Quantum Technologies Conference

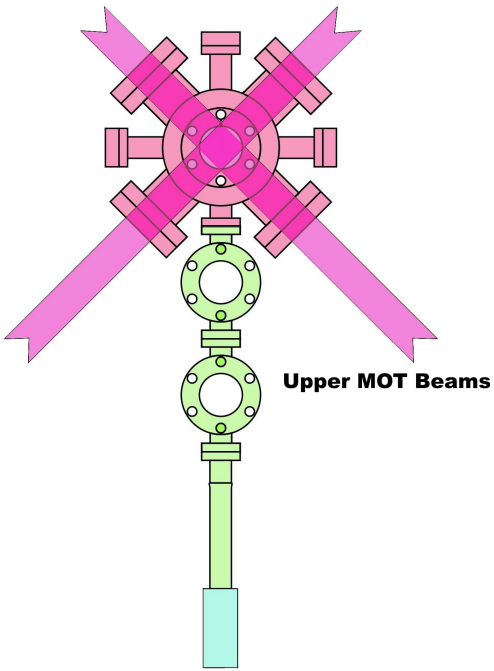
Spin domain formation in an expanding anti-ferromagnetic quantum gas

Marcin Witkowski
National Laboratory FAMO

September 2011

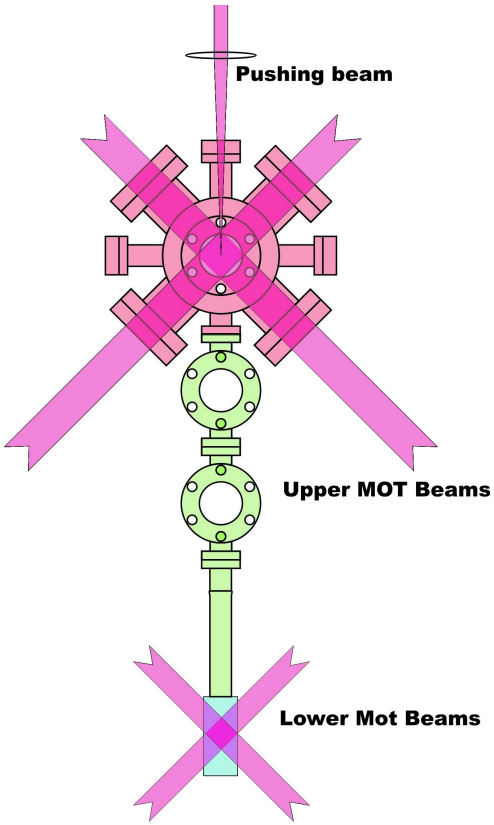
Table of Contents

Double MOT



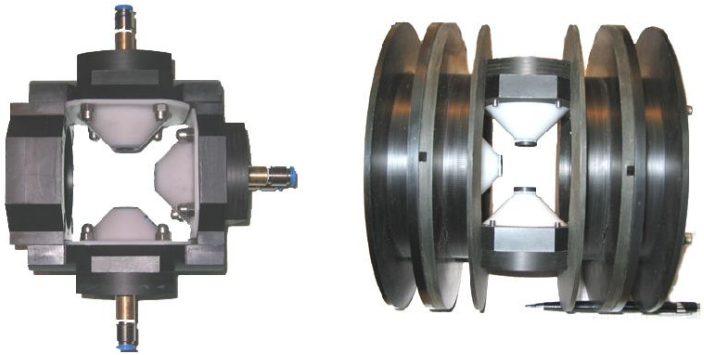
- The upper MOT is produced.

Double MOT



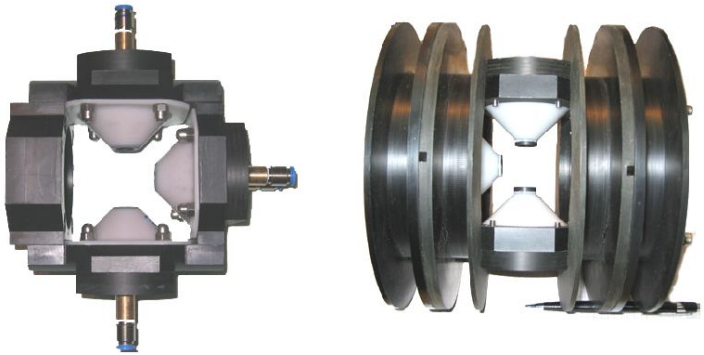
- The upper MOT is produced.
- Cold atoms from the upper MOT are pushed down into the lower MOT by a slightly focused near-resonance beam.

QUIC Magnetic Trap



- The heart of the magnetic trap consists of three identical conical coils. Two of them produce quadrupole field, the third one is the Ioffe coil.

