Optical Confinement of Rubidium Atoms in a Pulsed Dipole Force Trap

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March 9th, 2005

Support:

Jefferson Lab

NSF

KOSEF 한국과학재단

OLD DOMINION UNIVERSITY 1930

Goal and Benefits

Use the properties of the JLab Free Electron Laser (FEL) to trap cold atoms and molecules.

Use of a free electron laser (FEL) yields certain benefits:

- Wavelength tunability
- High average power
  - ability to construct deep traps
  - ability to construct large traps

Benefits of a *Pulsed* FORT

- The light is **OFF** most of the time and, therefore, one can obtain spatial confinement in a perturbation limited environment
  - (precision measurements)

- It is easier to to make blue and UV light with a pulsed laser than with a cw laser, thereby expanding accessible species which can be trapped or spatially manipulated

Motivations for FEL

- Working in the cold regime as opposed to ultra-cold
- Trapping of molecules
- Precision Measurements

The FORT

FORT is an acronym for “Far-Off-Resonance-Trap.” It is derived from the spatial dependence of the Stark shift of an atom or molecule in a light field. Consider a cw light field with intensity *I*:

For an atom $$U = \frac{\eta\Delta}{2}\ln(1+p)$$

where $$p = \frac{I}{I_{SAT}}\frac{\Gamma^2}{4\Delta^2+\Gamma^2}$$

FORT Depth and Scattering Rate

Usually, p << 1 and $\Delta >> \Gamma$, so that ln(1+*p*) ~ *p* and we can write the familiar result:

$$U = \eta \frac{I}{I_{SAT}} \frac{\Gamma^2}{8\Delta}$$

Similarly, the scattering rate for photons can be written:

$$S = \frac{I}{I_{SAT}} \frac{\Gamma^3}{8\Delta^2}$$

Why use a FORT?

Notice that the trap depth scales as $1/\Delta$ whereas the scattering rate scales as $1/\Delta^2$.

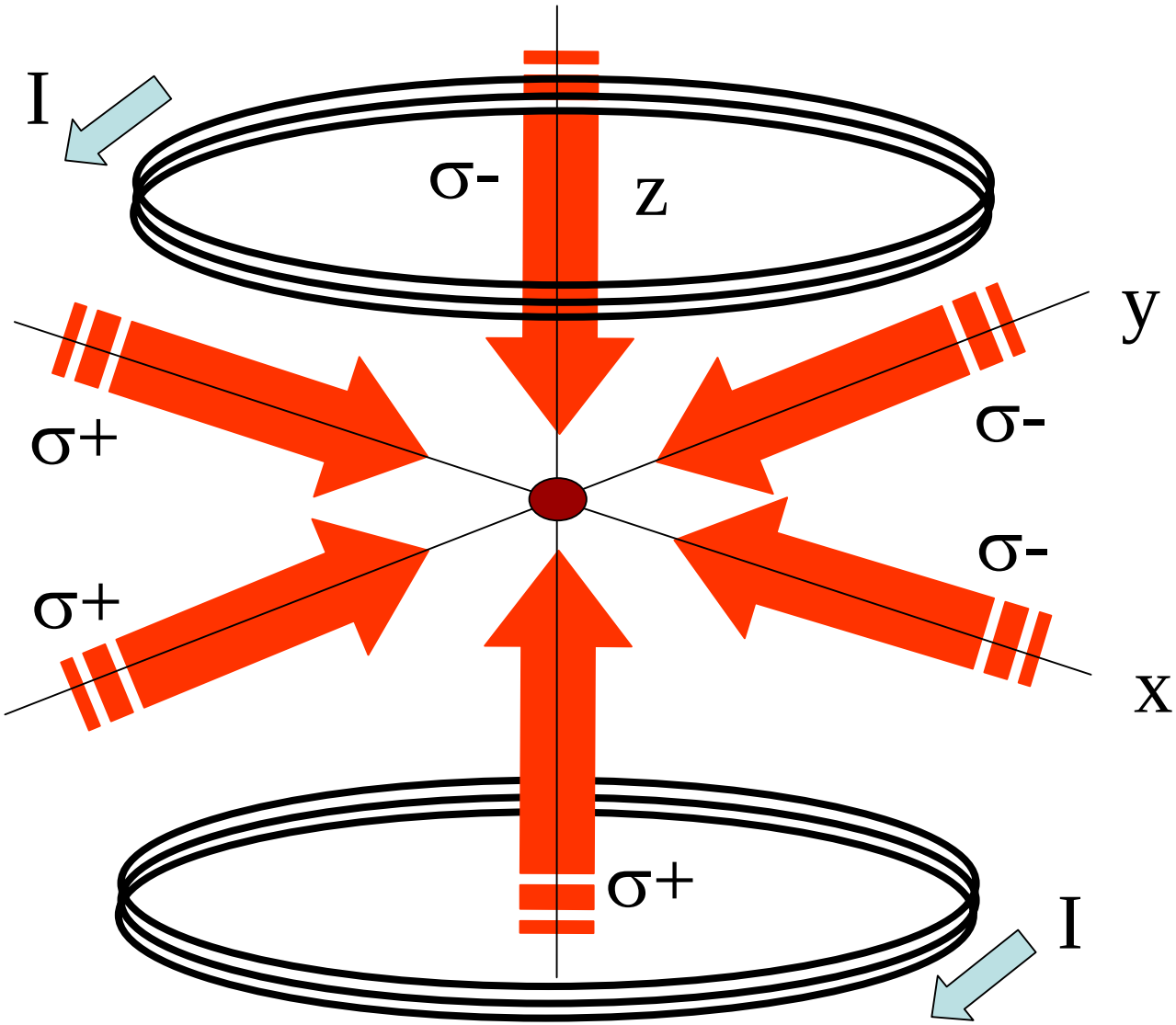
Heating in a FORT can be reduced by going to larger detuning and increasing the power.

