Off-The-Shelf Atom Trapping

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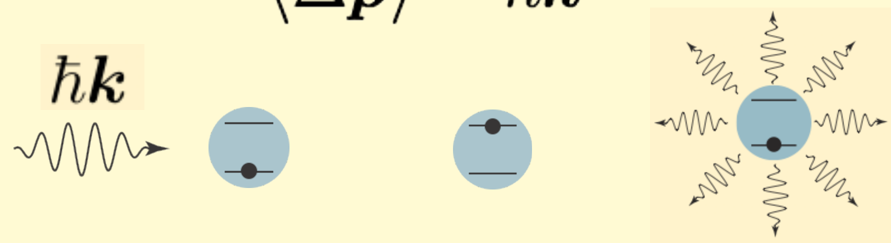
Why Cold Atoms?

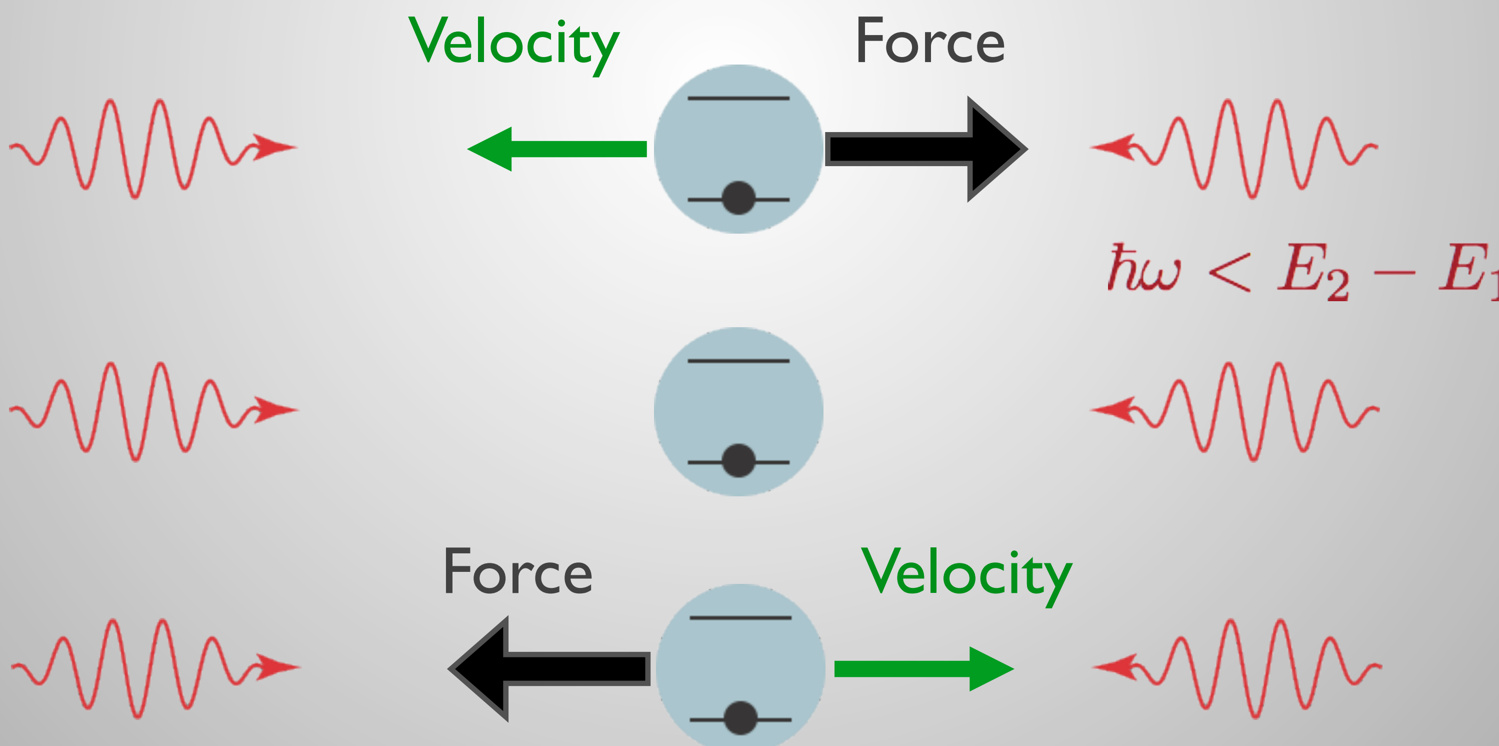
- Study quantum light-atom effects
- Quantum technology: Storing information in atomic ensembles
- Velocity is extremely slow, resolve atomic spectra
- Room temperature (295K) : Average velocity ~500 m/s
- Individual atoms are hard to interact with for very long
- Cold atoms (~100μK) : Average velocity ~9 cm/s
- Atoms are almost standing still