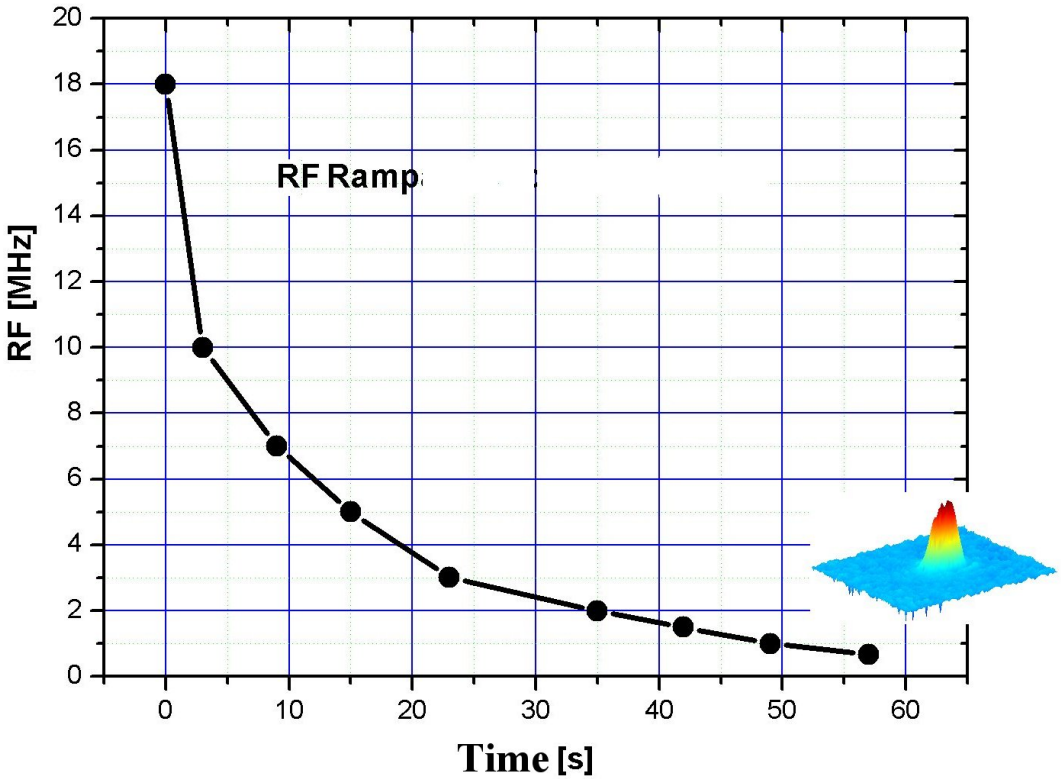
QUIC Magnetic Trap



- The heart of the magnetic trap consists of three identical conical coils. Two of them produce quadrupole field, the third one is the Ioffe coil.

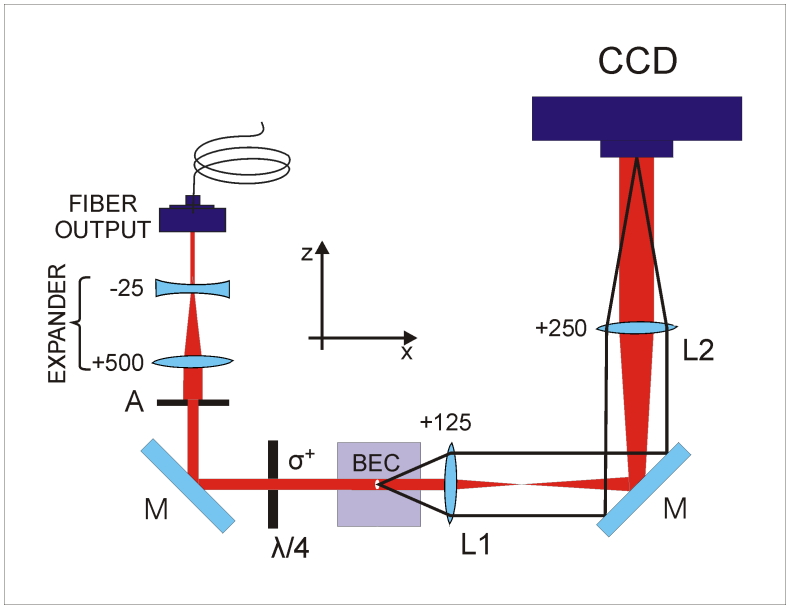
- Additionally there are two Helmholtz coils in the Ioffe coil axis, the offset coils. The working current is 39 Amps, all the coils are water cooled.

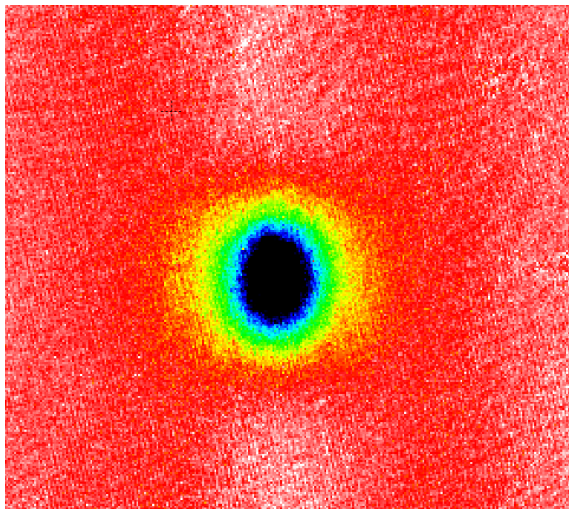
Evaporation RF



Detection

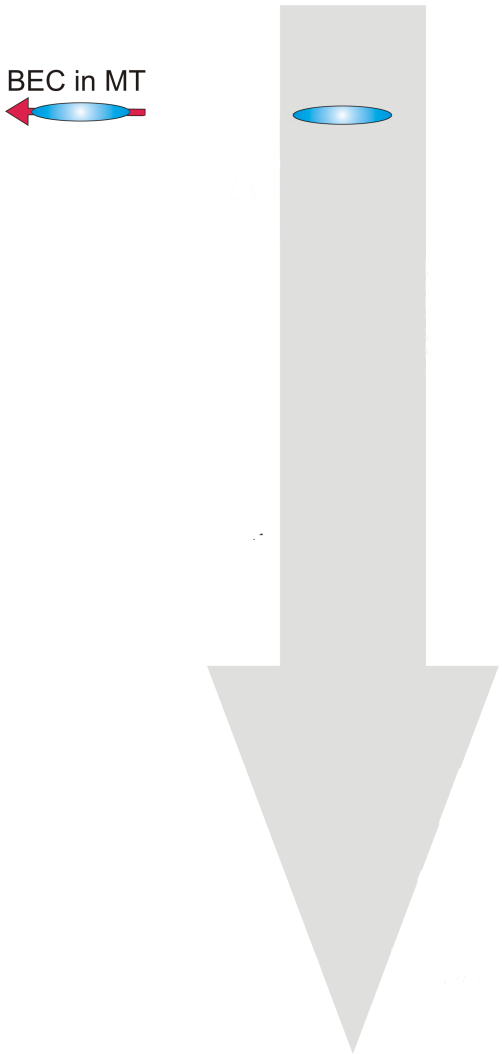
The BEC of ^{87}Rb atoms in the $F = 2$, $m_F = 2$ hyperfine state is produced in the magnetic trap. The cigar-shape harmonic potential has the axial frequency of $2\pi \times 12.1$ Hz and tunable radial frequencies in the range of $2\pi \times 137 \div 2\pi \times 230$ Hz.





