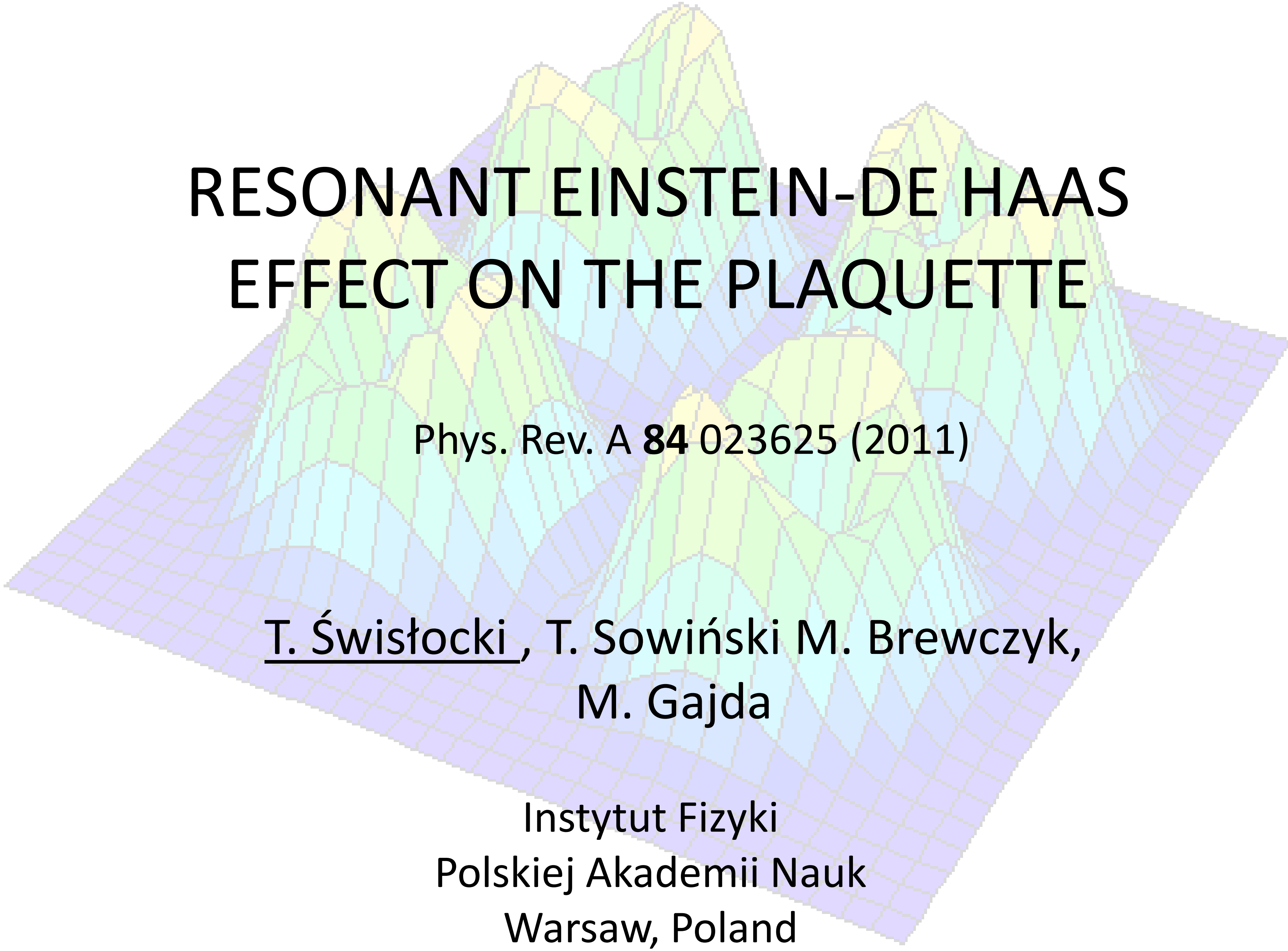


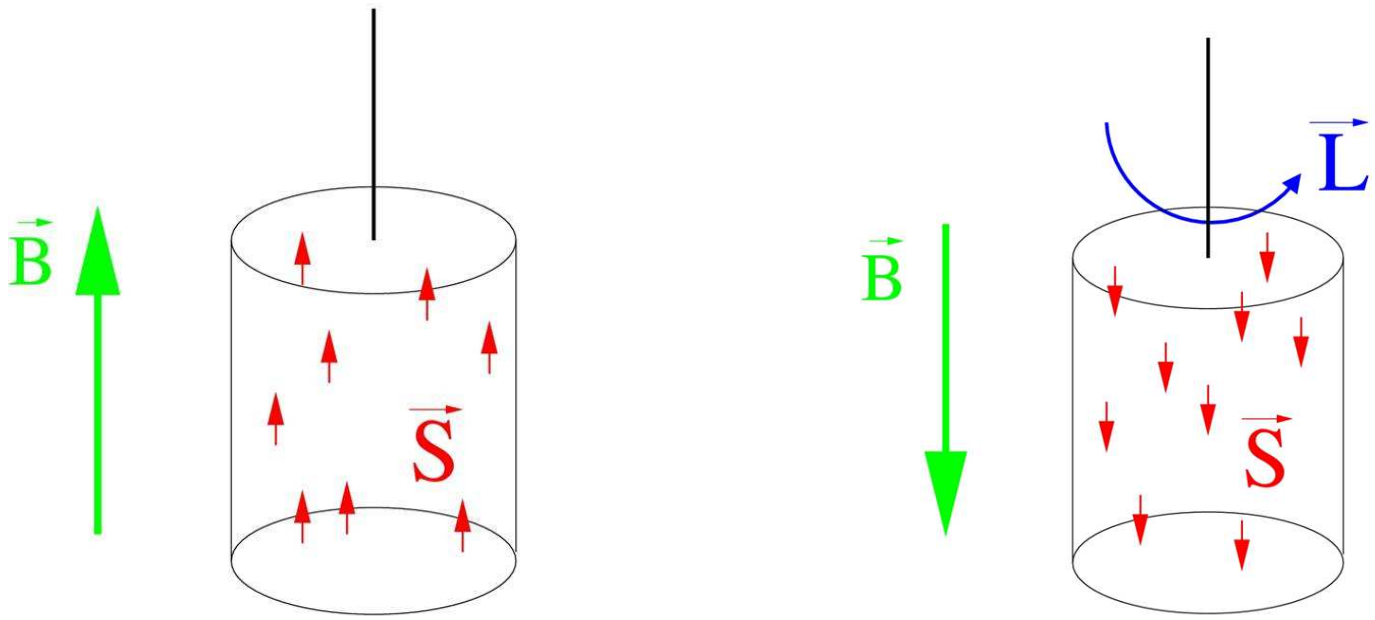
RESONANT EINSTEIN-DE HAAS EFFECT ON THE PLAQUETTE

Phys. Rev. A **84** 023625 (2011)

T. Świsłocki , T. Sowiński M. Brewczyk,
M. Gajda

Instytut Fizyki
Polskiej Akademii Nauk
Warsaw, Poland

Einstein–de Haas effect – spectacular manifestation of dipolar interactions



$$\vec{J} = \vec{S} + \vec{L} = const.$$

Spinor condensates

Rubidium 87 in F=1 hyperfine state

$$\Psi = \begin{pmatrix} \Psi_{+1} \\ \Psi_0 \\ \Psi_{-1} \end{pmatrix} \qquad i\hbar \frac{\partial}{\partial t} \begin{pmatrix} \Psi_{+1} \\ \Psi_0 \\ \Psi_{-1} \end{pmatrix} = (H_0 + H_B + H_c + H_d) \begin{pmatrix} \Psi_{+1} \\ \Psi_0 \\ \Psi_{-1} \end{pmatrix}$$

Characteristic dipolar energy $\mu^2 n$

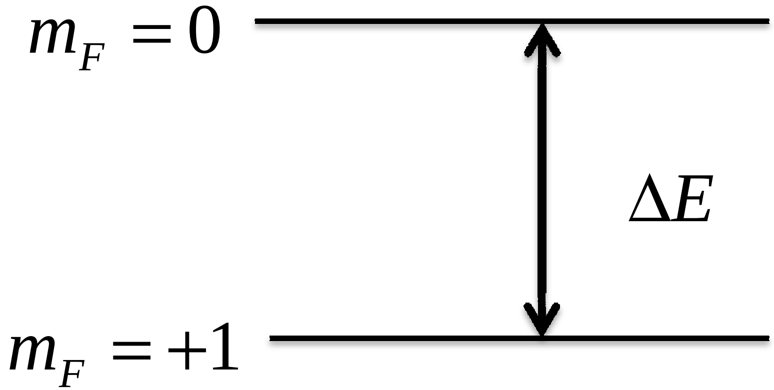
Characteristic contact interaction energy gn

Strength of dipolar interactions $\mu^2 / g = 0.00042$

Dipolar effects can be observed in Rubidium condensates even though small magnetic moment, because of dipolar resonances

