Diode Laser Absorption Spectroscopy of Rubidium

Iago B. Mendes
Lab partner: Avay Subedi

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Introduction

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- Study hyperfine splitting of the ground state of rubidium (^{85}Rb and ^{87}Rb)

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- Measure it using absorption spectroscopy
- Use a diode laser and a Fabry-Perot resonator
- Test consistency of measured hyperfine splittings with literature values

Theory

Energy splittings

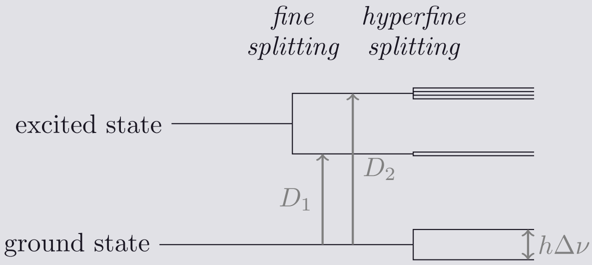
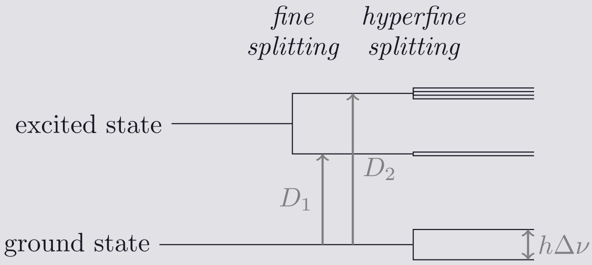


Figure 1

Energy splittings

- ^{85}Rb and ^{87}Rb outermost electron
  ground state $\rightarrow$ 5s ($\ell = 0$)
  excited state $\rightarrow$ 5p ($\ell = 1$)



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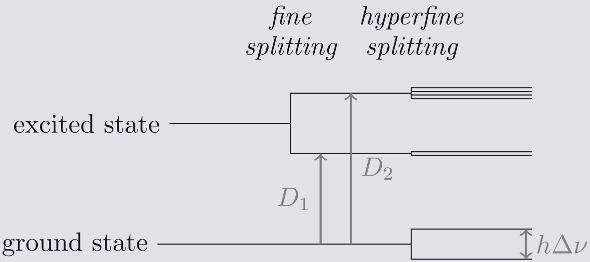
  different excitations: D_1 and D_2



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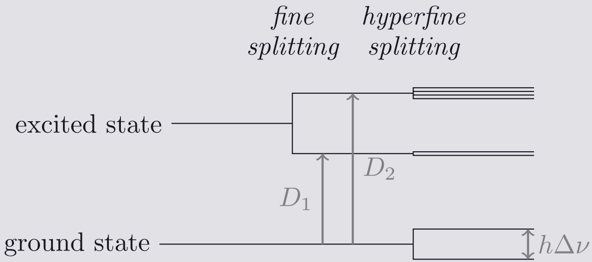
- Spin-orbit interaction $\rightarrow$ fine splitting
  different excitations: D_1 and D_2
- Electron-nucleus interaction $\rightarrow$ hyperfine splitting



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- Transmission spectrum shows dips at resonant frequencies

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- $\lambda \sim 780$ nm
  $\Rightarrow$ sweep current over time to get all peaks

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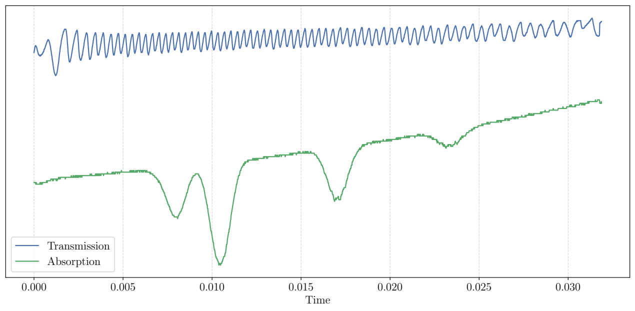
- Enables time-to-frequency conversion

Results

Transmission and absorption data



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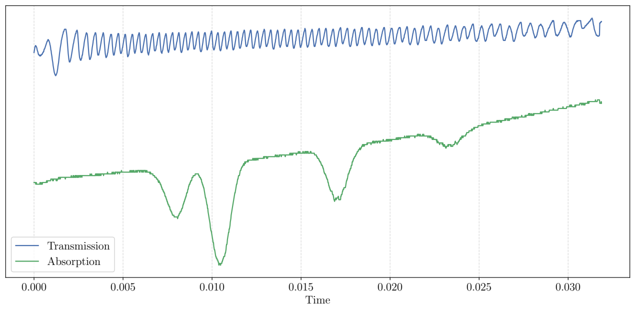
Transmission and absorption data

- Manually selected the times for each transmission peak



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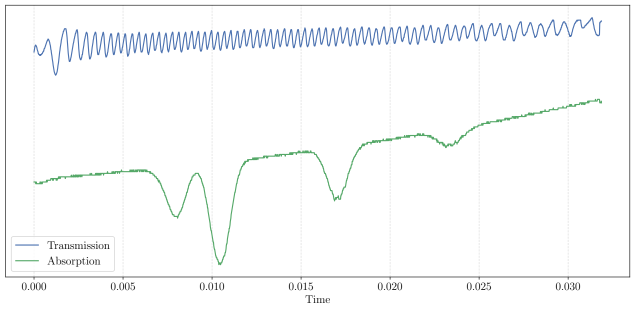
Transmission and absorption data

