OPTICAL PUMPING

Trapping Electrons With Light

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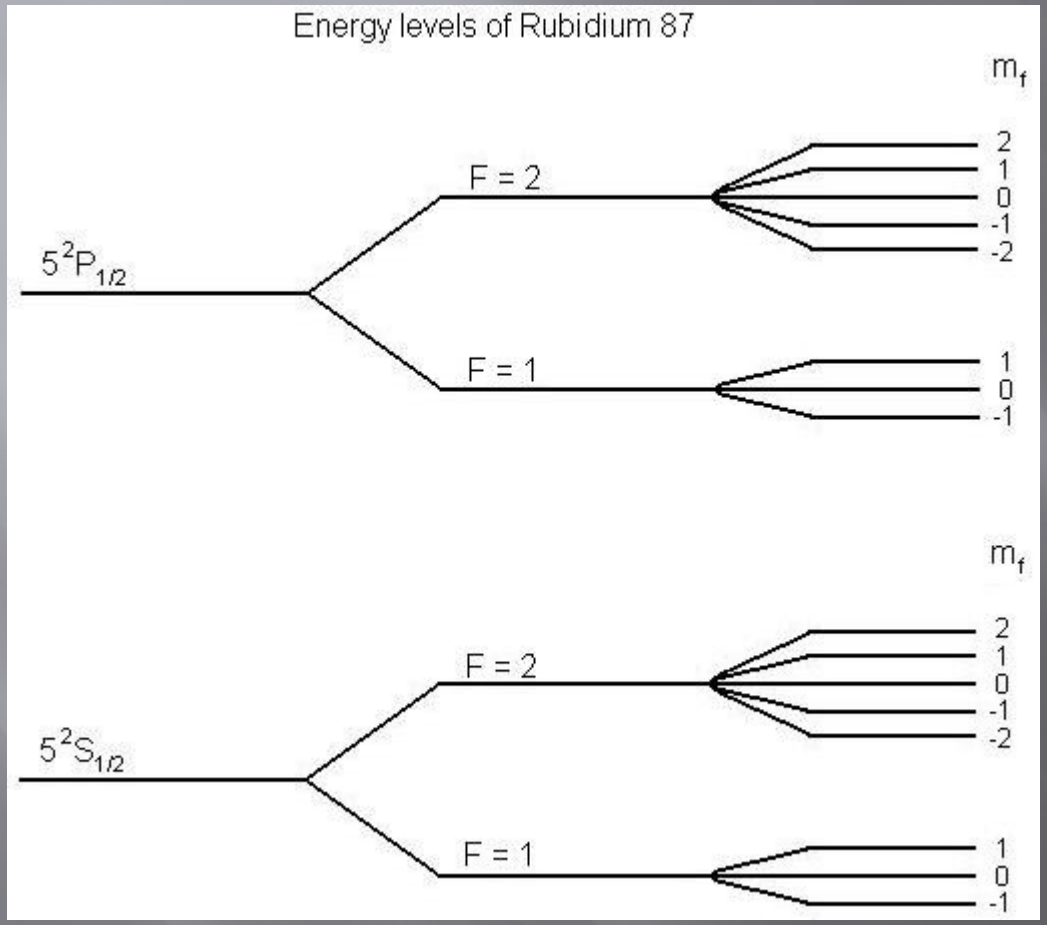
Motivation

- Demonstrate Zeeman Splitting
- Determine the g-factor of Rb^{85} and Rb^{87}
- Optical pumping lab rarely gets completed by students

“It is only a small exaggeration to claim these [optical pumping] experiments constitute an atomic physics course.”

