Papers_summary

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1 Critical Issues

1.1 Doppler Broadening

The Rb D2 line has a hyperfine splitting smaller than the Doppler broadening, thus I will never be really addressing only one hyperfine state. Therefore the effect of the neighboring states could have a very important effect on what I am seeing.

- population leakage: lower effective OD, less signal visibility
- signal from other transitions, how do the different signals "compete"?

1.1.1 Klabes (pg.63)

The Rb D2 F=1,mF=+-1, F'=1,mF'=0 theoretically provides a very clean Λ system, but the neighboring F'=0 state has opposite Clebsch-Gordan coefficient, so one's system dark state is another's dark state. This is detrimental for coherent effects to build up. They then shifted to Hyperfine EIT and then to D1 line

My understanding is that this is the EIA vs EIT competition that you get when multiple hyperfine states play a role, if most neighbor states give EIT you will see EIT, if some give EIA and some EIT it will depend and you will get a small signal, ecc.

1.1.2 Worth (pg.6)

For a chosen F->F' transition, if we consider all zeeman-sublevels, we have three cases:

- F'>F: the majority of V systems, EIA dominates
- F'=F: equal number of V and Λ systems, EIT dominates
- F'< F: more Λ systems, EIT dominates

With Doppler broadening we are in fact addressing all hyperfine excited levels, therefore the net effect will depend on what feature (EIT or EIA) each excited state yields and what is the relative strength of the transitions.

It seems like the only transition that could yield a EIT signal would then be the Rb85 Fg=2

1.2 Saturation

To improve the visibility of the classic EIT setup signal it is important to heat up the Rb cell to a relatively high temperature (>60°C) in order to increase the optical depth of the signal.

Out of the EIT region:

$$I(\omega) = I_0 e^{-OD(\omega)}$$

In the EIT region:

$$I(\omega) = I_0 e^{-OD(\omega)+OD_{EIT}(\omega)}$$

We have:

$$OD_{EIT,max} = OD(1 - \frac{\gamma_{g_1,g_2}}{\gamma_{EIT}})$$

with $\gamma_{EIT} = \gamma_{g_1,g_2} + \frac{|\Omega_c|^2}{4\gamma_{e,g}}$
while the width of the EIT will be:

$$\frac{\gamma_{EIT}}{\sqrt{OD_{EIT} - 1}}$$

Some numbers:

- γ_{g_1,g_2} motional component is 1.7MHz with 5mm/1m misalignment, 0.06MHz with 1mm/1m
- γ_{g_1,g_2} finite probe size is around 0.2MHz
- $\gamma_{e,g}$ is around 300MHz at room temp
- at 65°C considering only our 3-levels we get 7.5OD, compared to 0.14 at room temp
- $\Omega_c = 10MHz$ yields 0.9mW pump power (around 9mW/cm2), already strong saturation at 65°C

However, heating up to around 65°C improves greatly the OD for the probe-only regime, but when adding the pump beam, with reasonable intensity, the OD gets very low again, and going to much higher temps is not really an option right now due to melting risk in our components

1.3 Power Stabilization

When scanning the probe frequency the power of the probe beam changes in a non-negligible way. This makes it basically impossible to see any signal which is not very big.

We tried with PID and works a bit but needs to be improved by orders of magnitude to get rid of the noise. The alternative is to measure power before the cell and use info to compensate for this in post-process, but then you will not see anything on the oscilloscope

1.4 Magnetic Field Control

1.4.1 Stray Field Rejection

Our "kind" of mu-shield has not been properly tested, and the degaussing procedure is not easily implementable without a way to measure the residual field in our system.
Already the earth's magnetic field is non-negligible, as it has a magnitude of around 0.5G

1.4.2 Solenoid

A good solenoid should produce a field which is:

- uniform in the cell
- scannable

With the current solenoid the field:

- will not be super-uniform as the solenoid is not longer than the cell and is very close to the cell itself
- cannot be effectively scanned, with the current setup I can only manage around +-0.5G scan with a function generator

1.5 Locking in

Locking in with no PID is not so easy, but our systems beg the question of how critical is to lock at the exact frequency.

- is imperfect locking still good enough due to Doppler Broadening
- if "perfect" locking is required we need to better understand the SAS signal "jitter", laser not perfectly stable, temperature?, current?, artificial effect when modulating current with function generator?

2 Alternative Setup (Worth Thesis)

Instead of using two beams, we use one linearly polarized beam coaligned with the magnetic field, which will then effectively decompose into a left and right circularly polarized beam along the quantization axis, thus giving a pump-probe setup.

Advantages:

- perfect pump-probe spatial allineation
- perfect phase-locking
- no efficiency problems: the power of the laser is perfectly constant, as I am only modulating the magnetic field
- simple setup

Disadvantages:

- more complicated theoretical understanding
- impossible to sweep only probe frequency

2.1 Possible Implementation

1. Use the pump beam with the AOM turned off: open the iris to let the 0th order through
2. (Optional) Select the central part of the pump beam with an iris to have a cleaner/homogeneous beam profile
3. Set the beam intensity to be in the 0.4- 2.0 mW/cm2 range
4. Modulate the magnetic field: ideally, you want a fairly big, modulation, they use +/-20G

You can then look at two things:

- select a frequency far away from any resonances: you should not see anything
- select the Rb85 Fg=2 F' = 1 line, you should see an EIT feature

Some comments:

- they see that the signal gets worse at higher temperatures (basically disappears at 60°C)
- they see that transverse magnetic fields, relative to the beam propagation direction, make the EIT feature broaden and eventually disappears, but 1G transverse field should still display a feature, so in theory, even bad shielding should still display EIT

Relevant experimental "parameters" are:

- stray field compensation (they cancel up to 7mG with Helmotz coils, and then improve on that)
- polarization purity (use glan-thompson PBS) misalignment between the field and beam

3 Bejing Work

They make the D2 line work and study it in two regimes:

- scanning the probe frequency (at zero magnetic field)
- scanning the magnetic field

Relevant experimental details are:

- Rb87 Fg=1, Fe=0 states
- 75°C
- good mu-shield

They observe a signal of 0.6MHz width

CONCERN they then compare this signal successfully with theoretical calculation that does not take into account any broadening effects