Investigating a ladder-type Electromagnetically Induced Transparency (EIT) in cesium

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Introduction

Electromagnetically Induced Transparency (EIT) is a quantum interference effect that enhances light transmission through a medium by inducing a transparency window as a coupling light beam and probe light beam undergo superposition inside that medium. In this study, we delve into the EIT phenomena within a cesium gas cell, utilizing a coupling laser at 852.3570 nm with an intensity of 1.25 mW, and a probe beam at wavelengths 520.3086 nm, 520.3088 nm, and 520.90 nm with an intensity of 26.6 mW, all maintained at a controlled temperature of 25°C. This research aims to understand the dynamics of light-matter interaction in cesium vapor and to explore the potential applications of EIT in various fields such as quantum information processing and high-precision measurements. Through detailed experimental analysis and data collection, we aim to contribute to the broader understanding of EIT mechanisms and their practical implementations.

Experimental

- Two counter-propagating laser beams are overlapped inside a room temperature vapor cell using Dichroic mirrors which pass 852..3 nm weak probe light and 520.3 nm strong coupling beam through a Cesium cell.
- The two lasers create a coherent superposition of atomic states, allowing the normally opaque medium to become transparent to the probe beam
- The transmitted intensity of the probe light is detected using photodetectors, and the EIT signal is observed as a peak in transmission when the coupling and probe beams are resonant

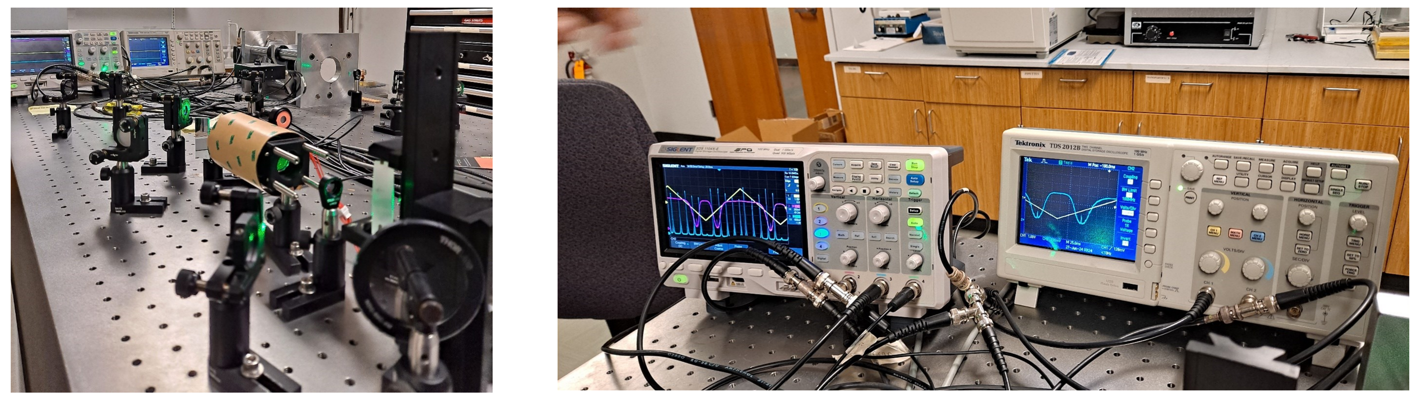

Figure 2: Experimental setup showing the equipment used.

