Towards Experiments with ultracold Cs atoms in optical lattices

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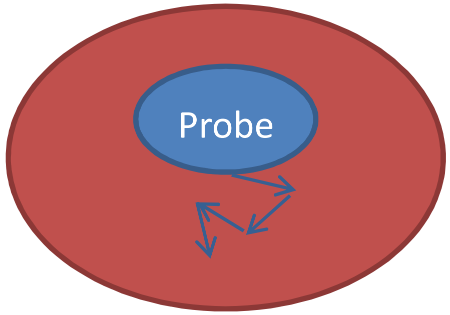
Motivation

Experimental setup built within the QuProCS framework to study **individual quantum probes in many-body systems**



- Many-body system – *superfluid (BEC of Cesium atoms)*
- Probes – *individual Cesium atoms (other internal state)*
- Environment – *lattice potentials*
- Goal – *use probe to determine temperature of the system*

Team

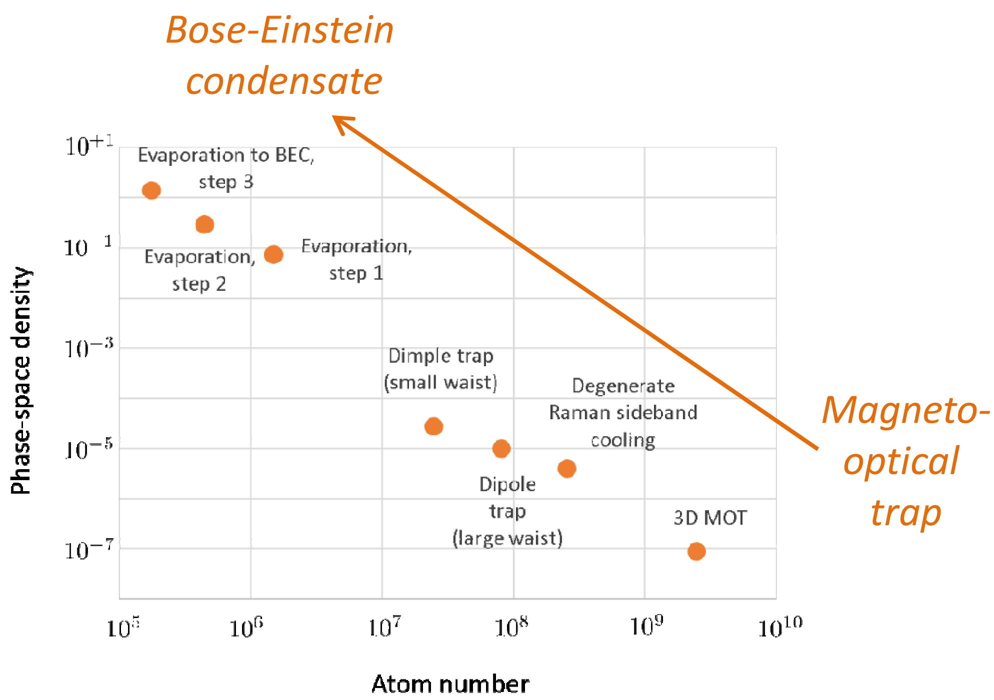
(two PhD students)

students started in Sep. 2015

Outline

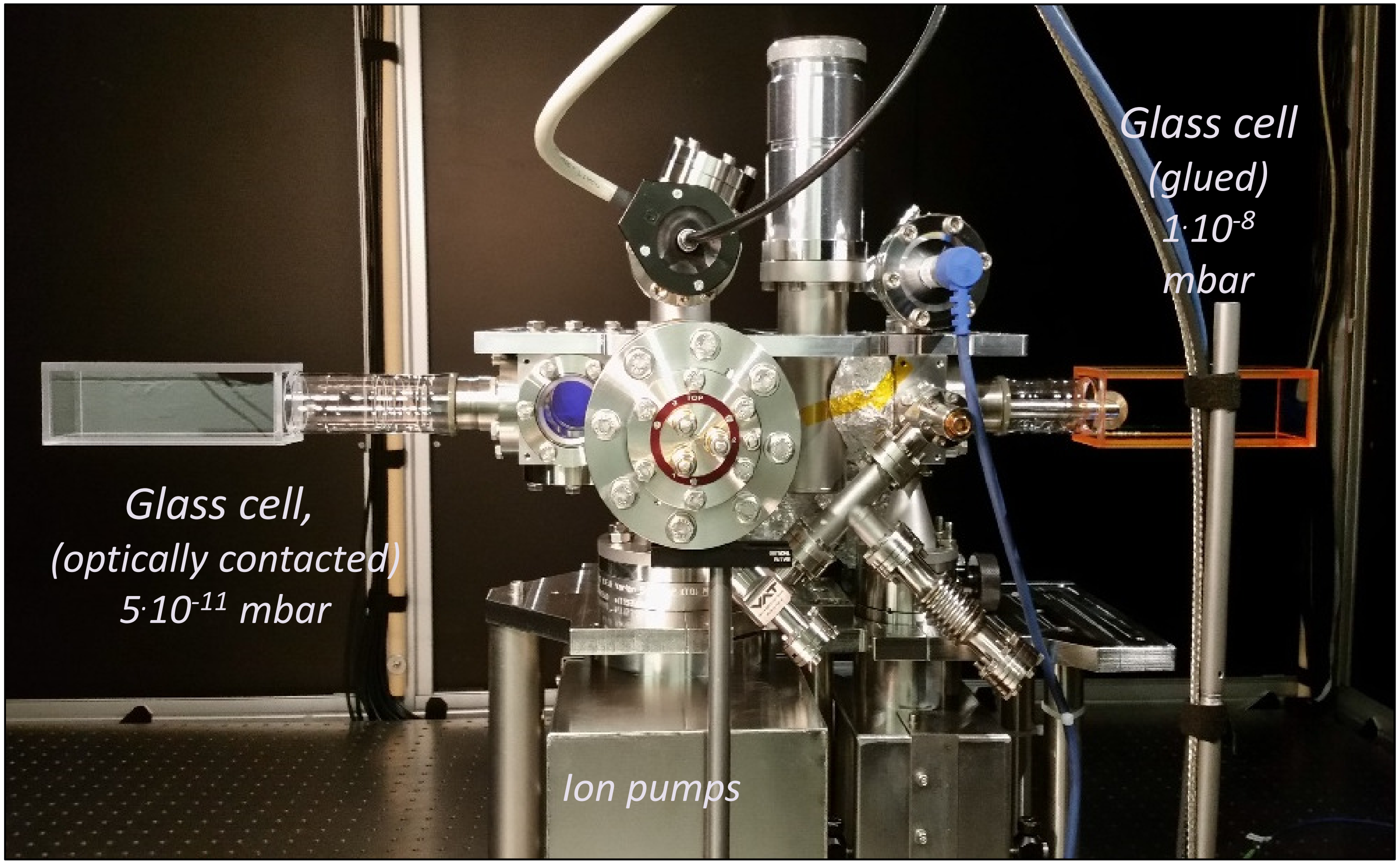
I. **Experimental setup and cooling to quantum degeneracy**

