Modeling Optical Pumping in Rubidium Vapor and Determining the Mean Free Path of Light

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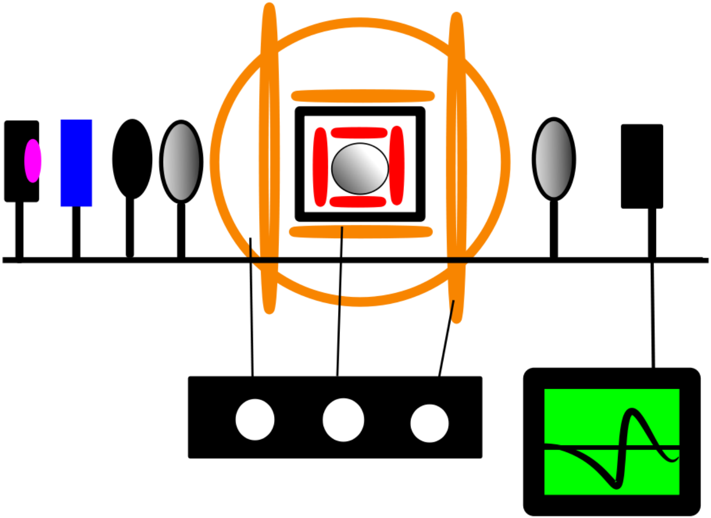
Outline

- Goals & Objectives
- Experimental Setup
- Optical Pumping: The Model
    - Simplifying the model
- The Decay Constants
- Mean Free Path
- Error Analysis and Conclusions

Goals & Objectives

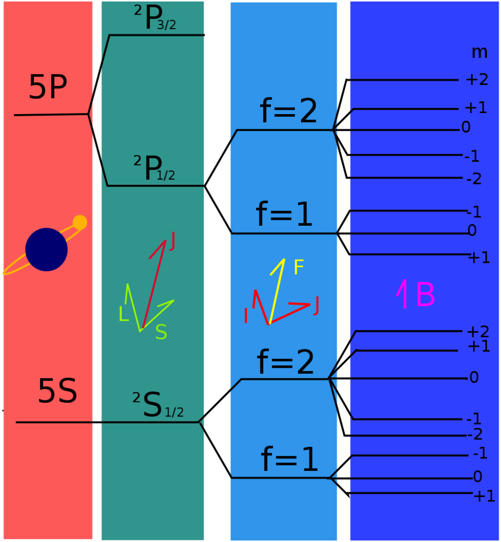
- Construct a model of optical pumping in rubidium vapor
- Determine the optical pumping and depolarizing collision time constants associated with optical pumping for our rubidium sample
- Calculate the mean free path of photons traveling through rubidium vapor

Experimental Setup



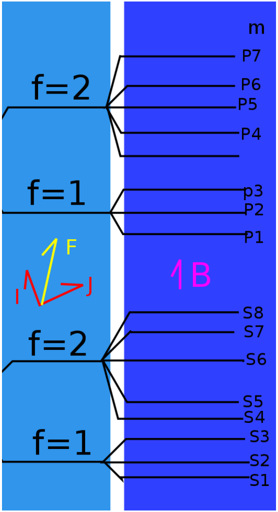
Optical Pumping: The Model

Energy Level Splitting



Optical Pumping: The Model

A (Nearly) Complete Model



$$s_1' = -P_1 s_1 + \frac{1}{3} D_1 p_1 - C_1 s_1 + \frac{1}{2} C_2 s_2$$

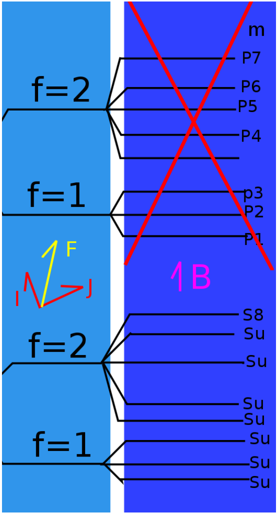
$$s_2' = -P_2 s_2 + \frac{1}{3}(D_1 p_1 + D_2 p_2) - C_2 s_2 + C_1 s_1 + \frac{1}{2} C_3 s_3$$

$$\ldots$$

$$s_8' = \frac{1}{2} D_7 p_7 + \frac{1}{3} D_6 p_6 - C_8 s_8 + \frac{1}{2} C_7 s_7$$

$$p_1' = P_1 s_1 - D_1 p_1$$

$$\ldots$$



$$s_8' = -Rs_8 + Ps_u$$

$$s_u' = -Ps_u + Rs_8 + To$$

$$o' = -To$$

Optical Pumping: The Model
A Solution

$$s_u = \frac{7(m-n)R(P+R-T)+7(m-n)P(T-R)e^{-Tt}+P(m(P+8R-8T)+7n(T-R))e^{-(P+R)t}}{7P(P+R-T)}$$