Doppler Cooling

Photons absorbed by atoms apply a net force on the atoms:

$$\langle \Delta \boldsymbol{p} \rangle = \hbar \boldsymbol{k}$$





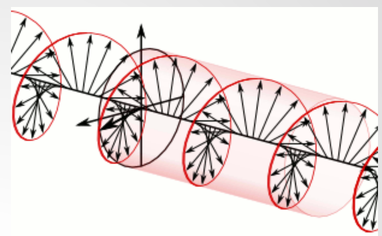
How Do You Trap Atoms?

- Circular Polarization

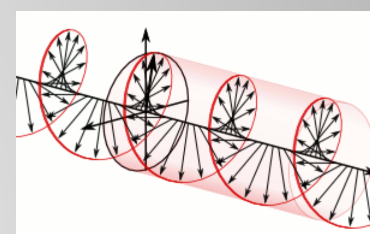
σ_- Carries (-) angular momentum

σ_+ Carries (+) angular momentum

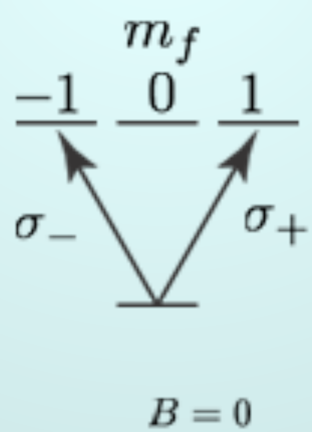
LCP



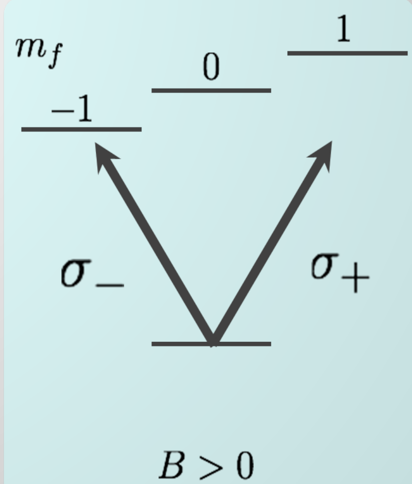
RCP



- Zeeman Shift