K. Gawryluk, M. Brewczyk, K. Bongs, and M.Gajda, Phys. Ref. Lett. **99**, 130401 (2007)

Resonant magnetic field in Einstein-de Haas effect



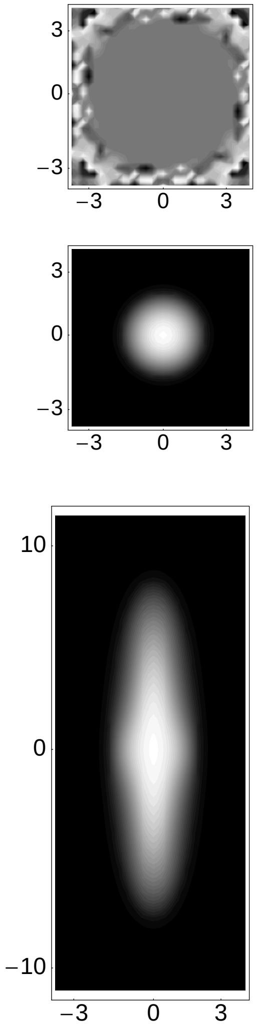
$$\Delta E = \mu B_{res}$$

K. Gawryluk, M. Brewczyk, K. Bongs, and M.Gajda, Phys. Ref. Lett. **99**, 130401 (2007)

Cigar shape harmonic trap

N_{+1}=50k

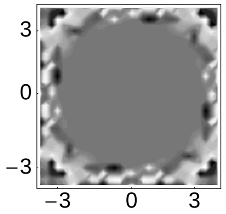
m_F=+1

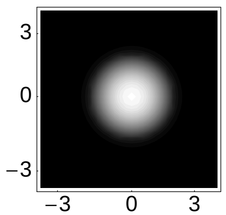


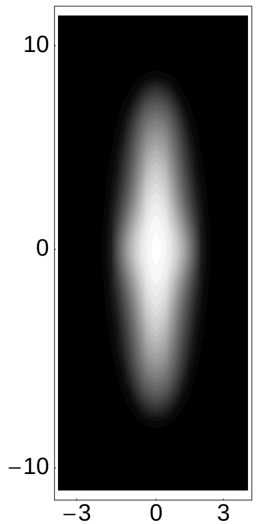
Cigar shape harmonic trap

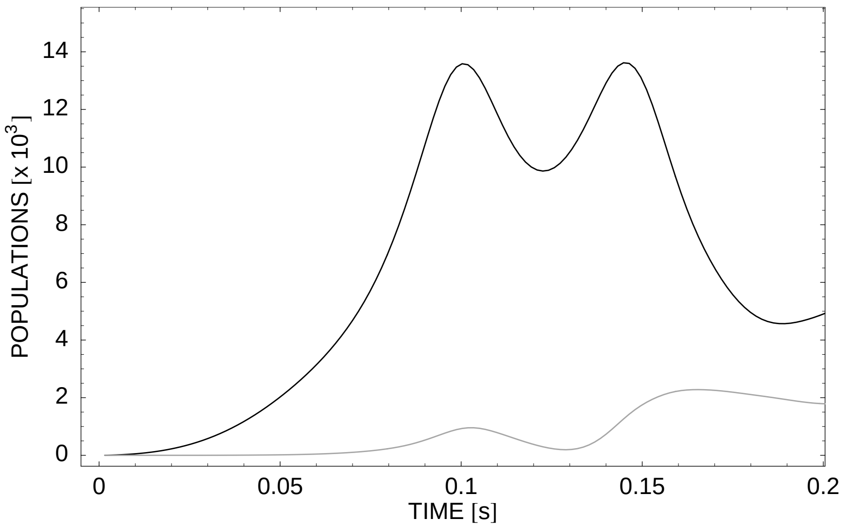
B_{res}=0.12mG, N_{+1}=50k, N_0=14k, N_{-1}=2k