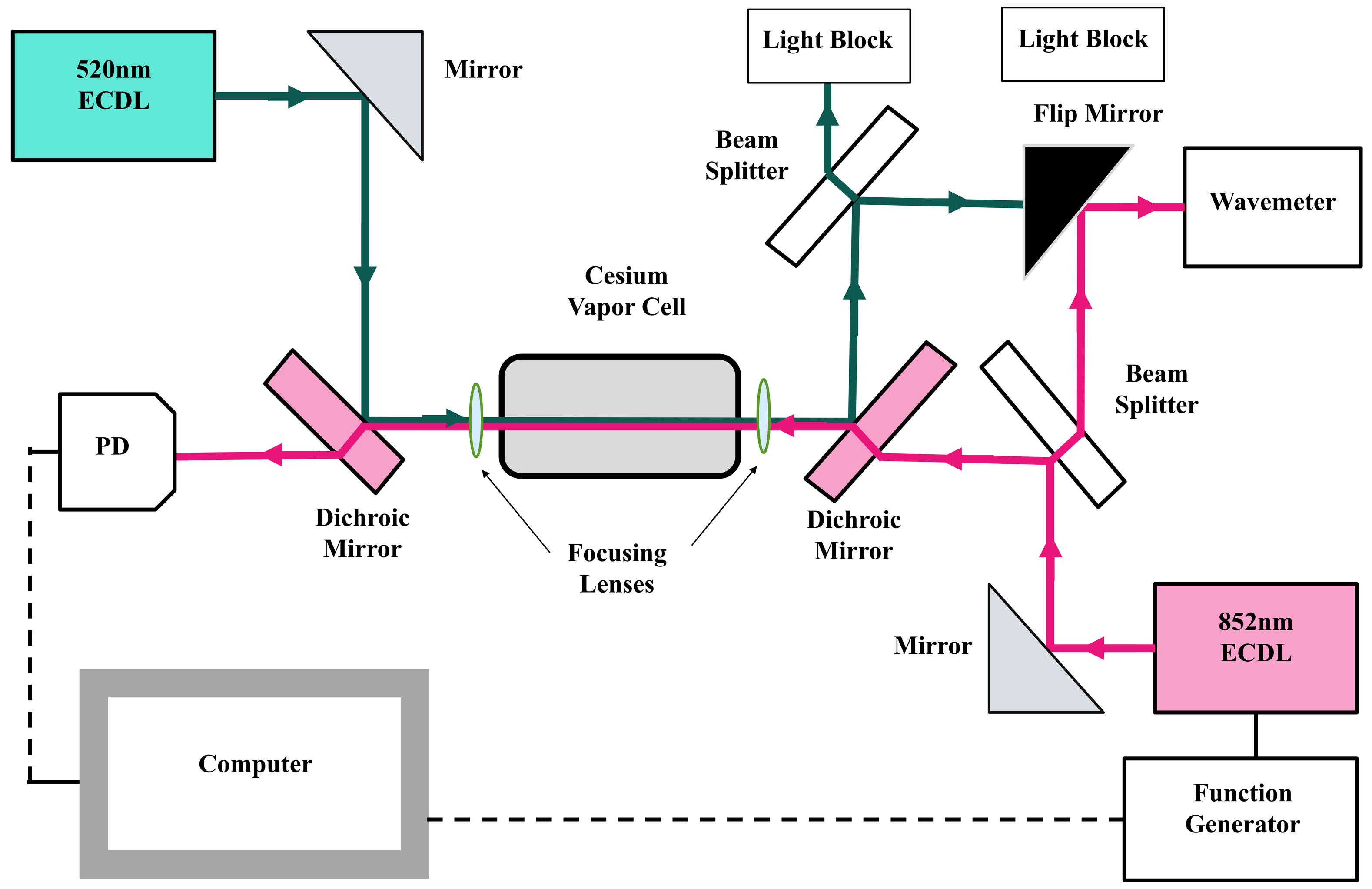

Figure 3: Schematic diagram of the experimental setup. [2]

