EIT Intensity Noise Spectroscopy Power-Broadening and Level Structure

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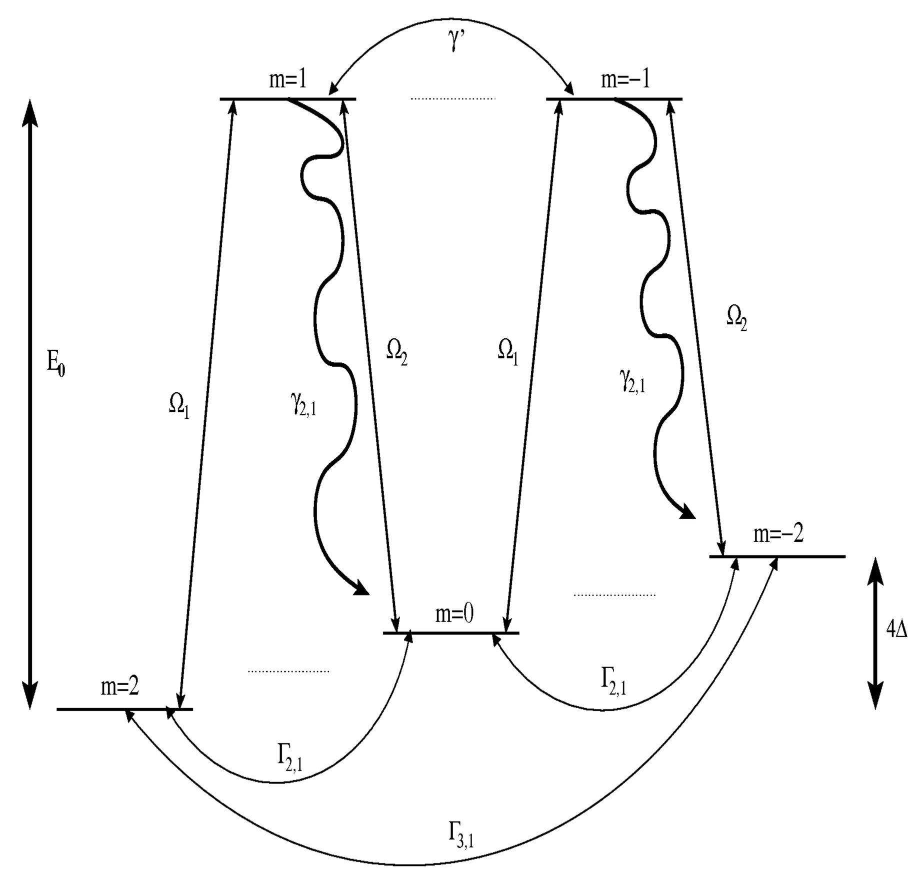
Introduction



The application of multiple light fields on atomic vapor with a degenerate ground state can pump the vapor into a dark state. EIT noise spectroscopy studies the stochastic response about this state.

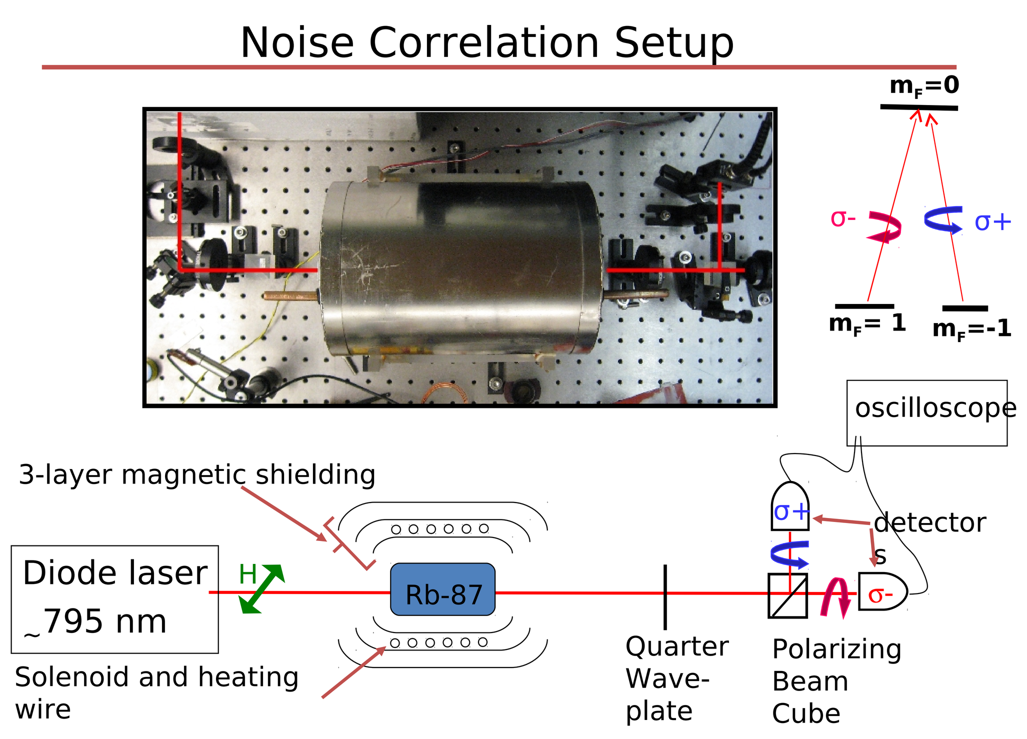
The 5 level quantum optics model describes EIT noise in the F=2 to the F'=1 D1 transition in ^{87}Rb. In actuality, there is also a 3 level lambda system superimposed on top of the 5 level system.

