

# Optical Pumping

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# Introduction

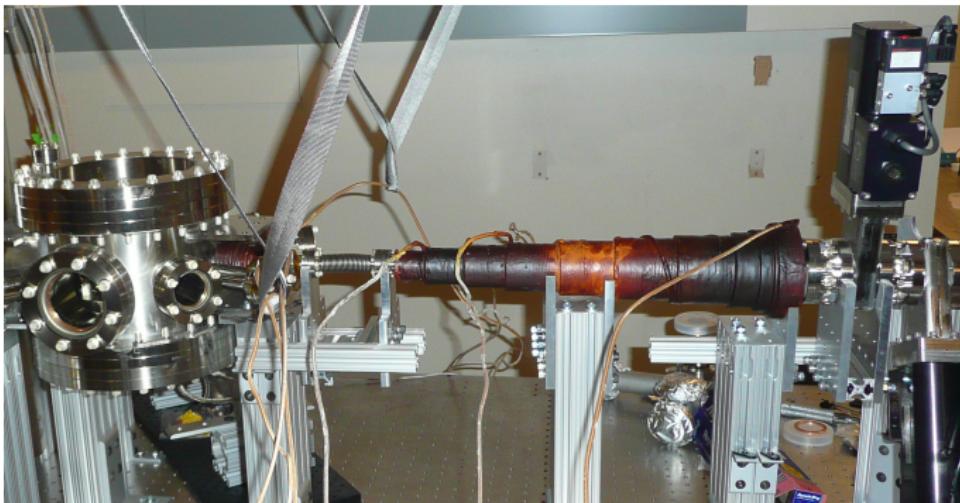
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- Atom state preparation.
- Laser cooling and trapping.

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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.

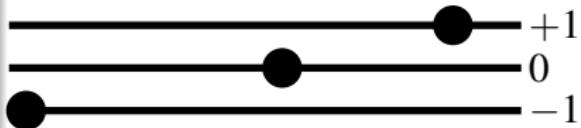
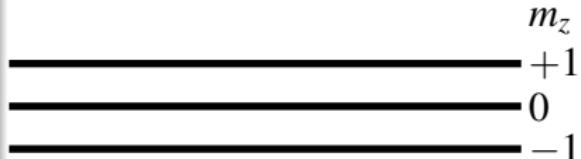
## Atom energy levels and optical pumping.

- Fine, hyperfine structure, Zeeman splitting.

$$\frac{n_1}{n_2} \Big|_{\text{fine}} = e^{-\beta \Delta E} \approx 1$$

- 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.