For example, a 10W YAG laser focussed to 50μm yields a trap depth of ~ 400 μK with a photon scattering rate of 2-3 photons / atom / second.

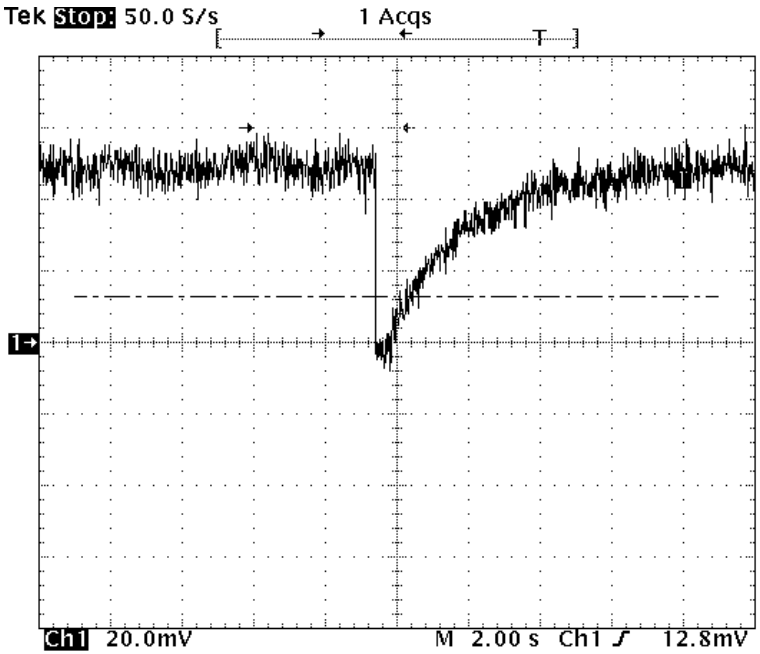
The Magneto-Optical Trap (MOT)

The MOT is the most common type of trap for ultracold atoms.

