Progress towards a Molecular BEC of Lithium Dimers

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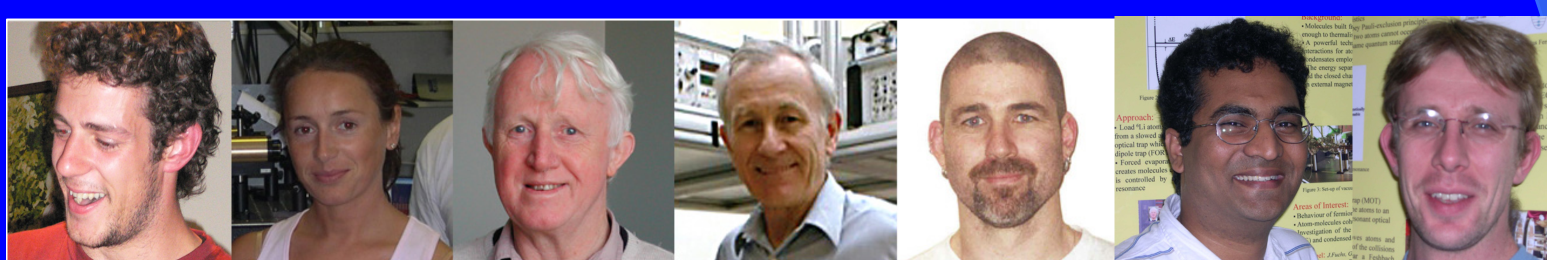


Quantum degenerate fermions

Lithium ^{6}Li:

Innsbruck (R. Grimm)
MIT (W. Ketterle)
Paris (C. Salomon)
Rice (R. G. Hulet)
Duke (J.E. Thomas)

Potassium ^{40}K:

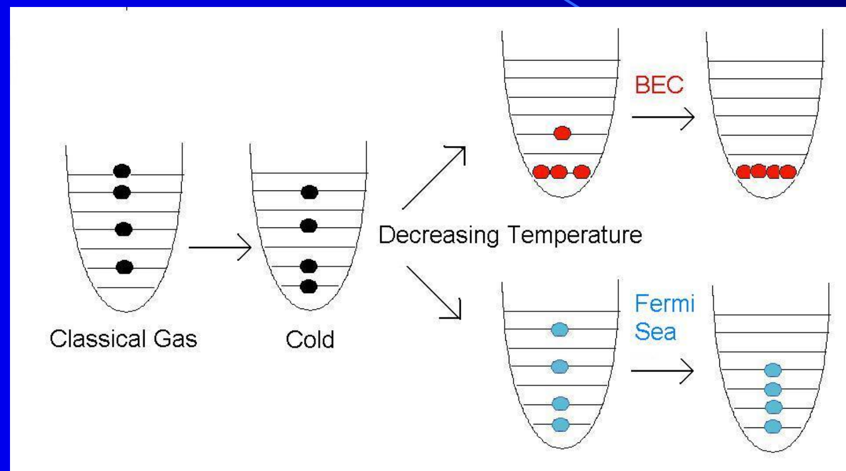
Boulder (D. Jin)
Florence (M. Inguscio)

Work in progress: Strontium, Ytterbium, Chromium

Aims

- To produce a BEC of composite bosons (molecules)
    - Load ^{6}Li atoms into the optical dipole trap
    - Evaporatively cool the atoms
    - Feshbach creation of molecules
- Work with theorists on understanding nature of dissociated atoms from MBEC and in general this complex system