m_F=+1



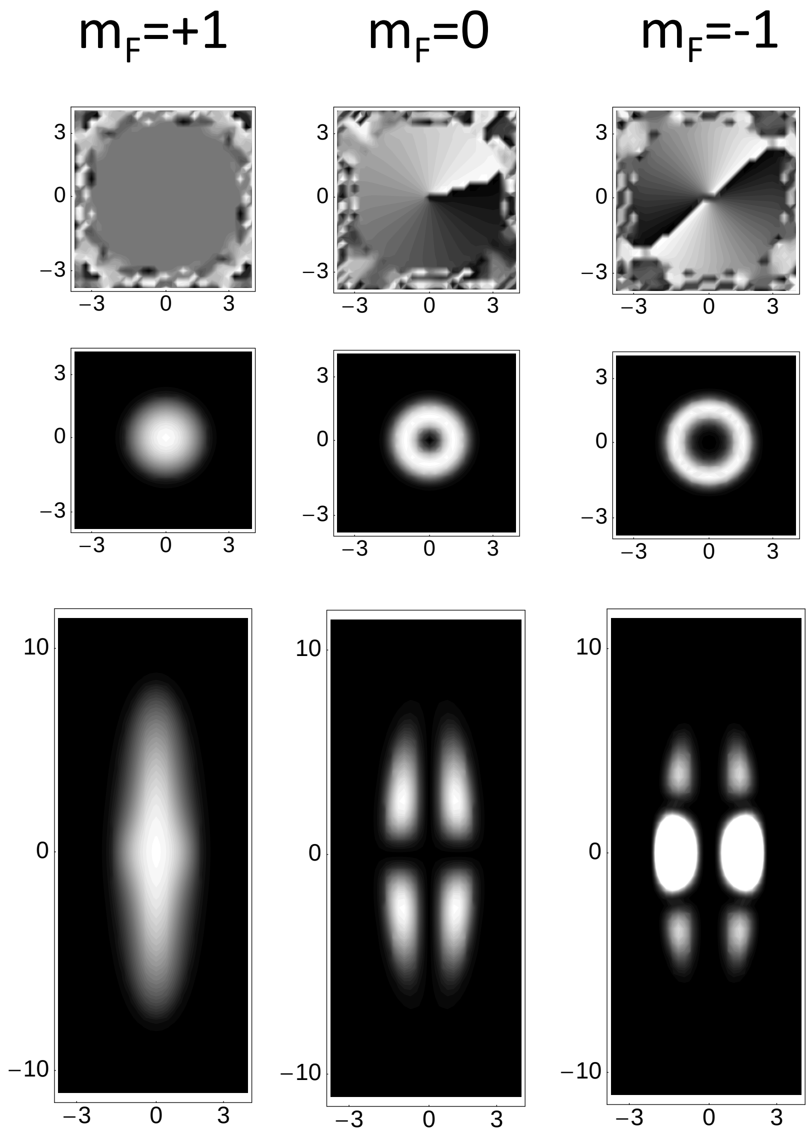


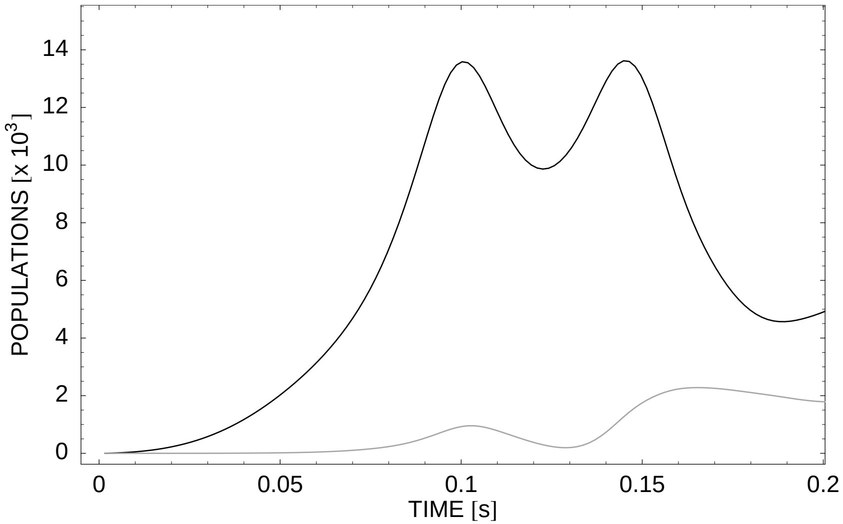




Cigar shape harmonic trap

B_{res}=0.12mG, N_{+1}=50k, N_0=14k, N_{-1}=2k





THE PROBLEM

Square optical lattice + weak harmonic trap

$$V_{trap} = V_0(\cos^2 kx + \cos^2 ky) + \frac{1}{2} m \omega_z{}^2 z^2$$

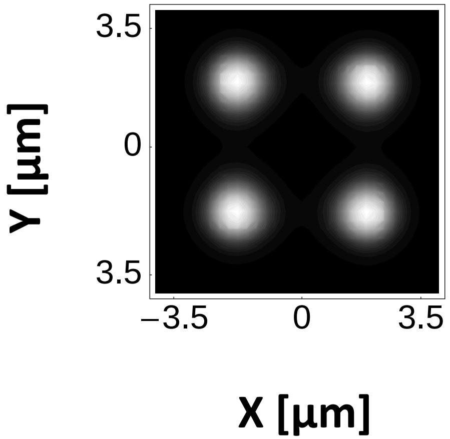
THE PROBLEM

Square optical lattice + weak harmonic trap

$$V_{trap} = V_0(\cos^2 kx + \cos^2 ky) + \frac{1}{2} m \omega_z{}^2 z^2$$

$$\omega_z = 2\pi 100\text{Hz}$$

$$E_R = \frac{k^2\hbar^2}{2m}$$



Periodic boundary conditions.
Initially all atoms are in m_F=+1 component.

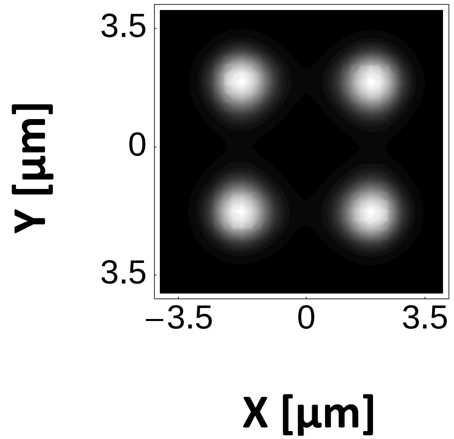
THE PROBLEM

Square optical lattice + weak harmonic trap

$$V_{trap} = V_0(\cos^2 kx + \cos^2 ky) + \frac{1}{2} m \omega_z^2 z^2$$

$$\omega_z = 2\pi 100\text{Hz}$$

$$E_R = \frac{k^2 \hbar^2}{2m}$$

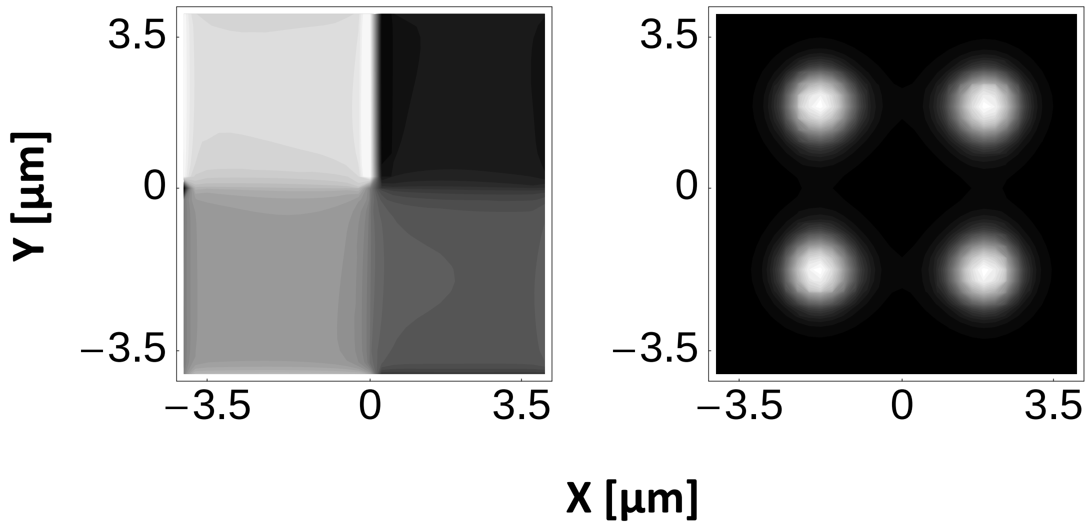


Periodic boundary conditions.
Initially all atoms are in m_F=+1 component.

Investigate a role of the discrete C_4 symmetry in resonant transfer of atoms due to the dipolar interactions.