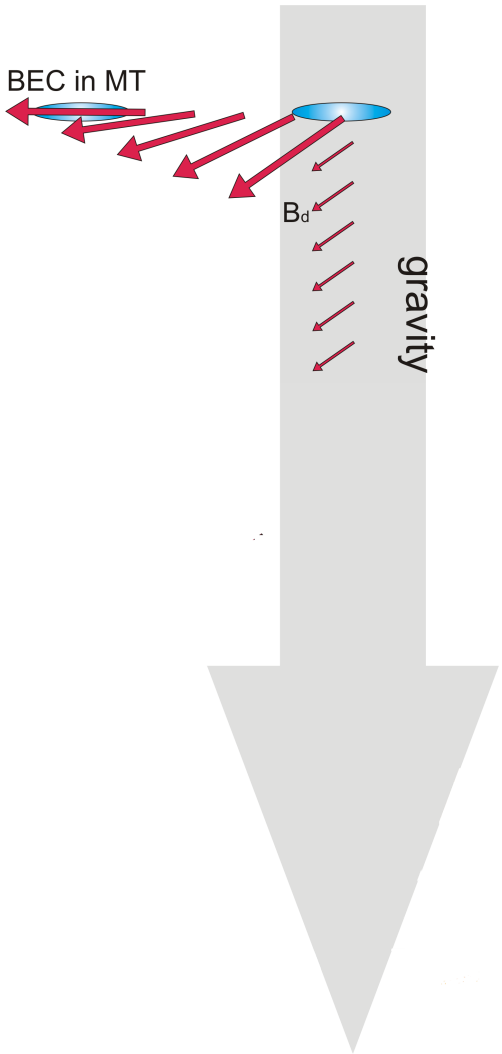
After a given time of a free fall expansion the atomic cloud is recorded by a standard absorption imaging.

Experiment layout



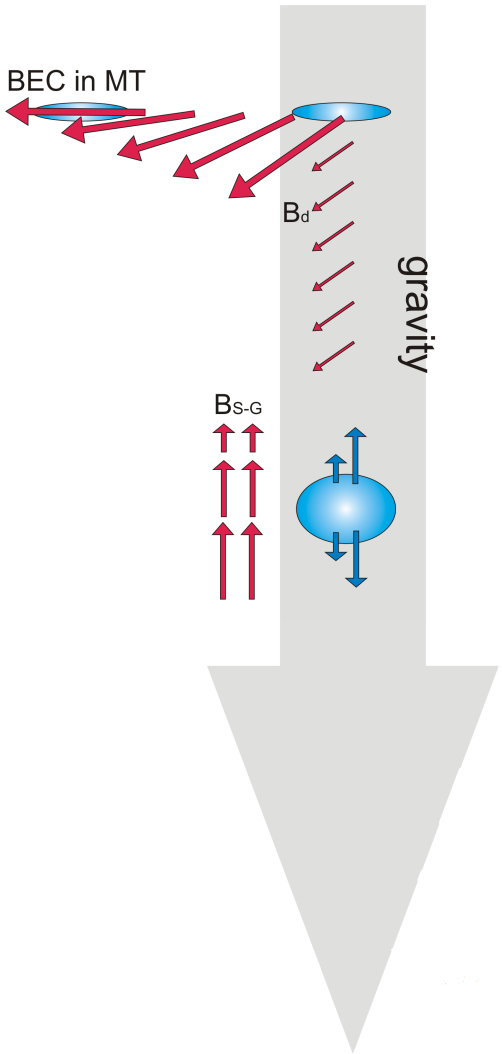
- BEC is produced

Experiment layout



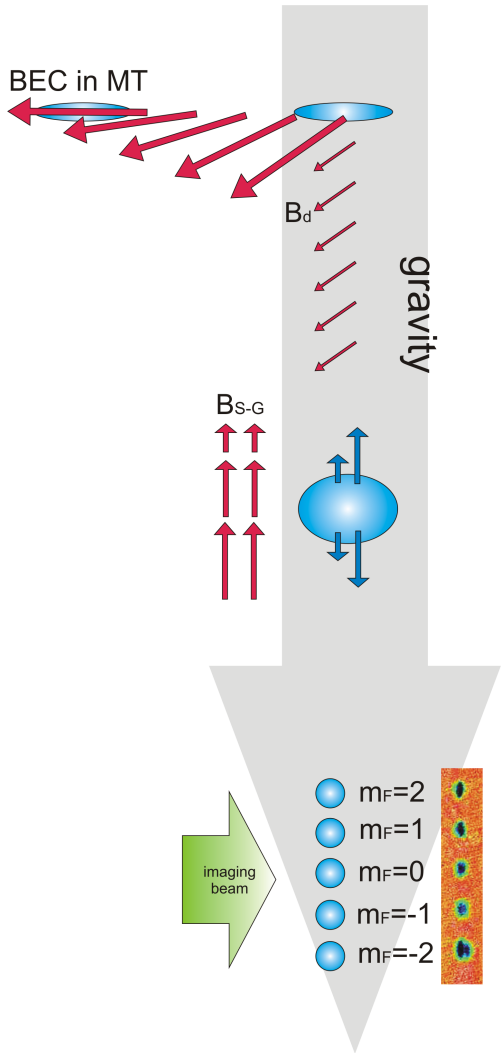
- BEC is produced
- The field of the magnetic trap is adiabatically replaced by a homogeneous, weak magnetic field B_d in a given direction.
- Atoms start to fall freely under gravity and their spins follow the magnetic field direction.