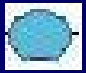
Bosons versus Fermions



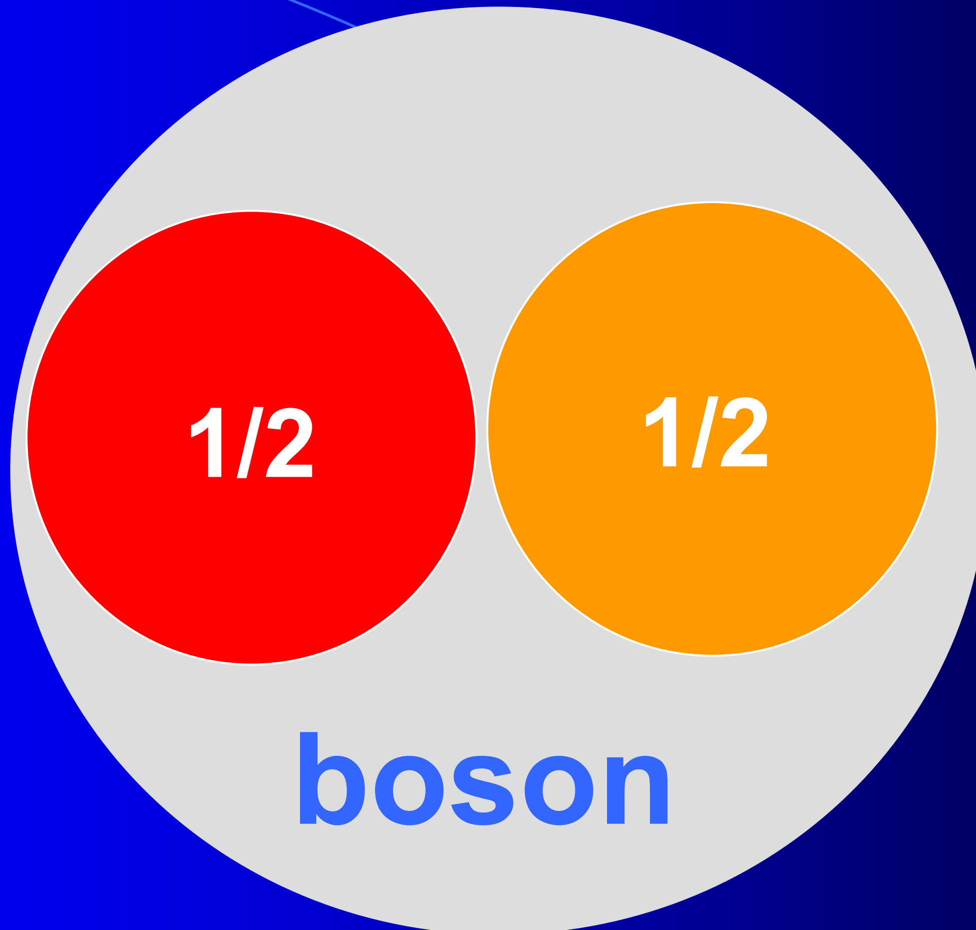
Bosons

- Integral spin 
- Conform to Bose-Einstein statistics
- Do not obey Pauli-exclusion Principle, i.e., bosons can collapse into the same quantum state

Fermions

- Half integral spin 
- Conform to Fermi-Dirac statistics
- Obey Pauli-exclusion principle, i.e., two atoms cannot occupy the same quantum state

fermion + fermion = boson

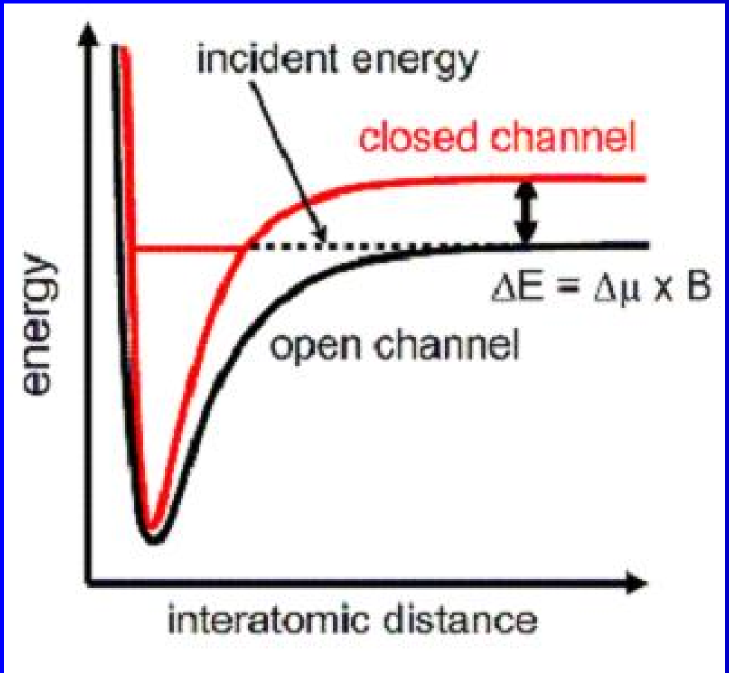


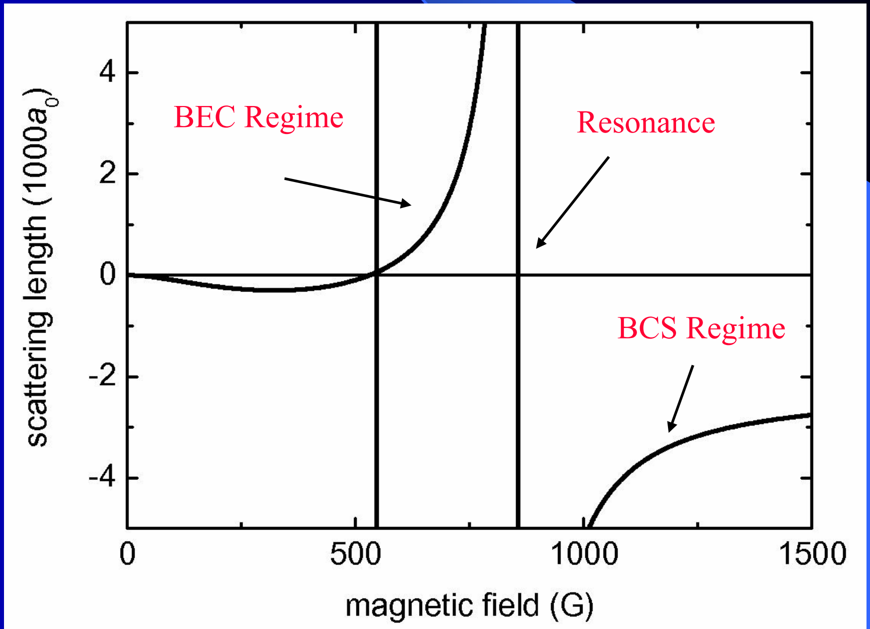
- Feshbach resonances are used to manipulate interactions in atomic gases
- Ability to resonantly control the scattering properties of the gas
- Fermion → composite boson gives long MBEC lifetimes (> 10 s)
- ^{40}K, bosonic Cs, Rb, Na, fermionic Li

(S. Jochim *et al Science*, ***volume 302***, *2101 2003*)

Feshbach Resonance

A Feshbach resonance occurs when a bound state for one spin combination has identical energy with the unbound state of another spin combination