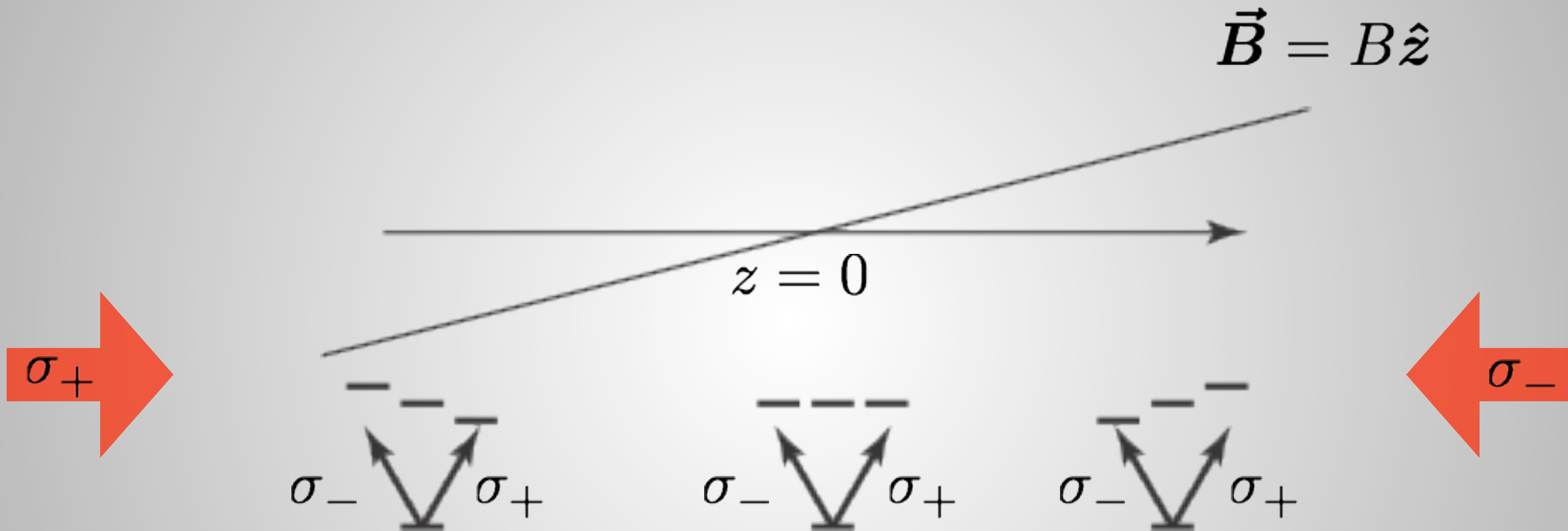


No external magnetic field



With external magnetic field

Magneto-optical trap 1D



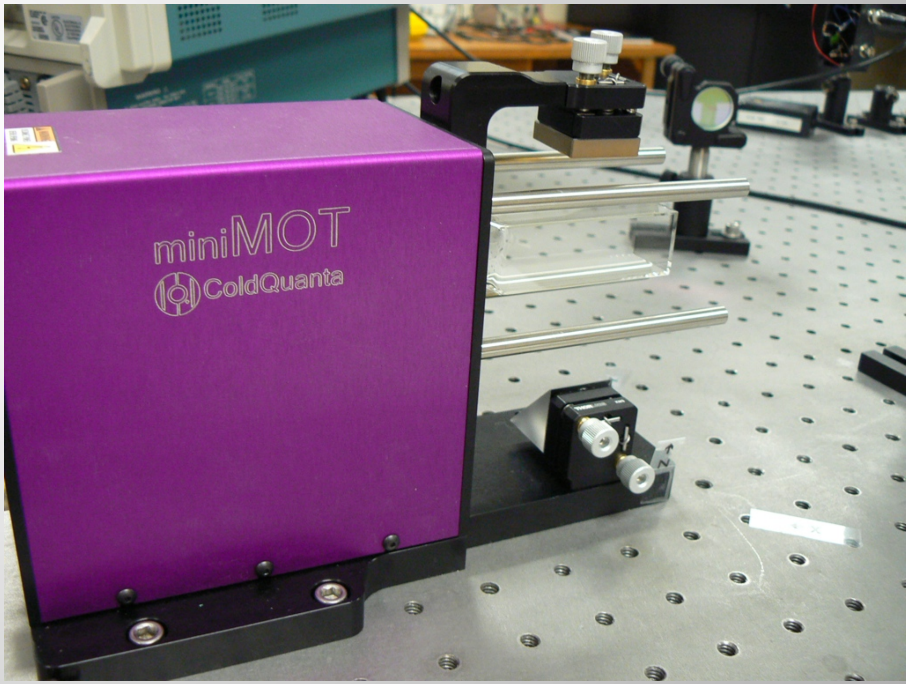
- Magnetic field gradient creates position-dependent resonance

(Red-detuned beams)

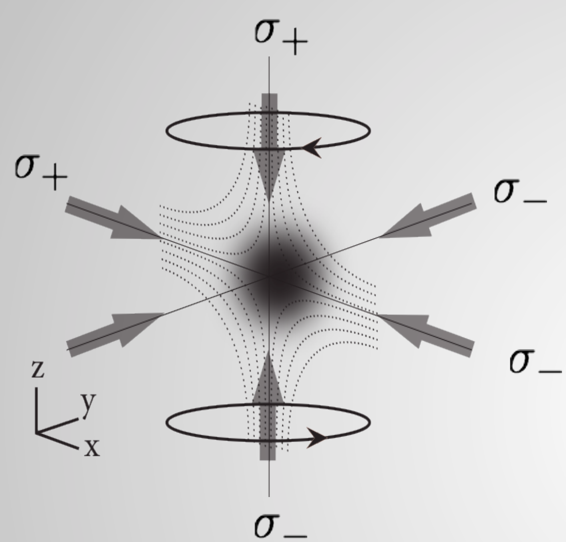
MiniMOT

www.coldquanta.com

- 5 x 2 x 2 cm cell
- Rb source (getter)
- Ion vacuum pump
- All contained in one unit
- Easy to set up and configure
- Maneuverable