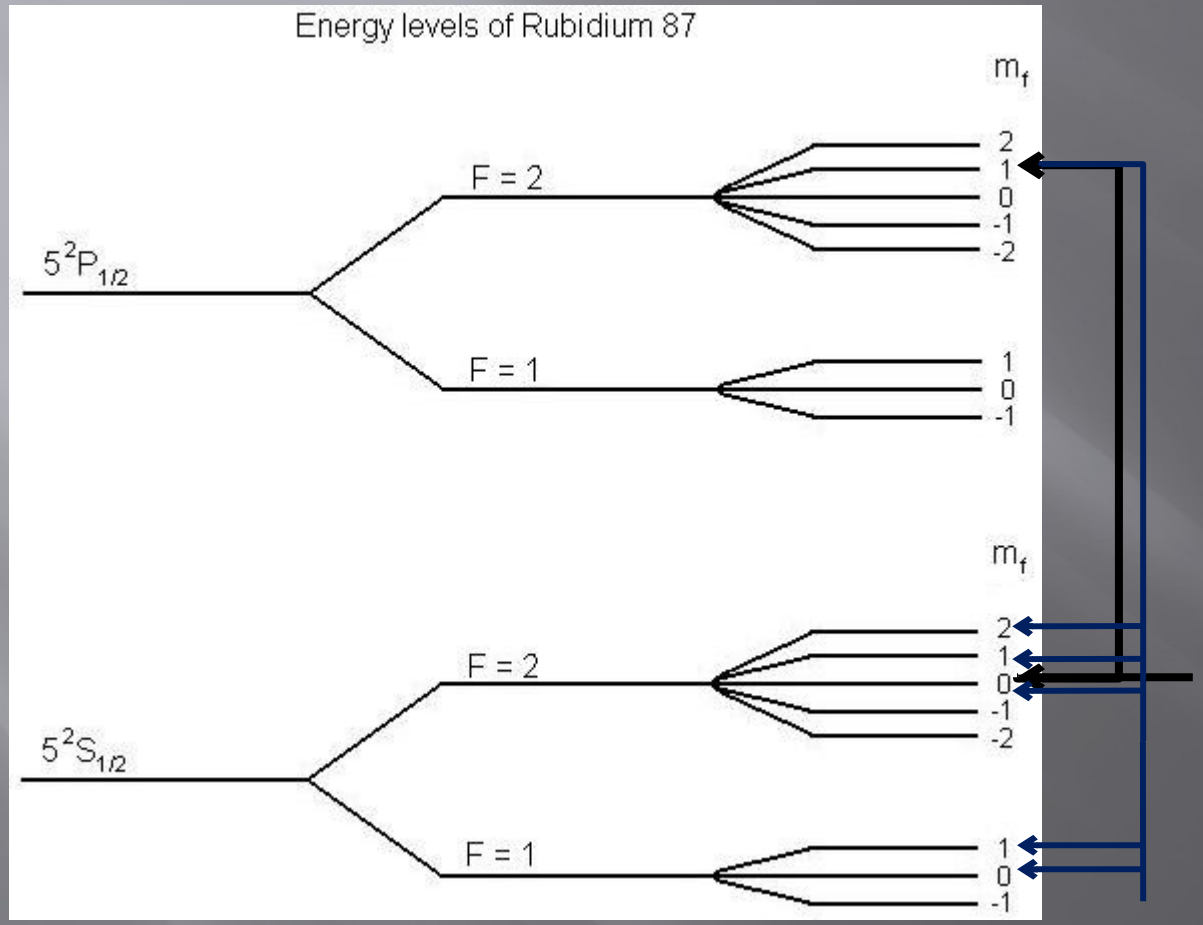
-TeachSpin Manual

Zeeman Splitting



- Fine and Hyperfine states from electron spin dipoles and orbit fields
- In the presence of a magnetic field Hyperfine energy states are split

Induced Transitions



- Electron in state
- 798.4 nm photon induces transition
- Spontaneous emission
- Emission in all directions
- Start again!

Pumping

- Electrons emit a photon and loose energy
- Electrons can deexcite to any Zeeman state with equal probability
- Highest Zeeman state of the non-excited energy level can not gain a unit of angular momentum
- Electrons cannot transition and will accumulate in that level
- They have been “pumped” with optical waves!