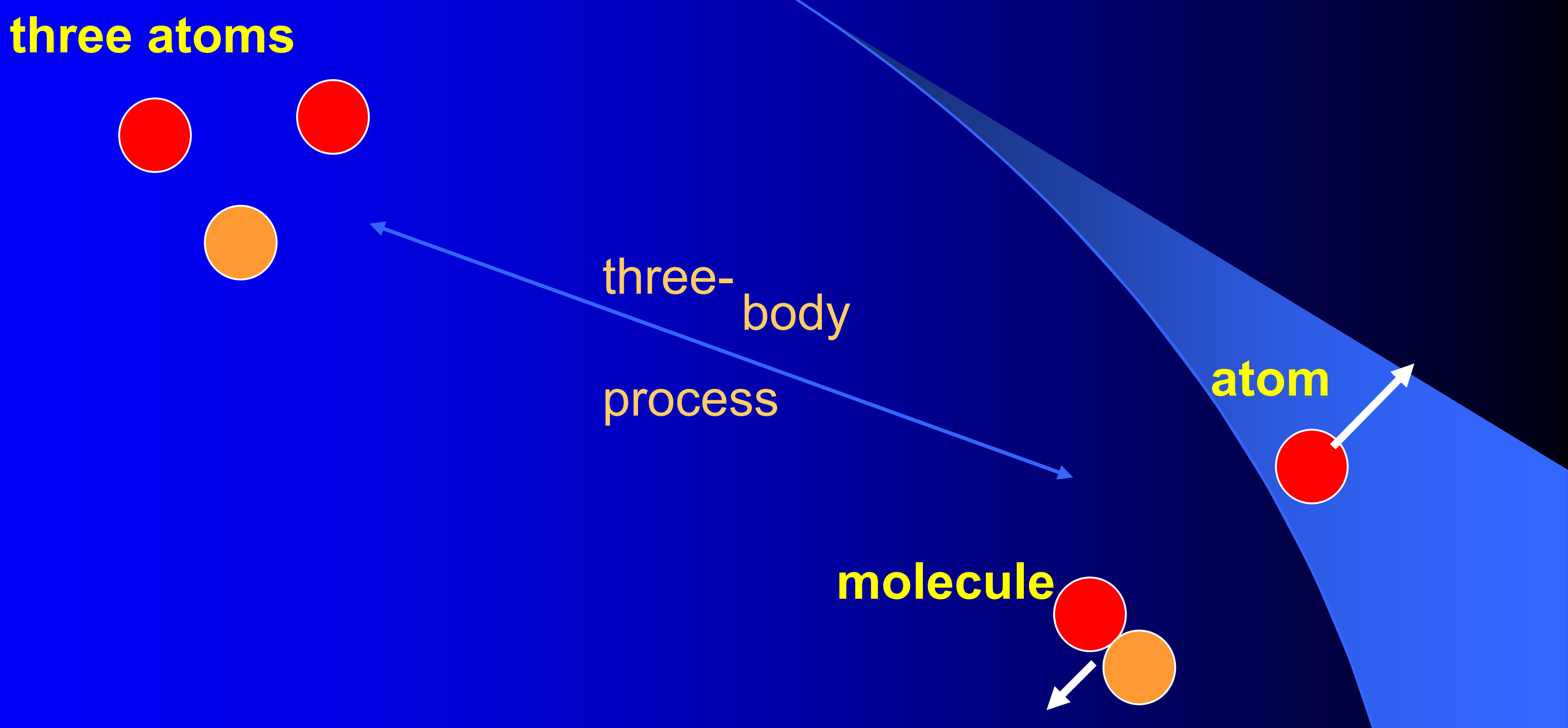


Weakly bound state (molecules)

No Bound State - only Fermi Gas

M. Houbiers *et.al.* PRA **57** R1497 (1998)

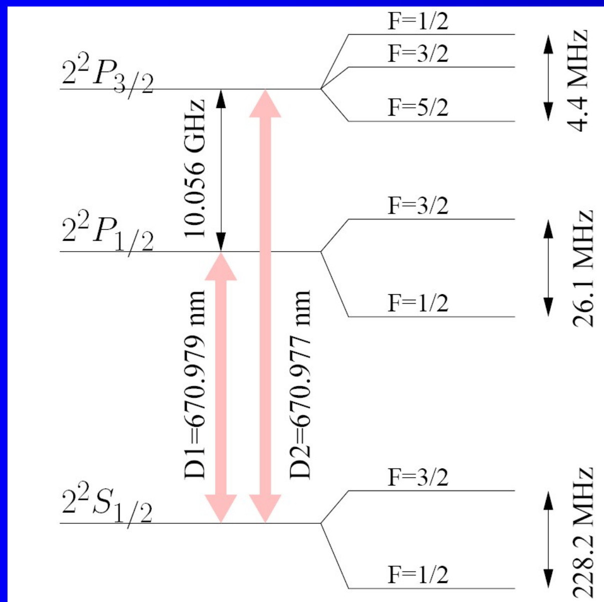
Making Molecules

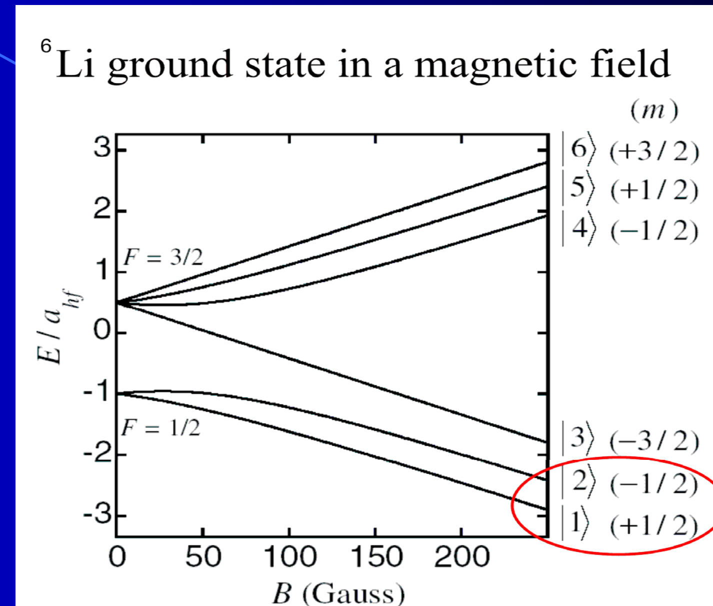


$^6Li_2$ molecules formed by 3-body recombination in tightly confining optical trap

