Construction of a Yb Laser Cooling and Trapping Apparatus

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Goal of this project

The long term goal of this project is to use an ultracold gas of Ytterbium (Yb) atoms for precision measurement of very weak forces (such as gravity on the micron scale) as well as studying atom-atom interactions in the context of ultra-cold collisions. On this poster, we describe the first steps towards making an ultracold Yb atom gas.

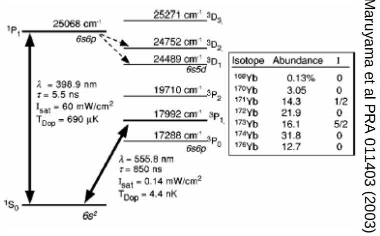
Advantages of Ytterbium for trapping

- Two laser transitions which are readily available for trapping and cooling: $^1S_0 \rightarrow {}^1P_1$ (399nm), and $^1S_0 \rightarrow {}^3P_1$ (556nm)
- Absence of hyperfine structure in ground state so there is no need for repumper laser
- Have 7 stable isotopes, and cooling transition is close to a pure two-state system

Advantages of ultracold Yb for precision measurement of very weak potentials

- Can choose magic wavelength such that the AC stark shifts of $^1S_0$ and $^3P_0$ are identical
- Narrow line laser cooling to T~10 μK
- $^1S_0$ and $^3P_0$ states have different static polarizabilities, which mean they will experience different Casimir-Polder shifts.
- Ratio of Casimir-Polder shifts is given by ratio of their polarizabilities.
- $^1S_0$ and $^3P_0$ have zero magnetic moment (J=0), therefore only electric forces need to be considered here

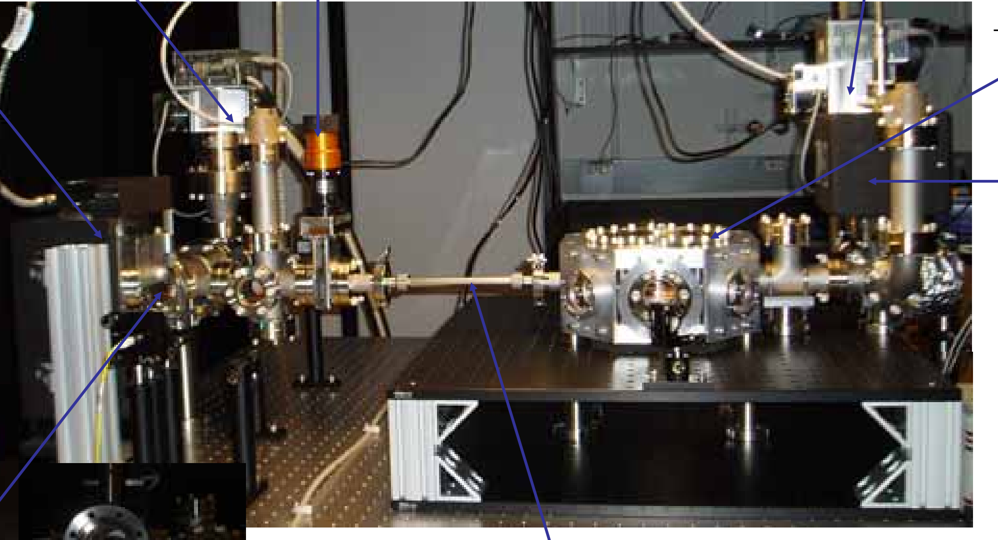
Relevant energy levels of Ytterbium

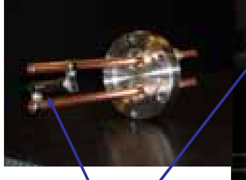


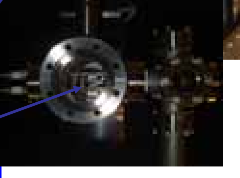
Isotope	Abundance	I
^{168}Yb	0.13%	0
^{170}Yb	3.05	0
^{171}Yb	14.3	1/2
^{172}Yb	21.9	0
^{173}Yb	16.1	5/2
^{174}Yb	31.8	0
^{176}Yb	12.7	0

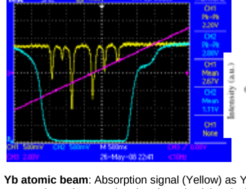
Maruyama et al PRA 011403 (2003)

Apparatus for laser cooling and trapping

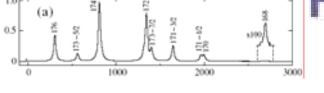






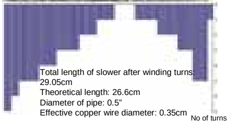


R Zinkstok. et al. J. Phys. B. 35 (2002) 2693-2701

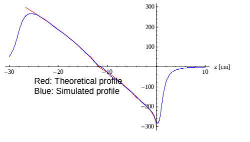


Yb atomic beam: Absorption signal (Yellow) as Yb is vaporized in vacuum by running current through a tantalum heating tube (electrical feed thru shown at far left). The atoms are probed with resonant laser light at 399 nm and absorption signals are shown in the inset for Yb atoms in the oven chamber (blue) and trapping chamber (yellow). In the chamber, the atomic density is on order 10^9 cm^{-3}, and the atomic flux is on order 10^{14} atoms per second.

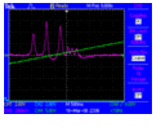
Winding pattern of spin flip slower

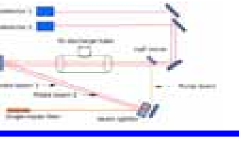


Zeeman slower profile



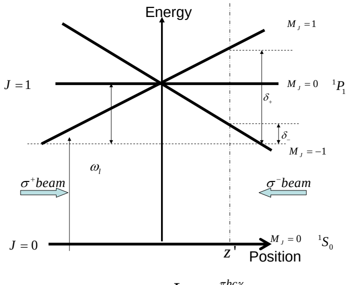
Laser locking setup:





Saturation absorption spectroscopy (SAS) signal for locking laser to Yb transition (purple). Yb is vaporized in a commercially available cathode discharge tube. The pump beam is overlapped with probe beam 1. Probe beam 1 and probe beam 2 are detected from which we get an SAS signal

Magneto optical trapping of Yb



Saturation intensity: $I_{sat} = \frac{\pi h c \gamma}{3\lambda^3}$

Scattering rate: $\gamma = \frac{1}{\tau}$

Life time of excited state: τ

The total force on an atom is given by:

$$F = F_+ + F_-$$

where

$$F_\pm = \pm \frac{\hbar k \gamma}{2} \frac{I/I_{sat}}{1 + I/I_{sat} + \left(2\delta_\pm/\gamma\right)^2}$$

And the detuning for each laser beam is given by,

$$\delta_\pm = \delta \mp k \bullet v \pm \mu' B/\hbar$$

Effective magnetic moment: $\mu' = (g_{J=1} M_{J=1} - g_{J=0} M_{J=0})\mu_B$

Since Yb has no magnetic moment in the $^1S_0$ ground state so the value of $g_{J=0}$ is zero

Zeeman shift: $\omega_z = \mu' B/\hbar$

Doppler shift: $\omega_D = -k \bullet v$

H.J. MetCalf, P Straten, Laser Cooling and Trapping, Springer-Verlag, New York, 1999