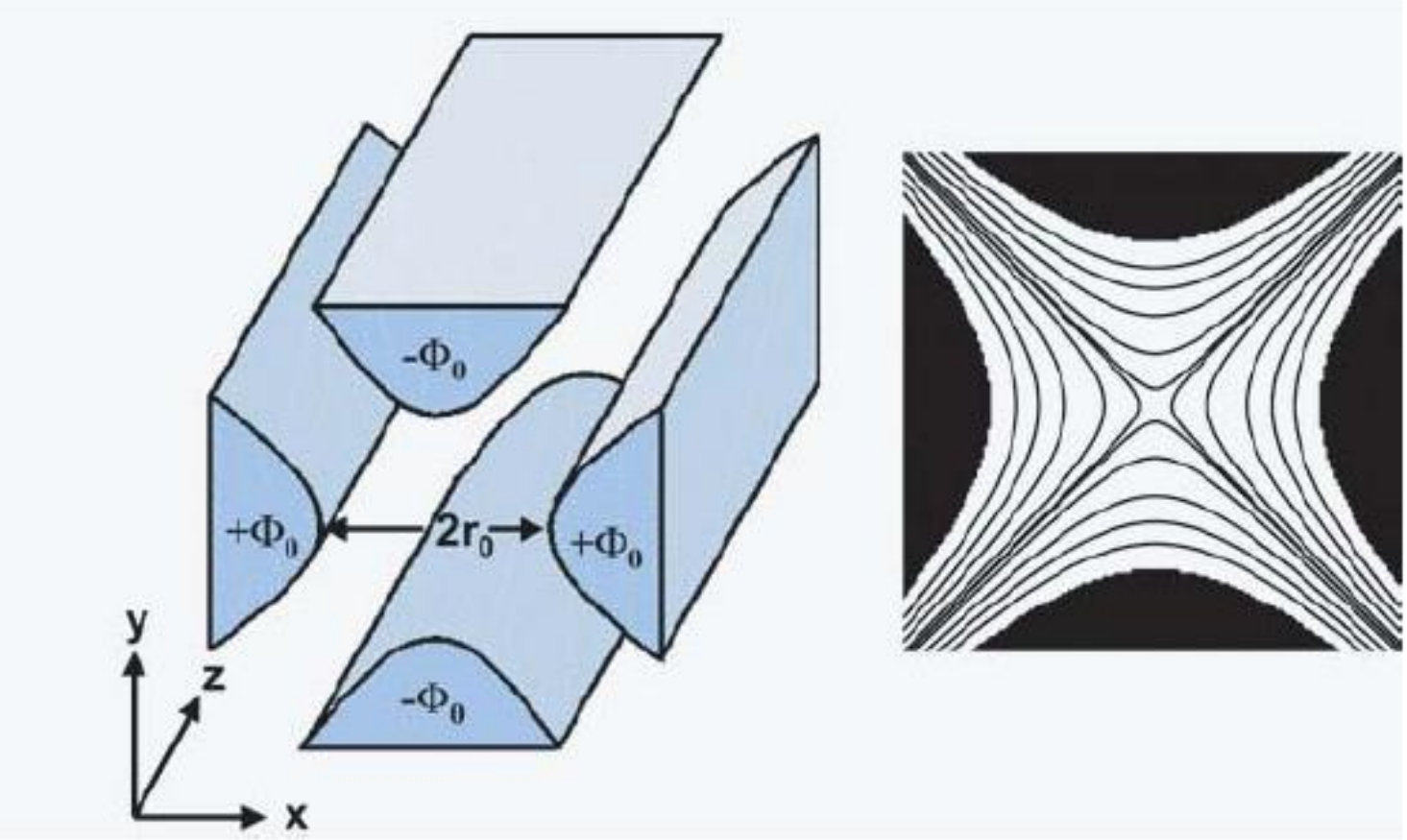
now:

- trapping and cooling of ions

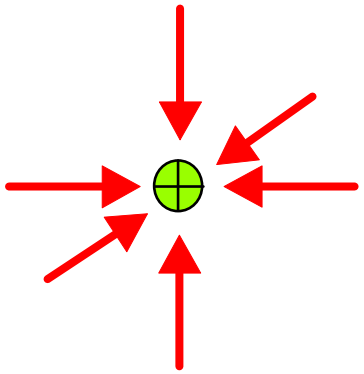
Ion traps: store, select and investigate particles in ‘free’ space



