Optical Pumping

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MIT

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Introduction

- Non-equilibrium energy levels population.
- Atom state preparation.
- Laser cooling and trapping.

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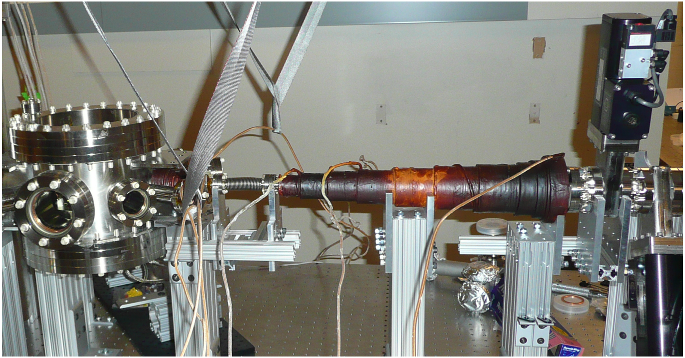


Zeeman slower which uses optical pumping and Zeeman effect to slow down a hot atom beam.

1. **Atom energy levels and optical pumping.**
2. **Apparatus and measurement.**
3. **Data and result.**
4. **Conclusion.**

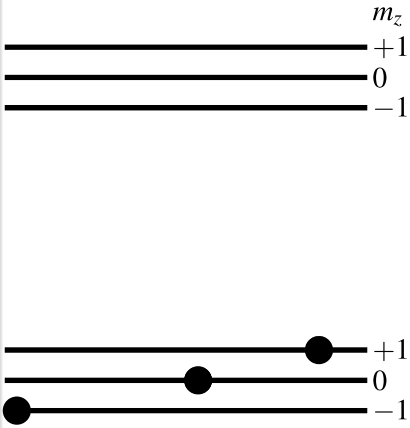
Atom energy levels and optical pumping.

- Fine, hyperfine structure, Zeeman splitting.

$$\left.\frac{n_1}{n_2}\right|_{fine} = \mathbf{e}^{-\beta\Delta E} \approx 1$$

- Optical pumping in m_z states.
  Circular polarization light,
  $\Delta m = +1$.
  Spontaneous emission,
  $\Delta m = 0, \pm 1$.
- Dark state.
- Depolarization using RF signal.

$$\Delta\mu B = hf$$



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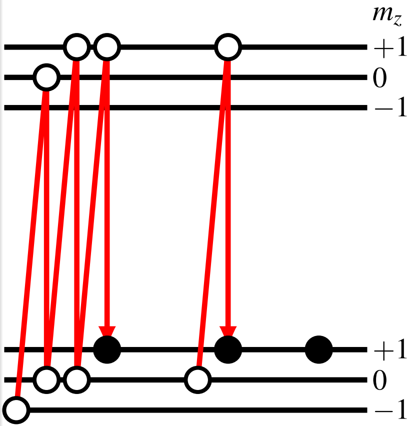

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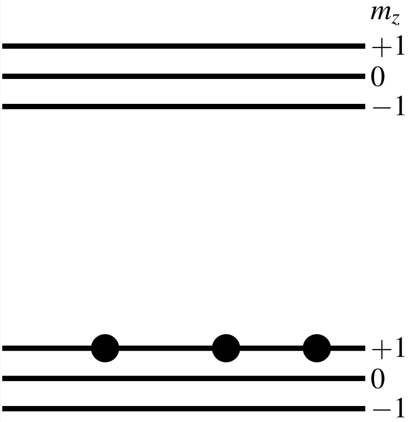

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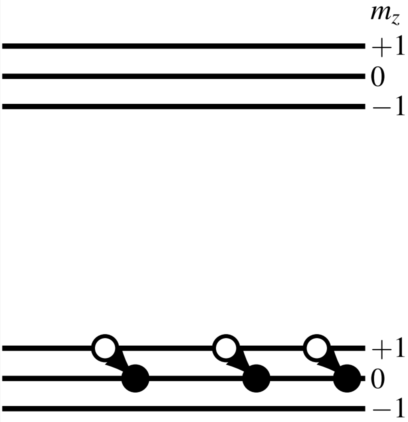
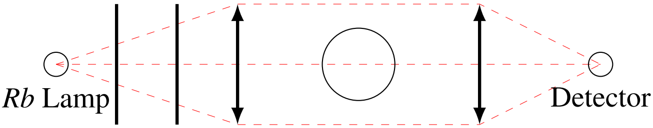


Apparatus.



