Towards Bose-Fermi Mixtures on a Chip

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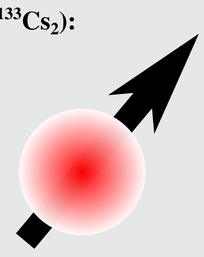
Motivation

Creation of multi species mixtures:
- Degenerate fermi gas (^{6}Li), together with a BEC (^{133}Cs)
- Reflect 2D dipole trap from atom chip [1] for good Cs/Li overlap
- Study fermions in low dimensions
- Impurities in quamtum liquids

Homonuclear, weakly bound molecules ($^6Li_2$, $^{133}Cs_2$):
- Study superfluidity in low dimensions
- BCS/BEC crossover
- Spatially dependent scattering length

Heteronuclear molecules (LiCs):
- Fermionic molecules
- Trap molecules on an atom chip



MUARC

Midlands Ultracold Atom Research Centre
http://mpa.ac.uk/muarc/

The University of Nottingham

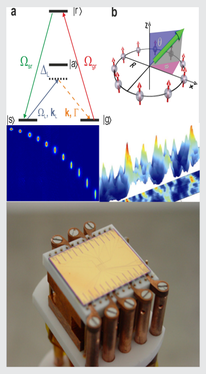
UNIVERSITY OF BIRMINGHAM

MIDLANDS PHYSICS ALLIANCE GraduateSchool

Mobile gravitational sensor

iSENSE Integrated Quantum Sensors

Opportunities



Join us:
- (Paid) Interns/summer projects
- Diploma/Master projects
- PhD projects
- Postdocs

Research interests:
- Ultracold gases in micro-engineered environments (atom chips)
- Quantum interfaces (atom-solid,atom-photon)
- Theory: Quantum simulation

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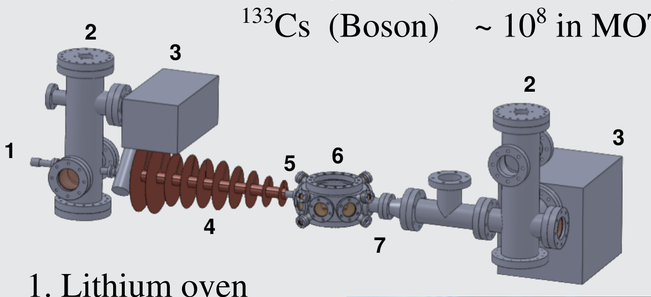
- Peter.Kruger@nottingham.ac.uk (experiment)
- Igor.Lesanovsky@nottingham.ac.uk (theory)

