A12 Controlled immersion of single neutral atomic impurities into a quantum gas of another species

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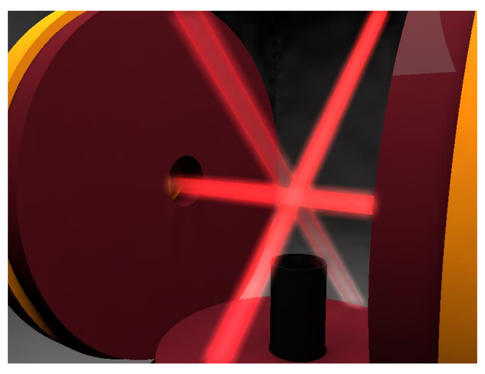
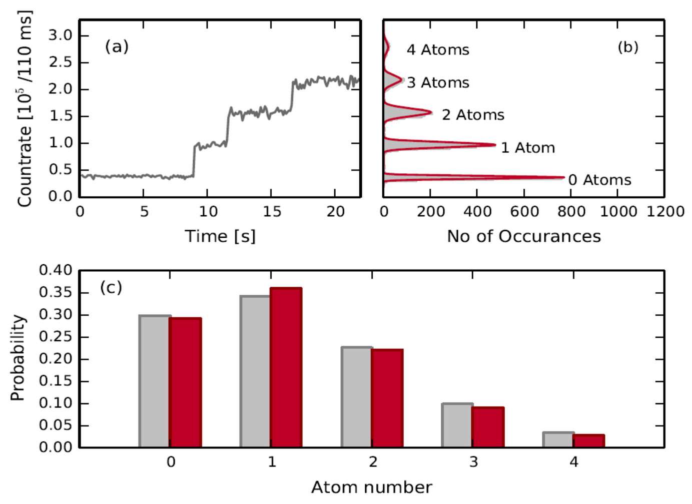
Single Atom MOT



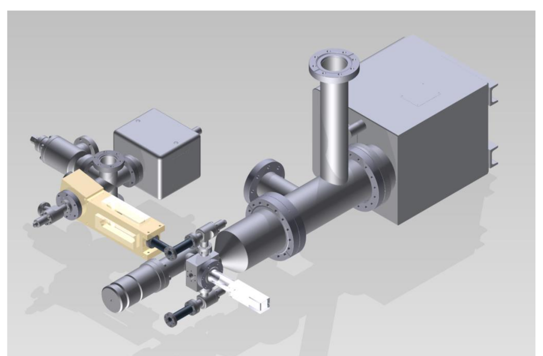
- 0-10 atoms are captured in the MOT following a Poissonian distribution
- Single atom MOT features small beam size, low power beams, and high magnetic field gradient [1]



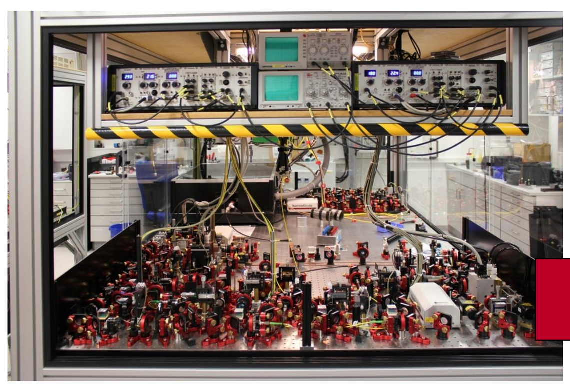
Imaging

- High NA Objective (0.36)
- Andor iXon 897 EMCCD Camera with 60% quantum efficiency
- Post processing of data[2]

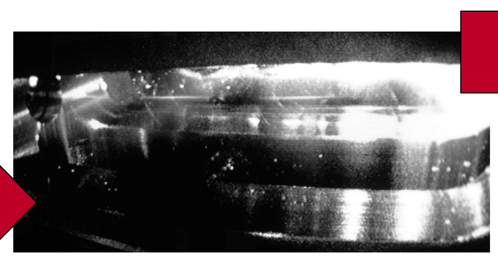
Preparation of the BEC

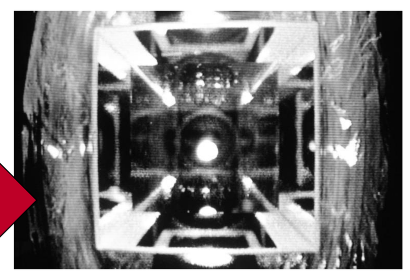


- Vacuum system with two regions
- 2D MOT with RB reservoir @ 3x10^{-7} mbar
- Glass Cell for 3D MOT and BEC @ 1x10^{-10} mbar