Experiment layout



- BEC is produced
- The field of the magnetic trap is adiabatically replaced by a homogeneous, weak magnetic field B_d in a given direction.
- Atoms start to fall freely under gravity and their spins follow the magnetic field direction.
- After a given time of free fall expansion (1-20 ms), the MT field is nonadiabatically pulsed for duration of 1-2 ms.

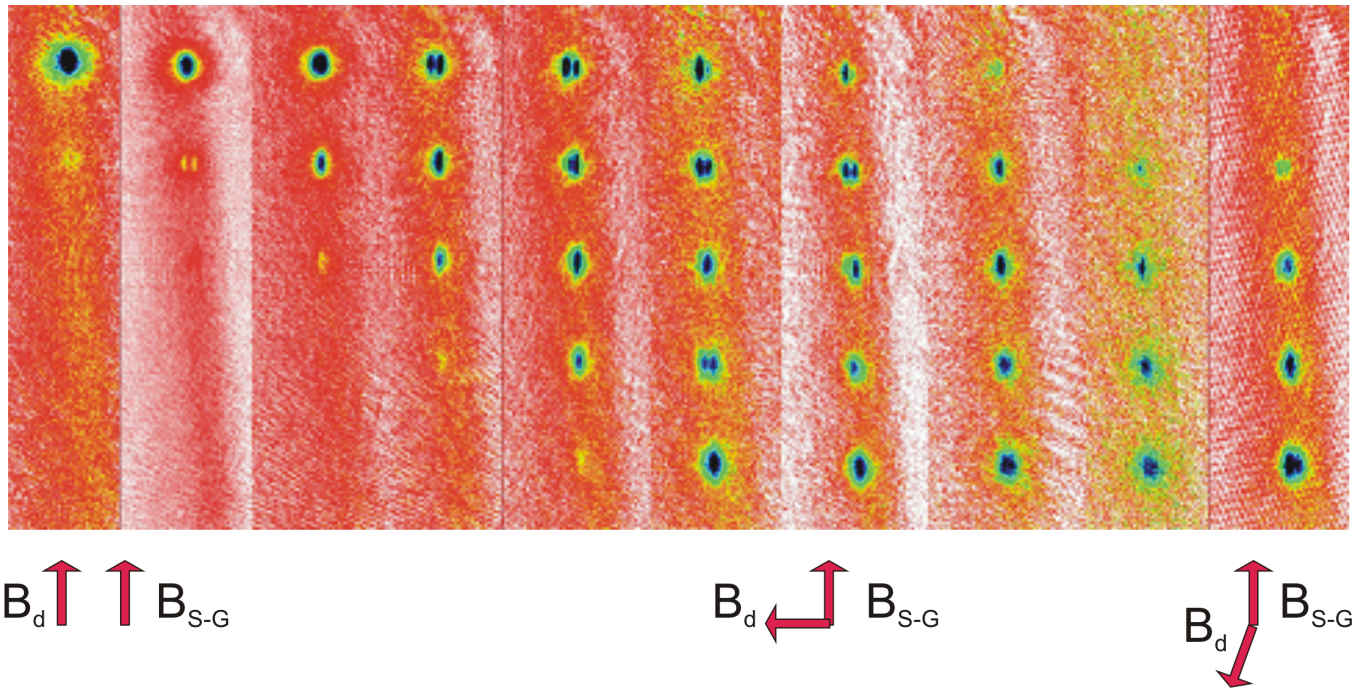
Experiment layout



- BEC is produced
- The field of the magnetic trap is adiabatically replaced by a homogeneous, weak magnetic field B_d in a given direction.
- Atoms start to fall freely under gravity and their spins follow the magnetic field direction.
- After a given time of free fall expansion (1-20 ms), the MT field is nonadiabatically pulsed for duration of 1-2 ms.
- The atomic spins are projected on the direction of the strong gradient of the magnetic field (B_{SG}). The Stern-Gerlach force separates the condensates.

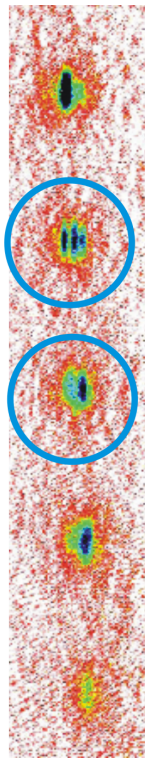
Population control

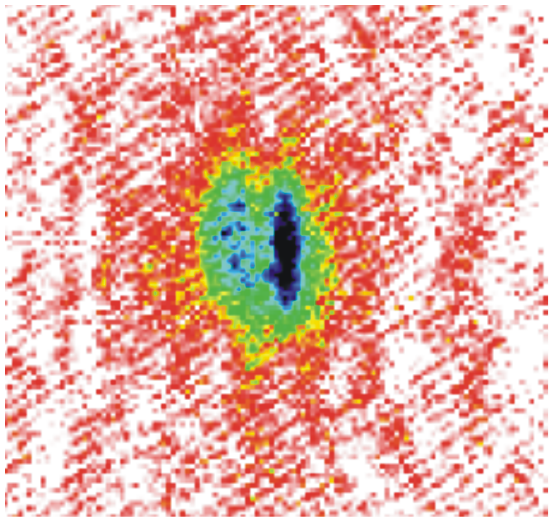
We can control population distribution among possible states.