$$\Delta \mu B = hf$$



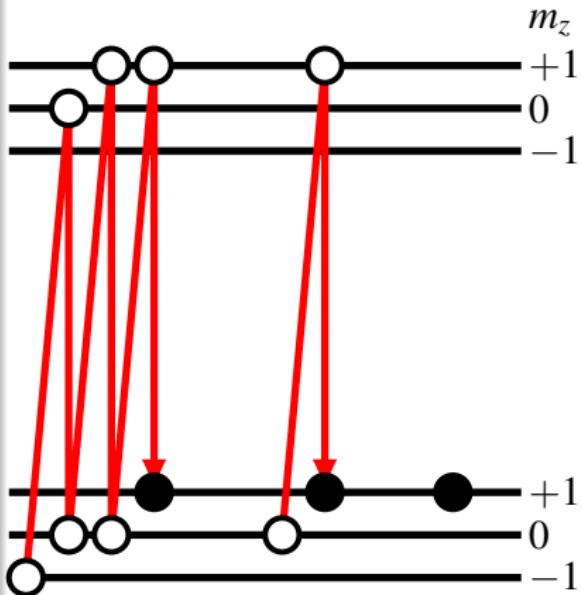
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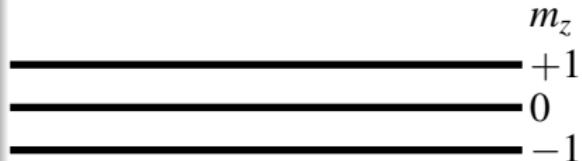
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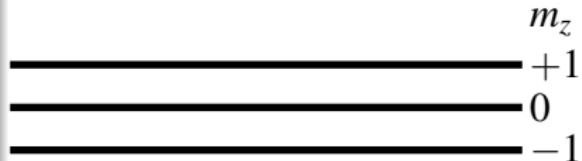
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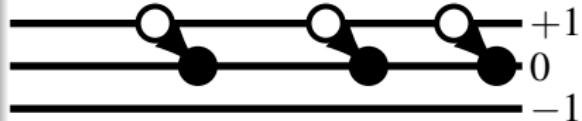
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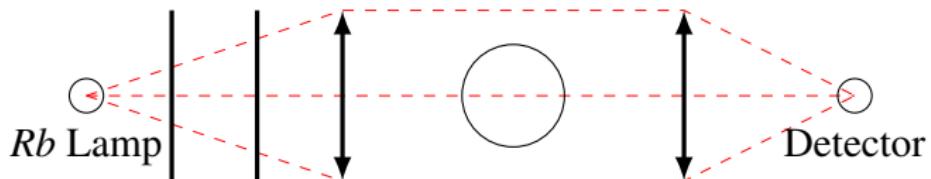


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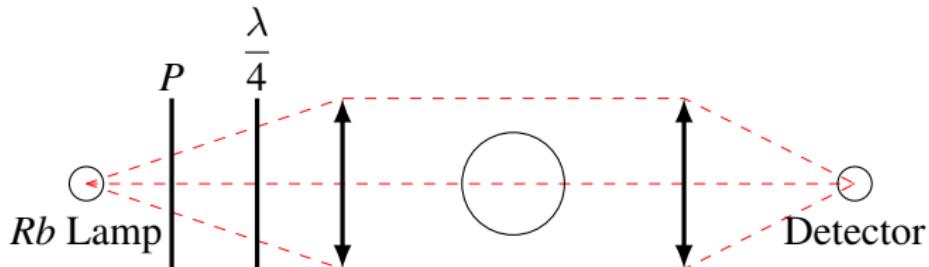


# Apparatus.



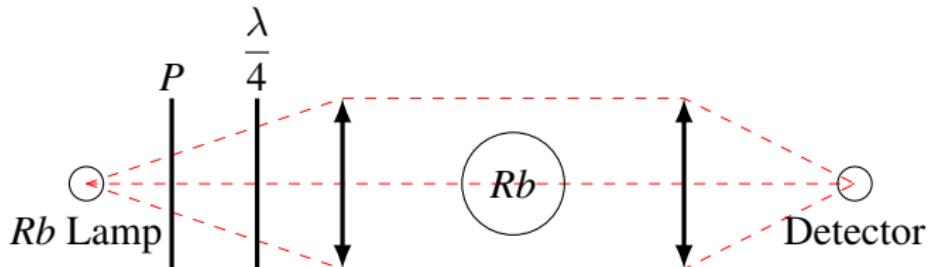
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- $^{85}Rb$  and  $^{87}Rb$
- $B$  field.
- RF field.