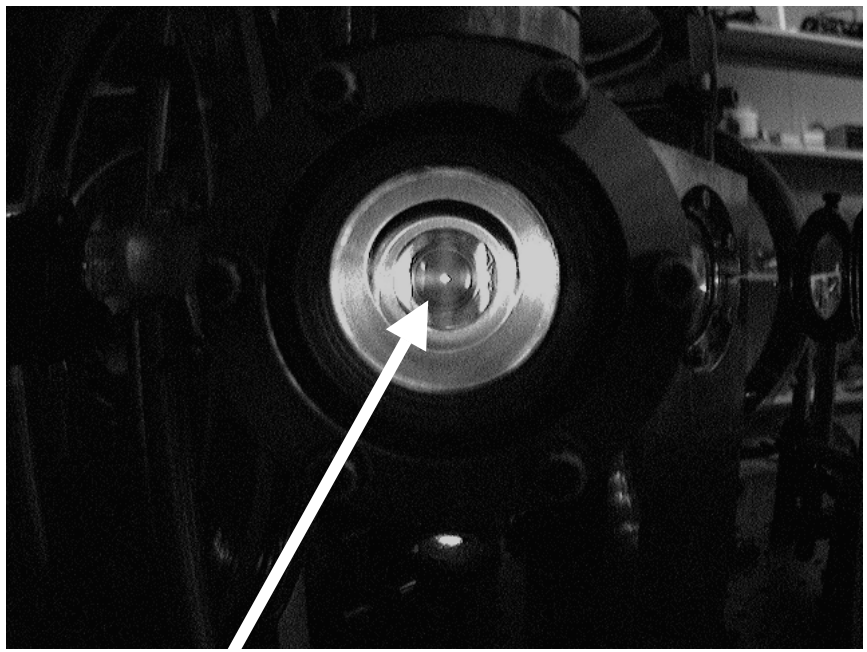
It is capable of simultaneously cooling and confining atoms, but does not work for molecules.



MOT Loading Curve



A photodiode monitors the MOT fluorescence as the trap loads



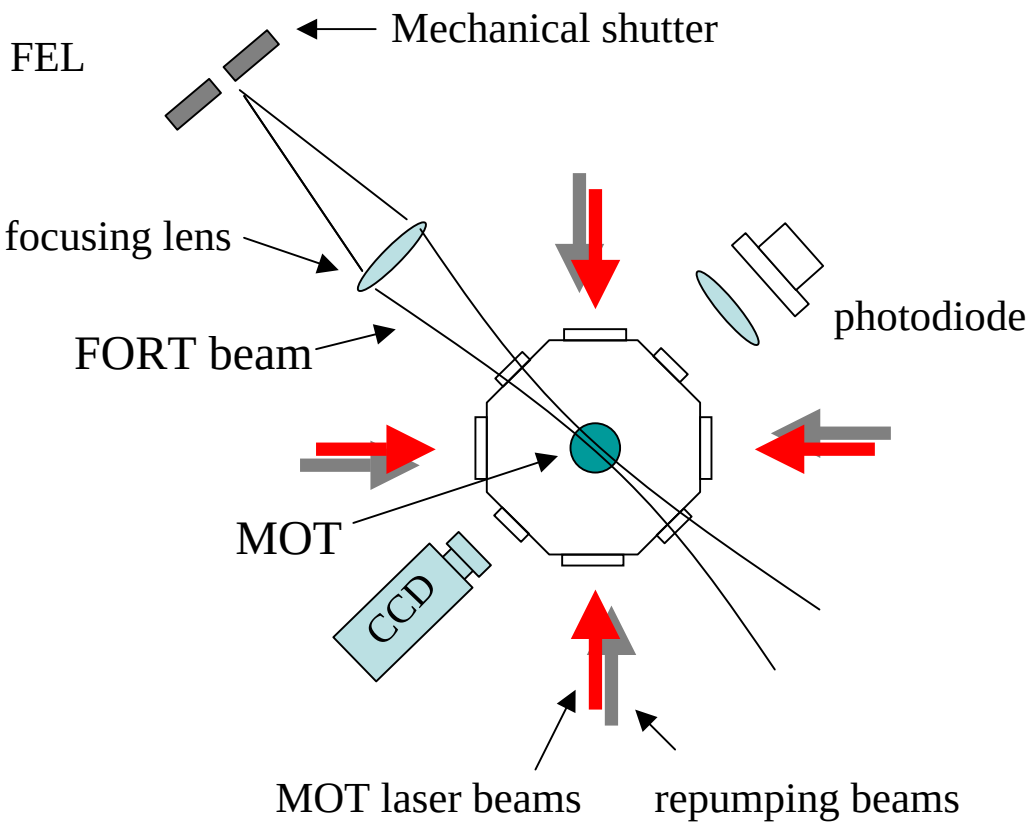
The Rb MOT can be seen at the center of the chamber