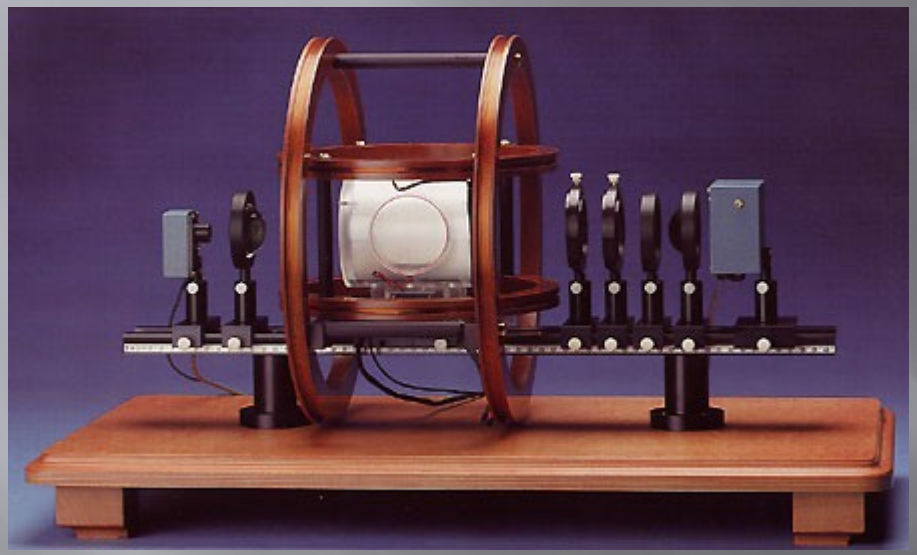
Zero Field Transition

- Electrons are in the pumped state
- Maximum transmission of light
- Magnetic field diminishes to zero
- Zeeman states collapse
- Light transmission decreases as absorption increases

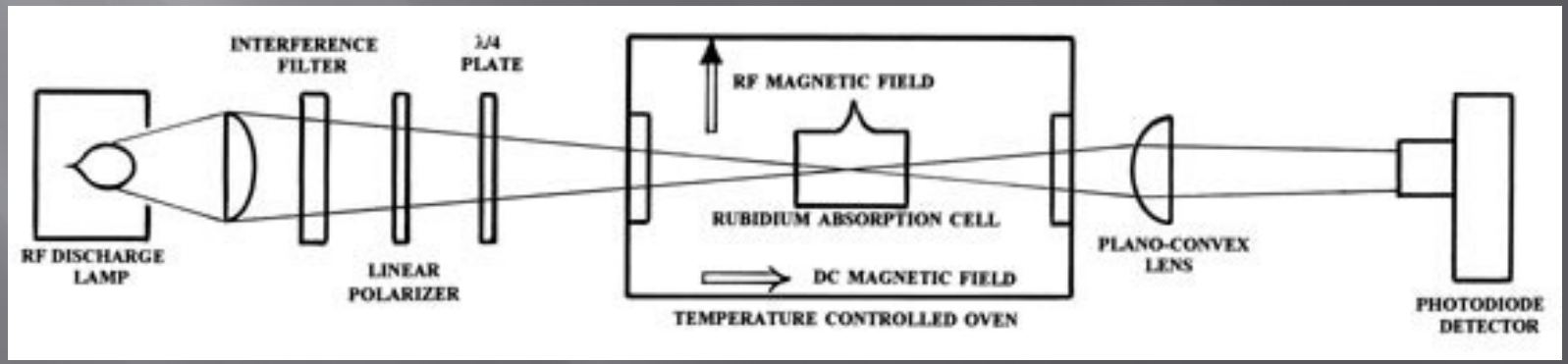
EM Transition

- Electrons are in the pumped state
- Maximum transmission of light
- Input EM wave matches the energy difference between Zeeman states
- Transitions occur that drop the electrons out of the pumped state
- Light transmission decreases as absorption increases