quadrupole trap in two dimensions

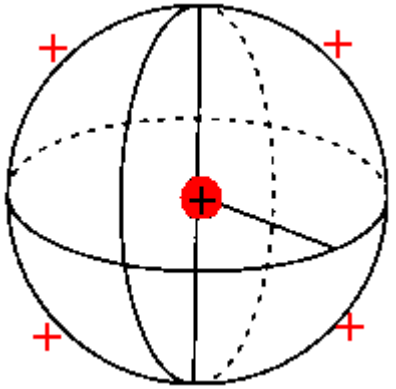


How to trap ions? Need potential minimum in 3 D

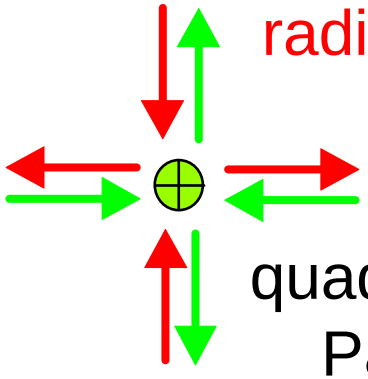


~~electrostatic trapping~~

not possible due to
Laplace: $\Delta\phi = 0$

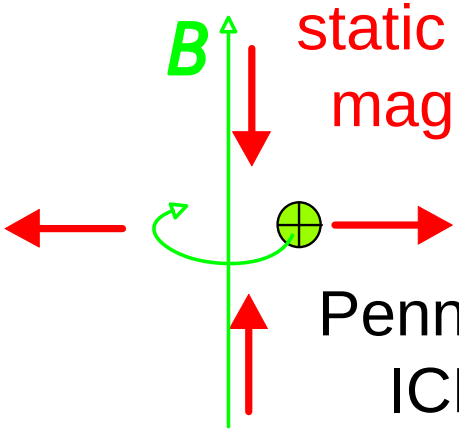


no field inside!