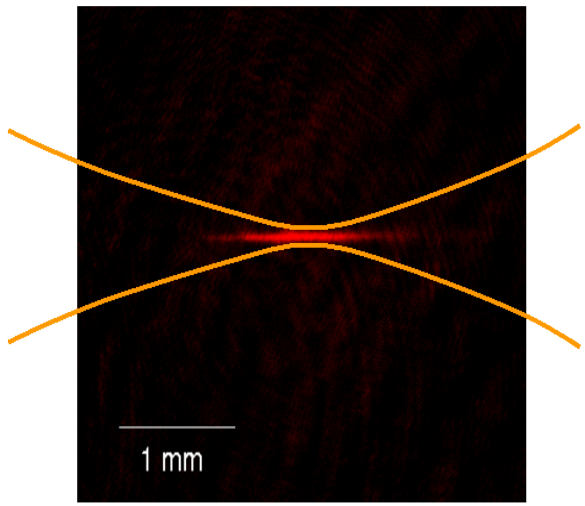
MOT Characteristics

- Temperature: 10 - 100 μK
- Density: 10^{10} - 10^{11} / cm^3
- Number of atoms: 10^5 - 10^7
- Capture velocity: 5 - 50 m/s
- Cloud size: 0.5 - 2 mm

Experimental Plan

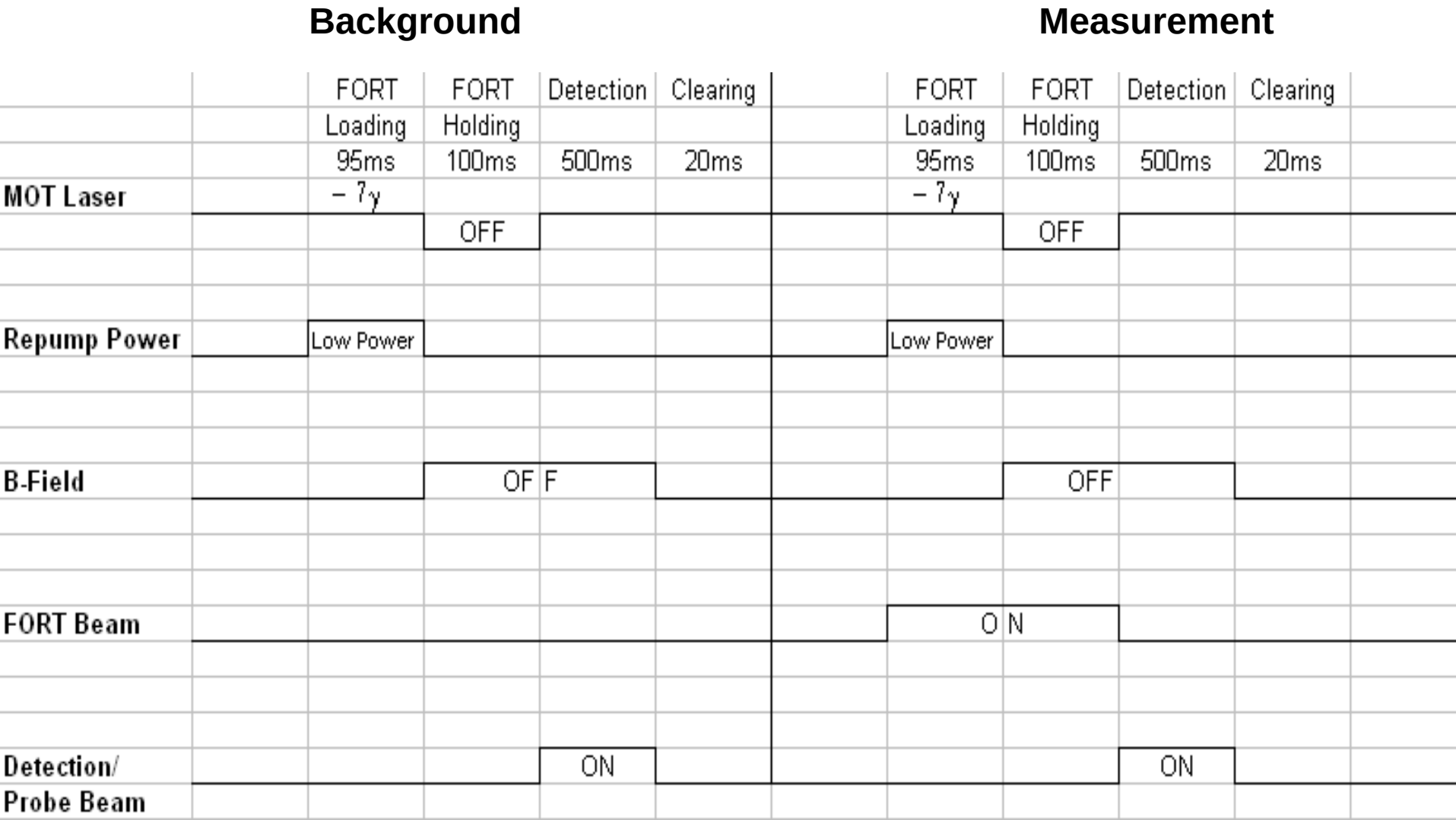
First, cool and confine Rb atoms in a MOT and then transfer them to the FORT.

