Lithium and Cesium Mixtures in Low Dimensions

MUARC

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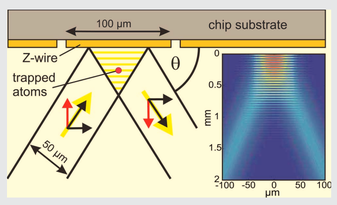
Motivation

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/bosons in low dimensions

Interspecies Interactions:
- Feshbach Resonances
- Heteronuclear Efimov states
- Fermionic molecules

Low Dimensional systems:
- Mixed Dimensions
- Impurities in a quantum liquid
- Study superfluidity in low dimensions
- BCS/BEC crossover



[1] Opt. Lett. 34, 3463-3465 (2009)

MUARC

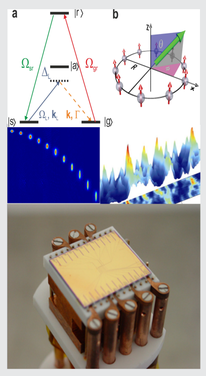
Midlands Ultracold Atom Research Centre
http://mpa.ac.uk/muarc/

The University of Nottingham
UNIVERSITY OF BIRMINGHAM
MIDLANDS PHYSICS ALLIANCE Graduate School

Mobile gravitational sensor

iSENSE Integrated Quantum Sensors

Opportunities



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

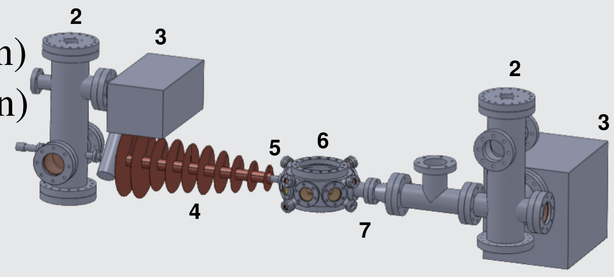
Research interests:
- Ultracold gases in micro-engineered environments (atom chips)
- Quantum interfaces (atom-solid,atom-photon)
- Theory: Quantum simulation

For further information contact:
- Peter.Kruger@nottingham.ac.uk (experiment)
- Igor.Lesanovsky@nottingham.ac.uk (theory)

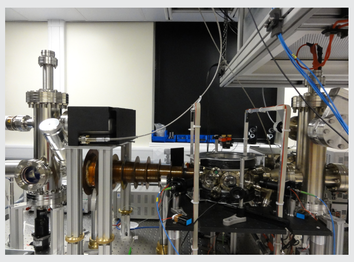
http://bit.ly/id0ZkM

Experimental Setup

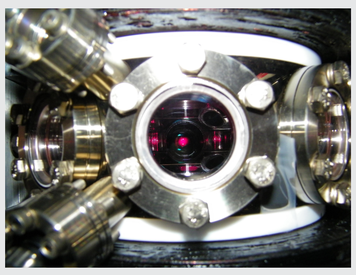
Species
^{6}Li (fermion)
^{133}Cs (boson)

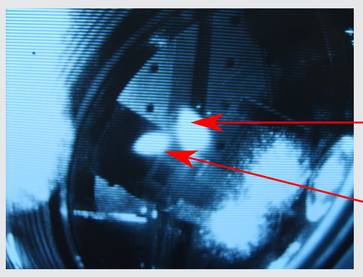


1. Lithium oven
2. Titanium sublimator
3. Ion pump
4. Zeeman slower
5. RF Coil
6. Main Chamber
7. Cesium Dispensers



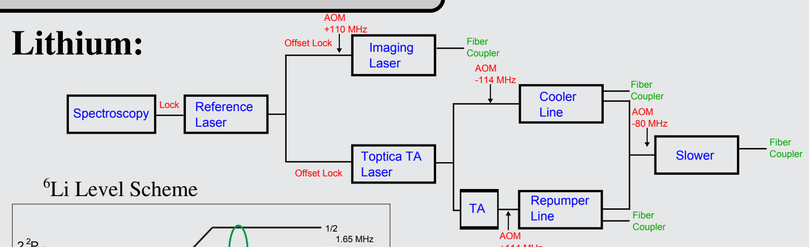
Experimental Parameters:
Lithium Oven : 400- 450 °C
Cesium Dispensers: 4.6 A
Experimental Chamber Pressure: 2 x 10^{-11} mbar
MOT Coils Gradient : **^{6}Li**: 16 G/cm; **^{133}Cs:** 3.5 G/cm
Double MOT: 4 G/cm
MOT Beams: **^{6}Li**: 40 mW/beam; **^{133}Cs**: 80 mW/ beam
Slower Beam (^{6}Li): 30 mW