RESULTS

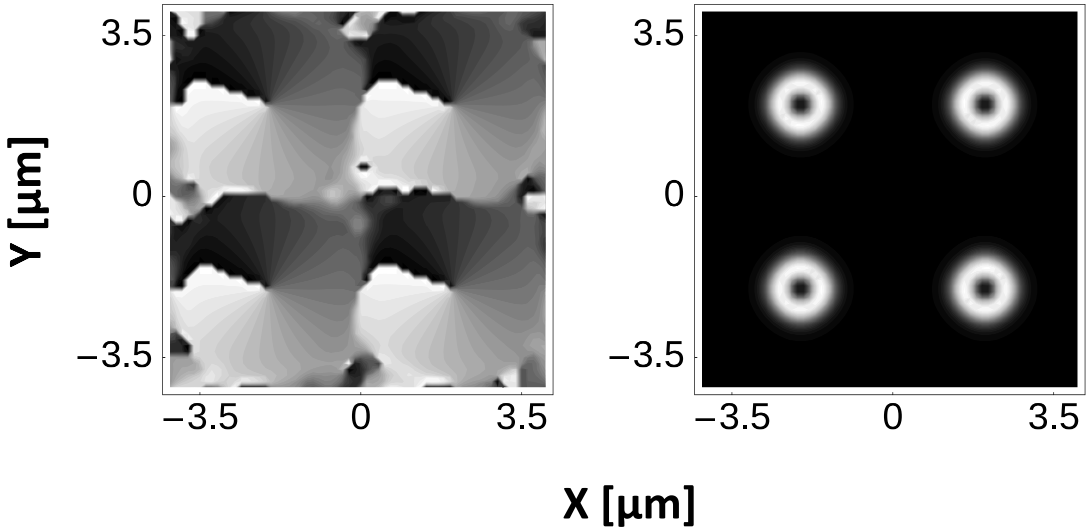
V_0=10E_R, B_{res}=0.08mG, N_0=80



Very different final state
(as compared to the harmonic trap).
Discreete vortex – phase jumps by pi/2
from site to site.

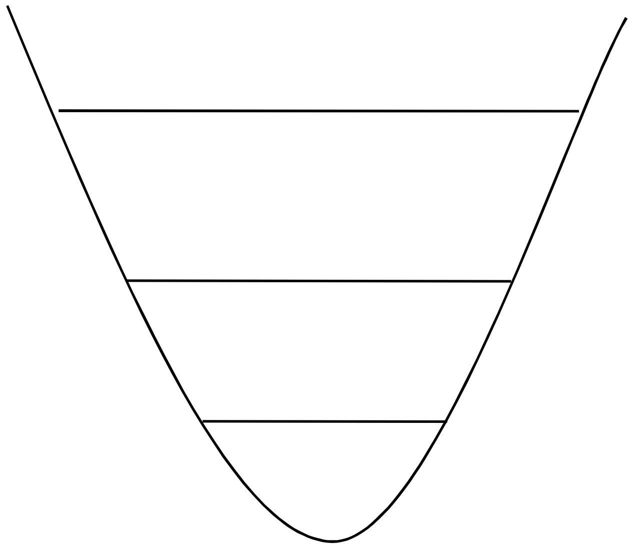
RESULTS

V_0=20E_R, B_{res}=0.85mG, N_0=160



For the higher barrier the tunneling is very weak
– we observe array of 4 vortices.