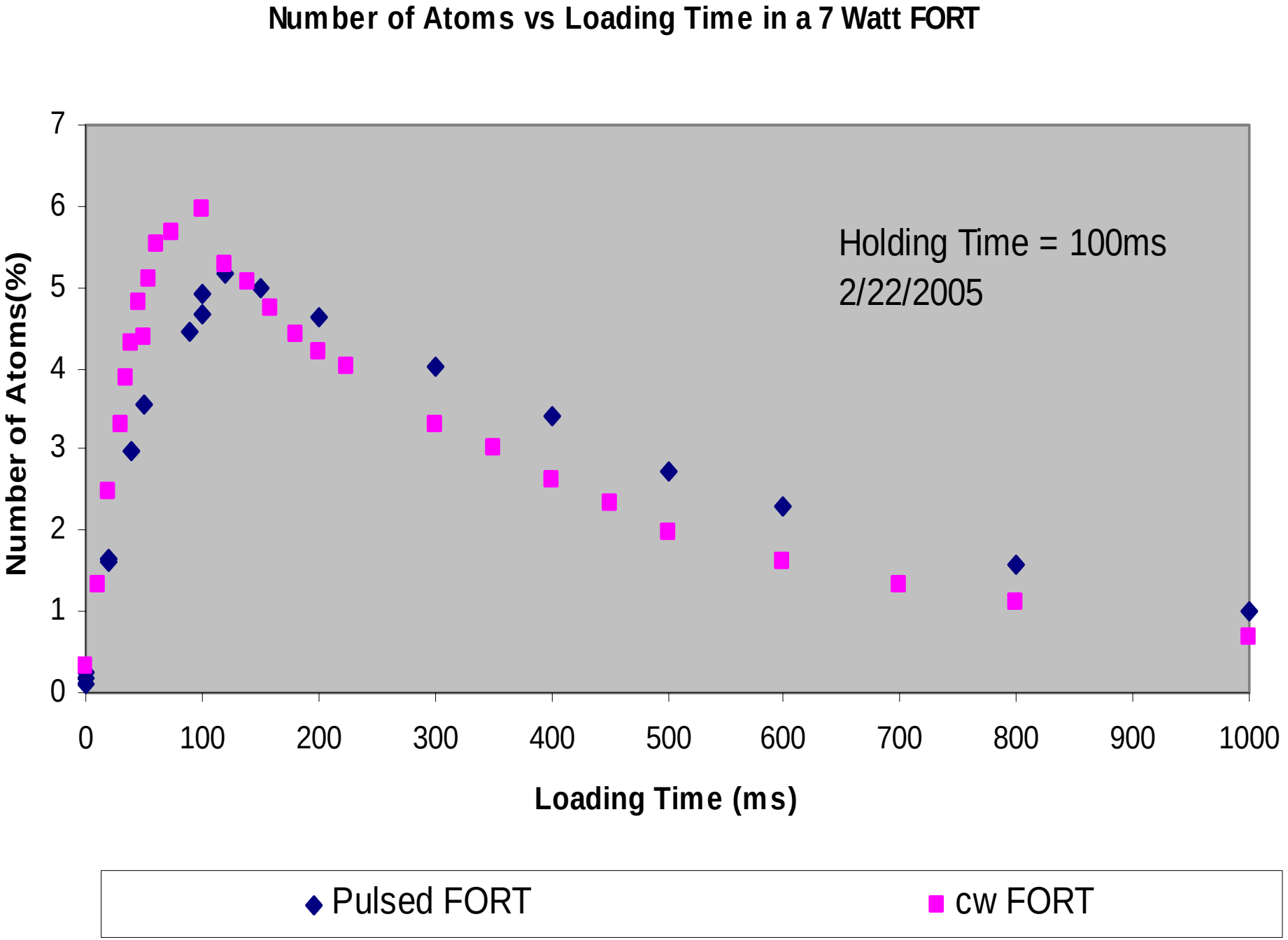




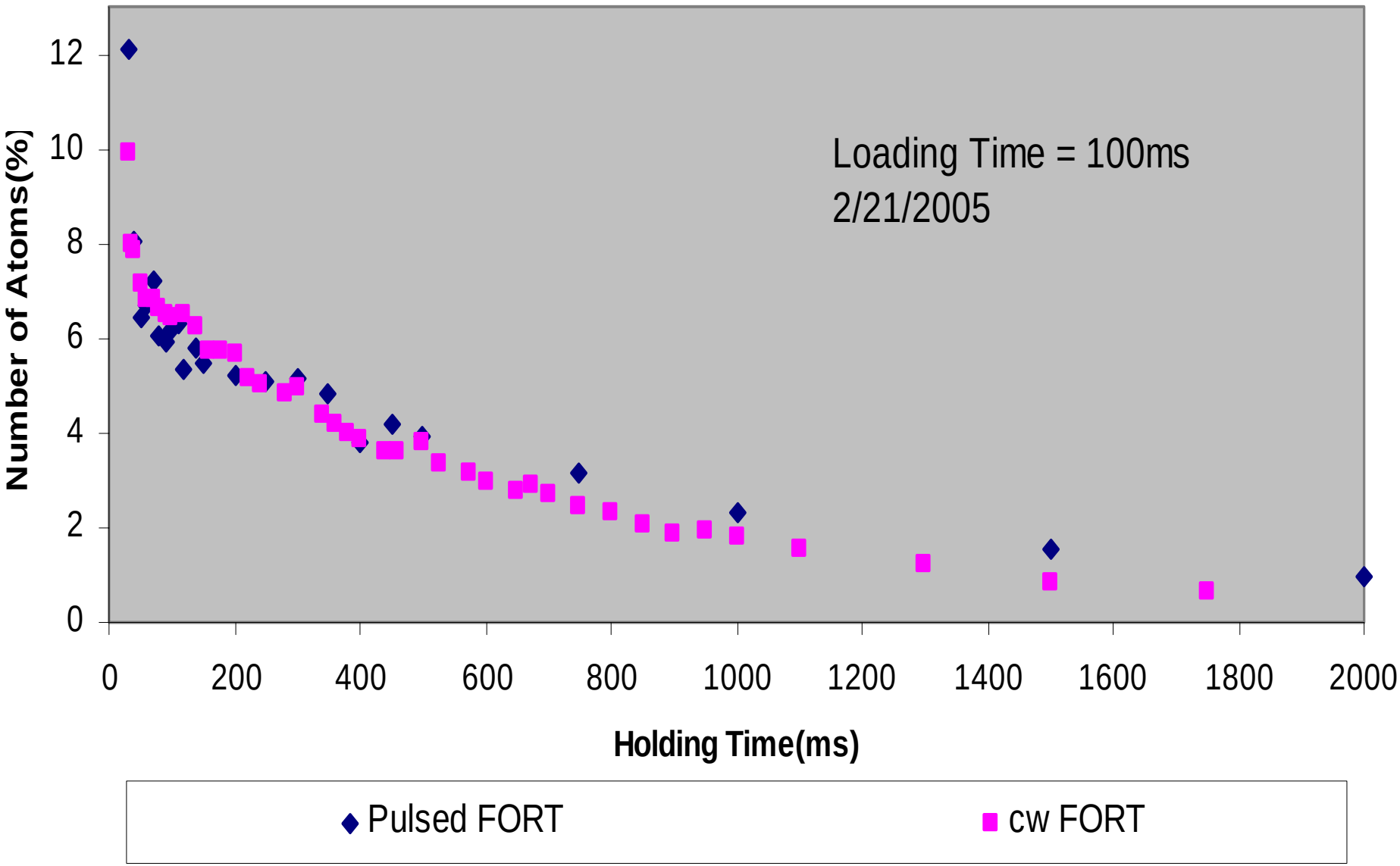
FORT

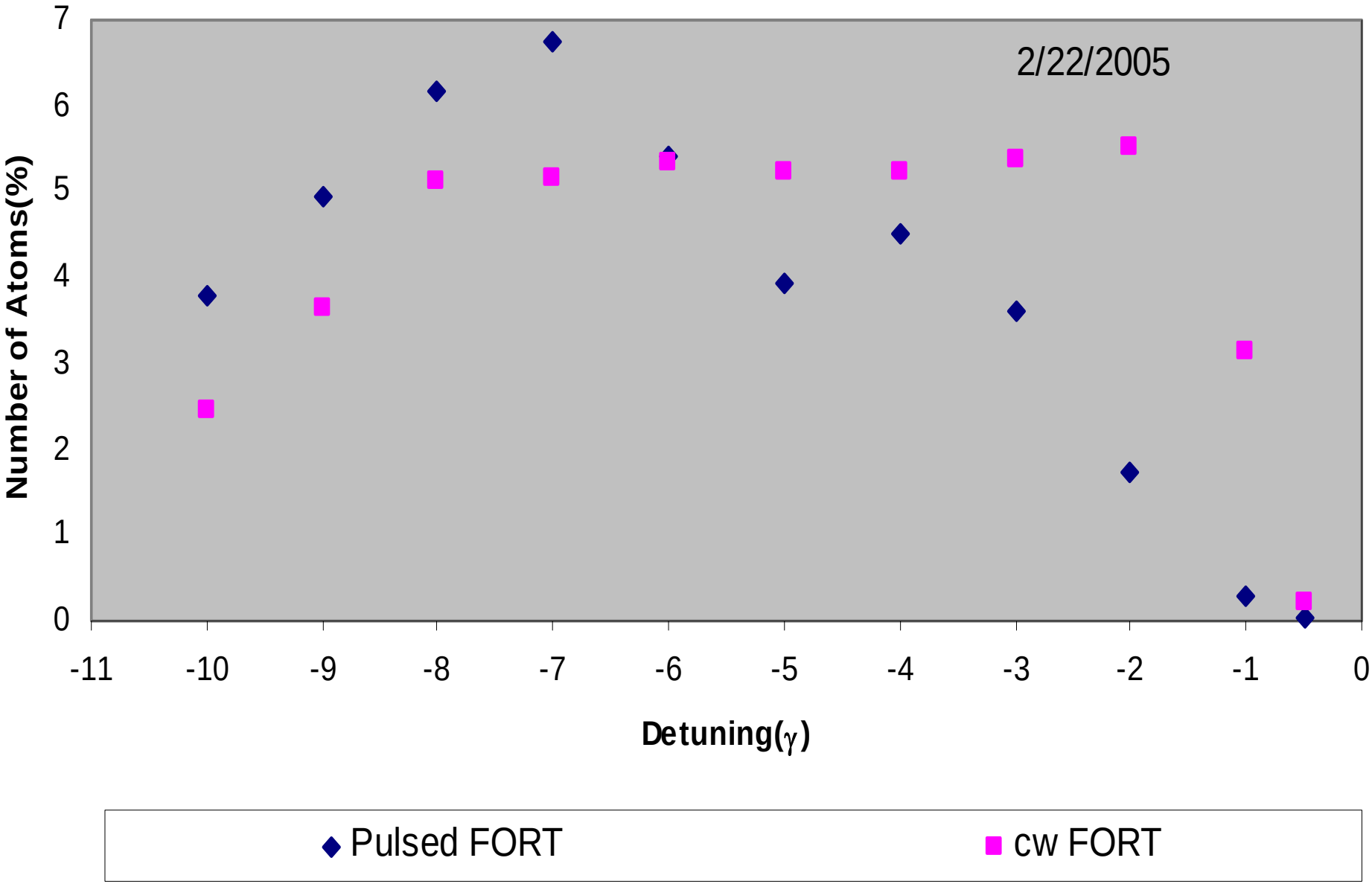
FORT Timing Scheme




Number of Atoms vs Loading Time in a 7 Watt FORT
Holding Time = 100ms
2/22/2005
Number of Atoms(%)
Loading Time (ms)
0
1
2
3
4
5
6
