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:

$$\langle \Delta p \rangle = \hbar k$$

$$\hbar \omega < E_2 - E_1$$
How Do You Trap Atoms?

- Circular Polarization
  - $\sigma_-$ Carries (-) angular momentum
  - $\sigma_+$ Carries (+) angular momentum

- Zeeman Shift

LCP

RCP

$B = 0$
No external magnetic field

$m_f$

$B > 0$
With external magnetic field

$m_f$

$\sigma_-$

$\sigma_+$

$\sigma_-$

$\sigma_+$
Magneto-optical trap 1D

- Magnetic field gradient creates position-dependent resonance

\[ \vec{B} = B \hat{z} \]

\[ z = 0 \]

\( \sigma_+ \) \( \sigma_- \) \( \sigma_+ \) \( \sigma_- \) \( \sigma_+ \) \( \sigma_- \)

(Red-detuned beams)
MiniMOT

- 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

www.coldquanta.com
Spherical MOT

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

- 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

- 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

- 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.

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

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Achievements

Spherical MOT

Anisotropic MOT

Spherical Mirror-MOT
Doppler-free spectrum without crossover resonances
Scattering rate per atom:
\[ R = 3.8 \text{ million photons/(s*atom)} \]

Power (into detector):
\[ P = 3.8 \times 10^{11} \text{ photons/second} \]

Number of atoms:
\[ \frac{P}{(R \times 0.06)} = 154 \pm 22 \text{ million atoms} \]

Surface area (lens) = 4.5 cm²
Surface area (light) = 7050 cm²
Percent of light into detector = 0.06%
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
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Foil Magnet Design

- 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.

Rb Levels

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