- Manually selected the times for each transmission peak
- Used Igor Pro to fit to a function for the cummulative number of peaks at a given time

$$N(t) = K_0 + K_1 t + K_2 t^2 + K_3 t^3 \tag{2}$$



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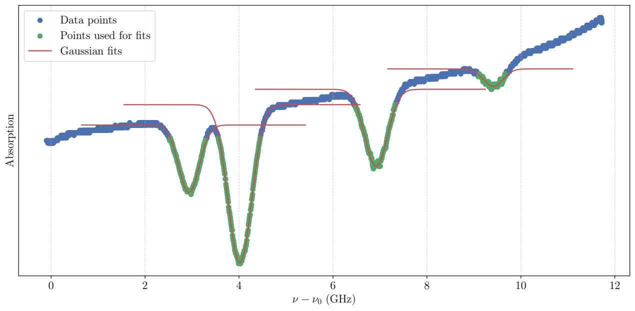
- Conversion function

$$\begin{aligned} \nu(t) &= \Delta\nu_{\text{FSR}} N(t) + \nu_0 && (6) \\ &= \Delta\nu_{\text{FSR}}(K_0 + K_1 t + K_2 t^2 + K_3 t^3) + \nu_0 && (7) \end{aligned}$$

Absorption spectrum



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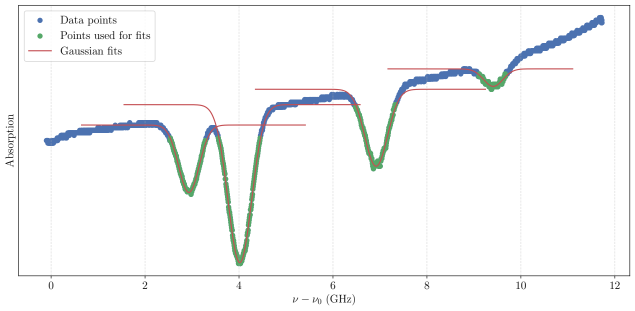
Absorption spectrum

- Gaussian fits with `scipy`



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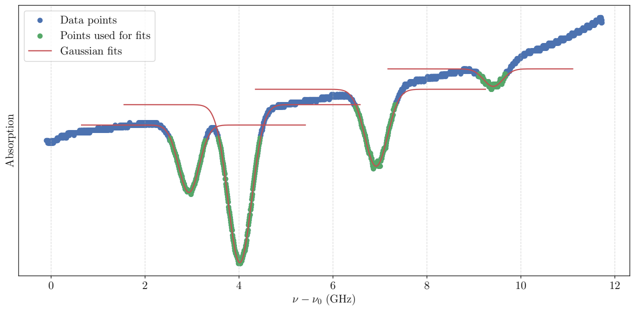

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Absorption spectrum

- Gaussian fits with `scipy`
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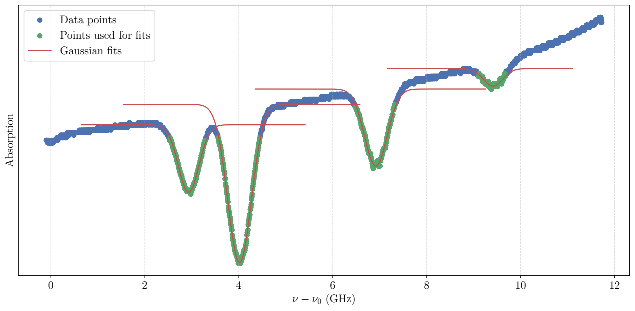
- Used literature values to identify peaks

$$\text{2nd and 3rd} \rightarrow {}^{85}\text{Rb}$$
$$\text{1st and 4th} \rightarrow {}^{87}\text{Rb}$$



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Hyperfine splittings

- Measurements

$$\Delta\nu(^{87}\mathrm{Rb}) = 6.5(5)\ \mathrm{GHz} \tag{8}$$

$$\Delta\nu(^{85}\mathrm{Rb}) = 2.9(3)\ \mathrm{GHz} \tag{9}$$

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- Literature values[1]

$$\Delta\nu_{\mathrm{literature}}(^{87}\mathrm{Rb}) = 3.035732439(6)\ \mathrm{GHz} \tag{10}$$

$$\Delta\nu_{\mathrm{literature}}(^{85}\mathrm{Rb}) = 6.83468261090429(9))\ \mathrm{GHz} \tag{11}$$

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Peak widths

- Expected width due to Doppler broadening for 780 nm laser[2]

$$\delta\nu_{\mathrm{Doppler}} = 502 \text{ MHz}. \tag{12}$$

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$$\delta\nu_1 = 520(10) \text{ MHz}, \tag{14}$$
$$\delta\nu_2 = 590(6) \text{ MHz}, \tag{15}$$
$$\delta\nu_3 = 570(20) \text{ MHz}, \tag{16}$$
$$\delta\nu_4 = 490(90) \text{ MHz}. \tag{17}$$

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Conclusion

Summary

- Successfully measured hyperfine splitting for ^{85}Rb and ^{87}Rb
- Results consistent with literature values within experimental uncertainty
- Peak width measurements affected by Doppler broadening and misalignment
- Possible improvements:
  - Adjust diode laser parameters to align peak offsets
  - Improve frequency resolution with better laser stability

The end

Thank you! Any questions?