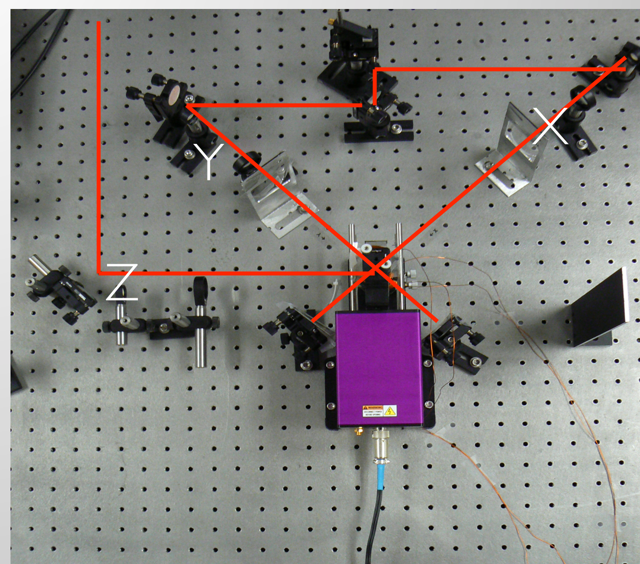


Spherical MOT

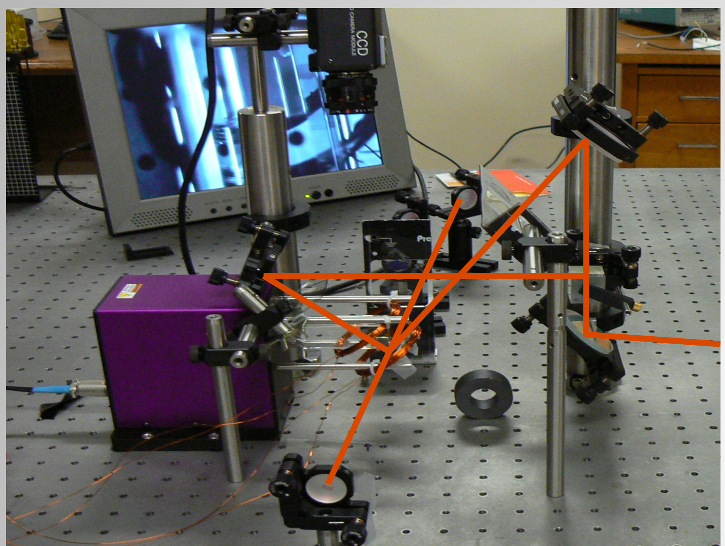


- -x and +y axis LCP
- -z axis RCP
- Reflected beams switch polarization
- Atoms trapped in cycling transition
- F = 2 → F' = 3

- x and y axis beams only interact at intersection
- z beam is reflected vertical