Apparatus



1. RF discharge lamp
2. Optics
3. Pumping Cell
4. Optics
5. Detector
6. Magnetic Coils



Optics

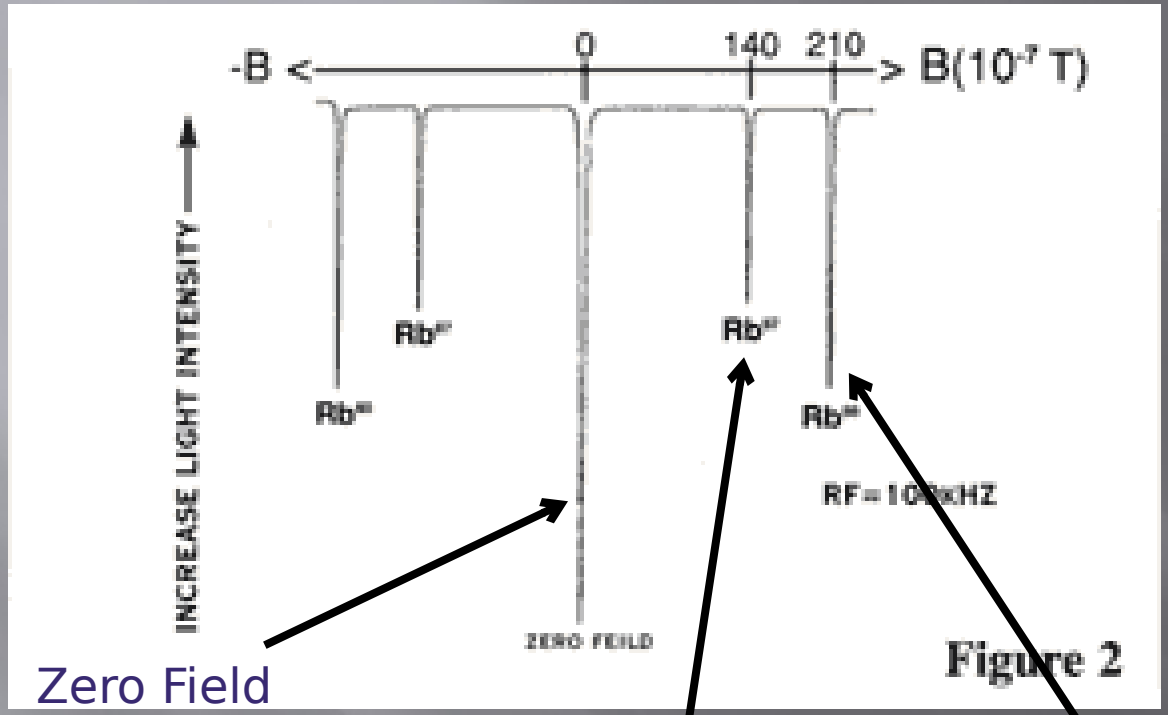
- RF discharge lamp provides light
  - Composed of Rb^{85}, Rb^{87} and Xenon gas (buffer)
- Plano-convex lens to collimate
- Interference filter to transmit 798.4 nm light
- Linear polarizer
- ¼ wave plate to circularly polarize light
  - Ensures direction independent absorption
- Plano-convex lens for focusing
- Photodiode detector

Magnetic Coils

- Three pairs of Helmholtz coils
  - Vertical field
    - 1.5 gauss/amp; 1.4 gauss max
  - Horizontal field
    - 8.8 gauss/amp; 8 gauss max
  - Horizontal sweep
    - 0.60 gauss/amp; 1 gauss max
- Radio Frequency (RF) coil
  - 10 kHz – 100 MHz range