http://bit.ly/id0ZkM

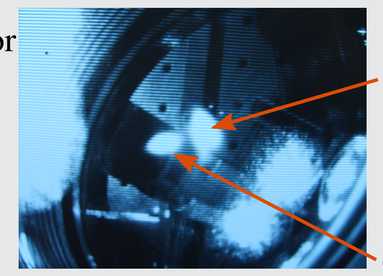
Experimental Setup

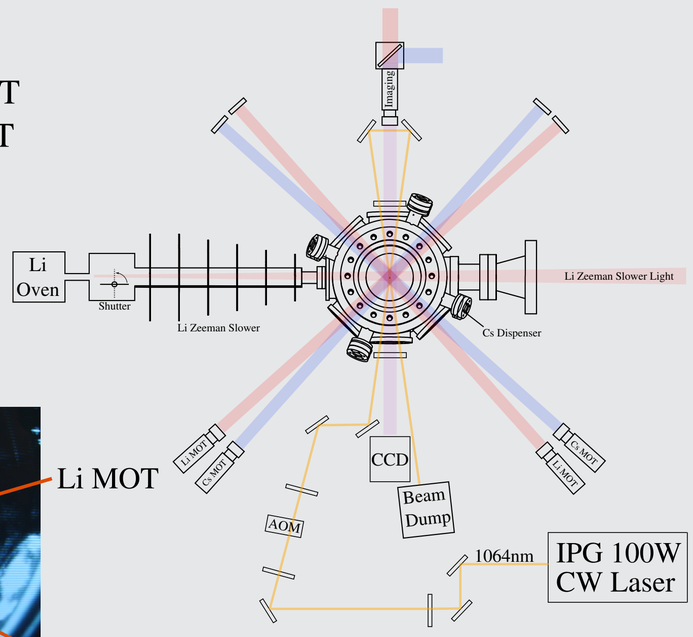
Species

^{6}Li (Fermion) ~ 10^9 in MOT
^{133}Cs (Boson) ~ 10^8 in MOT



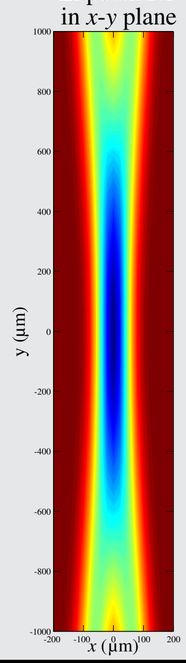
1. Lithium oven
2. Titanium sublimator
3. Ion pumps
4. Li Zeeman slower
5. RF Coil
6. Main Chamber
7. Cs Dispensers



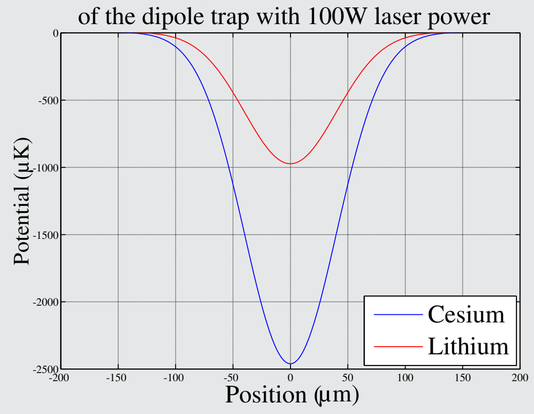


Dipole Trap

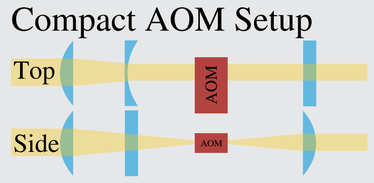
Li potential in *x*-*y* plane



Potential along the *x* axis, through the centre of the dipole trap with 100W laser power

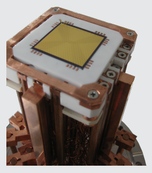


Compact AOM Setup



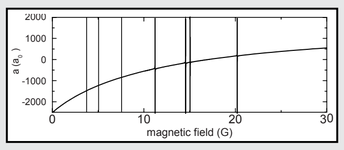
Beam Dump

Proximity Effects

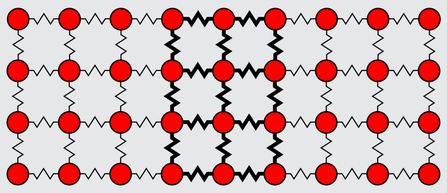


Local Fields

+



Interacion Tunning[2]



Spatially Varying Interaction Landscapes

Thomas-Fermi approximation:

$$\mu = V + ng \qquad \left(g = \frac{4\pi\hbar^2}{m}a_s\right)$$

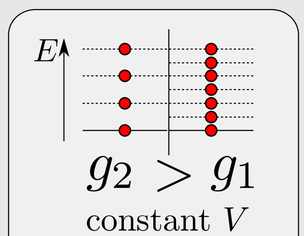
chemical potential — trapping potential — density — coupling constant

Automatic compensation condition:

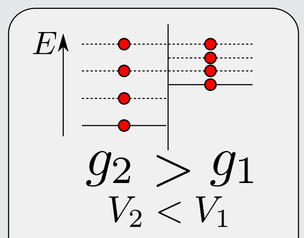
$$-\frac{\partial V}{\partial B} = n\frac{\partial g}{\partial B}$$

Example:

At n~10^{13} cm^{-3} and B~50G this condition is fulfilled in a narrow Feshbach resonance.