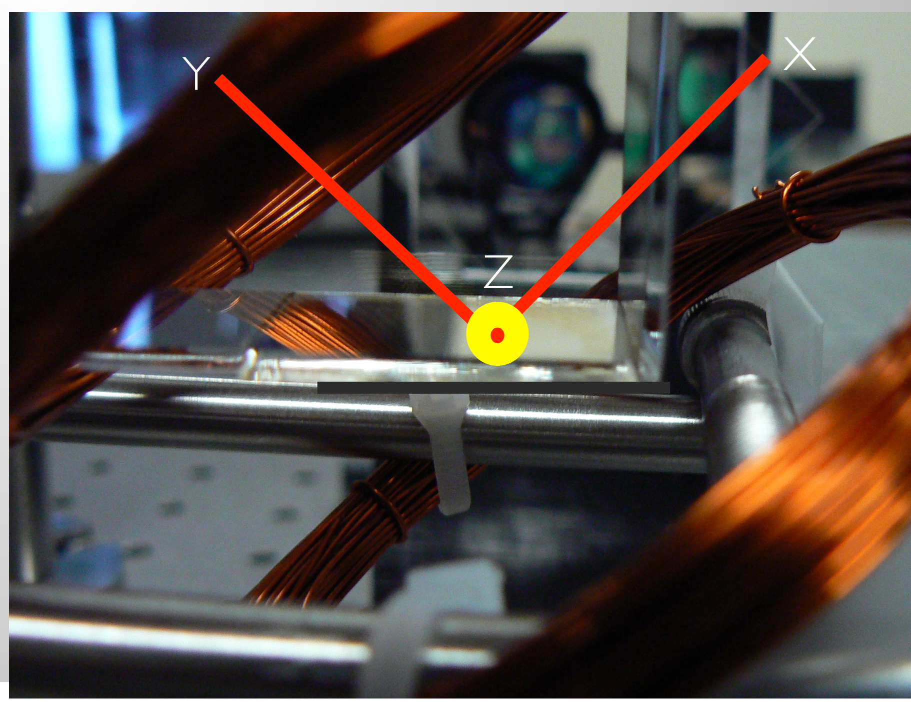


Spherical Mirror MOT



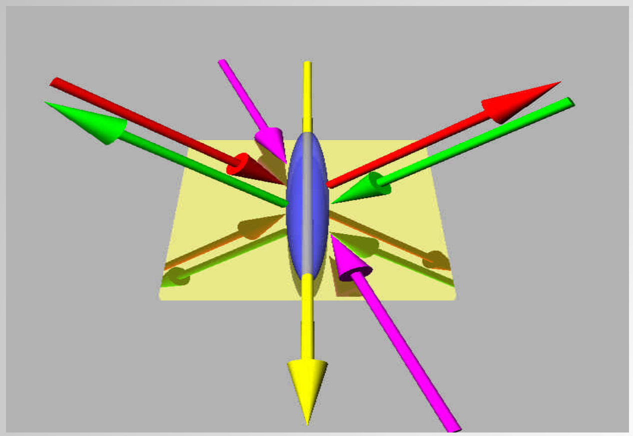
- The mirror setup uses two beams to create a 6 beam affect
- x and y are retro-reflected on each other
- z is a separate beam

coil & beam setup



- Coils are set up parallel to each other
- At a 45 degree angle from the mirror so that x and y beams enter through coil perpendicularly

Anisotropic Mirror MOT



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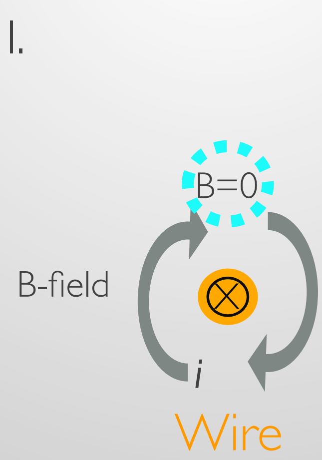
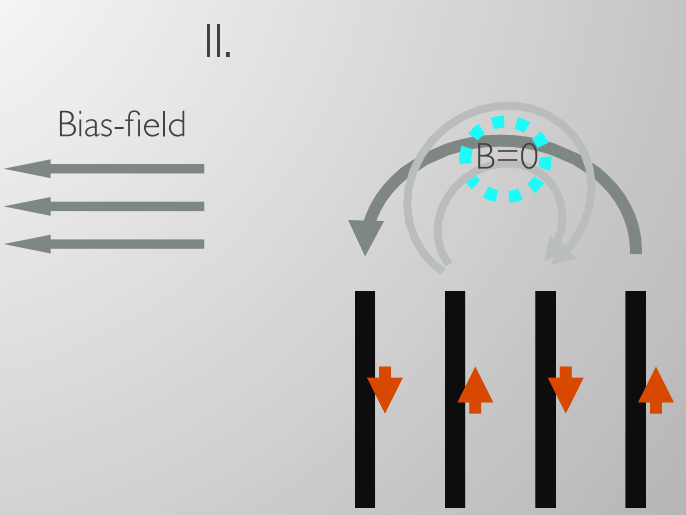
- A MOT where the x and y axes are trapping beams, while the z axis is a cooling beam.
- Proportionally 1000 times longer than it is wide.

- Two magnetic field variations
- We found the second variation more stable and linear