Single harmonic trap

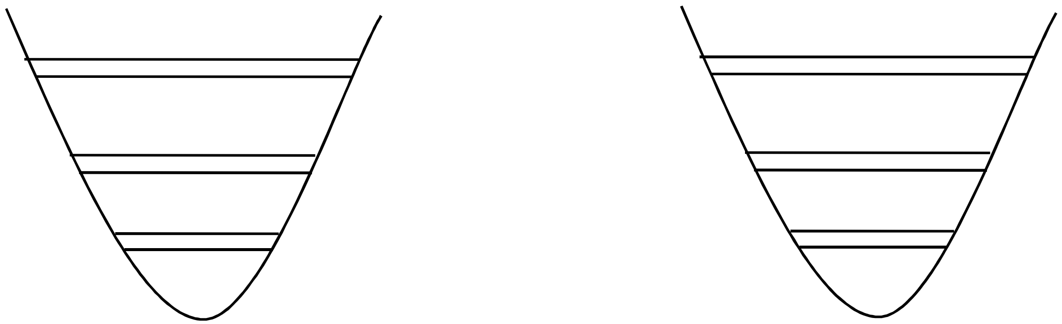


E_{e2} $\quad \propto (x+iy)ze^{-z^2}$

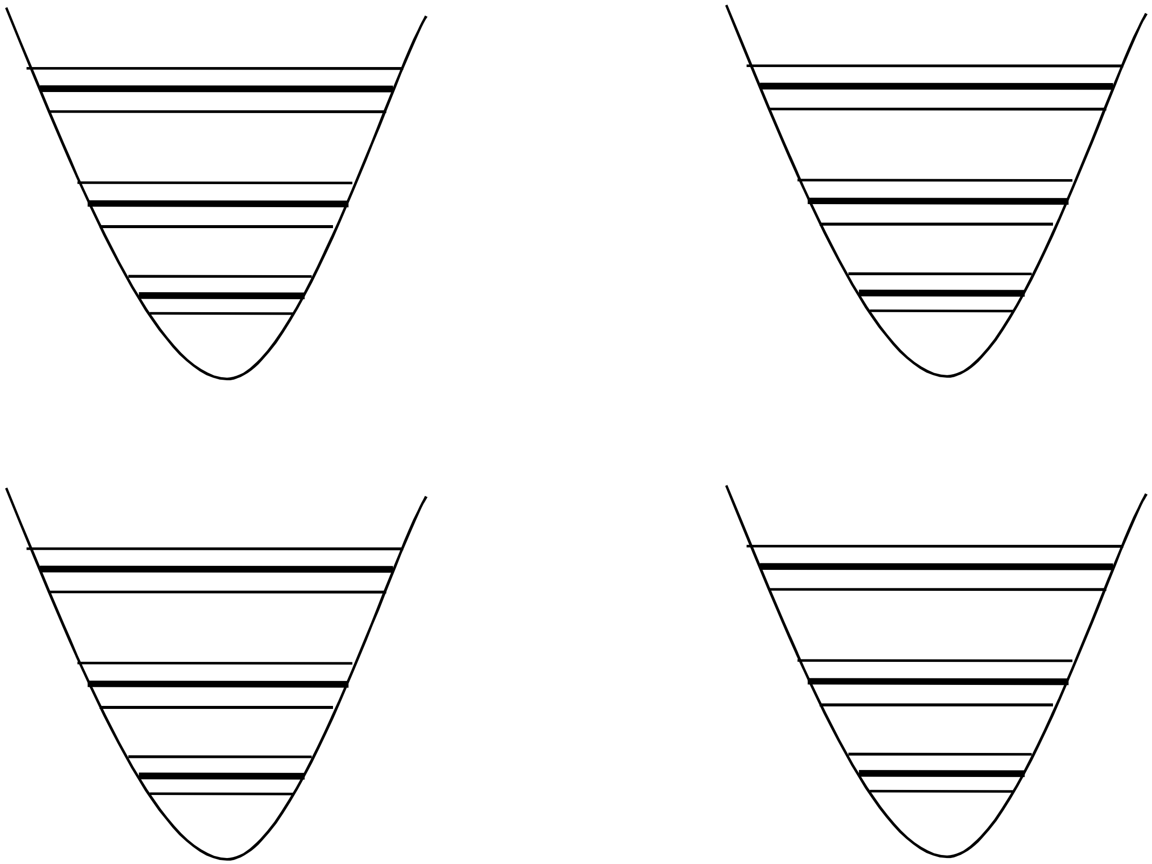
E_{e1} $\quad \propto ze^{-z^2}$