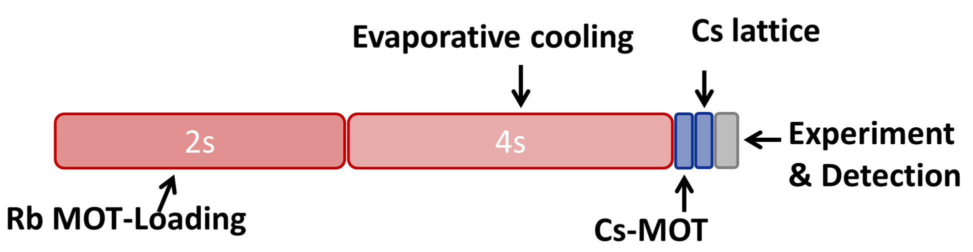
2D MOT





3D MOT

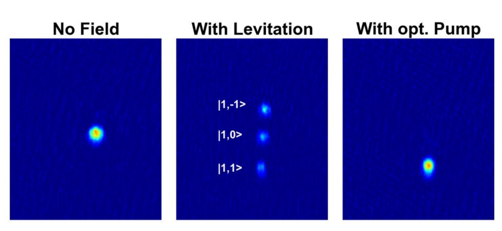
Laser Table



- Atomic flux of 10^9 atoms/s
- experimental cycle of about 6s

Dipole Trap Parameters

- total power of 16W @1064 nm giving a trap depth of 1mK
- one beam with 12W and waist of 150 µm
- second beam with 4W power and waist 21µm

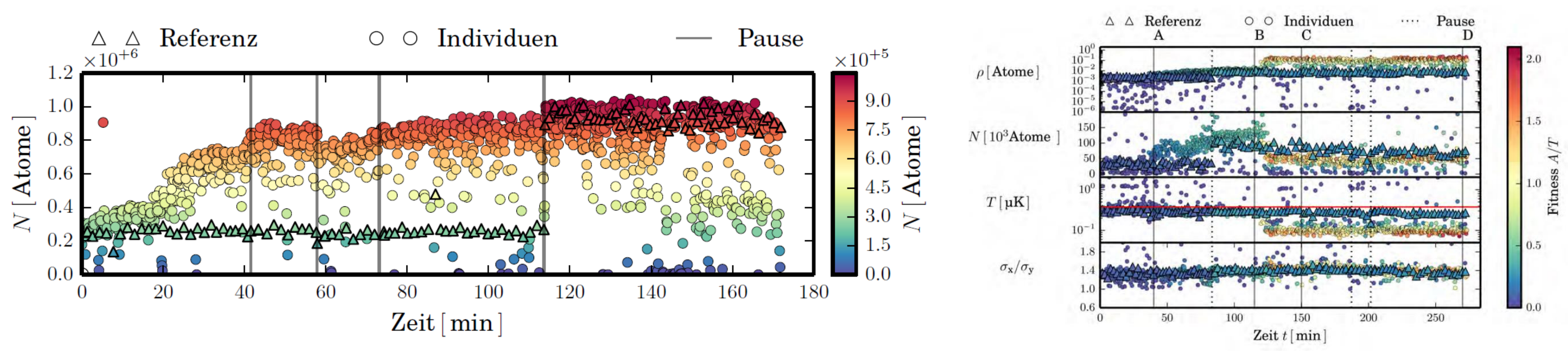


State Preparation

- Control of the internal degree of freedom via optical pumping and RF/MW-Spectroscopy

Evolutionary Algorithm [4]

- Experiment is optimized by computer algorithm, for given parameters and 'Fitness'
- Usable for almost every experimental parameter which is controllable by the timing system
- Converges faster than optimization by hand

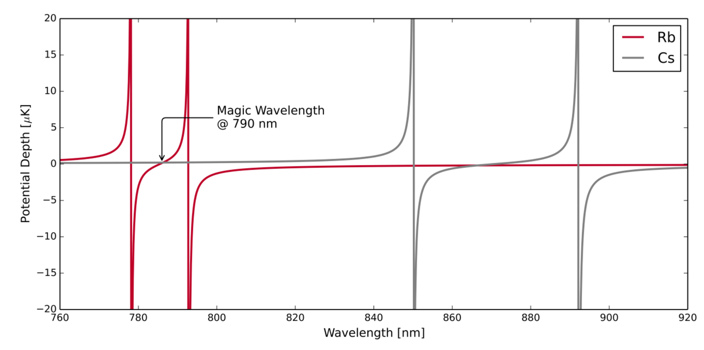


Reliable statistics on single atom measurements possible

References

1. D. Haubrich, et al. ,Europhys. Lett. 34, (1994)
2. M. Karski et al.,Phys. Rev. Lett. 102, 053001 (2009)
3. S. Kuhr, et al., Science 293, 278 (2001)
4. I. Geisel, et al.,Appl. Phys. Lett. 102, (2013)
5. S. Marksteiner, et al., Phys. Rev. A, 53 (1995)

