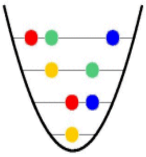
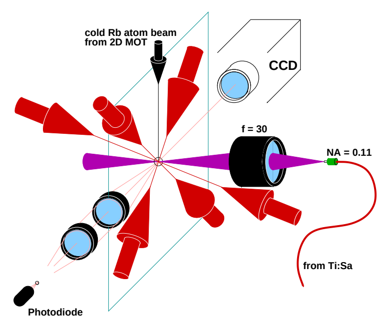
A strongly confining dipole trap for Rubidium atoms



Matthias Schulz, Herbert Crepaz, Michael Chwalla, Jürgen Eschner and Rainer Blatt
Institut für Experimentalphysik, Univ. Innsbruck, Technikerstr. 25, A−6020 Innsbruck, Austria
http://heart−c704.uibk.ac.at

Experimental Setup



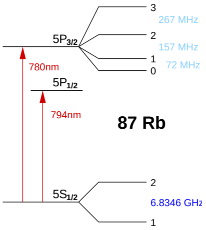
Trap Parameters

λ_{D1}	= 795 nm	trap depth	= 30 MHz
λ_{D2}	= 780 nm		= 1.4 mK
λ_{trap}	= 810 nm	scattering rate	= 20 /s
w_0	= 15 µm	trap frequency (r)	= 8 kHz
P	= 400 mW	trap frequency (z)	= 100 Hz

Doppler cooling limit : 1,46 MHz (144 µK)
recoil limit : 3,75 kHz (370 nK)

Abstract

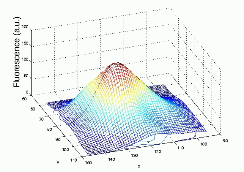
Rubidium atoms are accumulated in a conventional MOT and transferred into a dipole trap produced by a 1W Ti:Sapphire laser which is tuned to 810nm and focused to a waist of about 15 µm. We achieve trapping frequencies above the recoil frequency, such that the Lamb−Dicke regime of cooling can be reached, and we observe trap lifetimes of several seconds. We report about the experimental setup and the characterisation of the trap. Measurements of the trap loss show a strong wavelength−dependent quadratic contribution due to inelastic collisions, including photoassociation. Measured trap frequencies agree with the expectation.
We also present the first steps towards a blue−detuned trap consisting of two crossed hollow laser beams.



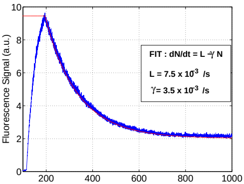
This work is supported by the FWF (Austrian Science Fund, SFB 15) and the European Commission (QBITS, IST−1999−13021)

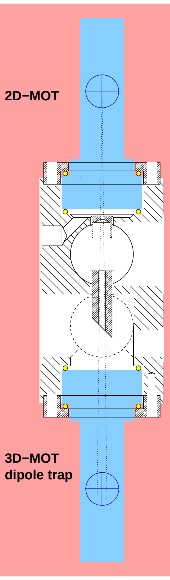
Double MOT system

CCD−image of 3D−MOT

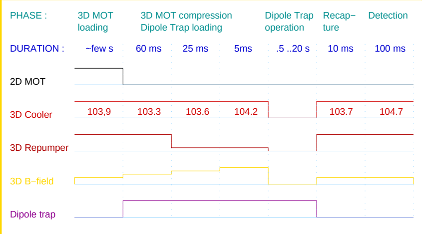


Typical loading and loss





Loading Process and Detection



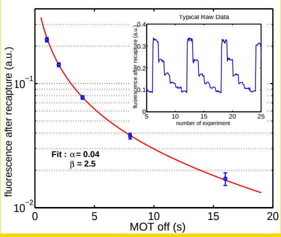
Loading Process:

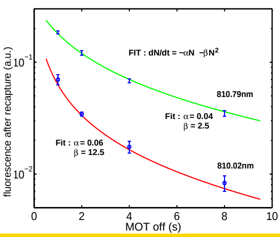
Few seconds of 2D−MOT operation yields approx. 10^6 Atoms in 3D−MOT.
While the dipole laser is on,
the atom sample is compressed by increasing the magnetic field gradient and tuning the cooling laser close to the atomic resonance.
The MOT is switched off.
Transfer efficiency to dipole trap: 20%

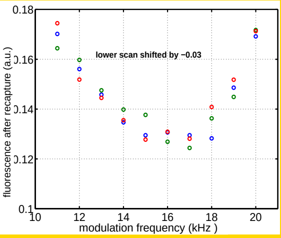
Detection:

The atoms are released from the dipole trap and recaptured by the MOT.
During fluorescence detection, the cooling laser is tuned close to resonance, such that loading from background vapor equals losses due to heating.
Detector Signal : 1 V / 10^6 Atoms
(estimated)

Dipole trap measurements







LIFETIME and LOSS

Dipole trap operation of 0.2 to >20s gives reliable values for the atom number in the trap.
We fit the experimental data assuming linear loss (due to background gas collisions) and quadratic losses (inelastic collisions of trapped atoms):

$$\frac{dN}{dt} = -\alpha N - \beta N^2$$

Result : Since linear losses are rather low, quadratic processes dominate for times up to 15s !

PHOTOASSOCIATION

The quadratic loss depends strongly on the detuning of the trap laser. Results are shown for trapping light wavelengths of 810.02 nm and 810.79 nm, where the quadratic loss coefficient varies by a factor of five.

Photoassociation loss spectra for ^{85}Rb are given in :
J. D. Miller, R.A. Cline and D.J. Heinzen, PRL 71, 2204 (1993)

TRAP FREQUENCIES

The focused dipole trap beam has a waist of approx. 15µm and a focus depth (Rayleigh range) of >800 µm. Therefore, the radial trap frequencies are two orders of magnitude higher than the axial trap frequency, which leads to a broad range of radial frequencies as a function of position along the beam axis.

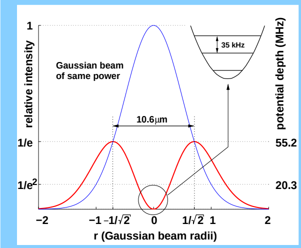
trap frequencies: $\omega_r = \sqrt{4U / m\, \omega_0^2}$; $\omega_z = \sqrt{2U / m\, z_R^2}$

R. Grimm and M. Weidemüller in Adv. At. Mol. Opt. Phys. 42, 95 (2000)

The measurement uses parametric excitation at 2 ω_r which leads to increased trap loss.

OUTLOOK: Blue detuned Trap

Intensity profile of TEM01*−mode



Trap Parameters

λ_{atom}	= 780 nm	trap depth (y,z)	= 55 MHz (2.7 mK)
λ_{trap}	= 733 nm	trap depth (x)	= 78 MHz (3.8 mK)
Δ	= 47 nm	trap frequency (y,z)	= 35 MHz
w_0	= 7.5 µm	trap frequency (x)	= 50 MHz
P	= 0.75 W	Lamb−Dicke Param.	= 0.33

ground state :	extension	40 nm
	scattering rate	0.02 /s

Doppler cooling limit : 1.46 MHz (144 µK)
recoil limit : 3.75 kHz (370 nK)

WHAT ?

trapping few atoms in the dark

trap depth > Doppler temperature

harmonic potential

Raman spectroscopy

resolved Raman sideband cooling

cooling to 3D ground state of trap

HOW ?

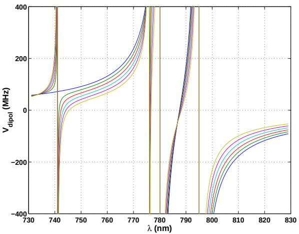
generate trap by two crossed blue detuned doughnut modes

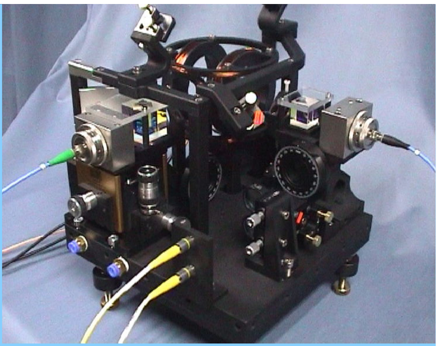
loading of the dipole trap with precooled atoms from a 3D MOT

Raman sideband cooling with phaselocked diode lasers

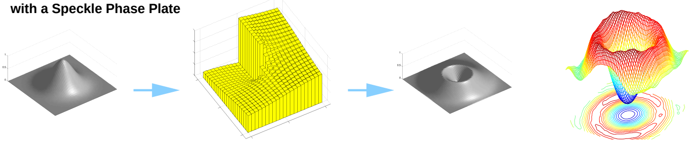
Trap Potential vs. Wavelength

for different population of excited state





Generating a Hollow Beam with a Speckle Phase Plate



Matthias Cumme, Institut für angewandte Physik, Universität Jena