E_{g} $\quad \propto e^{-z^2}$

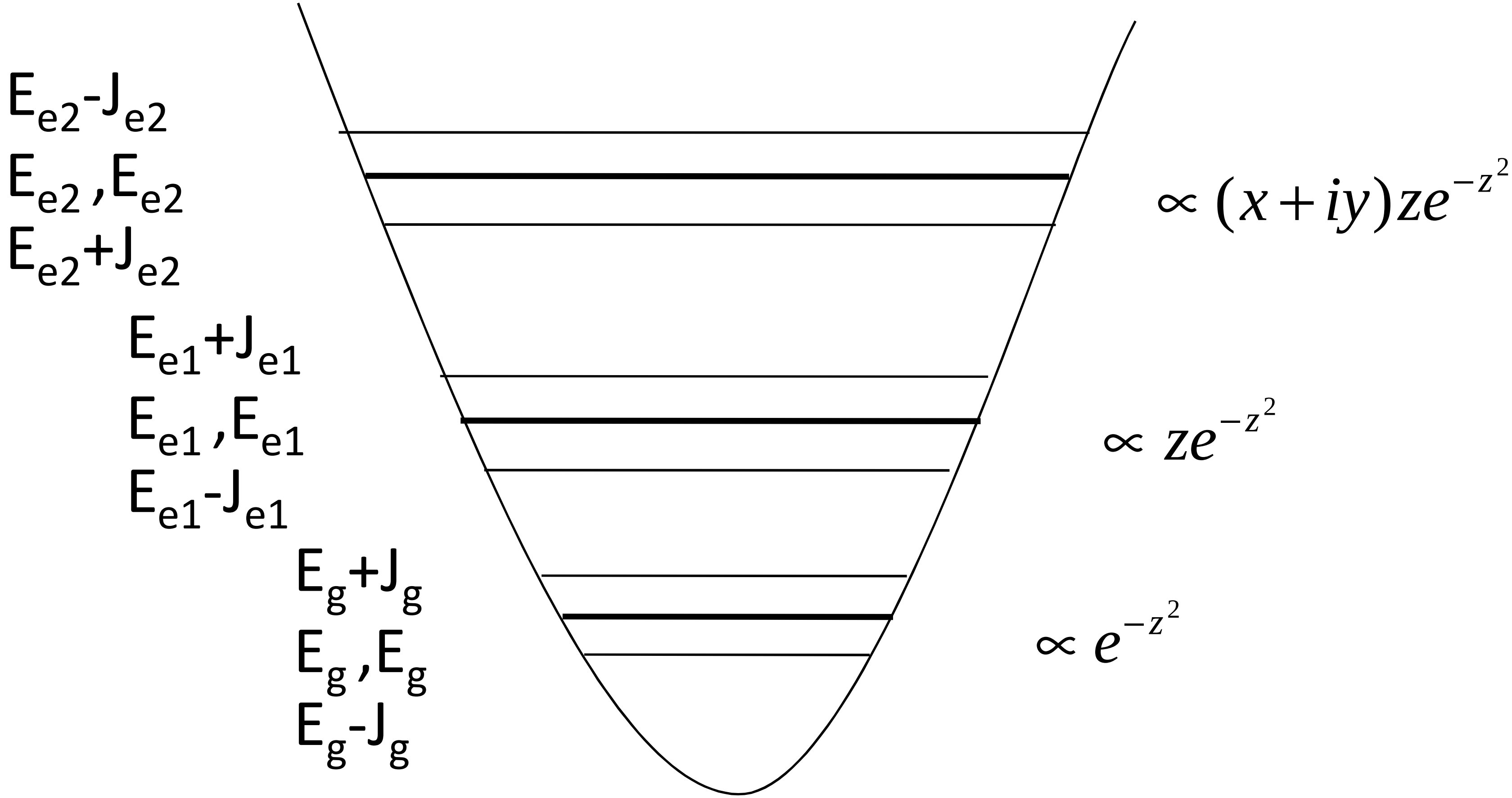
Two harmonic traps with tunneling



Four harmonic traps with tunneling - plaquette 2x2