Optical Pumping: The Model

To Opacity

$$I = I_0 e^{-\frac{kxs_u M_{Rb}}{VNa}}$$

Fit Function

$$I = A - Be^{-Qt} + Ce^{-Tt}$$

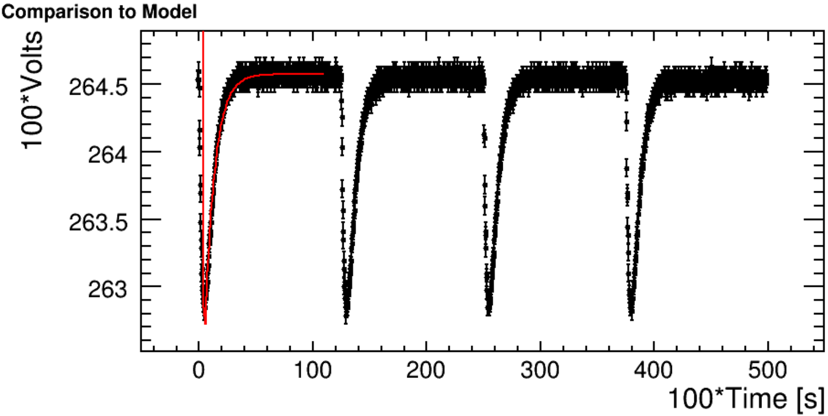


Figure: χ^2/NDF = .68

The Decay Constants
Pumping Rate

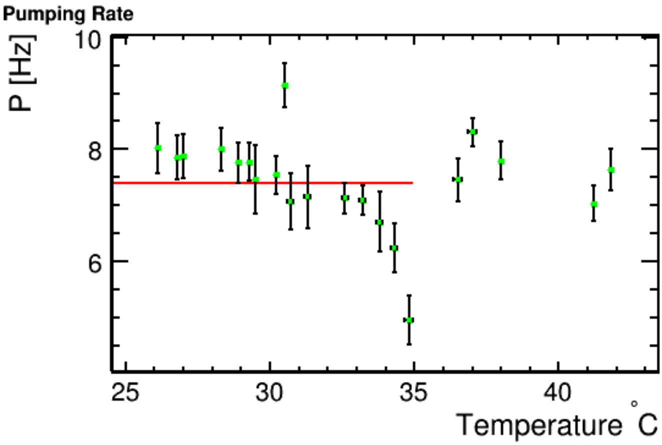


Figure: Average P = 7.4 ± 0.1 Hz

The Decay Constants
Relaxation Rate

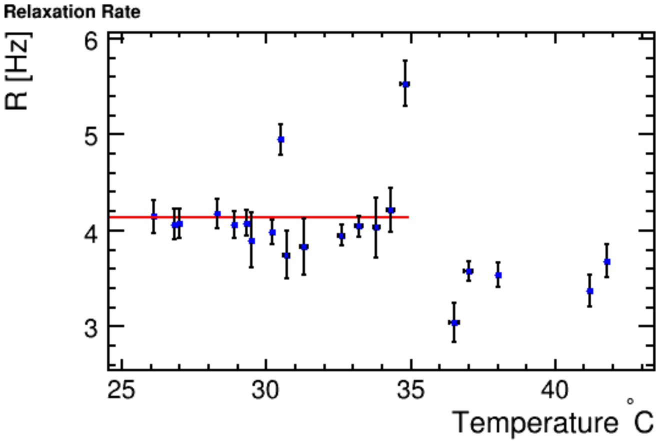


Figure: Average R = 4.14 ± 0.04 Hz

Mean Free Path

Mean Free Path of a Photon in Unpumped Rubidium

$\lambda = 1000 \pm 100$ cm at 26.6 °C

Error Analysis and Conclusions

Error Analysis

- Dominating aparatus source of error from digitzation of signal
  - 0.000655 V
  - 0.00125 s
- Dominating statistical error is fitting error: $\approx 2\%$
- In calculating λ, additional statistical error in bulb size $\approx 0.012\%$
- Additional unknown systematic error in measurement if I_0

Error Analysis and Conclusions

Conclusions

- Model fit data well
- Average P = 4.7 ± 0.1 Hz
- Average R = 4.14 ± 0.04 Hz
- $\lambda = 1000 \pm 100$ cmat 26.6°C

Acknowledgements

We would gratefully like to thank the Junior Lab faculty for helping us understand this experiment and learn what to do