electric
radiofrequency
fields

quadrupolar potential:
Paul trap, rf trap,
QUISTOR, „ion trap“

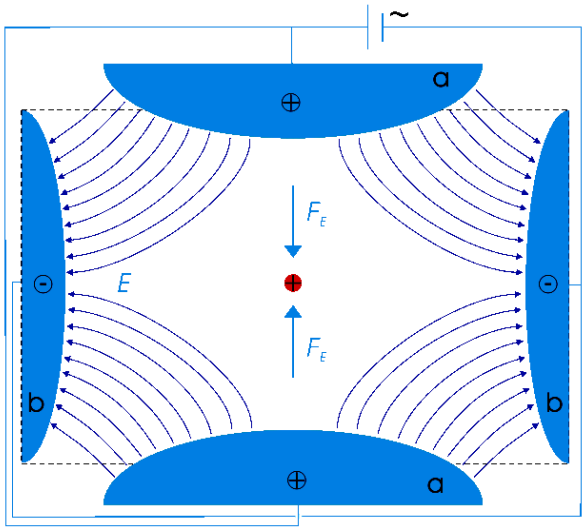


static electric and
magnetic fields

Penning trap
ICR cell
(ion cyclotron resonance)
FT-ICR MS, FTMS

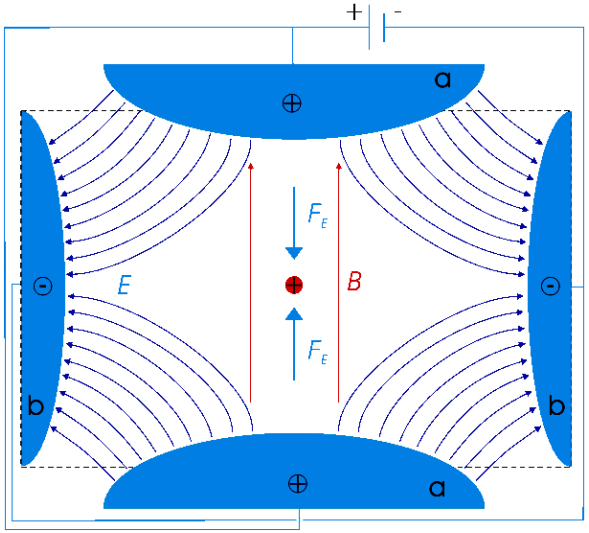
Paul trap

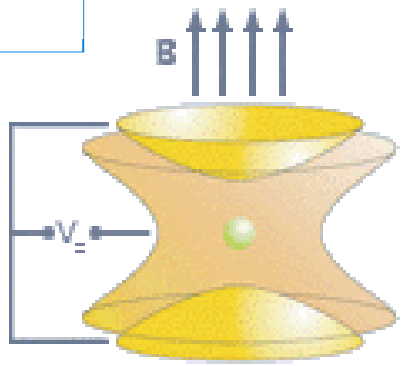
principle: electric alternating field



Penning trap

principle: superposition of a magnetic field



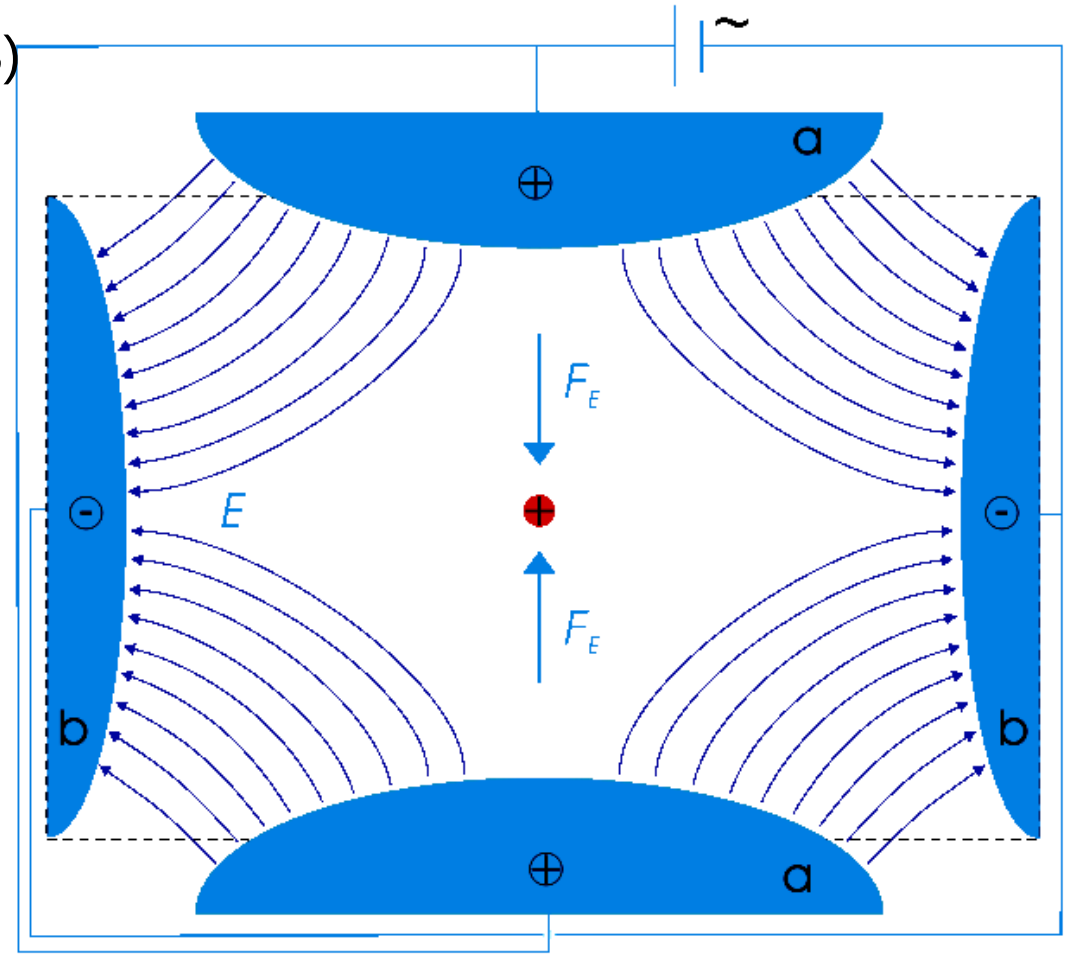


[K. Blaum, Phys. Rep. 425, 1-78 (2006)

the Paul trap

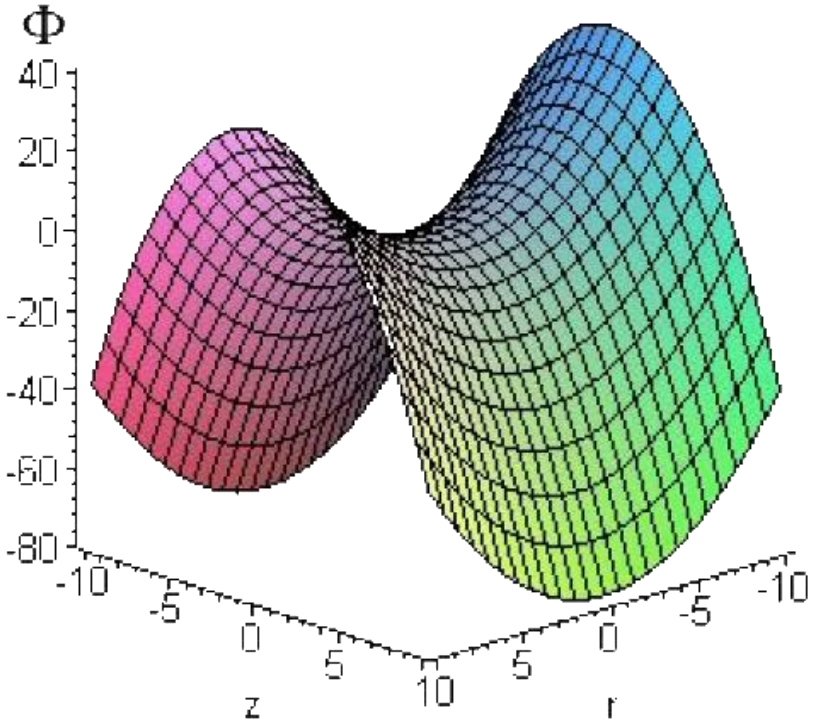
developed by
Wolfgang Paul (1913-1993)
in the 1950ies