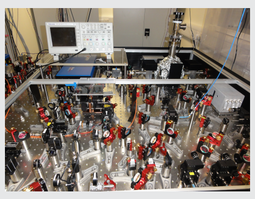




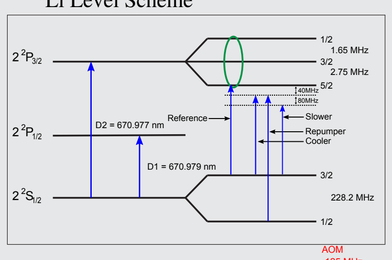
Optics

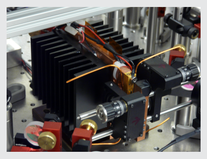
Lithium:

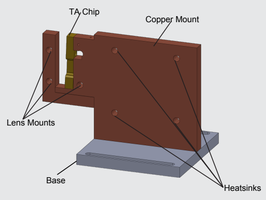




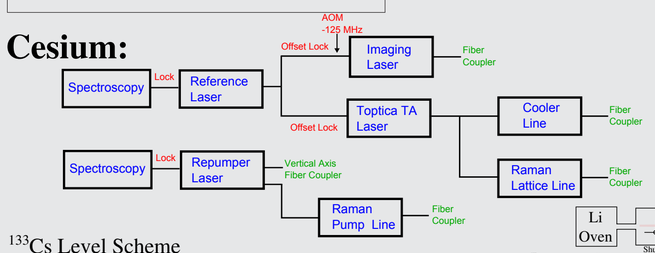
^{6}Li Level Scheme



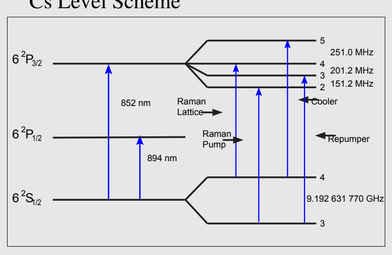


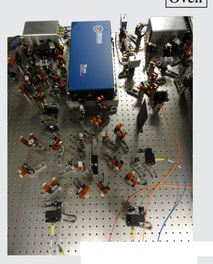


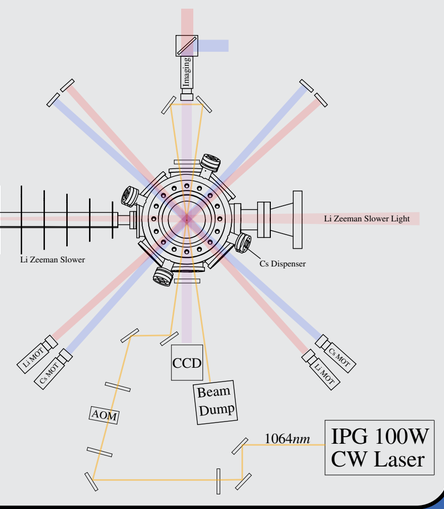
Cesium:



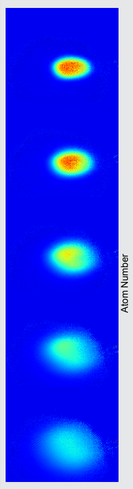
^{133}Cs Level Scheme





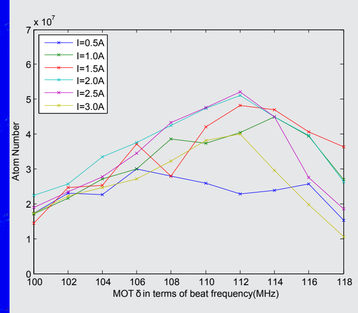


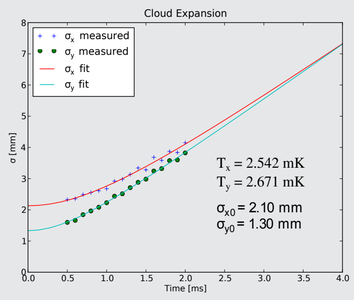
MOT Measurements



Cesium :
Atom number: 10^8
Lifetime: unknown

Lithium :
Atom number: 10^9
Lifetime: 35 s

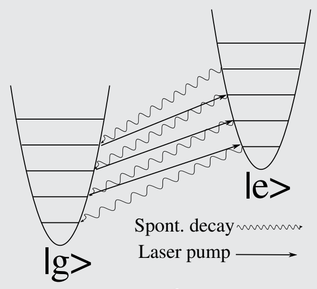




Next Steps

Raman Sideband Cooling of Cs:

The preecooled-by-MOT sample is loaded into an optical lattice in which the vibrational quantum number of the ^{133}Cs atoms is decreased via Raman sideband cooling

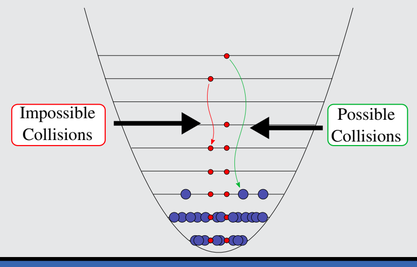


Raman cooling of ^{6}Li?

Sympathetic Cooling:

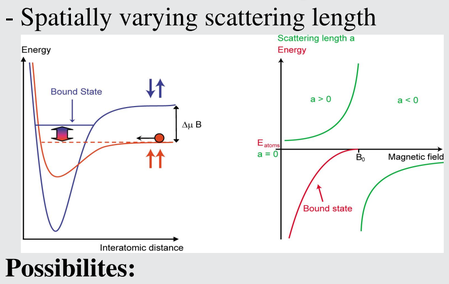
Lower temperature of ^{6}Li by overlapping it with ^{133}Cs in a far detuned optical dipole trap

Constraint:
For a Bose Gas at $T < T_c$, $v_f > v_s$ to avoid the suppression of elastic Fermi-Bose collisions



Feshbach Resonances:

- Use magnetic fields to tune the interaction between atoms of different species
- Spatially varying scattering length



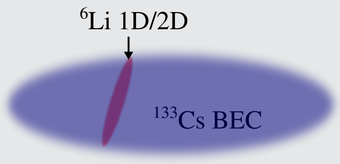
Possibilites:
- Creation of homonuclear or heteronuclear molecules in a Bose-Fermi mixture
- Experimentally observe ^{6}Li - ^{133}Cs resonances (predicited value ~ 750 G)

Low Dimensional Systems

Criterion:

$$k_B T, \mu \ll \begin{cases} \hbar\omega_\perp^{1D} & \text{for } 1D \\ \hbar\omega_z^{2D} & \text{for } 2D \end{cases}$$

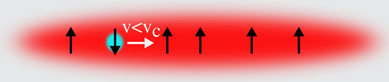
Mixed dimensions:

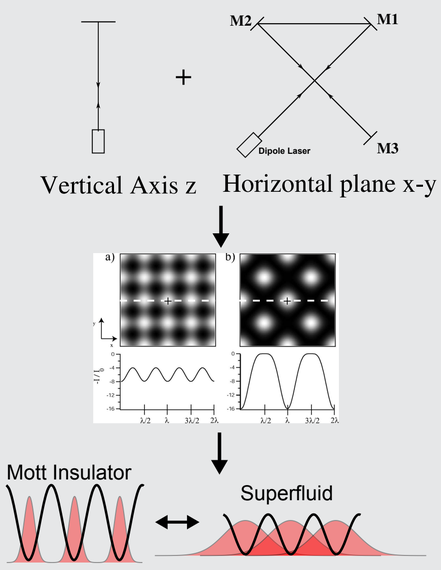


Unitary Fermi gas for certain mass ratios?

Impurities in a quantum liquid:

Impurity feels a viscous force from superfluid component at $v < v_c$
Friction Coefficient $\propto T^8$ in 3D
$\propto T^4$ in 1D
Mechanism : Raman scattering of phonon excitations





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[3] J. Sebby-Strabley, M. Anderlini, P. S. Jessen, J. V. Porto, "Lattice od doublewells for manipulating pairs of cold atoms", Phys. Rev. A 73, 033605 (2006)
[4] M. Köhl, H. Moritz, T. Stöferle, C. Schori and T. Esslinger, "Superfluid to Mott Insulator transition in one, two and three dimensions", Journal of Low Temperature Physics Volume 138, Numbers 3-4, 635-644
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[6]M. Schecter, D.M. Gangardt, A. Kamenev, "Dynamics and Bloch oscillations of mobile impurities in one-dimensional quantum liquids.", arXiv:1105.6136v1 [cond-mat.quant-gas]