Theory

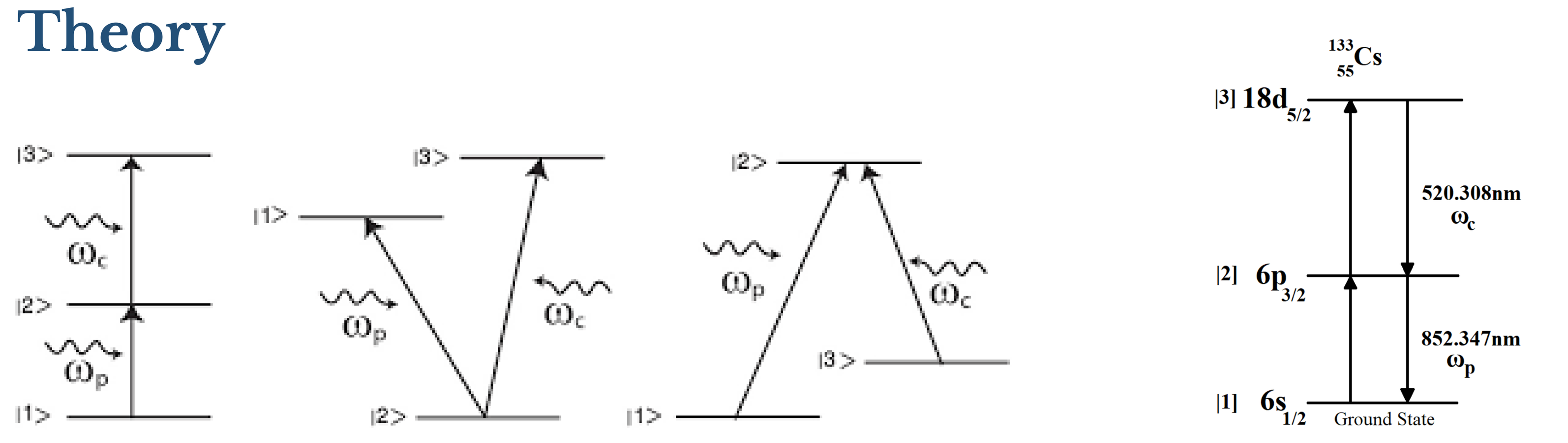

Figure 1: Diagrams showing the three different types of EIT: ladder-type, V-type, and lambda-type respectively from the left. In our experiment, we studied the Ladder-type EIT in cesium. The diagram on the right shows cesium energy transitions within the hyperfine structure.

- The probe beam transition corresponds to the energy levels ($6s_{1/2} \rightarrow 6p_{3/2}$) and the coupling beam corresponds to ($6p_{3/2} \rightarrow 18d_{5/2}$)
- The Doppler width is defined by the following:

$$\Delta\omega_D = \frac{2\omega_p}{c} u \sqrt{\ln 2}$$

- Susceptibility equation when the Doppler-broadening of the two-photon transition is neglected:

$$\chi = \frac{4i\hbar c g_{12}^2 N_0 \sqrt{\pi}}{\epsilon_0 u \omega_p} e^{z^2}(1 - \mathrm{erf} z)$$

- Susceptibility equation when the Doppler-broadening neglected: [1]

$$\chi = \frac{2c}{n_0\omega_p}\left[\beta + i\frac{\alpha}{2}\right] = \frac{2i\hbar c g_{21}^2 N_0 \sqrt{\pi}}{\epsilon_0 u \omega_p}\{(1-d)s_1 e^{-z_1^2}[1 - s_1 \mathrm{erf}(iz_1)] + (1+d)s_2 e^{-z_2^2}[1 - s_2 \mathrm{erf}(iz_2)]\}$$

- The imaginary value of susceptibility was used to determine the intensity absorption coefficient:

$$\chi = \chi' + i\chi''$$

- The intensity absorption coefficient is given by:

$$\alpha = \omega_p n_0 \chi''/c$$

Data Analysis and Results

- We have carried out theoretical simulations and experimental analysis of the data collected on multiple trials
- Isolated the EIT signal dip in theoretical modelling
- Used Fabry-Perot data to create the frequency axis for EIT plot
- In our Cesium system, there are two unresolved absorption peaks which result in the slanted shoulder. These unresolved peaks arise from the doppler broadening effect

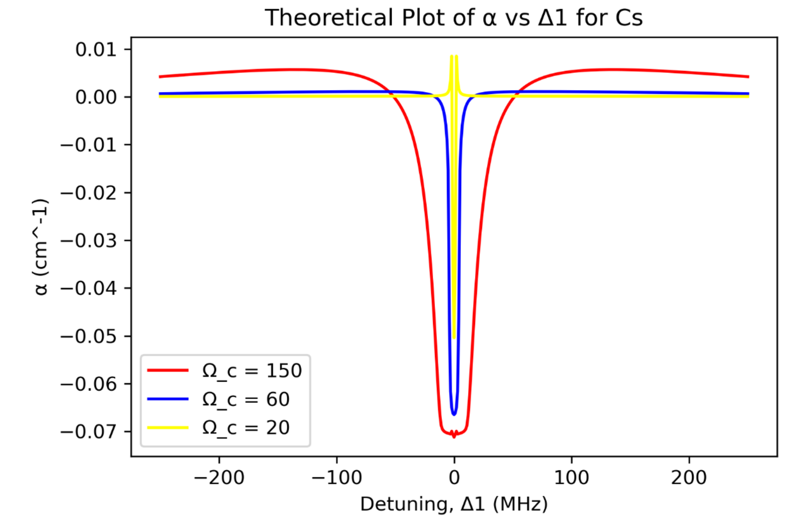

Figure 6: EIT signals at various Rabi frequency isolated from the absorption curve.