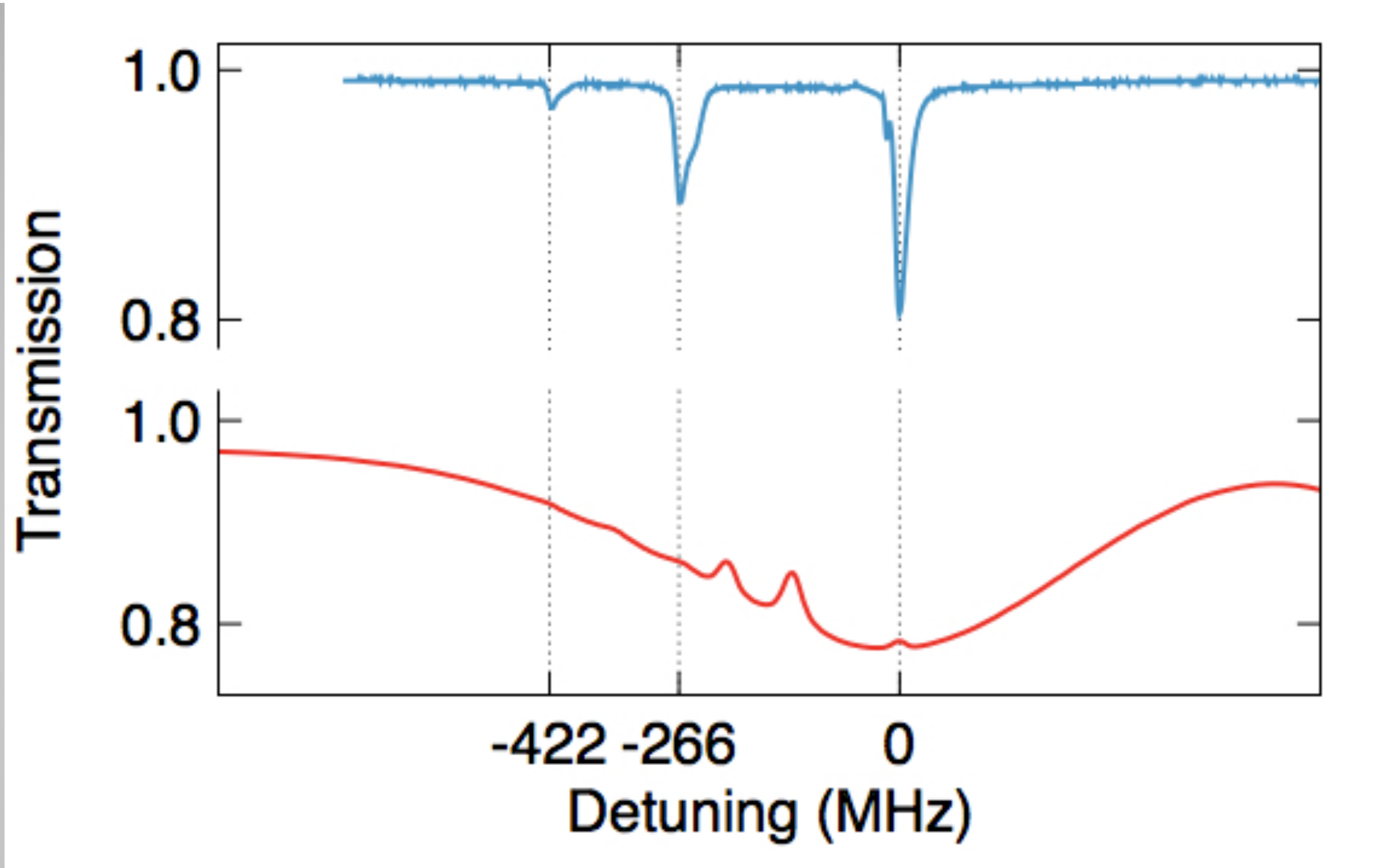


Achievements

Spherical MOT

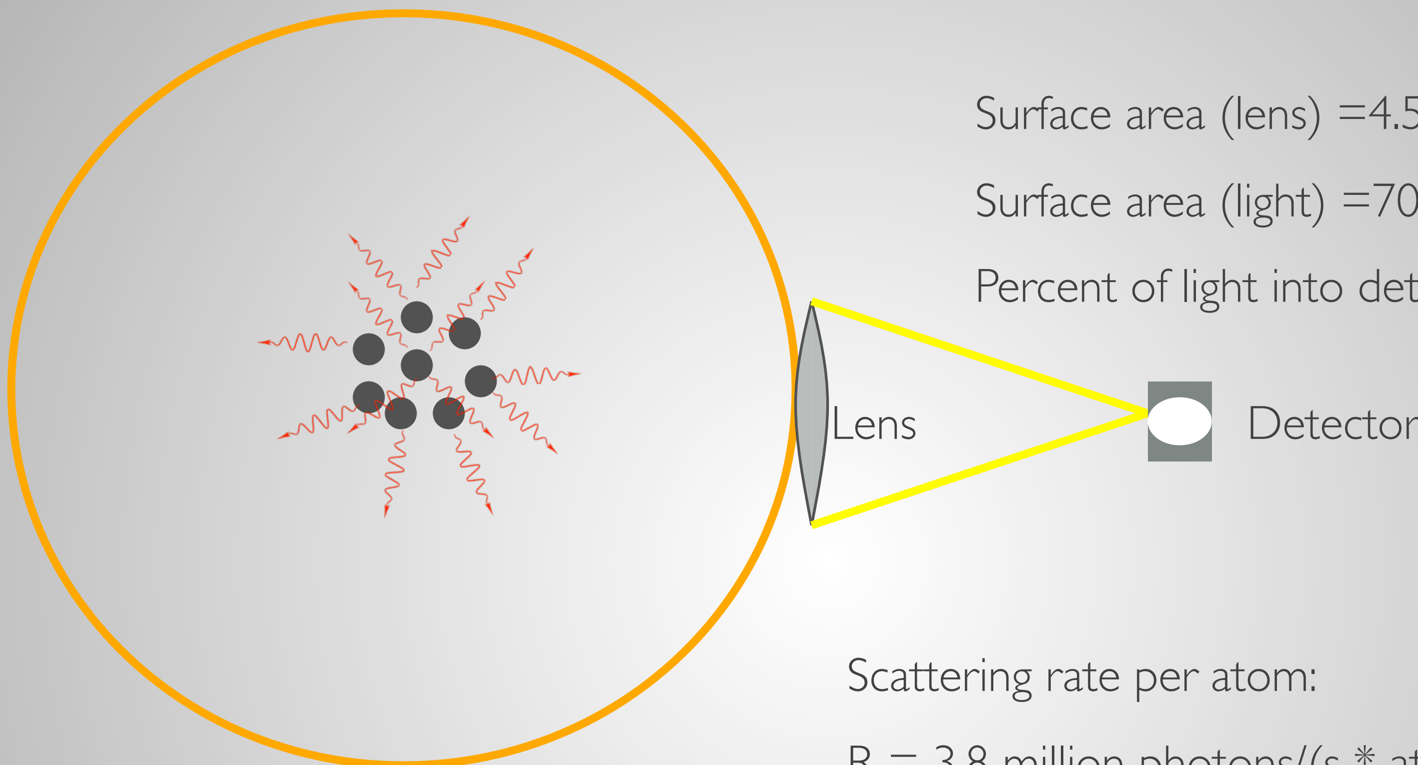
Spherical Mirror-MOT

Anisotropic MOT



Doppler-free spectrum without crossover resonances

Atom Number



Surface area (lens) $=4.5\ cm^2$

Surface area (light) $=7050\ cm^2$

Percent of light into detector = 0.06%

Scattering rate per atom:

R = 3.8 million photons/(s * atom)

Power (into detector):

P = $3.8E^{11}$ photons/second

Number of atoms:

P/(R*0.06) = 154 ± 22 million atoms

Summary

- The miniMOT allows the study of cold atoms in a small undergraduate lab
- Takes away hassle of vacuum pumps & cells
- Small and compact
- Easy to move around optics table or another lab space