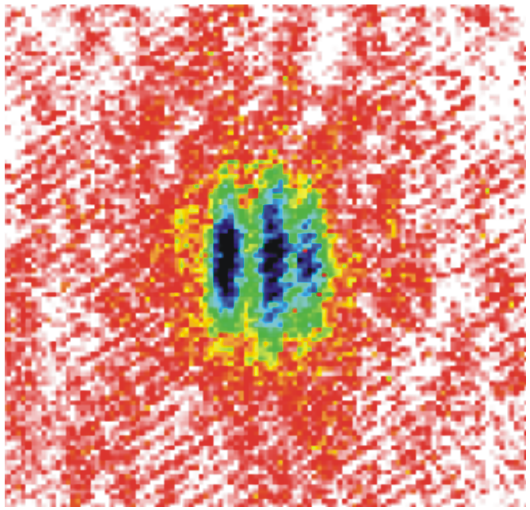


Absorption images of the spinor condensates expanded by the Stern-Gerlach force taken for different orientation of the B_d vs the B_{SG} field.

Spin domains

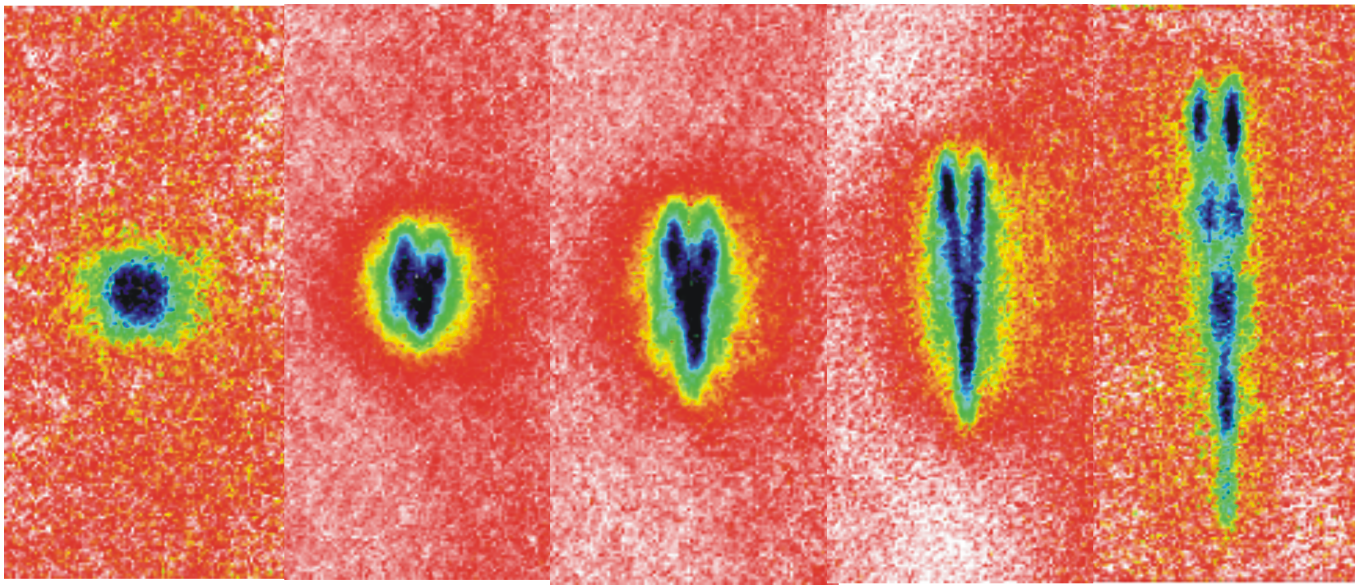






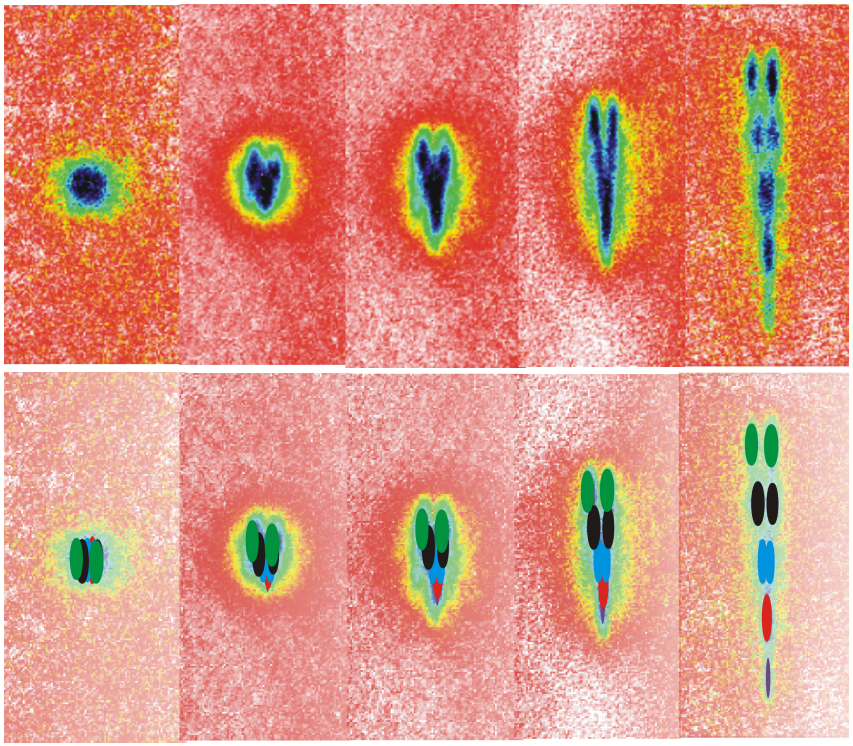
Careful examination of the absorption picture reveals atomic density modulation in the spinor condensates.