II. **Generation and study of quantum probes**

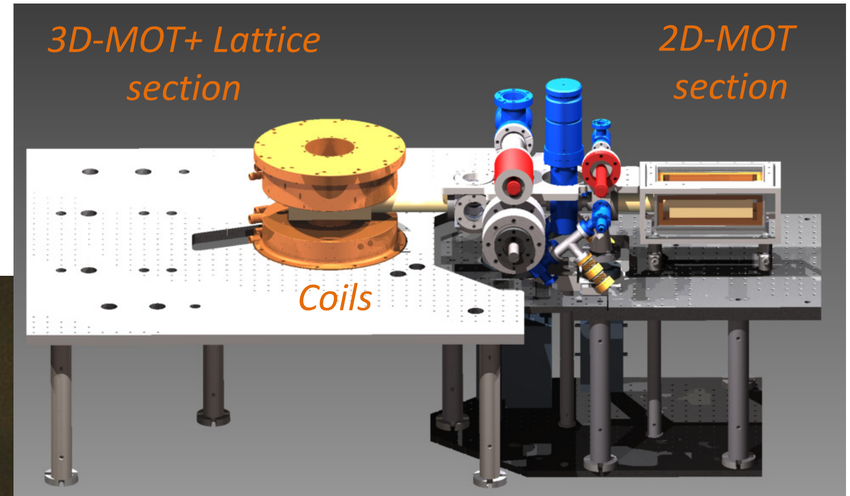


Vacuum setup

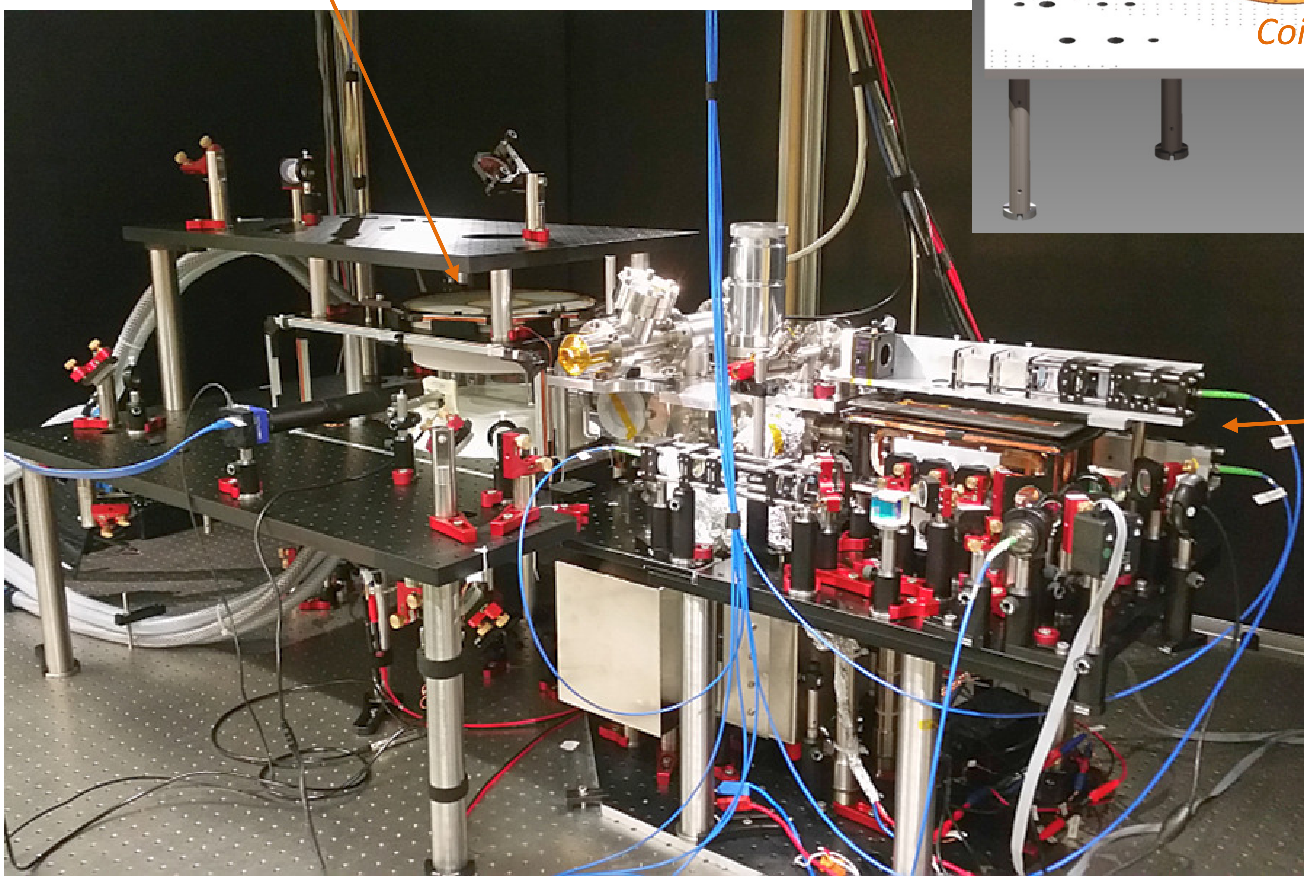
- Two sections with low and high vacuum
- Middle: shielded pumps and gauges