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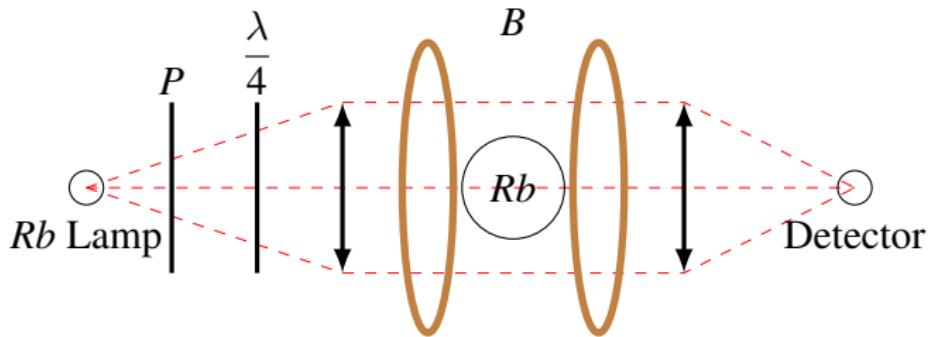
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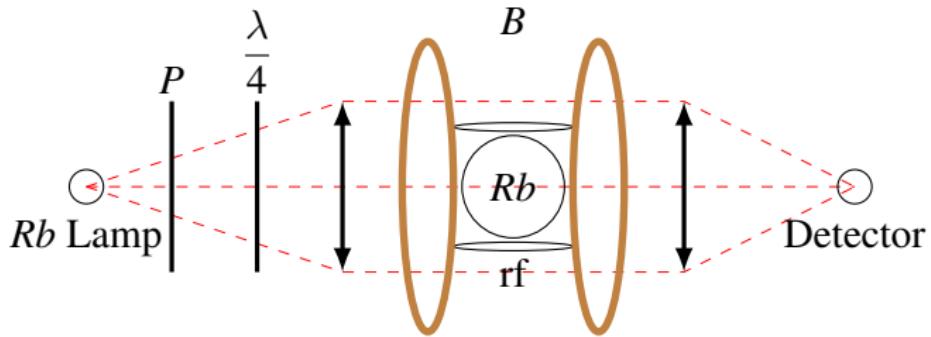
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## Measurement

$$\Delta\mu B = hf$$

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

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

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## Scanning RF frequency at different $B$ field.

- Scan RF frequency.
  - Scan  $B$  field.
  - Switch  $B$  field.
- Measure/cancel earth magnetic field.
  - Natural Abundance. Different from the strength of the absorption.

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

# Measurement

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

**Scan  $B$  field at different RF frequency.**

- Measure resonance frequency.

# Measurement

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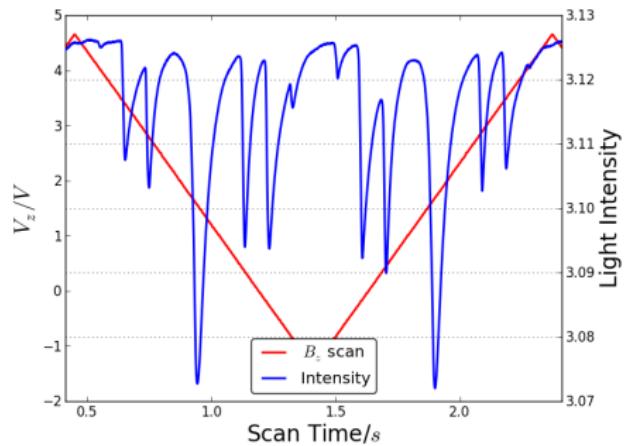
- Scan RF frequency.
- Scan  $B$  field.
- Switch  $B$  field.

**Switch  $B$  at different light intensity.**

- Measure pumping rate.

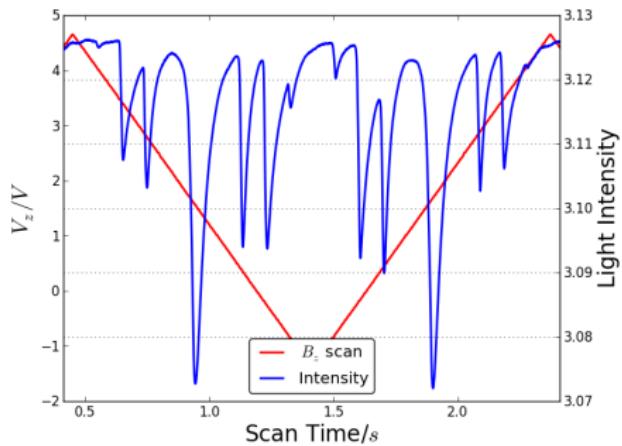
$$R \propto I_{light}$$

## Scanning $B$ field.



Light intensity when scanning  $B$  field.