(D. Petrov PRA **67**, 010703 (2003))

Lithium features





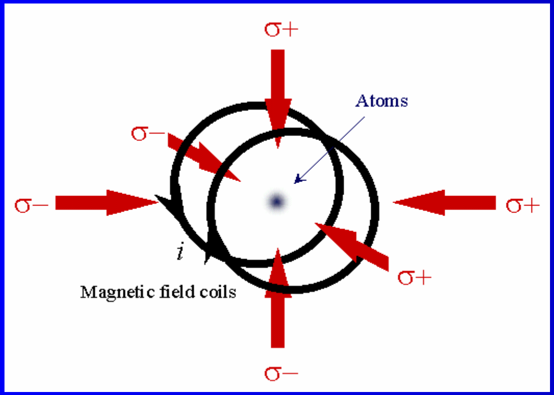
- Melting point : 180° C, At 400° C vapour pressure is 5×10^{-5} mbar
- Isotope: ^{6}Li ^{7}Li

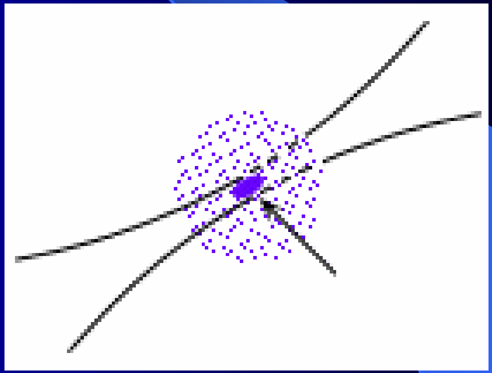
	^{6}Li	^{7}Li
Natural Abundance :	7.5%	92.5%
Nuclear Spin :	1	3/2

- Lithium corrosive to glass
- 50% - 50% mixture of ^{6}Li atoms in the lowest two ground states (not magnetically trappable). Avoids any two body decay channels

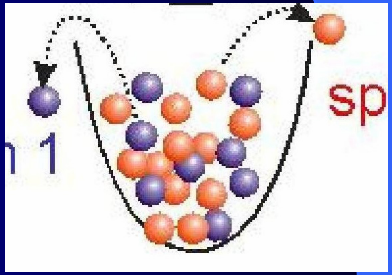
General approach

- Load ^{6}Li atoms into a MOT from a slowed atomic beam





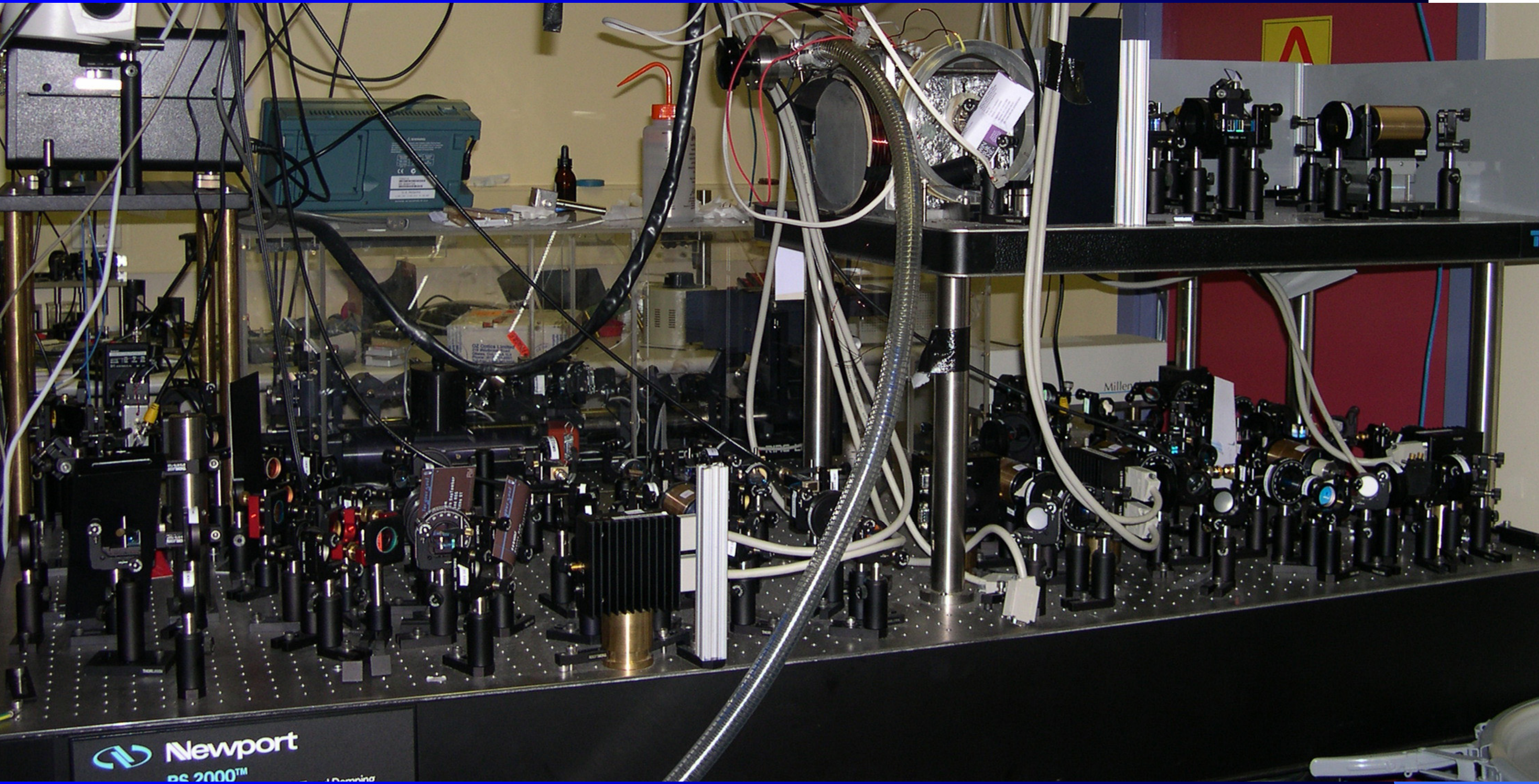
- Transfer atoms to a far-off-resonant optical dipole trap (FORT, *Yb:YAG, 25 W,* λ : 1030nm)
- Evaporatively cool by reducing FORT depth
- Evaporation is performed at a magnetic field strength that enhances 3-body recombination (molecules) - *Feshbach resonance at ~ 834 G*
- Continue evaporation to remove atoms, and condense remaining molecules