Experimental setup



3D-MOT section with breadboards and coils

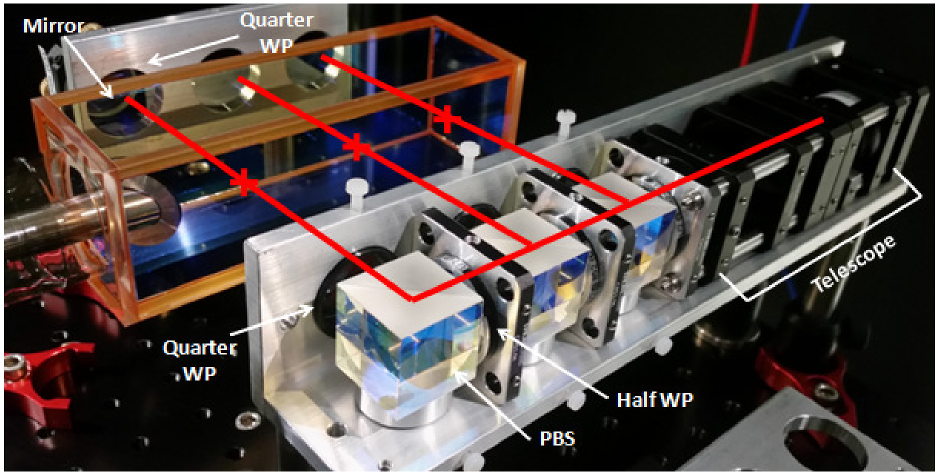


2D-MOT section

Magneto-optical traps

2D magneto-optical trap

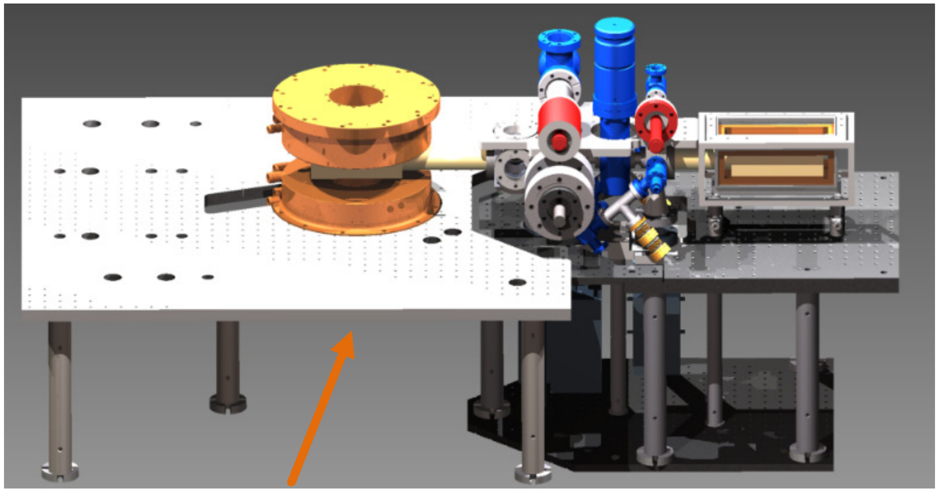
- *large cooling volume with 3 parallel laser beams (total 400mW)*



2D-MOT setup (horizontal beams)

3D magneto-optical trap

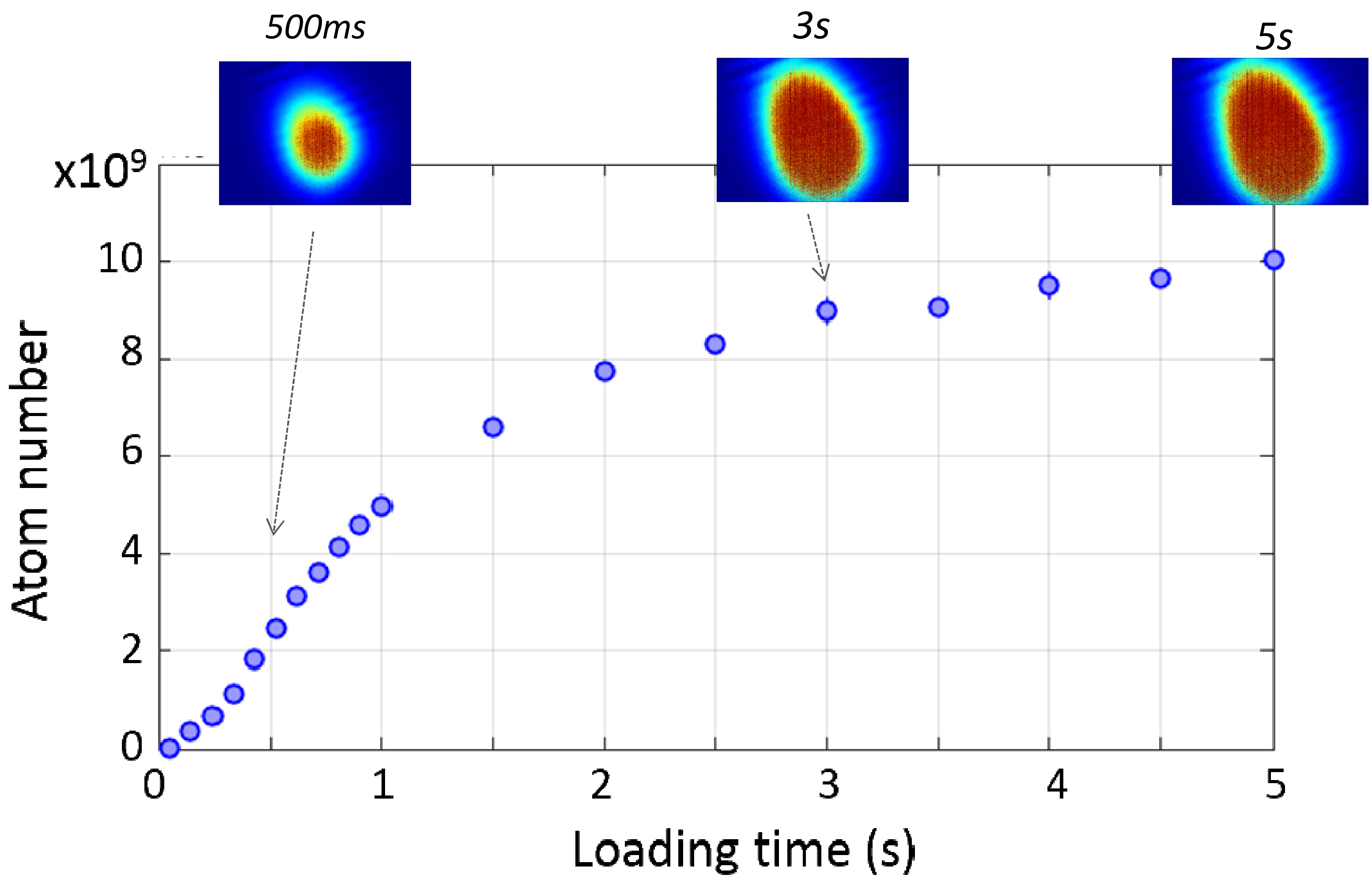
- *Optics is under the main breadboard to improve optical access to glass cell (total 200mW)*