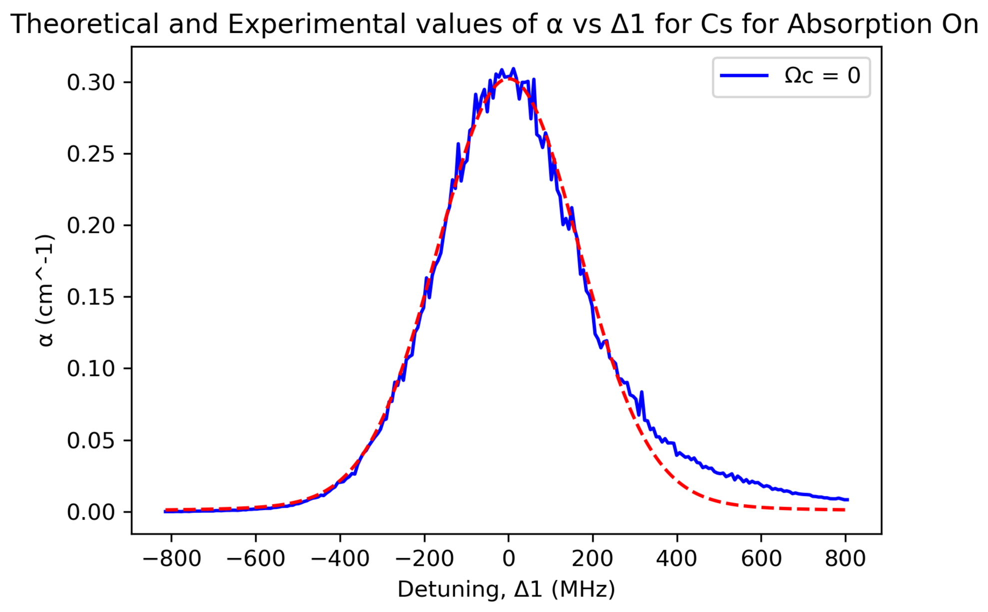

Figure 4: Theoretical and experimental plots obtained when no coupling beam is applied.

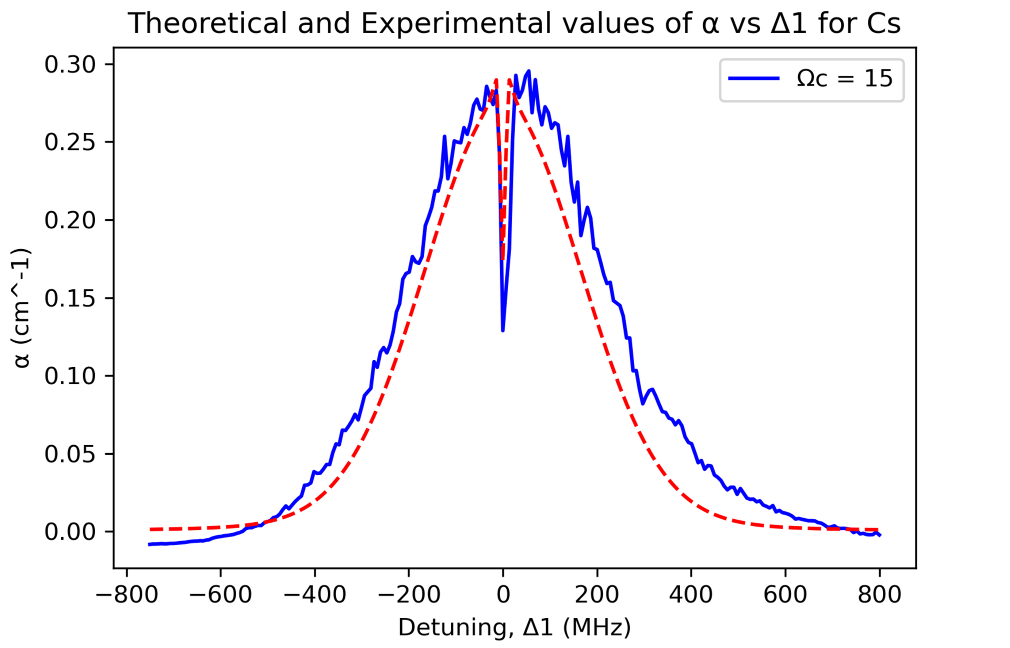

Figure 5: Theoretical and experimental plots when coupling beam is on.

Conclusions

We have observed a Ladder-type EIT in Cesium gas using a weak probe beam . We see a good agreement between the theory and the experimental absorption coefficients for the case without the coupling laser. However, we are still working on improving the agreement between the theoretical and experimental plots.

References

[1] Gea-Banacloche, J. et al. (1995) 'Electromagnetically induced transparency in ladder-type inhomogeneously broadened media: Theory and experiment', Physical Review A, 51(1), pp. 576–584.

[2] Rupasinghe, P.M, Austin, A., Observing Electromagnetically Induced Transparency in Cesium, SUNY Oswego ORSP (The authors would like to thank the Office of Research and Sponsored Programs of SUNY Oswego for supporting this Project.

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