SPECTROSCOPY

We will proceed in steps:

1) If a light with power P_{pd} hits the photodiode we will see a voltage

$$V_{pd} = G\, P_{pd} \quad , \quad G := \text{photodiode gain}$$

2) If a light intensity I_0 enters the cell we will have

$$I_{out} = I_0\, e^{-K(\omega)\Delta z} \qquad \Delta z := \text{cell length},\quad K(\omega) := \text{absorption profile}$$

3) If I modulate my laser current I get

$$\omega_\ell = a_\omega V_{fg} + b_\omega \qquad I_\ell = a_I V_{fg} + b_I$$

Taking everything into account I should have

$$V_{pd}(V_{fg}) = G(a_I V_{fg} + b_I)\, e^{-K(a_\omega V_{fg} + b_\omega)\Delta z} \quad , \quad (P_{pd} \propto I_{out})$$

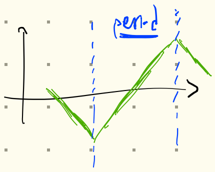
Our aim is to get $K(\omega)$, so how to proceed?

Doppler - Broadened

1) Record

- Function generator signal (FG) in AC (zero offset)
- SAS photodiode signal in DC and AC

2) Select a single period looking at FG signal



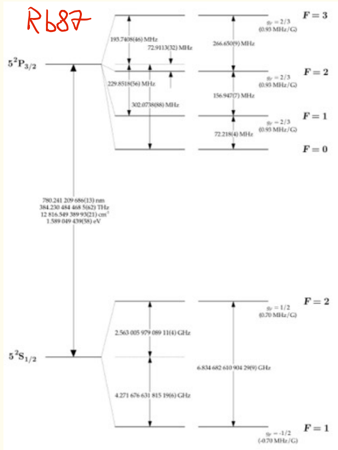
3) Cut both SAS signal outside the period

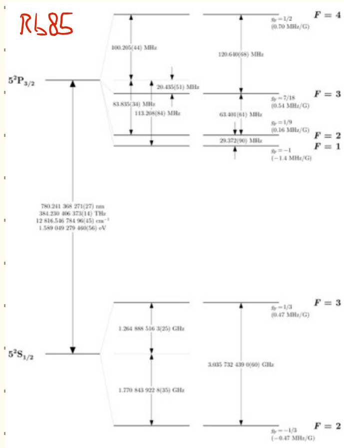
4) Take AC signal and correct with DC offset

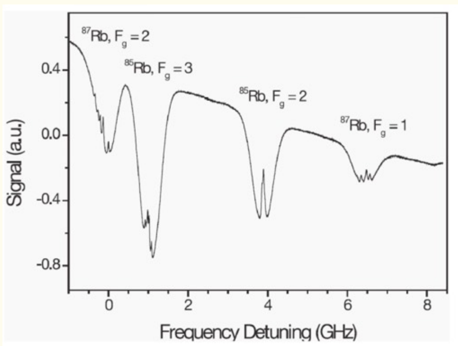
$$AC \to AC - \overline{AC} + \overline{DC}$$

5) Linearize FG signal: a) Fit FG signal with linear fit
b) Replace FG values with linear fit values

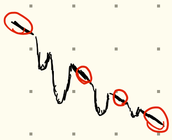
This is done because FG signal points are not "well behaved", especially for small voltage modulations







5) Select regions far from resonance



They should obey $V_{pd} = G(a_I V_{fg} + b_I)$

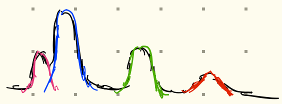
as $\kappa \sim 0$ here

Fit these regions and find Ga_I, Gb_I

Now we compute

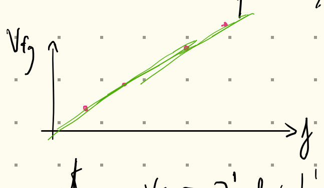
$$\kappa(a_w V_{fg} + b_w)\Delta z = -\ln \frac{V_{pd}(V_{fg})}{G(a_I V_{fg} + b_I)}$$

7) Since frequency w is linear in V_{fg} we can now fit each Doppler broadened spectroscopy signal with a Gaussian



8) We now have the four center positions in V_{fg} units, but we know their "true" frequencies/detunings

We then fit

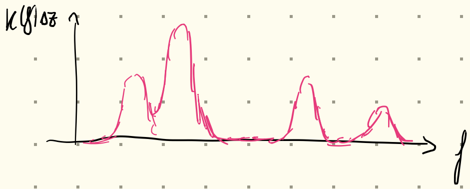


In this way we get $V_{fg} = a'_w f + b'_w$, which relate with

$$f = a_w V_{fg} + b_w \Rightarrow V_{fg} = \frac{1}{a_w} f - \frac{b_w}{a_w}$$

$$\Rightarrow a'_w = \frac{1}{a_w}, \quad b'_w = -\frac{b_w}{a_w} \Rightarrow a_w = \frac{1}{a'_w} \quad b_w = -\frac{b'_w}{a'_w}$$

9) We can now relate V_{fg} to f, so we plot



Remember, for Doppler Broadened spectroscopy we should have

$$\Delta f = \frac{\sqrt{\frac{k_B T}{m}}}{\lambda}$$

Doppler - Free

1) Measure FG, and signal with and without probe with the AC-DC trick

You should then have

$$V^1_{pd} = G\left(a_2 V_{fg} + b_I\right) e^{-\kappa_{DF}\left(a_2 V_{fg} + b_w\right)\Delta z}$$

$$V^2_{pd} = G\left(a_2 V_{fg} + b_I\right) e^{-\kappa_{DB}\left(a_2 V_{fg} + b_w\right)\Delta z}$$

κ_{DF} := doppler-free

κ_{DB} := doppler-broadened

2) We can now simply get

$$\left(-\kappa_{DF} + \kappa_{DB}\right)\Delta z = \ln\left(V^1_{pd} / V^2_{pd}\right)$$

from "theory" we should have

$$\kappa_{DF} \simeq \text{Gaussian}\left(1 - \beta \cdot \text{Lor}\right)$$

So $\ln\left(V^1_{pd} / V^2_{pd}\right) = \beta \cdot \text{Gaussian} \cdot \text{Lor}$

3) So I can simply fit $\beta \cdot \text{Gauss} \cdot \left(\text{Lor}1 + \text{Lor}2 + \dots\right)$

with the different Lor representing the different SAS peaks

⚠ Initializing parameters for convergence is not so easy