3D-MOT optics is under the main breadboard

Loading of magneto-optical traps

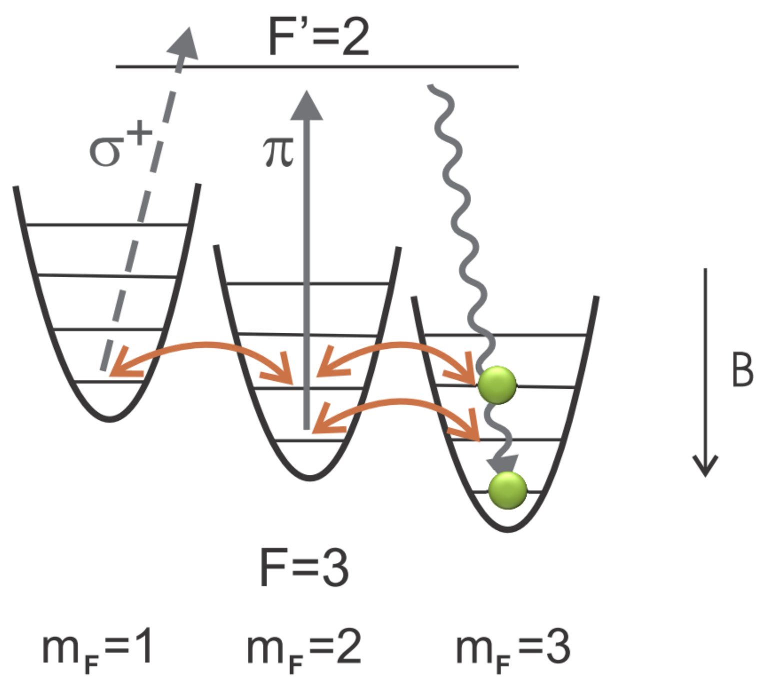
3D-MOT:
- Fast initial loading rate *4 x 10^9^* atoms/s
- Large atom number *8 x 10^9^ a*fter 2.5s

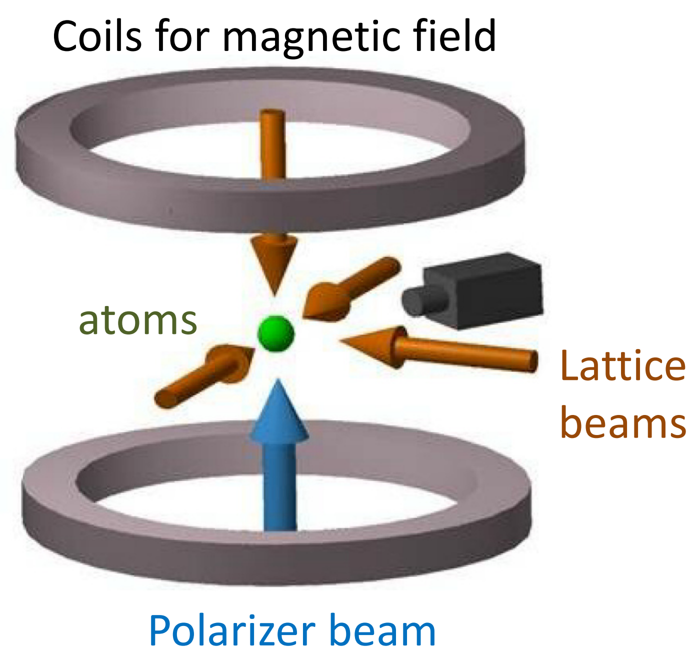


Degenerate Raman sideband cooling

Lattice based cooling scheme

- Popular for cooling of ions
- Developed in group of Steve Chu for ultracold atoms





Goals:

- Cool atoms to 1uK
- Spin polarize atoms in F=3,m_F=3 state

Degenerate Raman sideband cooling

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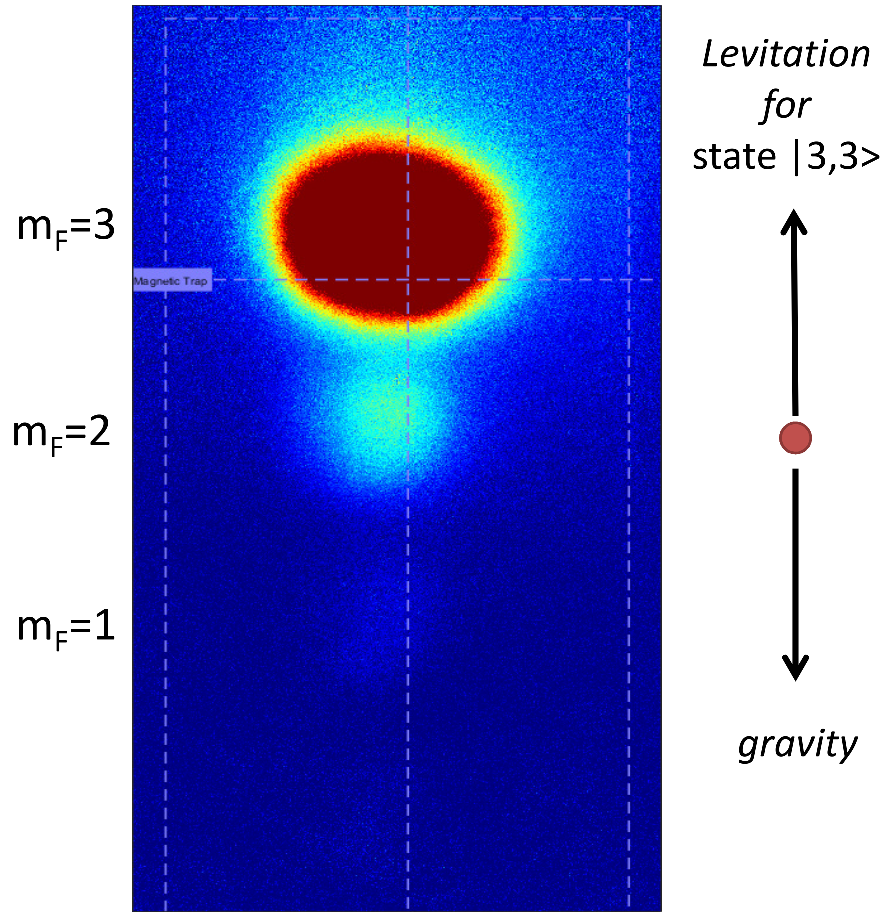
Results:

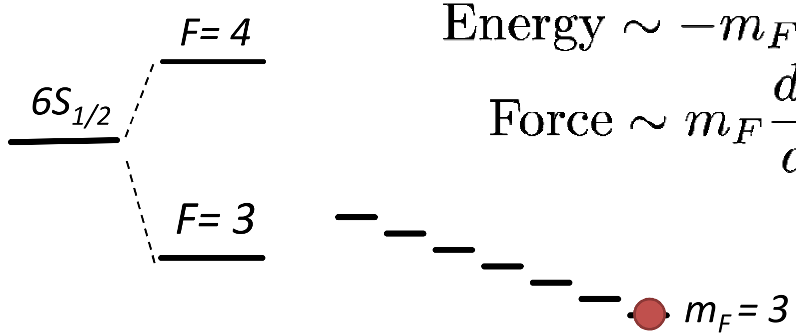
- Cold atoms at 1.1uK
- $3 \cdot 10^8$ atoms in state |F=3,m_F=3>
- Levitated atoms in |3,3>



Magnetic levitation

$$\text{Energy} \sim -m_F B$$

$$\text{Force} \sim m_F \frac{dB}{dz}$$



Hyperfine splitting for Cesium atoms

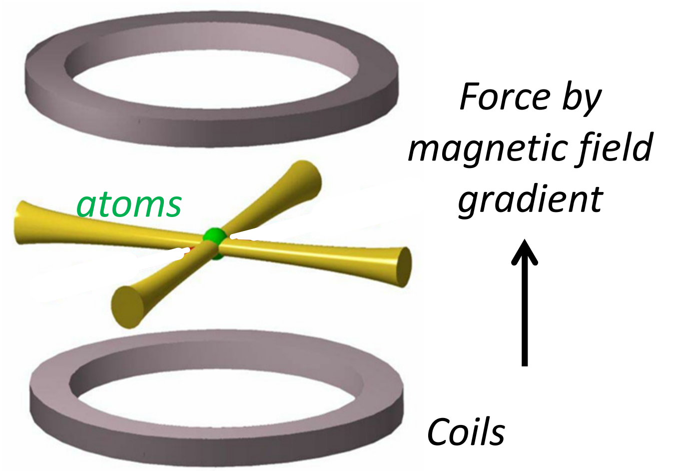
Zeeman splitting in magnetic field

Crossed dipole traps

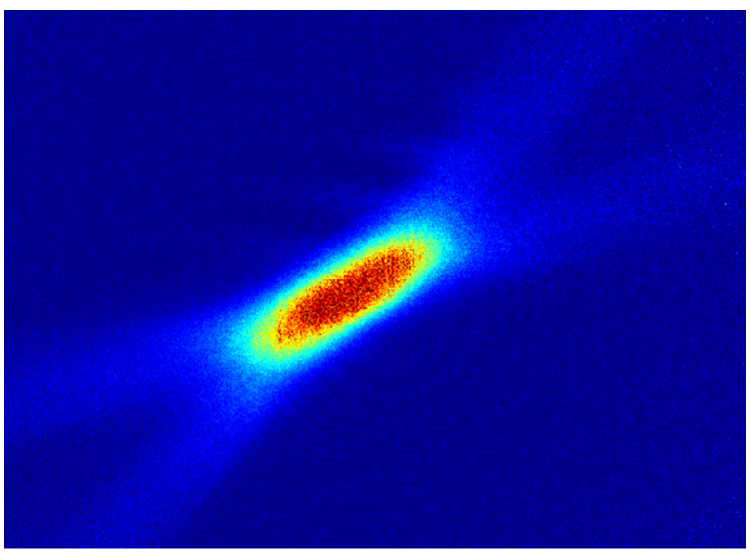
Trap atoms in two laser beams

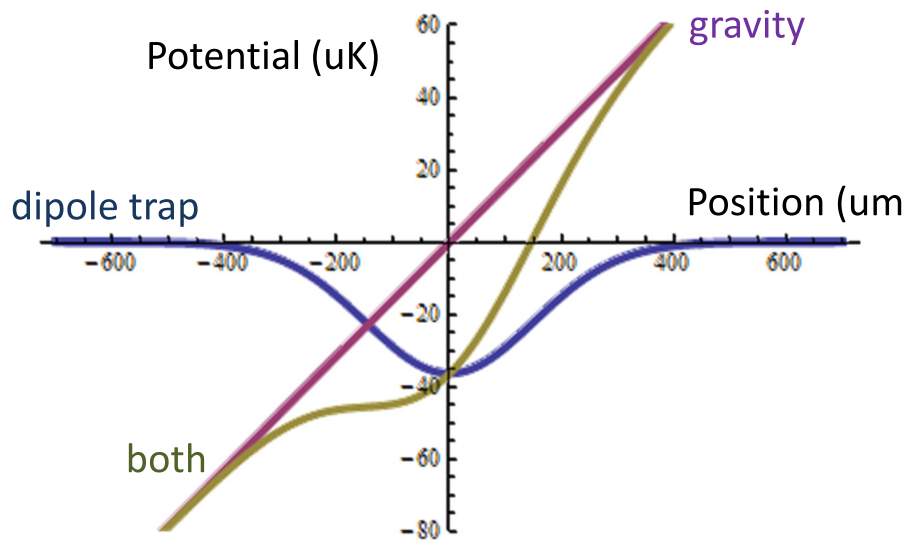
(Dipole potential)