From the point of view of EIT noise these two systems are independent.

Description of variables in system:

Γ_2 is the rate that ground state coherences equilibrate
γ_2 is the rate that excited state coherences equilibrate
Γ_1 is the rate that ground state populations equilibrate
γ_1 is the rate that excited state populations equilibrate
Γ_3 is the rate the the m=2 and m=-2 populations equilibrate

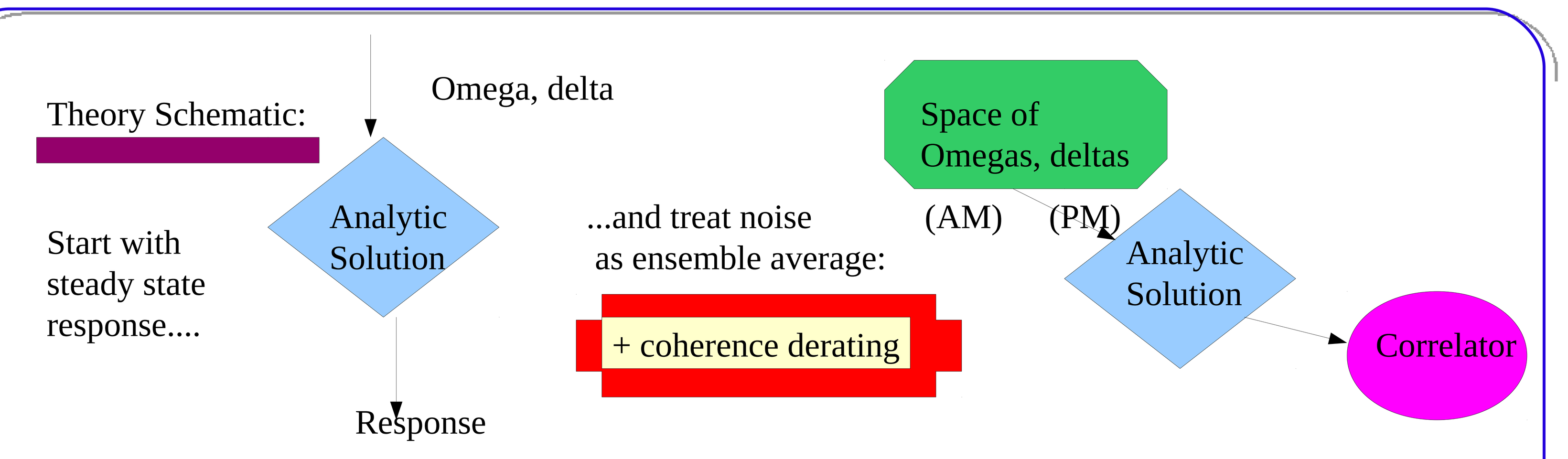
Experimental Setup



A 795nm laser diode is used to interrogate the isotope, ^{87}Rb. A cell of ^{87}Rb and a buffer gas with clear windows at each end of the cylindrical cell to allow for the beam's passage. The cell was magnetically shielded and also encased in a heating apparatus used to take data at different cell temperatures. A quarter wave plate is used to change the linearly polarized light into circularly polarized light before entering into a polarizing beam cube that split the beam into the right and left circularly polarized parts. The detectors then measure the fluctuations of light from the right polarized, σ_+, and left polarized, σ_-, parts of the beam[2].