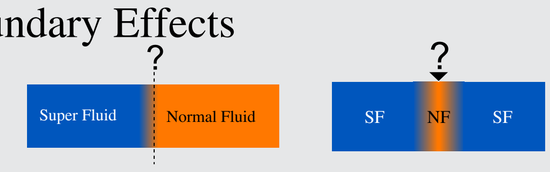


Atoms preferably sit in low g region so $n_2 < n_1$.



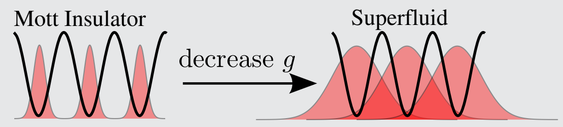
Atoms distribute evenly (constant n).

Boundary Effects

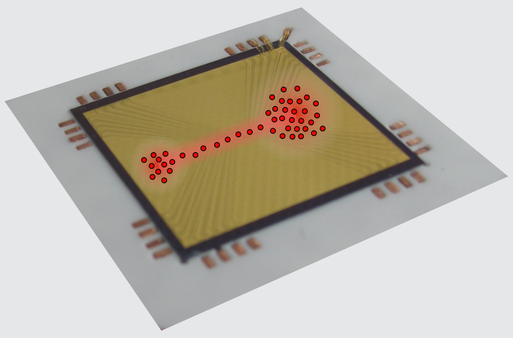


-Classical Phase Transition
(Berezinskii-Kosterlitz-Thouless Transition[3])

-Quantum Phase Transition
(Mott Insulator → Superfluid)

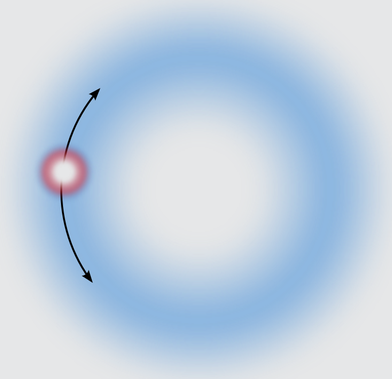


Outlook



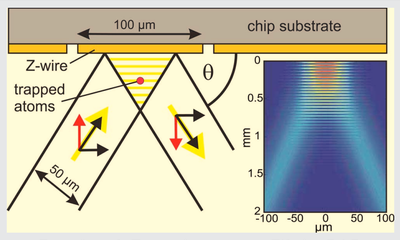
Atomic transport trhough narrow constriction

Flow of fermions is quantised whereas with non-interacting bosons is not quantised. Interacting bosons may show quantisation.

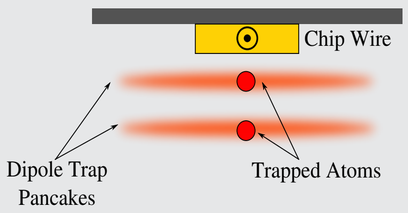


Mobile Impurity

Changing the internal state of a few particles one can create a mobile impurity which is, in turn, affect and probe the state of a quantum liquid[4].



Optical Lattice on Chip[1].



1D Trap for High-Field-Seeking states:

Reflected from chip surface optical pancake stack traps atoms in 2D pancake-shaped traps. Applying a magnetic field from the chip wires further traps atoms in 1D trap.

References

[1] Gallego, D., Hofferberth, S., Schumm, T., Krüger, P. & Schmiedmayer, J. Optical lattice on an atom chip. Optics Letters 34, 3463 (2009).

[2] Chin, C. et al. Precision Feshbach spectroscopy of ultracold Cs_2. Physical Review A 70, 1-13 (2004).

[3] Hadzibabic, Z., Krüger, P., Cheneau, M., Battelier, B. & Dalibard, J. Berezinskii-Kosterlitz-Thouless crossover in a trapped atomic gas. Nature 441, 1118-21 (2006).

[4] Gangardt, D. & Kamenev, A. Bloch Oscillations in a One-Dimensional Spinor Gas. Physical Review Letters 102, 1-4 (2009).