Spin domains



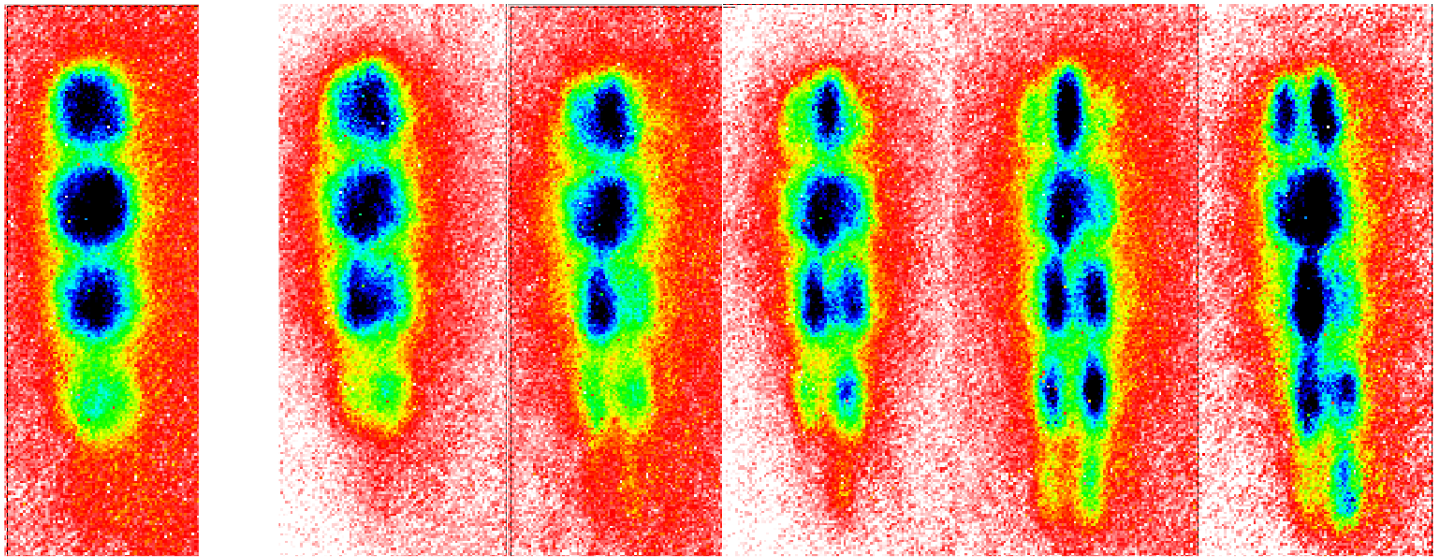
Absorption images of the spinor condensates taken during their separation after the Stern-Gerlach pulse.