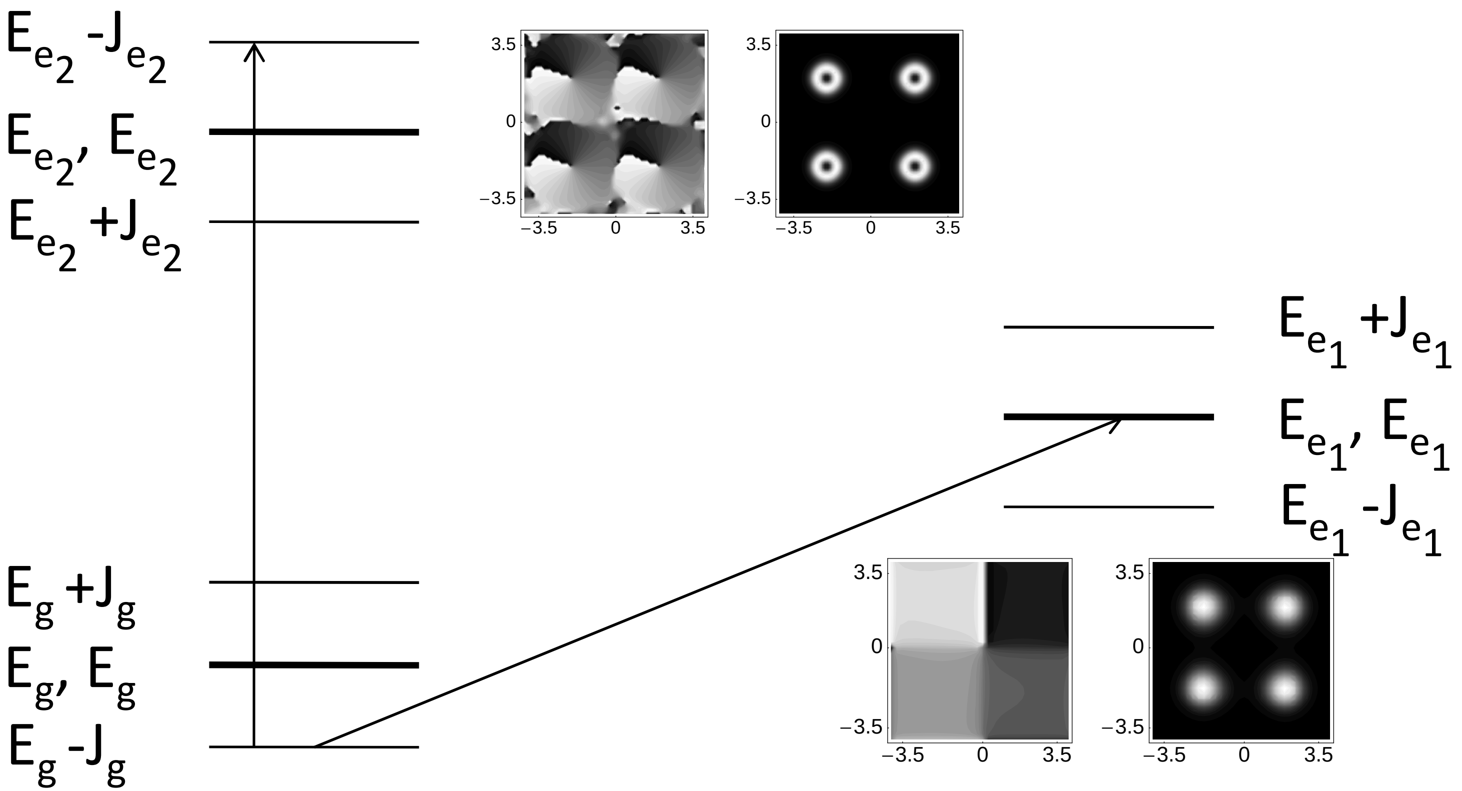
Formation of the discrete and the local vortex states



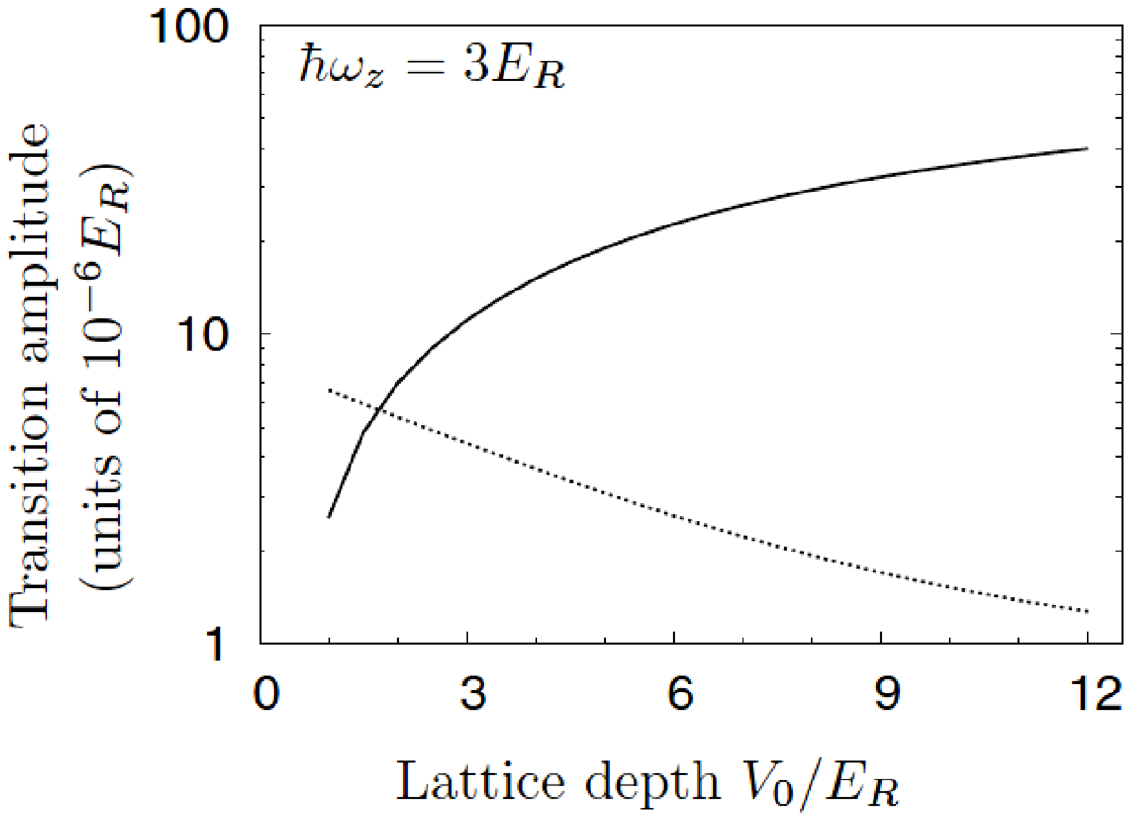
Formation of the discrete and the local vortex states