- Fiber laser wavelength @1070nm
  Levitate atoms with magnetic gradient
- Power 200W, waist 800um



5x10⁷ atoms in crossed dipole trap





Transfer to smaller dimple trap

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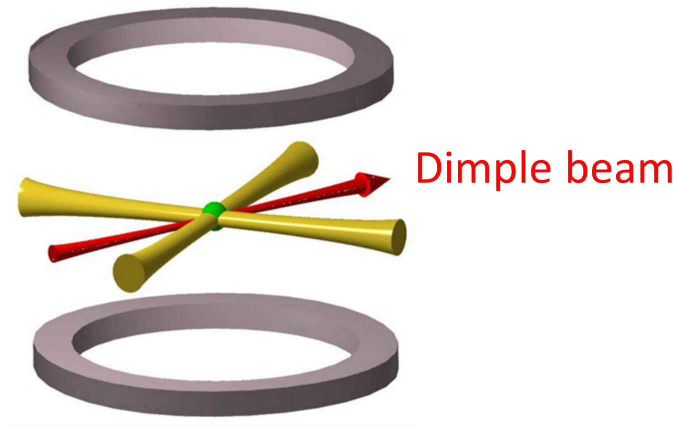
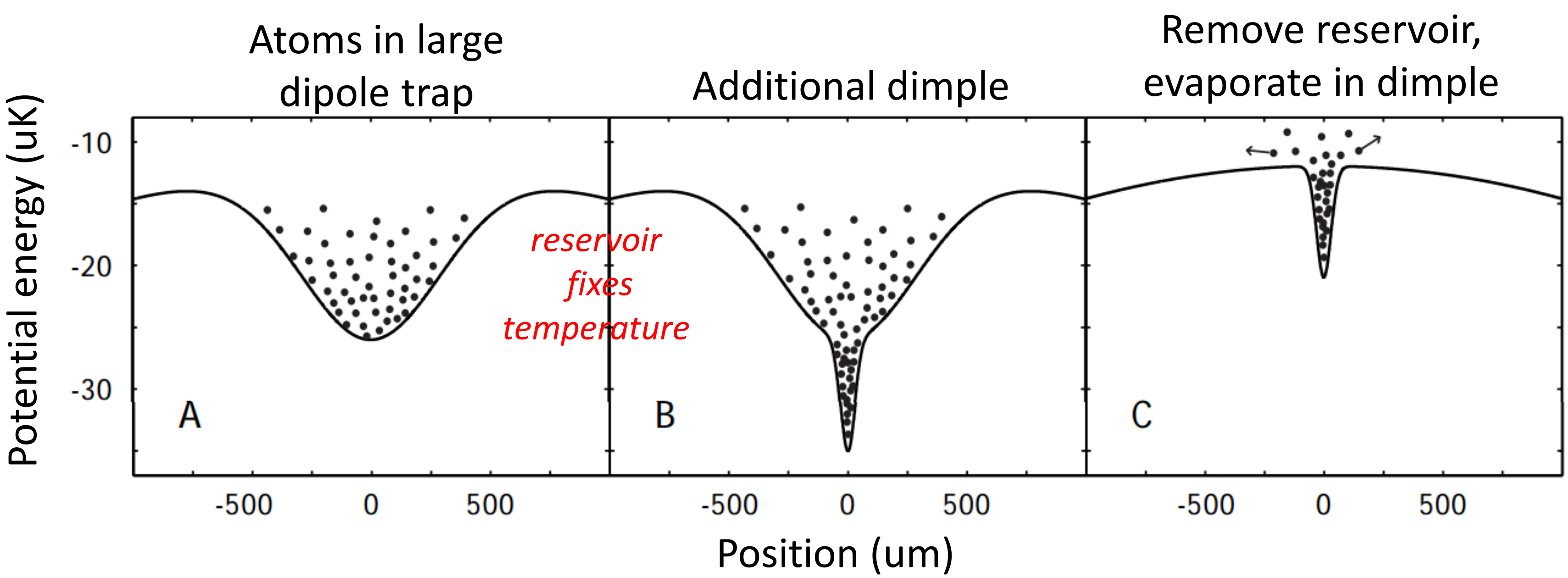
Goal: Evaporation in smaller laser beam (“dimple”) to BEC

Smaller beam waist :