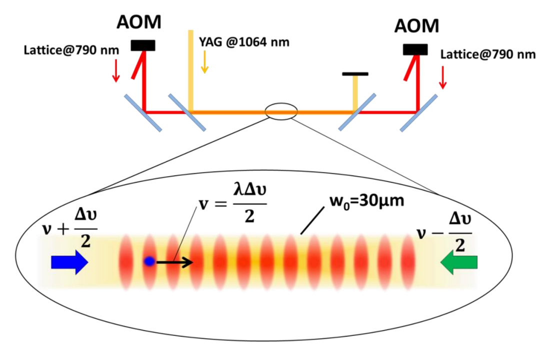
Species Selective Lattice

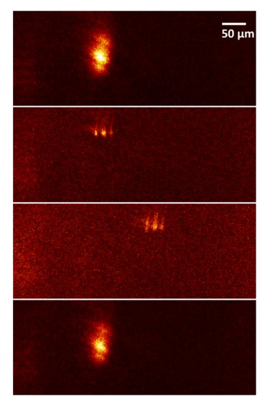


- A 1D optical lattice formed of 2 counter propagating beams
- Lattice should not be seen by BEC: wavelength between Rb D-Lines

A moving lattice[3]

- self build AOM driver electronics allows precise frequency control
- lattice beam one with frequency v=Δv/2 and lattice beam two with frequency v=-Δv/2
- a moving lattice potential is created

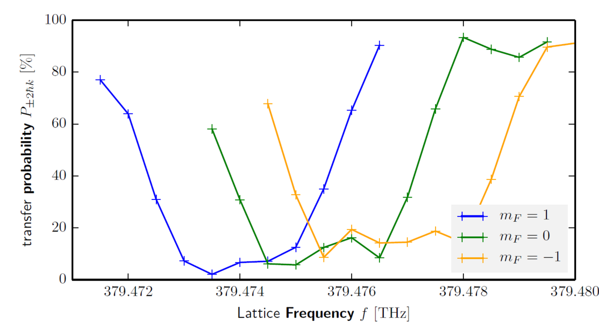


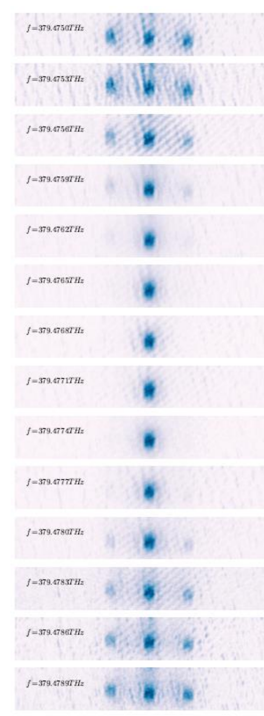


Full control over the atomic position

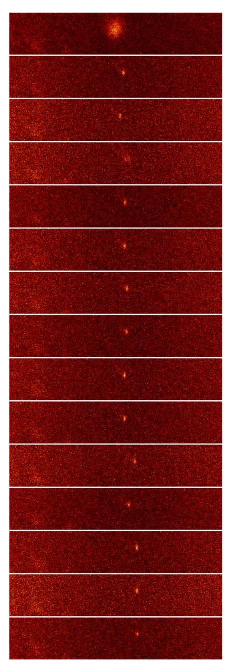
Measuring the selectivity

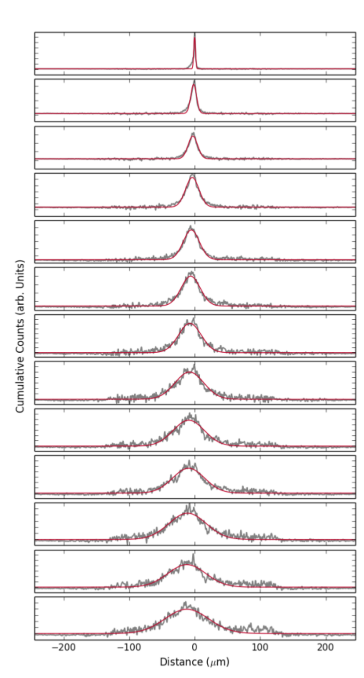
- Kapitza-Dirac scattering for short lattice pulses
- At the "magic" frequency no scattering into higher bands as no potential is present
- For $U_{Cs} \approx 4000\ E_r^{Cs}$ the potential for Rb is only $U_{Rb} \lesssim 4\ E_r^{Rb}$
- ⇒ **Selectivity of 10³**
- State dependence to be resolved