7
0
100
200
300
400
500
600
700
800
900
1000
Pulsed FORT
cw FORT

Number of Atoms vs. Holding Time in a 5 Watt FORT




Number of Atoms vs MOT Laser Detuning in a 8 Watt FORT
2/22/2005
Number of Atoms(%)
0
1
2
3
4
5
6
7
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
Detuning(γ)
Pulsed FORT
cw FORT

Conclusion

- We are investigating atomic trapping in a FORT with particular attention to the high power, pulsed laser regime.
- We will be using the JLab Free Electron Laser to carry out our studies this summer (2005)

Acknowledgements

M. Shiddiq ,C.I.Sukenik, M.D. Havey
Old Dominion University

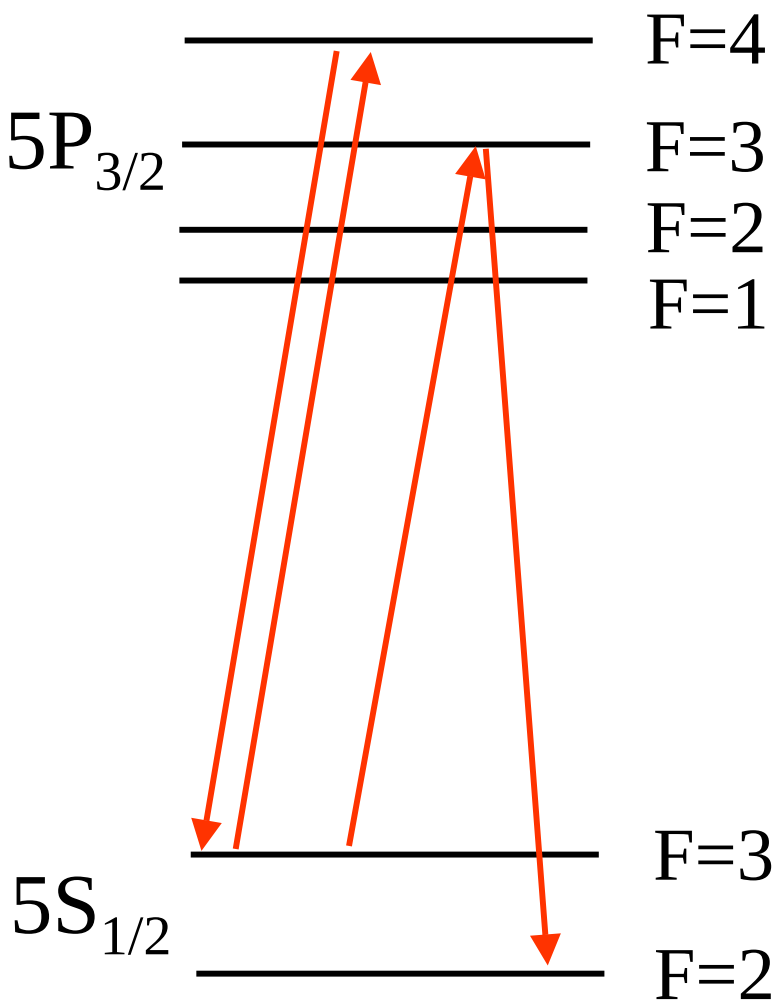
G. Williams
Thomas Jefferson National Accelerator Facility

R.R. Jones
University of Virginia

D. Cho, J.Y. Kim, C.Y. Park
Korea University

Cooling Atoms vs. Cooling Molecules

^{85}Rb Atom



$^{85}Rb_2$ Molecules