At the top right of the image is a diagram of the 3 level system showing the transition from the m=1 and m=-1 ground states to the m=0 excited state. It then goes on to show how the left and right circularly polarized parts of the beam excite from ground states into the same excited state with equal probability of decay back into either ground state.

Theory and Analysis

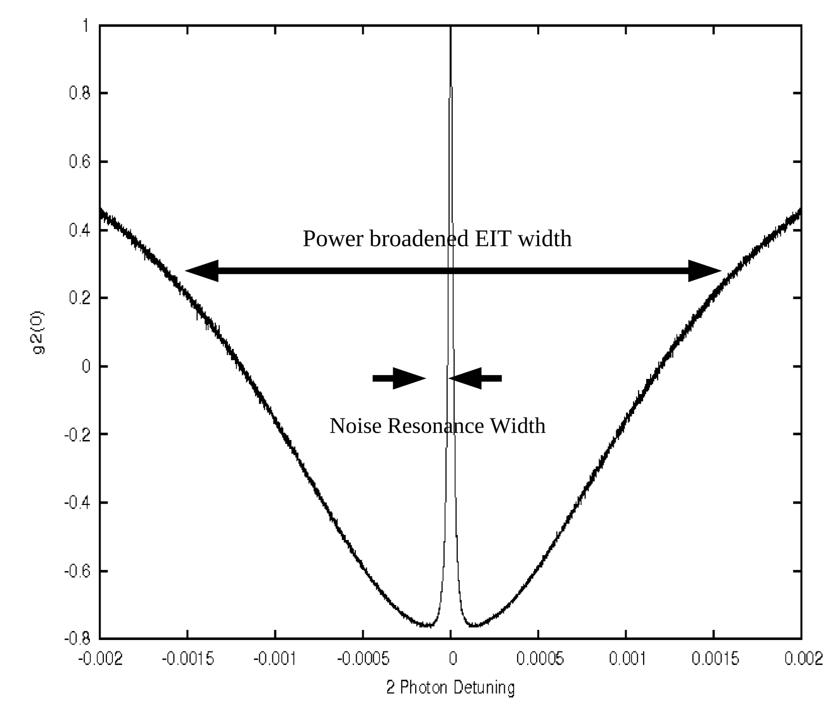


Correlator: We measure:

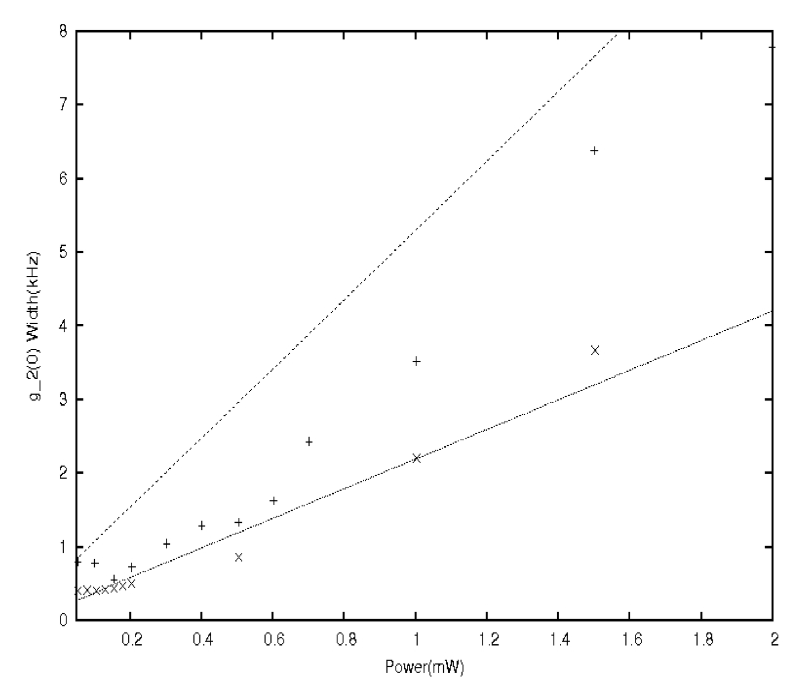
The so-called

$$g_2(0) = \frac{<\sigma_+\sigma_->}{\sqrt{<\sigma_+^2><\sigma_-^2>}}$$

Where σ_+, σ_- are the light power noise (AC) in the two terminal photodetectors.