To Achieve a MBEC ……

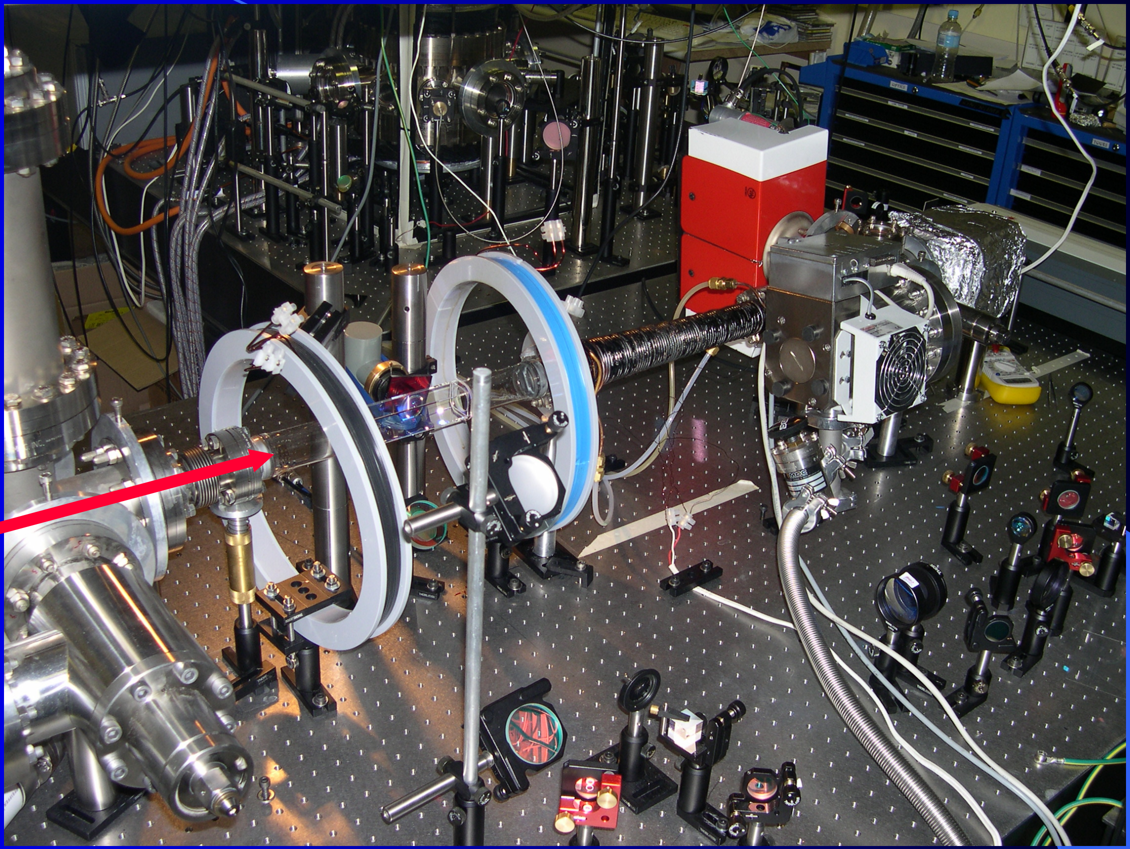
- Laser system
- Vacuum system
- Optical dipole trap

Laser System



- Saturation spectroscopy of lithium vapour produced in a vapour cell provides the frequency reference for the experiment.
- We lock our lasers using frequency modulation spectroscopy-modulation directly applied to the laser diode current

Vacuum System



Slowing Zeeman beam

- Oven : 400 °C
- atom velocity from oven 1500 m/s
- σ^- Zeeman Slower
- Max B field: 600 G
- Capture velocity : 50 m/s
- Pressure : 1 x 10^{-11} Torr