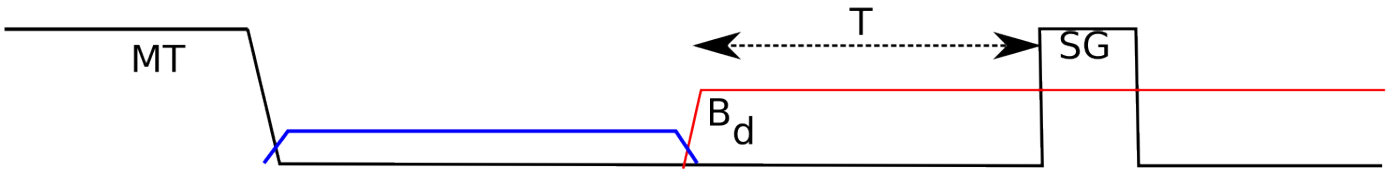
Spin domains



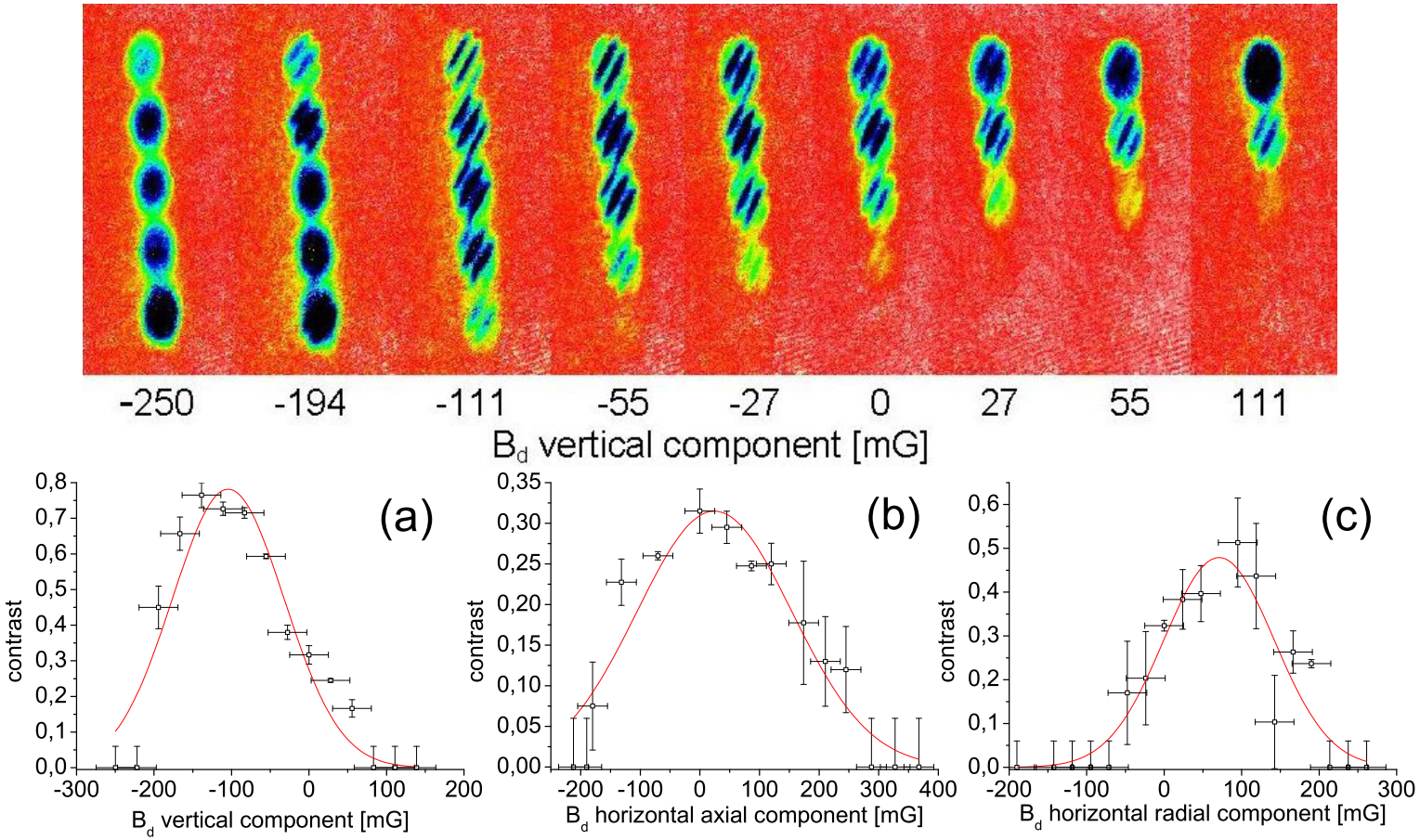
The spatial modulation of the spinor condensates is most likely caused by the presence of spin domains before the B_{SG} field.