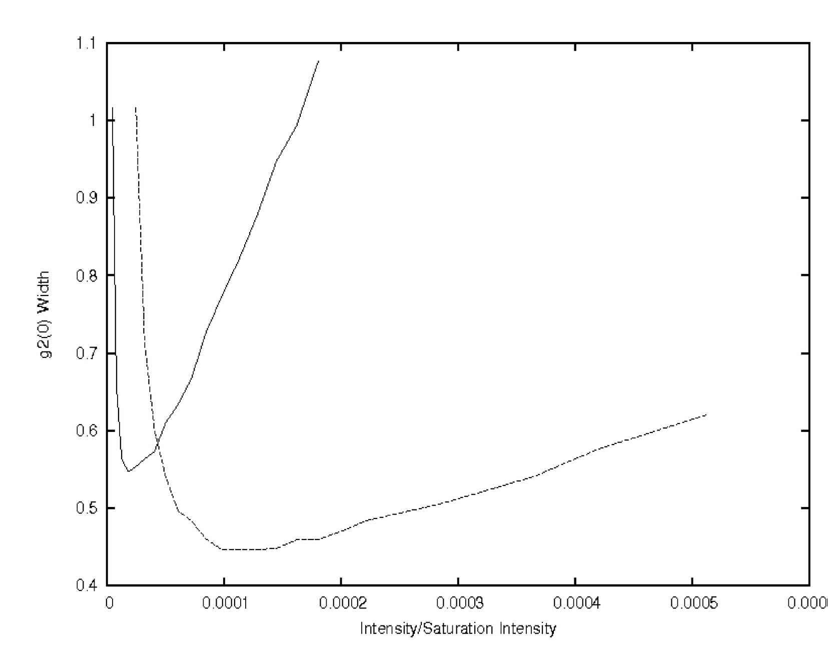
Caption: Experimentally[1] it is known that the noise resonance width narrows with power at low light power. Our recent experiment and theory indicate that the noise resonance power broadens after a threshold.



Caption: Experimental (points) and theory expectation for power broadening in the same cell with different beam sizes.

This power broadening depends on several factors. At the left is a graph of the power broadening in the same 2Torr , 5cm cell at 38°C with a beam diameter of 3.3mm (upper data) and 5.5mm (lower data). Our theory indicates (lines) that power broadening slope should be just proportional to the intensity, all else being the same.

Atomic structure plays an important role in the power broadening of the noise resonance. On the right is the theoretical expectation of the noise resonance width as a function of optical power for the F=1 to the F'=1 (solid line) and the F=2 to the F'=1 (dashed line) in an Alkali, all other parameters the same.



Caption: Theory plot of width of noise resonance -vs-optical power for the F=1 to F'=1 (solid line) compared to the F=2 to F'=1 (dashed line).

It is important to realize that cell parameters and beam details have a profound effect on the slope of these graphs chiefly through the depolarization factor we call the "derating".

Conclusions

Our theory indicates:

1) **Little optical density dependence**: At low O.D., the power broadening slope of the noise resonance is constant.

2) **Dependence on Level Structure:** All things being otherwise equal, the 1-1' transition has a higher power broadening slope than the 2-1'

3) **Noise Resonance power broadening:** processes not in the naïve steady state model that reduce the ground state coherences that are responsible for the noise resonance power broadening.

4) **Noise Resonance and Intensity:** the growth of the noise resonance width is proportional to the intensity

Applications

The non-power broadened EIT noise resonance has been demonstrated in both Zeeman and Hyperfine configurations. As such it is hoped that this statistical technique may increase the S/N ratio of the lock signals for magnetometer and clocks.

Our theoretical and experimental work indicates that there is a limit to the utility of this approach and indicate the optimal optical power at which to operate such a lock. Noise spectroscopy of this type is useful for quantifying the contribution of various depolarizing effects (diffusion+inhomogeneity, radiation trapping) that would degrade this lock.

References

1. Xiao, Yanhong, Tun Wang, Maria Baryakhtar, Mackenzie Van Camp, Michael Crescimanno, Michael Hohensee, Liang Jiang. Electromagnetically induced transparency with noisy lasers. Physical Review A 80, 041805R (2009).

2. V.A. Sautenkov, Y.V. Rostovtsev, M.O. Scully, Switching between photon-photon correlations and Raman anticorrelations in a coherently prepared Rb vapour, Physical Review A 72, 065801 (2005).