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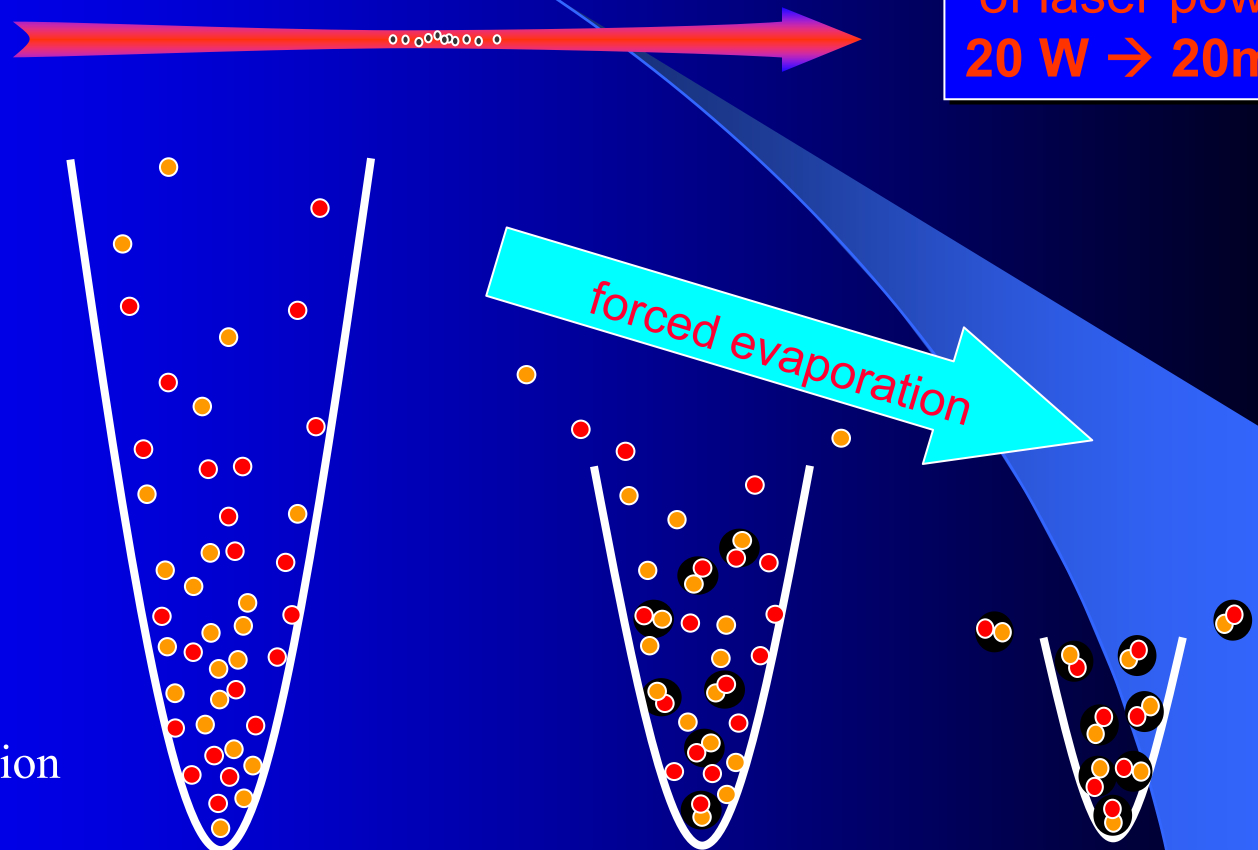
Optical Dipole Trap

precise control of laser power
20 W → 20mW



Parameters for FORT:

- Wavelength : 1030nm
- Power : 20 W
- Waist : 40 μm
- Trap Depth: 930 μK
- Single dipole trap
  Single with retro reflection
  Crossed dipole trap
- ω : 2□ x (4.5, 4.5, 6.4) kHz

Results……So far

- Slowed Atomic Beam
- Magneto Optical Trap
- EIT and EIA spectra

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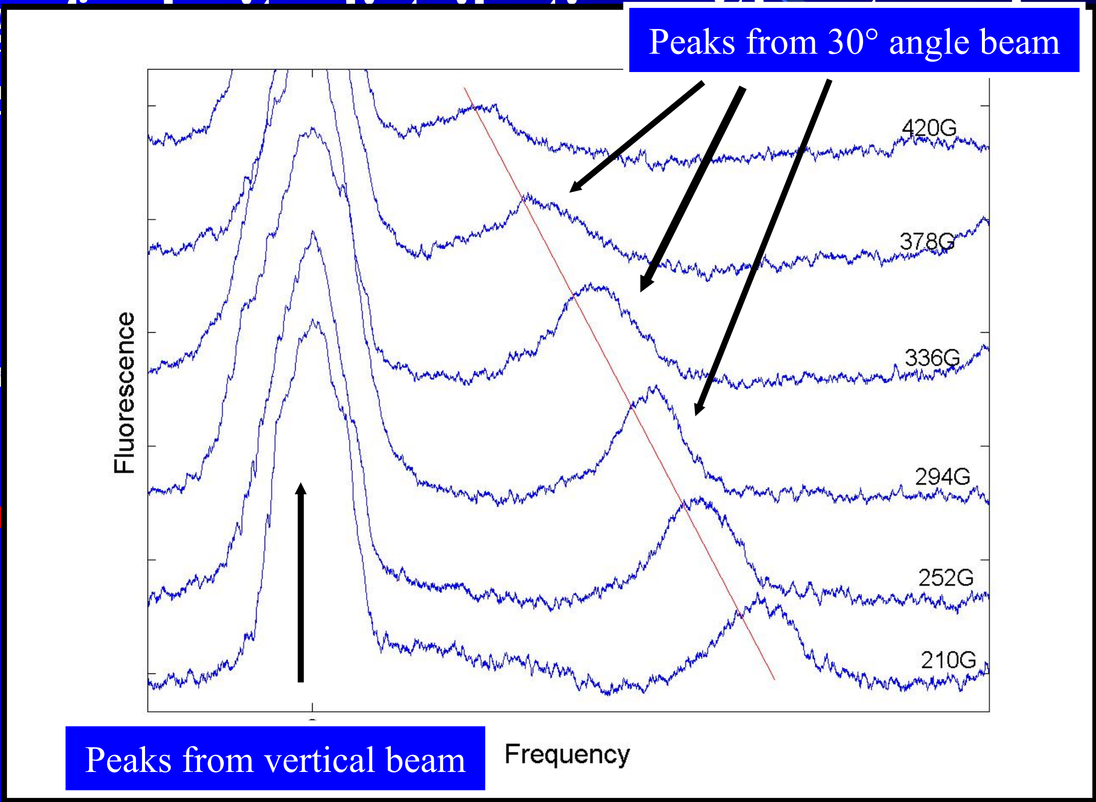
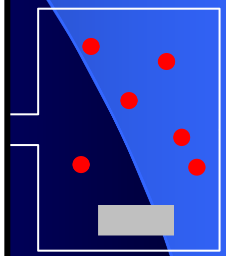
Slowed Atomic Beam