- Progression of starting with spherical MOT, then spherical mirror MOT, then anisotropic MOT makes transitions easier and more reliable
- Making your own mirrors is easy and efficient

Acknowledgements

- Pacific Research Institute for Science and Mathematics (PRISM)
- M.J. Murdock Charitable Trust
- Research Corporation for Science Advancement
- Dan Steck – U. Oregon
- Cold Quanta Inc.

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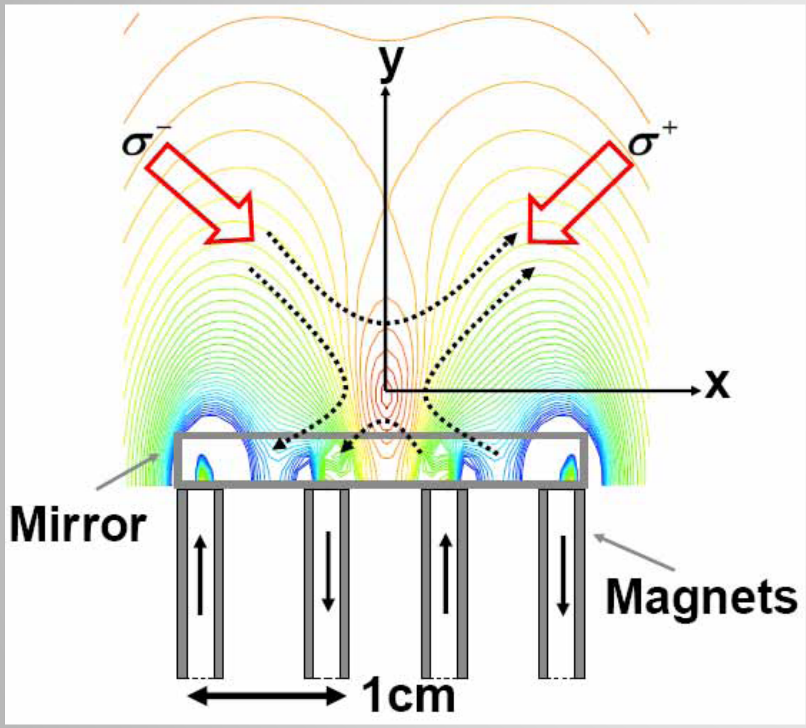
Foil Magnet Design



Greenberg et al., Opt. Express, 15, 17699 (2007)

- 4 Electro-Magnets, set in alternating field directions.
- Using these magnets in order to create the proper separation of levels, since our beams are now coming in at a 45 degree vertically.
- Creates a cloud very close to the bottom of the cell.