- larger trap frequencies
- faster evaporation



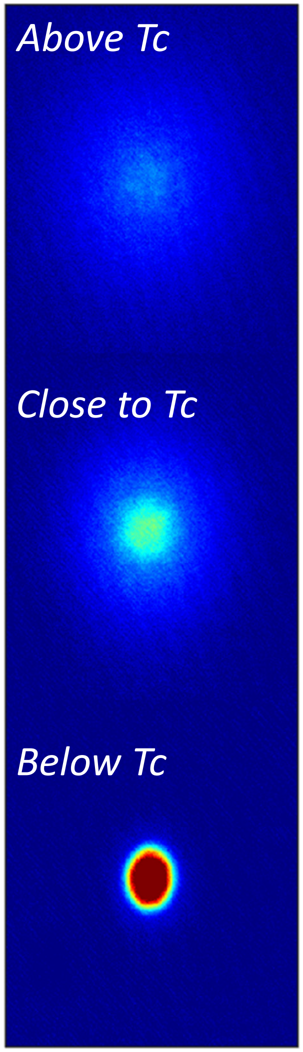


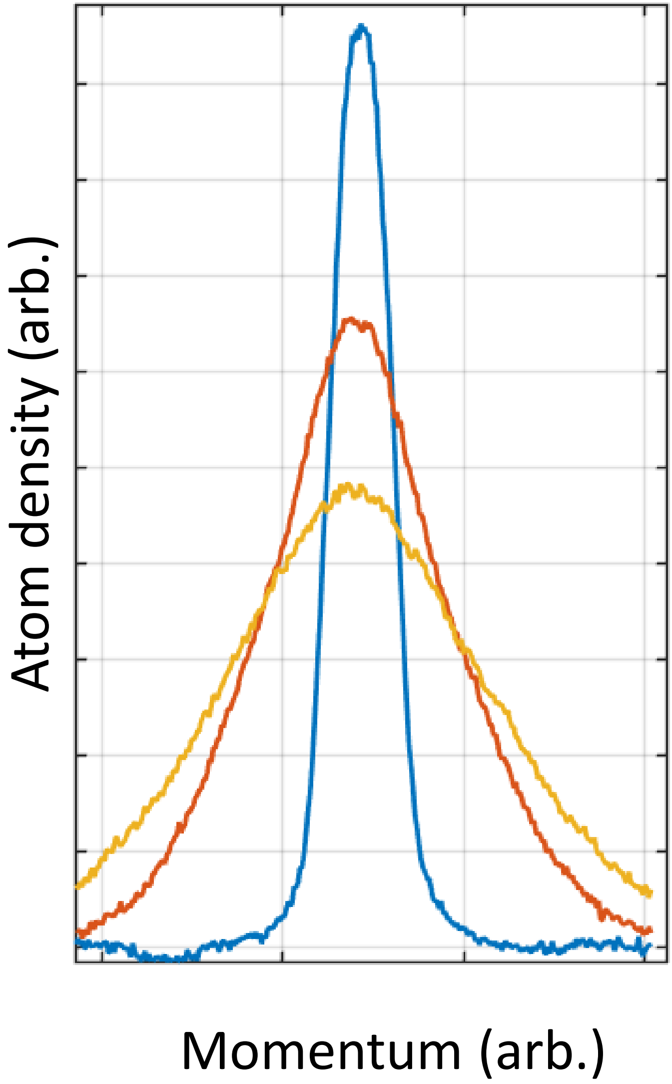
Evaporation to quantum degeneracy

Absorption images after evaporative cooling (momentum distribution)

(approaching the transition temperature Tc approx. 50nK)