How did we probe the velocity distribution?

- **Probing** … **vity laser unde** …

Zeeman Slowing B…





Detuning

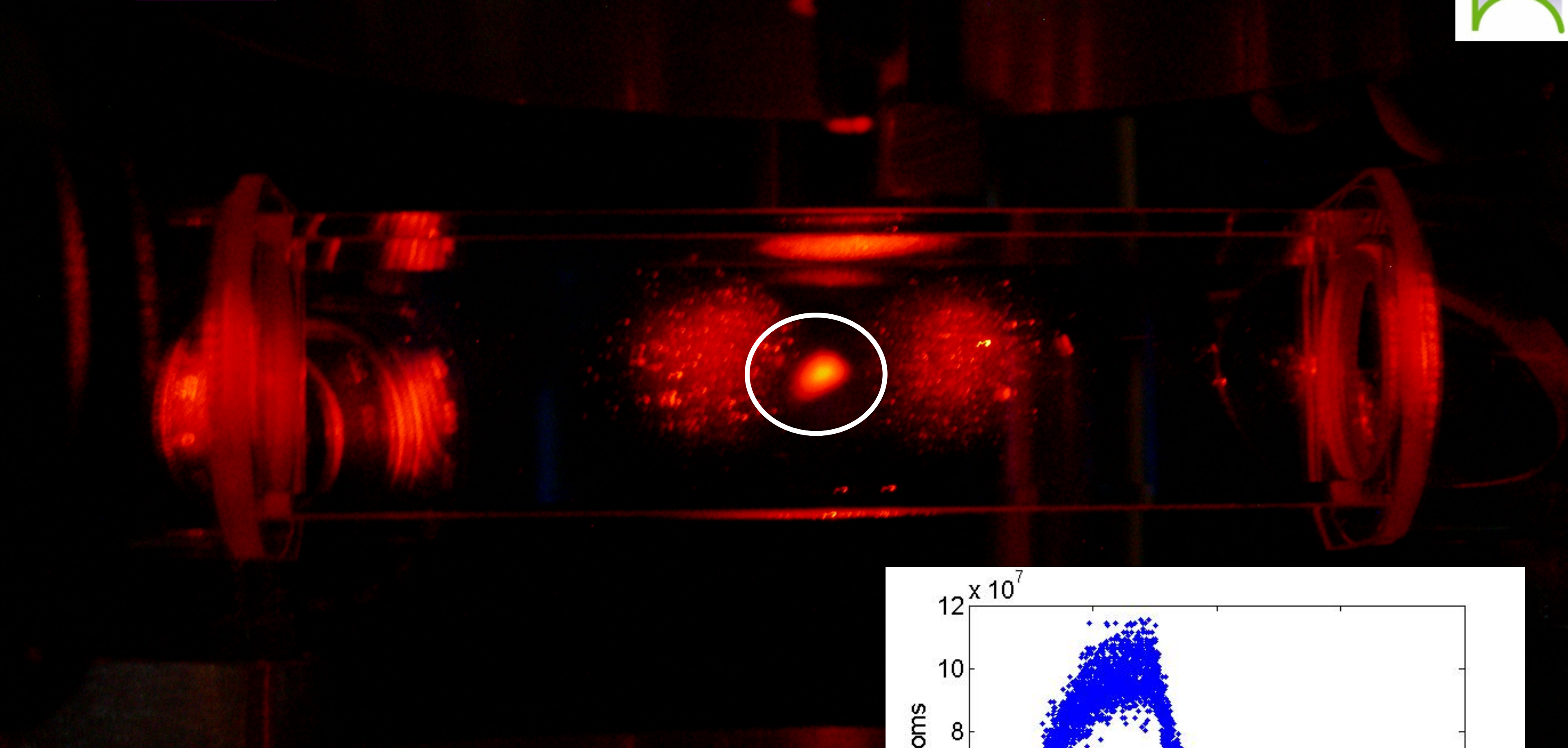
•Zeeman:8…

•Repumper:(820-228)MHz

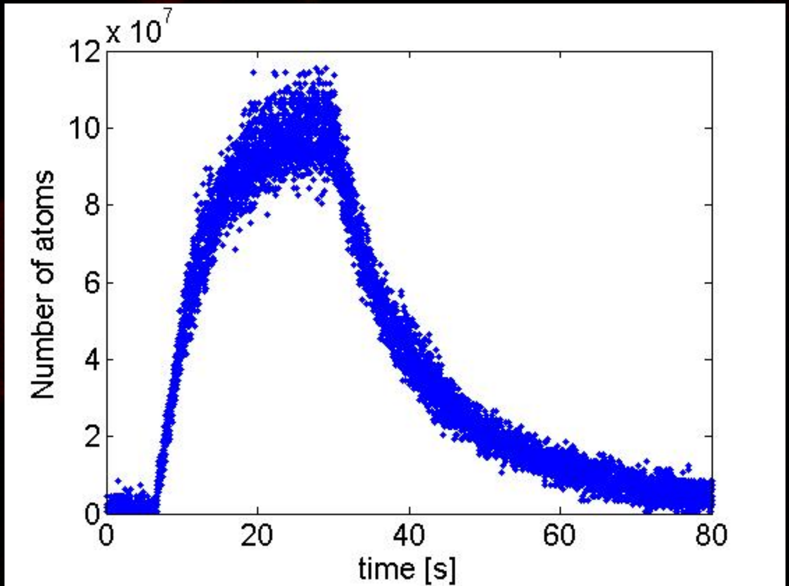
Frequency of probe laser is swept over 1-2 GHz