Nobel price
in physics 1989



Electrically alternating field creates a static pseudopotential

the potential of the Paul trap



$$\Phi(x, y, z, t) = \frac{U_0 \cdot sin\omega t}{2r_0^2} \cdot (x^2 + y^2 - 2z^2)$$

equation of motion

$$\frac{d^2 r}{dt^2} + \frac{e(U_0 + V_0 \cos(\Omega t))}{m r_0^{\,2}} r = 0 \qquad \frac{d^2 z}{dt^2} - \frac{2e(U_0 + V_0 \cos(\Omega t))}{m r_0^{\,2}} z = 0$$

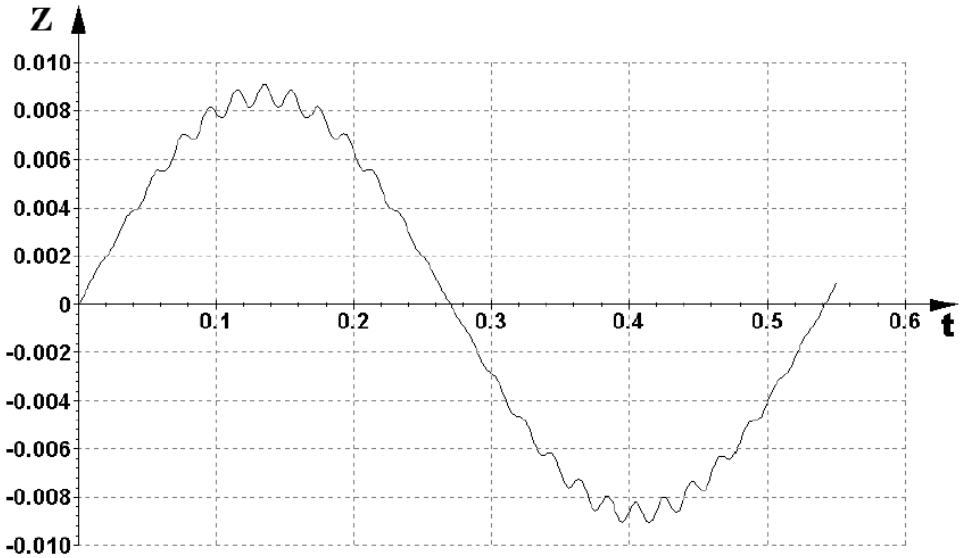
special cases of the der Mathieu- DGL

equation of motion derived from the static 'pseudo potential':

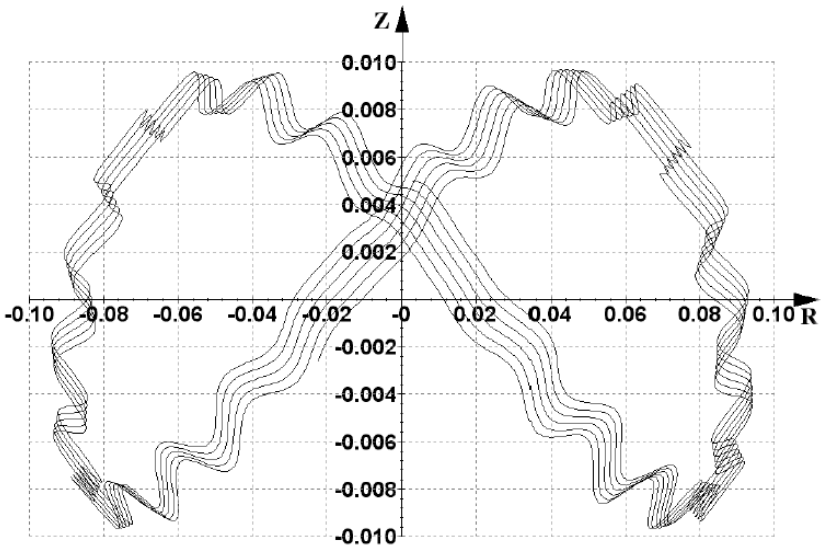
$$u(t) \propto \left[1 - \frac{q_u}{2}\cos(\Omega t)\right]\cos(\omega t - \varphi) \qquad \omega = \frac{\beta_u}{2}\Omega$$

- micro motion: driven oscillation with phase locked to the exciting field
- macro motion: free oscillations of the ions in the pseudopotential

ion motion in time and space



micro and macromotion



trajectory