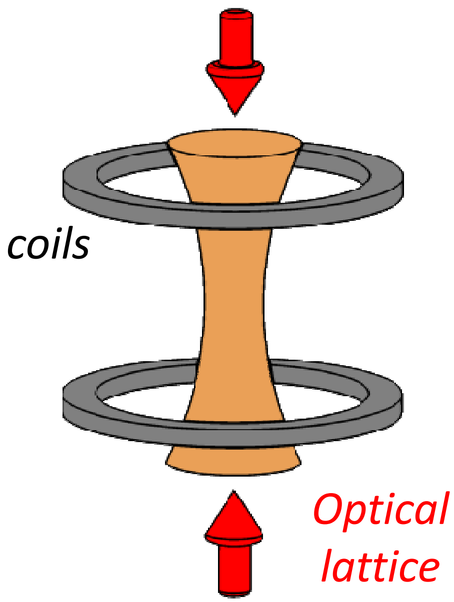
BEC of 1.5 x 10^5 atoms



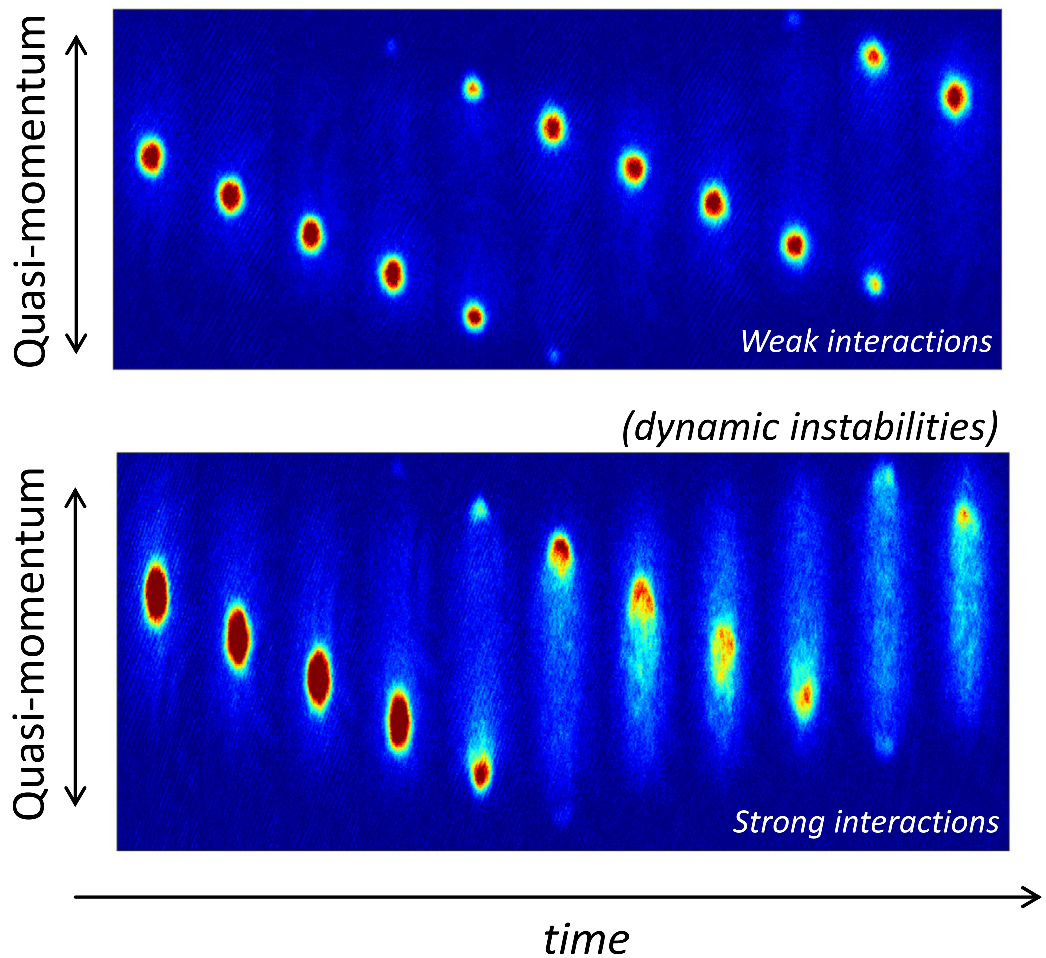


Curent construction work

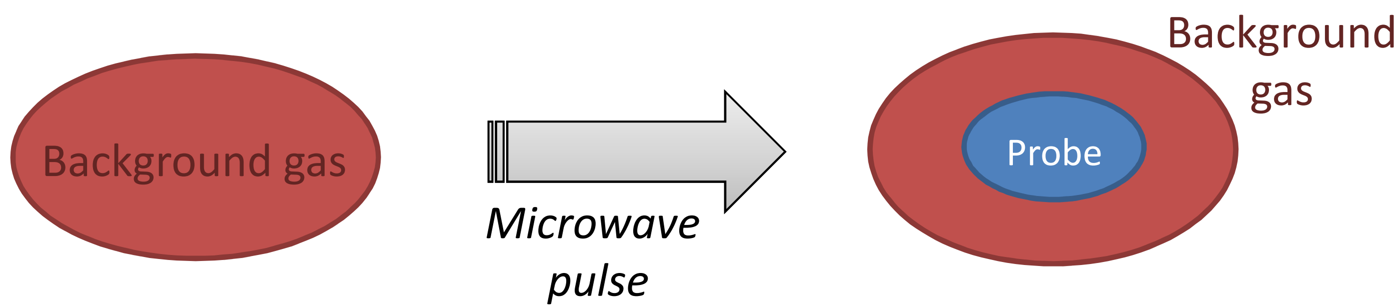
We added an optical lattice

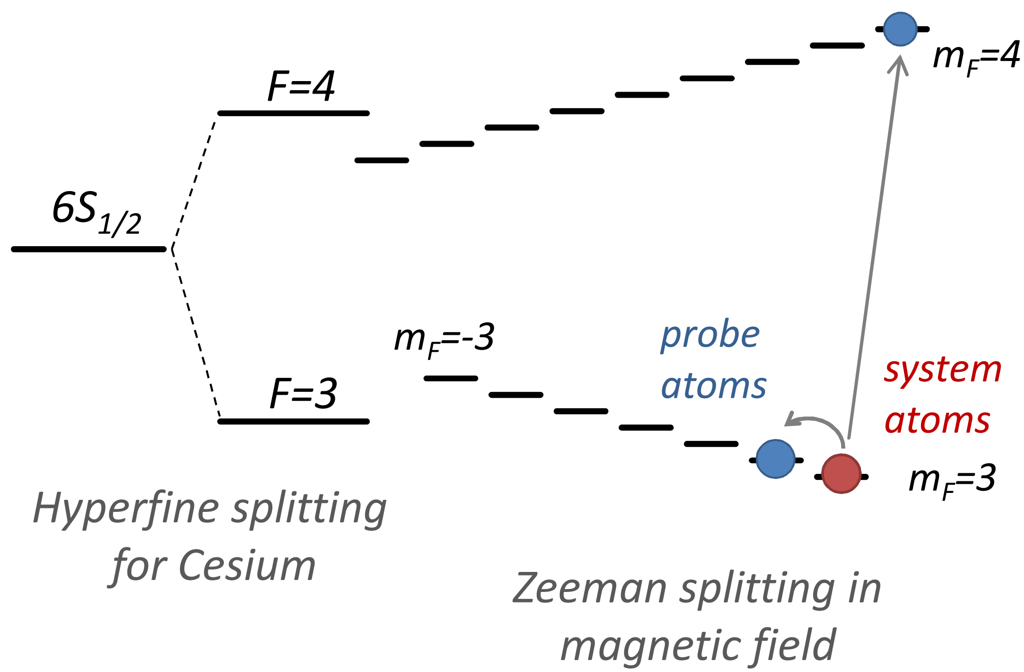


Bloch-oscillating atoms



Generation of the quantum probes





Questions about the creation of the probes:

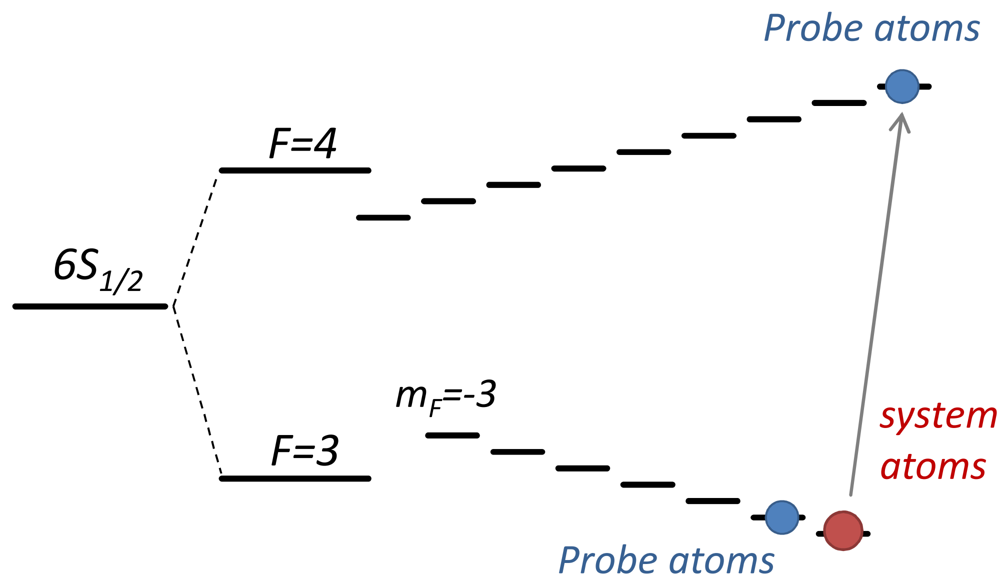
- Effect on the background gas?
- Evolution of the probe atoms?

Summary and outlook

- Creation of the state F=4, mF=4 excited the background gas strongly.

- The state F=3, mF=2 is a better choice for probe atoms.
  (better control of interactions with Feshbach resonances)

- Add optical lattices with longer observation times



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