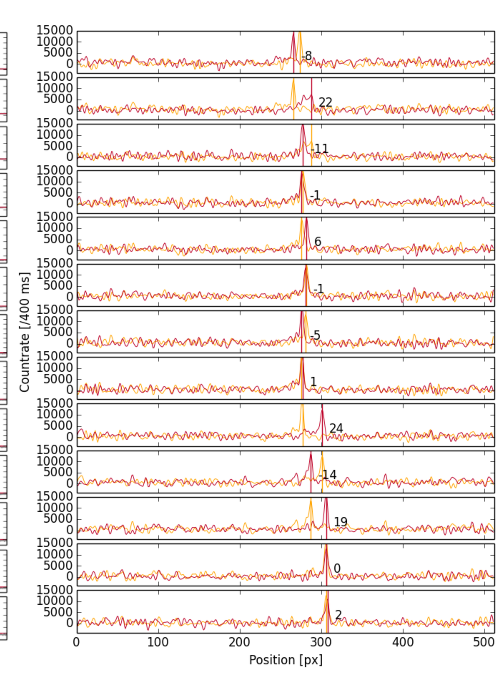




Dynamics of driven single atoms





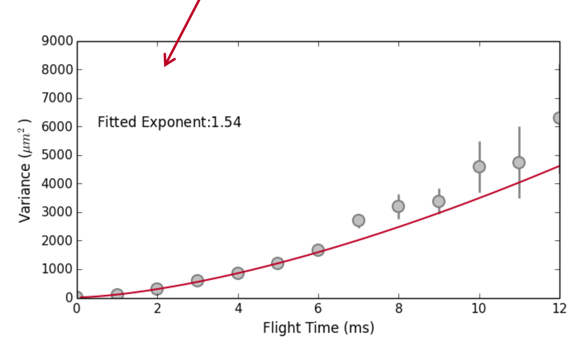


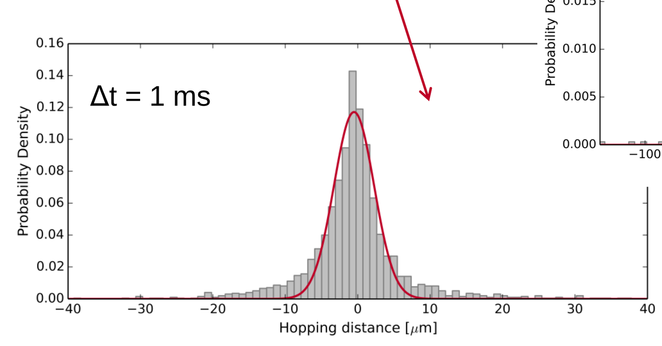
Experiment

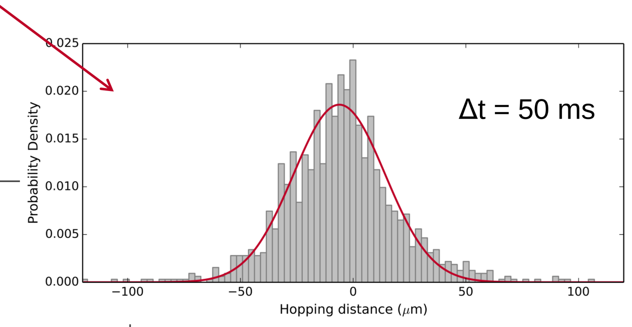
- Load atoms from MOT in Lattice
- adiabatically ramp down the lattice and switch on Molasse for flight time Δt
- ramp up lattice and take an image
- start over with the same atom

Atom distribution for every step

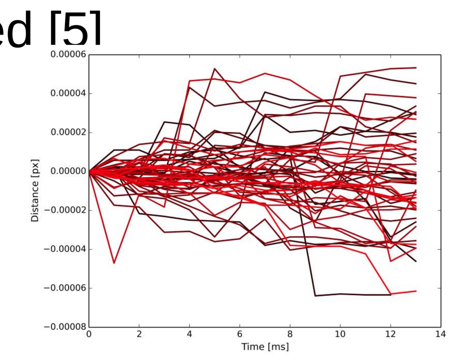
Single Step distance

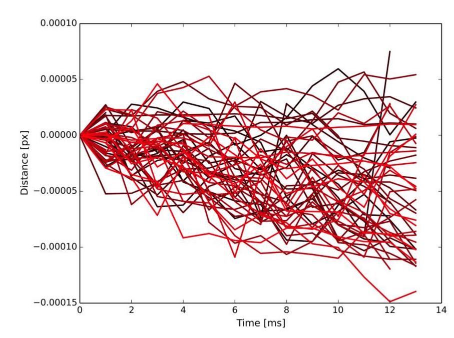






- Images binned vertically and added up for every single step reveals the single shot atom distribution
- Width of distribution grows faster with time than expected from diffusion
- This is supported by overall flight length distribution, which is not the expected Gaussian
- For long times the single step distance distribution converges to a Gaussian as theoretically predicted [5]
- the traces look different for non-gaussian and gaussian diffusion





Starting point to study impurity dynamics in a bath

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