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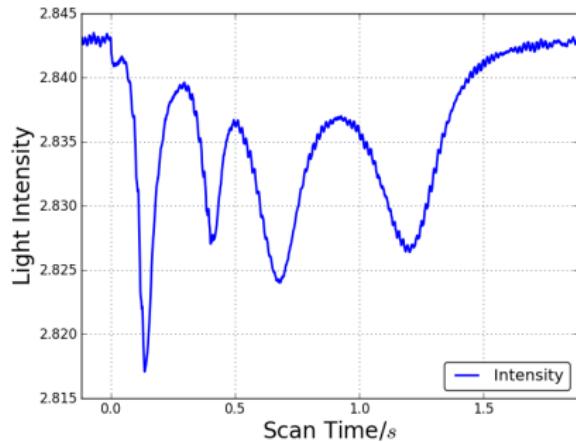


$g_F$  factor.

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

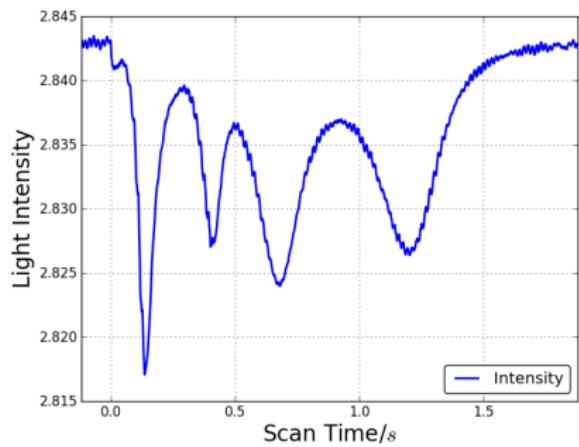
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## Scanning RF frequency.

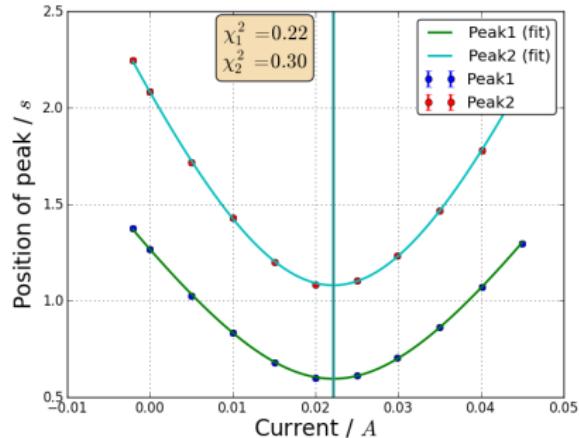


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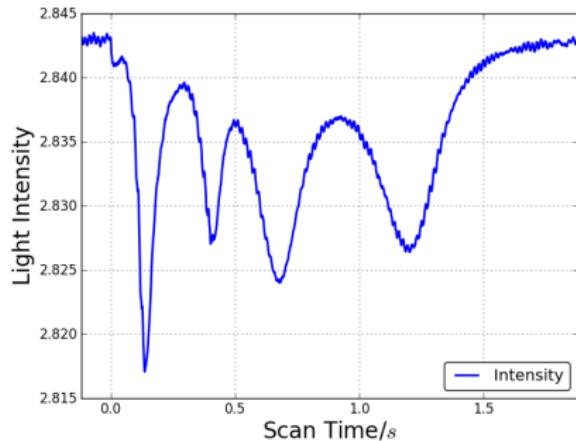


Peak positions at different y current

## 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.

Isotope	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 magnetic field.
- $g_F$  factors.
- Natural abundance of  $^{85}Rb$  and  $^{87}Rb$ .

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## Landé g-factor

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

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

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

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

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

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