- Circular polarization.
- ^{85}Rb and ^{87}Rb
- B field.
- RF field.

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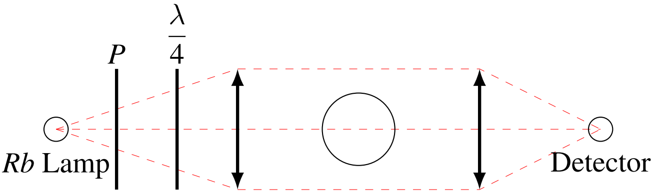

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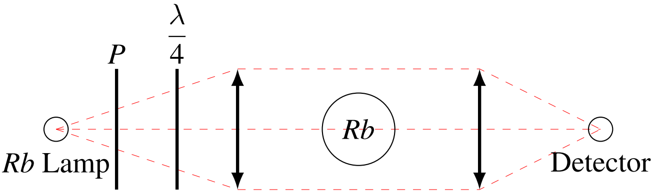

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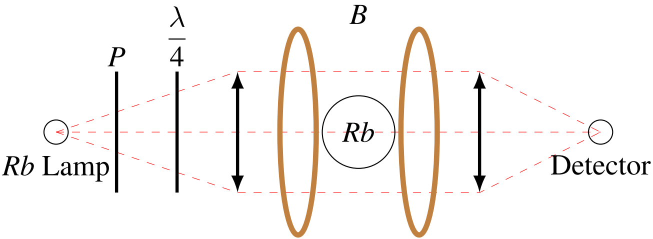

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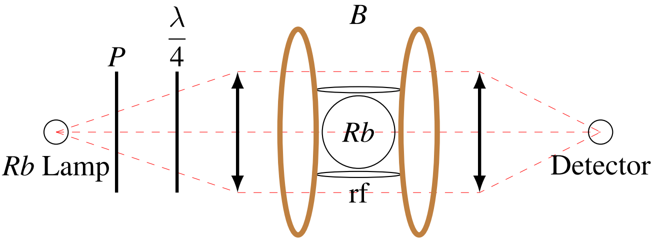

- Circular polarization.
- ${}^{85}Rb$ and ${}^{87}Rb$
- B field.
- RF field.

Measurement

$$\Delta\mu B = hf$$

$$f_{RF} = \frac{g_F\mu_B}{h}\sqrt{(B_x + B_{x0})^2 + (B_y + B_{y0})^2 + (B_z + B_{z0})^2}$$

- Scan RF frequency.
- Scan B field.
- Switch B field.

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- Scan RF frequency.
- Scan B field.
- Switch B field.

Scaning RF frequency at different B field.

- Measure/cancel earth magnetic field.
- Absorption strength (Natural Abundance).

$$I_{absorb} \propto NA \cdot g_F^2$$

Measurement

$$\Delta \mu B = hf$$

$$f_{RF} = \frac{g_F \mu_B}{h} \sqrt{(B_x + B_{x0})^2 + (B_y + B_{y0})^2 + (B_z + B_{z0})^2}$$

- Scan RF frequency.
- Scan B field.
- Switch B field.

Scan B field at different RF frequency.

- Measure resonance frequency.

Measurement

$$\Delta\mu B = hf$$

$$f_{RF} = \frac{g_F \mu_B}{h}\sqrt{(B_x + B_{x0})^2 + (B_y + B_{y0})^2 + (B_z + B_{z0})^2}$$

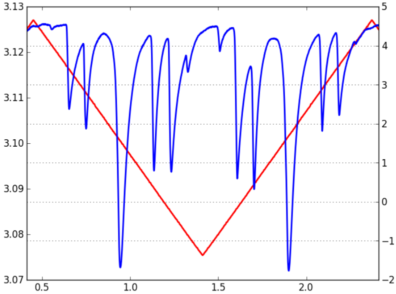
- Scan RF frequency.
- Scan B field.
- Switch B field.