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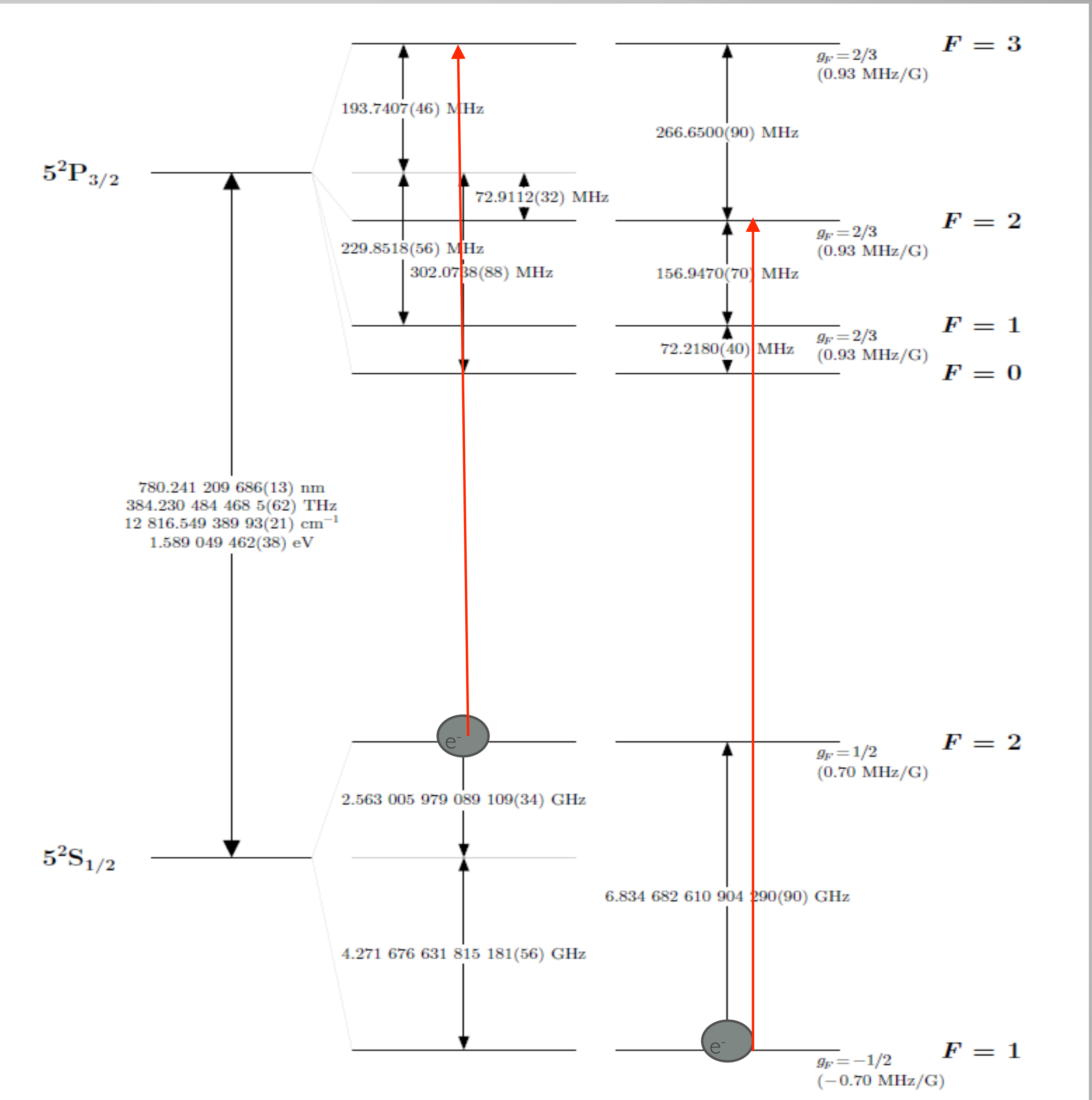
Rb Levels



Daniel A. Steck, "Rubidium 87 D Line Data," available online at http://steck.us/alkalidata (revision 2.1.2, 12 August 2009).

Scattering Rate

$$R = \frac{(I/I_s)\pi\Gamma}{1 + (I/I_s) + 4(\Delta/\Gamma)^2}$$

$I \rightarrow$ total optical intensity

$I_s \rightarrow$ saturation intensity

$\Gamma \rightarrow$ natural linewidth

$\Delta \rightarrow$ detuning from resonance

Wieman, Flowers, & Gilbert, Am. J. Phys. 63, 317 (1995)