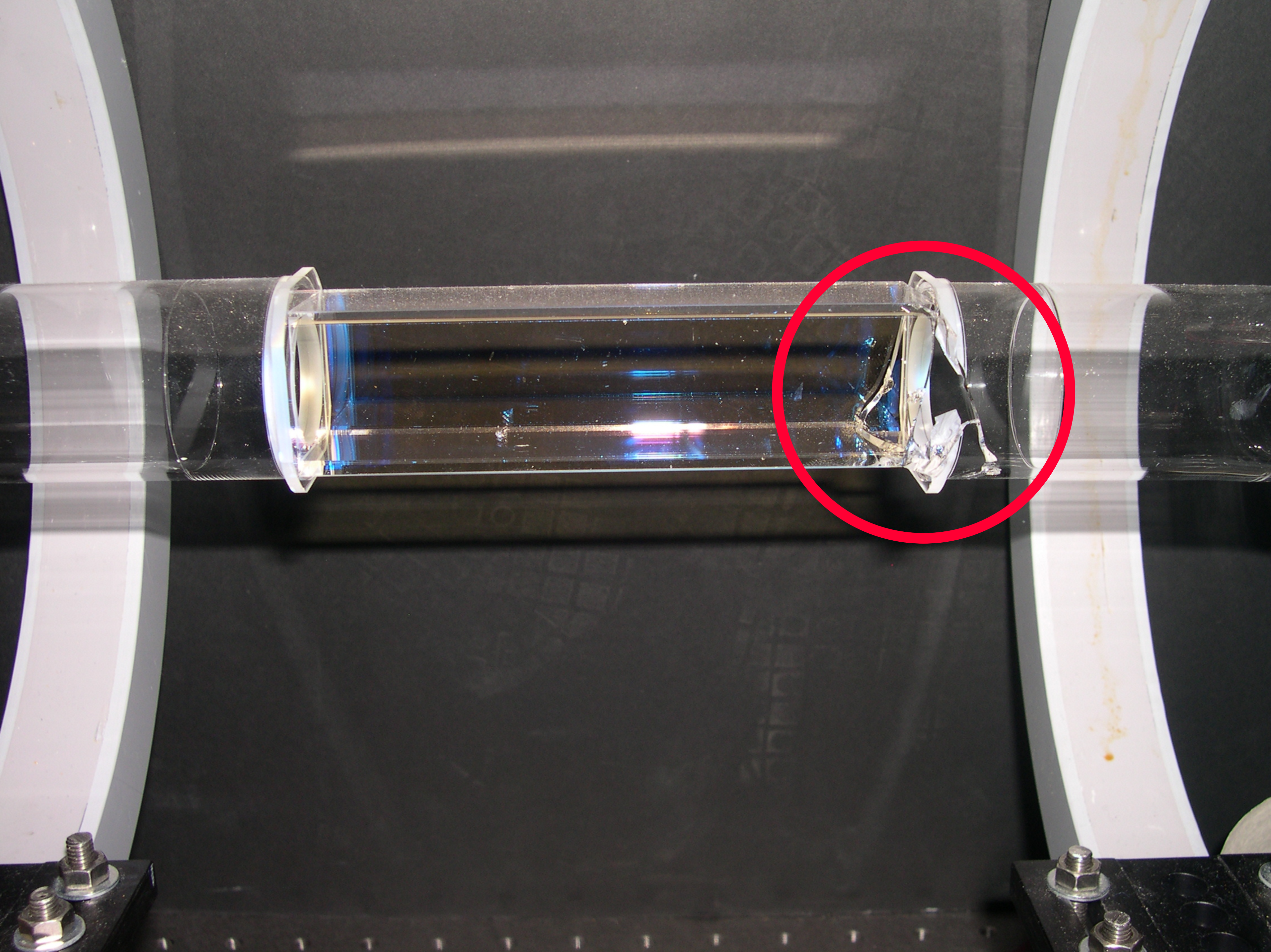
Can slow down lower velocities at higher fields

^{6}Li Magneto Optical Trap



- Atom Number : 2×10^{8} Atoms
- Lifetime : 35s
- Loading Time : 15secs
- Flux : 2×10^{7} At/s
- Oven Temp : 400°C
- Pressure : 1×10^{-11} T





Future Work

- To study the dissociation of the condensate molecules into correlated atom pairs
    - MBEC created from fermionic atoms – dissociation of MBEC

Kheruntsyan & Drummond
Phys. Rev. A, 66, 031602

- Future prospects for the BCS-BEC crossover regime for our parameters

- Collective Excitations
    - investigate interactions
    - probe finite temperature effects

- Experiments on fermionic atoms in optical lattices

Proposed Outline

- ✓ Slowed lithium beam
- ✓ ^{6}Li MOT
- Atoms loaded in FORT – *May 2006*
- Evaporative cooling - *Oct 2006*
- Feshbach creation of molecules – *Dec 2006*
- Molecular BEC – *early 2007*

Go Raibh Mile Maith Agat