Switch B at different light intensity.

- Measure pumping rate.

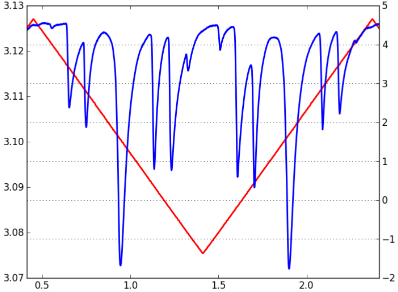
$$R \propto I_{light}$$

Scanning B field.



Light intensity when scanning B field.

Scanning B field.

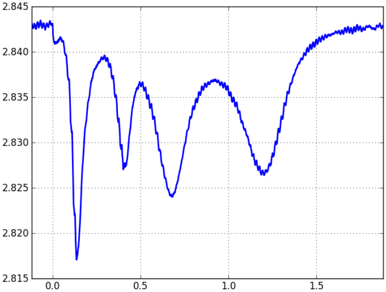


Light intensity when scanning B field.

g_F factor.

Isotrope	Measured	Expected
^{85}Rb	$0.498(19)$	0.500
^{87}Rb	$0.331(13)$	0.333

Scanning RF frequency.



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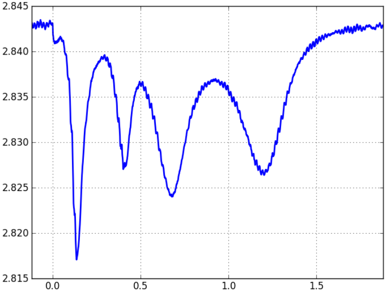

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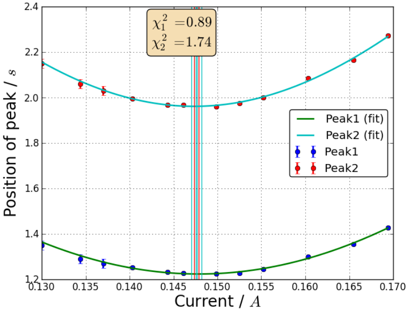
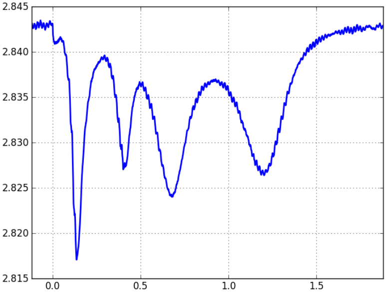


Peak positions at different y current

Ambient magnetic field.

B_x/mGs	$361(10)$
B_y/mGs	$72.2(1.6)$
B_z/mGs	$191.6(5.2)$

Scanning RF frequency.



Light intensity when scanning RF frequency.

Natural Abundance.

Isotrope	Measured	Expected
^{85}Rb	$72.0(2.2)\%$	72.168%
^{87}Rb	$28.0(2.2)\%$	27.835%

Conclusion.

- Observed optical pumping and depolarization.
- Ambient megnetic field.
- g_F factors.
- Natural abundance of ^{85}Rb and ^{87}Rb.

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Landé g-factor

$$g_J \approx \frac{3}{2} + \frac{S(S+1) - L(L+1)}{2J(J+1)}$$

$$g_F \approx g_J \frac{F(F+1) - I(I+1) + J(J+1)}{2F(F+1)}$$

$$S = \frac{1}{2} \qquad L = 0 \qquad J = \frac{1}{2}$$

$$I = \begin{cases} \frac{5}{2} & (^{85}Rb) \\ \frac{3}{2} & (^{87}Rb) \end{cases}$$

$$F = \begin{cases} 3 & (^{85}Rb) \\ 2 & (^{87}Rb) \end{cases}$$

$$g_F = \begin{cases} \frac{1}{3} & (Rb^{85}) \\ \frac{1}{2} & (Rb^{87}) \end{cases}$$