$$|\downarrow\rangle_g \rightarrow \frac{1}{2}(|1\rangle_{e_1} + i|2\rangle_{e_1} - |3\rangle_{e_1} - i|4\rangle_{e_1})$$

$$|\downarrow\rangle_g \rightarrow \frac{1}{2}(|1\rangle_{e_2} + |2\rangle_{e_2} + |3\rangle_{e_2} + |4\rangle_{e_2})$$



Transition amplitudes induced by dipolar interactions for the 2x2 plaquette



For deeper lattices, the transition to the four independent vortices located at lattice sites (solid line) always dominates over the transiton to the discrete vortex (dotted line).

Transfer of atoms to the m_F=0 state as a function of magnetic field

$$\Delta E_1 = E_{e_1} - E_g + 2J_g = \mu B_1$$

$$\Delta E_2 = (E_{e_2} - E_g) - 2(J_{e_2} - J_g) = \mu B_2$$

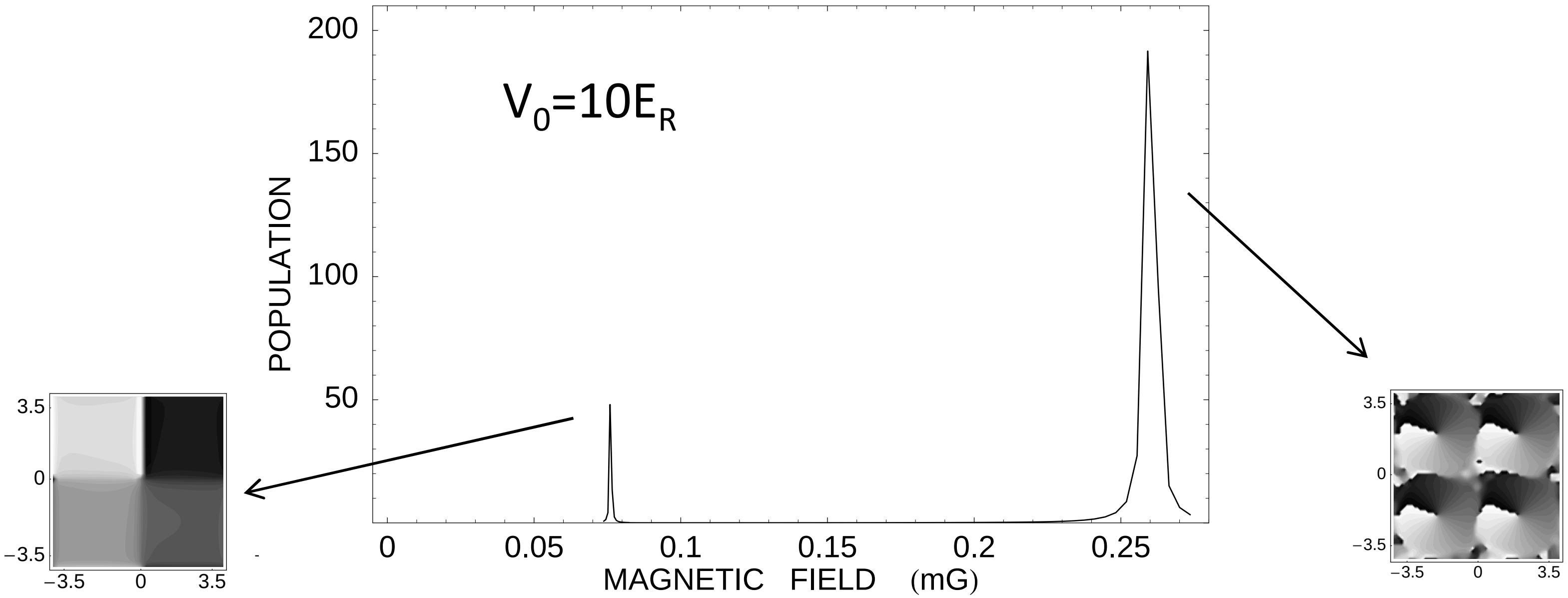
$$\Delta E_1 < \Delta E_2 \Rightarrow B_1 < B_2$$

Transfer of atoms to the m_F=0 state as a function of magnetic field

$$\Delta E_1 = E_{e_1} - E_g + 2J_g = \mu B_1$$

$$\Delta E_2 = (E_{e_2} - E_g) - 2(J_{e_2} - J_g) = \mu B_2$$

$$\Delta E_1 < \Delta E_2 \Rightarrow B_1 < B_2$$



CONCLUSIONS

- Two different topological structures are created depending on the value of the magnetic field and depth of the optical lattice.
- Topological states are created dynamically with the help of the resonant Einstein-de Haas effect.

CONCLUSIONS

- Two different topological structures are created depending on the value of the magnetic field and depth of the optical lattice.
- Topological states are created dynamically with the help of the resonant Einstein-de Haas effect.
- Experimental group (B. Laburthe-Tolra et al.) is interested in doing experiments with the Einstein-de Haas effect on the lattice with chromium atoms – PRL **106** 015301 (2011).