Spin domains

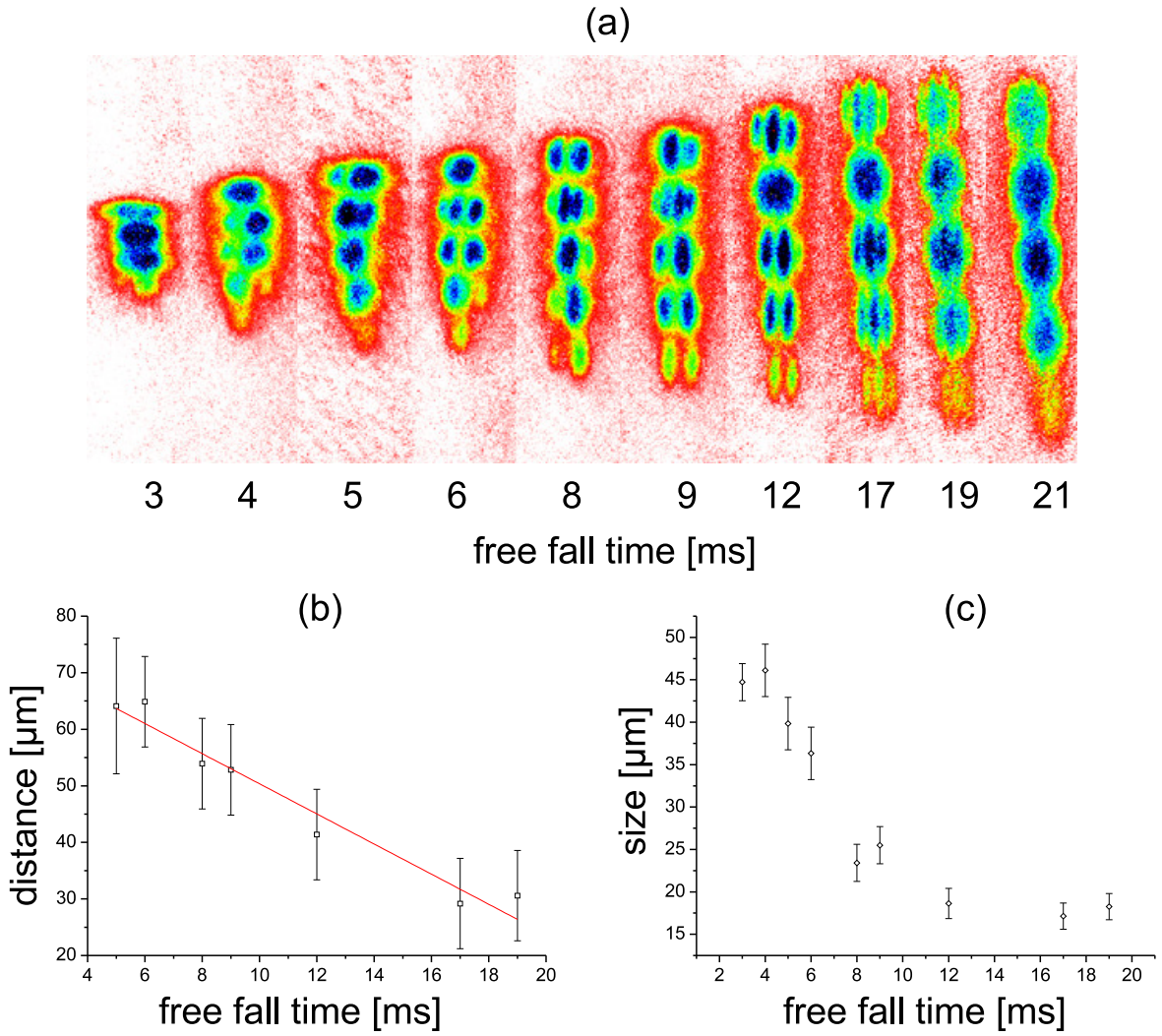




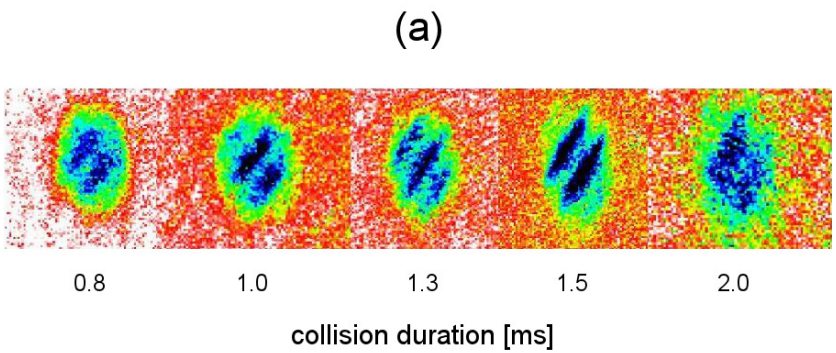
Spin domains – resonant character



Spin domains

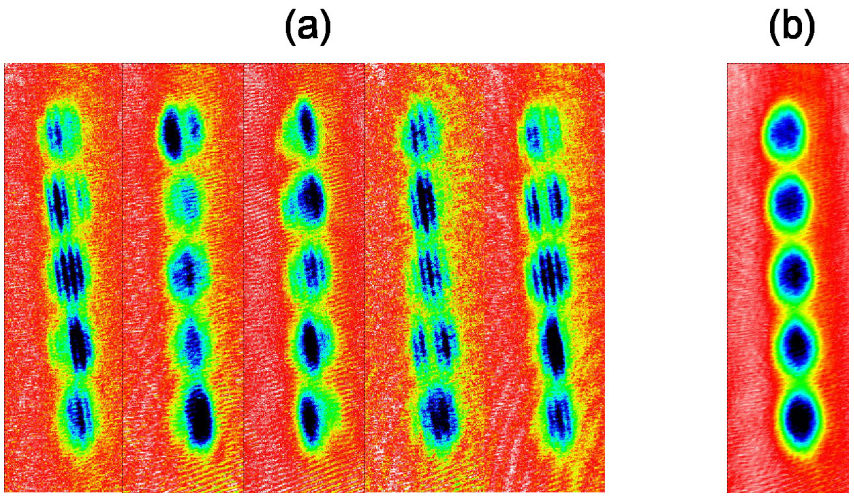


Spin domains – pattern rotation

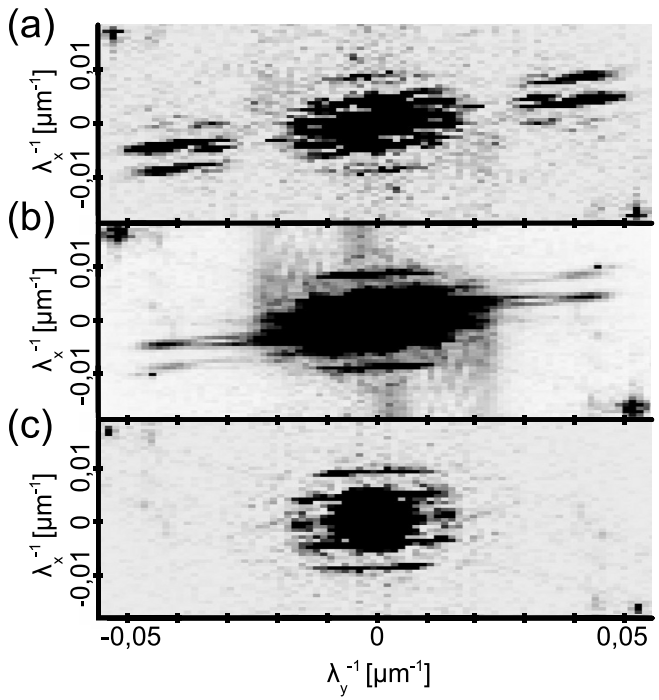


a) $m_F = 0$ component only during the separation. States with $m_F \neq 0$ are out of resonance.
b) The angle between spin domains and the vertical direction vs collision duration. Black: the angle variation caused by the BEC free-fall evolution.

Spin domains



a) Succesive realizations of the spin domains in the same experimental conditions
b) The image averaged over 72 realizations.



a) PS of the single image.
b) Averaged PS over 72 images.
c) PS of the averaged image.

Conclusions

- We observe spatial modulation of the density of spinor condensates. The modulation is attributed to spin domains in the ^{87}Rb BEC in the F=2 state.
- The proces is resonant in the magnetic field.
- The question about the origin is still open...

The Team

KL FAMO, the National Laboratory of AMO Physics

Members

Experiment

- W. Gawlik, Jagielonian Univ., Kraków
- R. Gartman, Nicolaus Copernicus Univ, Toruń
- J. Szczepkowski, IF PAN, Warsaw
- M. Witkowski, Nicolaus Copernicus Univ, Toruń
- M. Zawada, Nicolaus Copernicus Univ, Toruń

Theory

- M. Matuszewski, Institute of Physics, Polish Academy of Sciences, Warsaw
- K. Sacha, Jagielonian Univ., Kraków