Homogeneity > 2 Gauss over cell

Detection



- Photodiode converts light to voltage
- Oscilloscope plots photodiode voltage versus coil current
- A decrease in light intensity: dip in the scope trace
- Dip less than 1% magnitude
- High gain (1-1000) allows easy detection

Zero Field Transition

Rb^{87} EM Dip

Rb^{85} EM Dip

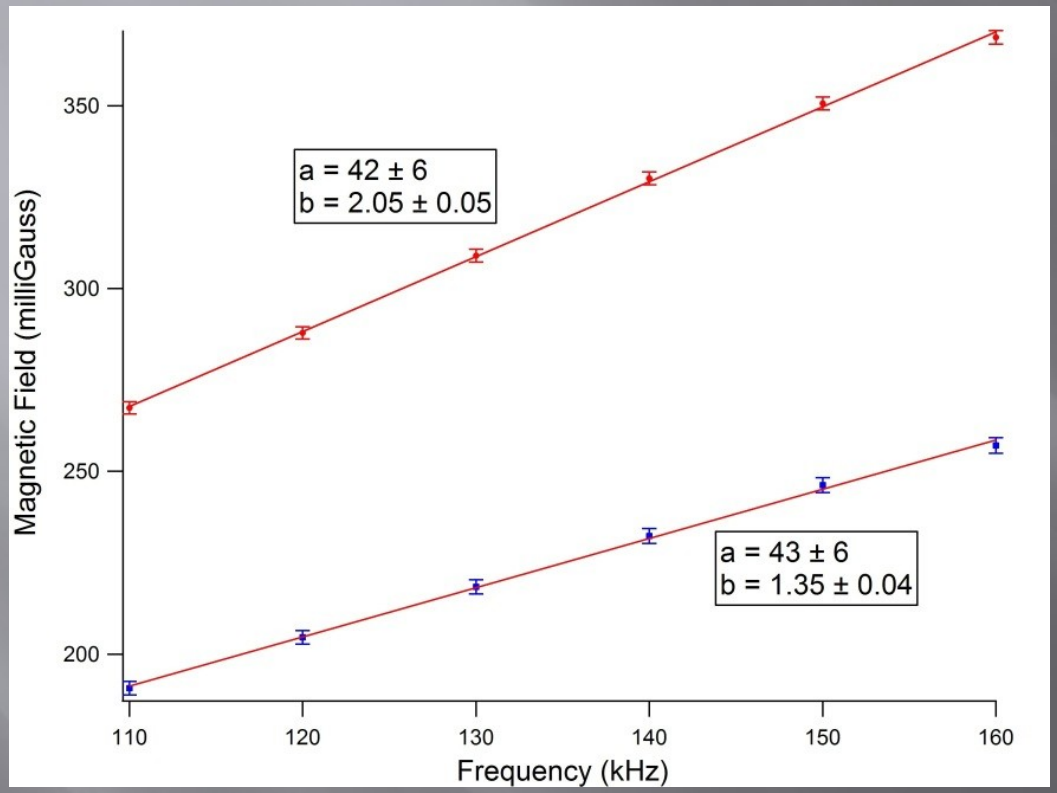
Methodology

- Temperature stabilization
- Alignment
- Gain settings
- Sweep the horizontal field
- Locate Zero Field Transition
- Minimize width with vertical field coil
- Input EM wave
- Search for EM dip
- Change frequency

Error and Uncertainty

- Coil Current
  - Current conversion less than 1% offset
  - Voltmeter uncertainty (0.15%±2)
- Inhomogeneity of Helmholtz coil fields
- Alignment parallel to geomagnetic field
- Area magnetic fields
  - Moving elevator
  - Metallic structure

Results



$$g_{Rb^{85}} = 0.531 \pm 0.007$$
$$g_{Rb^{87}} = 0.340 \pm 0.003$$
$$B_E = 106 \pm 12\text{mG}$$

Acknowledgements

- My partner: S. Halder
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- Prof. Han for suggestions and help