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Velocity selective resonances and electromagnetically induced transparency in atomic rubidium

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Abstract : Using the same experimental setup, two different configurations of the pump and probe laser fields are studied in this work. When the pump and probe laser fields together produce a Λ system, we get a centrally located dip due to Electromagnetically Induced Transparency. However, when the pump and probe laser fields produce a *V*-system we observe Velocity Selective Resonance Dips.

Keywords : Velocity selective resonance, hyperfine spectra, shifting of resonances, electromagnetically induced transparency, optical pumping, Rb-D transition

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1. Introduction

The atomic response to a probe radiation field can be manipulated by using an intense pump laser. Typical atomic systems considered for the purpose are three-level atoms in the V or Λ configuration. For the Λ-system the upper level of the probe transition is coherently coupled to a third level by a strong coupling laser field. In this case, there is reduction of probe absorption leading to electromagnetically induced transparency (EIT) [1,2], if the frequency difference of the two laser fields coincides with the lower energy level difference *i.e.* the Raman resonance condition is satisfied. With a V-type system having a common lower level for the pump and probe transition, difference frequency crossing resonances have been reported [3].

In this work, we report results for two separate configurations using the same experimental setup. In the first case (Figure 1), we consider a four-level atom with one lower ($S_{1/2}$) level and three upper hyperfine ($P_{3/2}$) levels, while in the second case (Figure 2), two lower ($S_{1/2}$) hyperfine levels and one common upper ($P_{3/2}$) level for Rubidium D_2 transitions are considered.

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2. Experimental

In this experiment, we have used two external cavity diode lasers (Figure 3). One of them having higher power (22 mW) is used as the pump laser. It is locked to the ^{87}Rb $F = 2 \rightarrow F'$ D2 Doppler transition. The weaker probe laser having lower power (1.27 mW) is scanned over a frequency range of 4 GHz. We use two Rb vapour cells having pressure of the order of 10^{-6} torr. The pump beam is split into two components using a 70 : 30 (R : T) beamsplitter. The transmitted beam is sent through one cell to lock the pump laser to the ^{87}Rb $F = 2 \rightarrow F'$ D2 Doppler transition. The lock circuit is homebuilt with a frequency stability of 1 MHz. We pass two laser beams through the second Rb vapour cell, one from the probe laser and the other from the pump laser. The strong pump beam intersects the probe beam inside the Rb cell. The probe beam falls on the photodiode of a single detector. The net output from the detector shows three transitions on the Doppler background. The separations between these transitions match well with the actual hyperfine separations on the ^{87}Rb D2 energy level diagram. The set of dips shifts when the pump laser is tuned across the Doppler profile thus

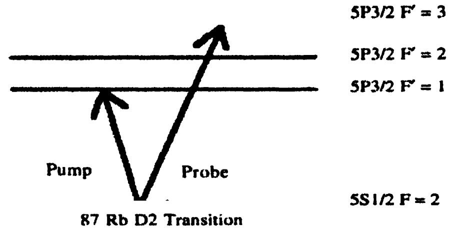

Figure 1. Four-level V-type atomic system.

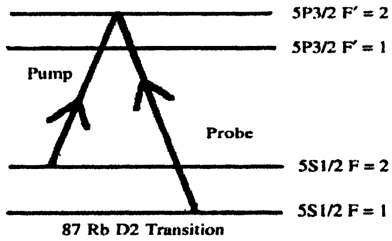

Figure 2. Four-level double Λ-type atomic system.

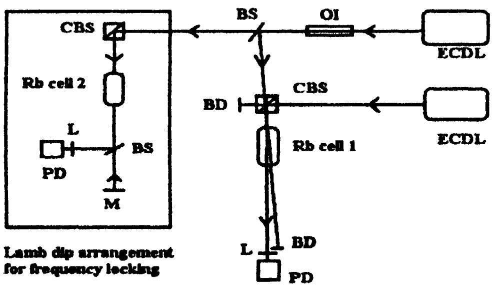

Figure 3. Schematic representation of the experimental setup. OI : Optical isolator, BS : Plate beam splitter, L : Lens, CBS : Cubic beam Splitter, Rb-cell : Rubidium vapour cell, BD : Beam dump, PD: Photo diode, M : Mirror, ECDL: External cavity diode laser.

exhibiting *Velocity Selective Resonances* [4] *(VSR)*. By changing the pump power the peak height and width of the dips could also be changed. When the pump laser is locked to a certain frequency it is detuned from all three allowed transitions. This leads to reduced population of the lower level of three velocity groups of atoms. When the probe laser is tuned across the velocity profile it interacts with three velocity groups and hence shows reduced absorption or dips. A similar set of triplet VSR spectra representing the hyperfine triplet is presented in Figure 4.

In the second experiment, the pump laser having power 1.48 mW is locked to the ^{87}Rb $S_{1/2}F = 2 \rightarrow P_{3/2}F'$ transition while the probe laser having power 0.07 mW is tuned across the ^{87}Rb $S_{1/2}$ $F = 1 \rightarrow P_{3/2}F$ transition.

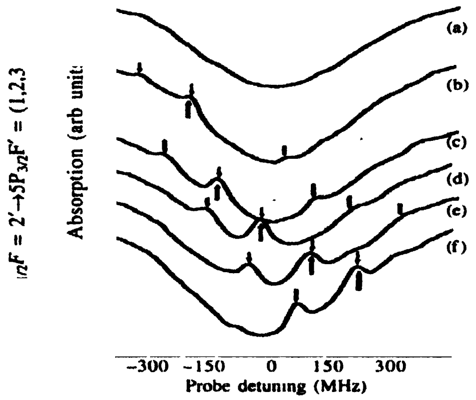

Figure 4. Probe absorption profile of ^{87}Rb transition representing velocity selective resonances (a) Pump switched off, (b-f) Pump locked to various points (red arrows) on the Lamb Dip Spectrum of ^{87}Rb transition

When the Raman resonance condition is achieved where both the pump and probe lasers share a common upper hyperfine level we observe a narrow dip in the center of the probe absorption profile giving a reduction in absorption. This *Electromagnetically Induced Transparency (EIT)* results from a destructive interference between two pathways to the excited state. Due to double Λ-system two additional satellite transmission peaks symmetrically displaced from the central EIT are observed (Figure 5).

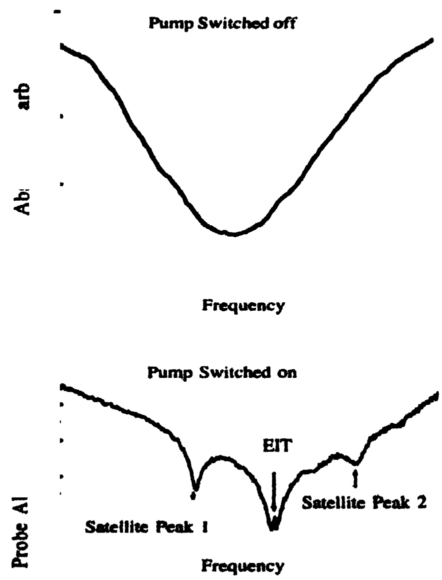

Figure 5. Effect of pump laser on pure Λ-system showing electromagnetically induced transparency; Pump laser locked to ^{87}Rb $5S_{1/2}F = 2 \rightarrow 5P_{3/2}$ $F' = 1,2,3$ Transitions, Probe laser tuning ^{87}Rb $5S_{1/2}F = 1 \rightarrow 5P_{3/2}$ $F = 0,1,2$ Transitions.

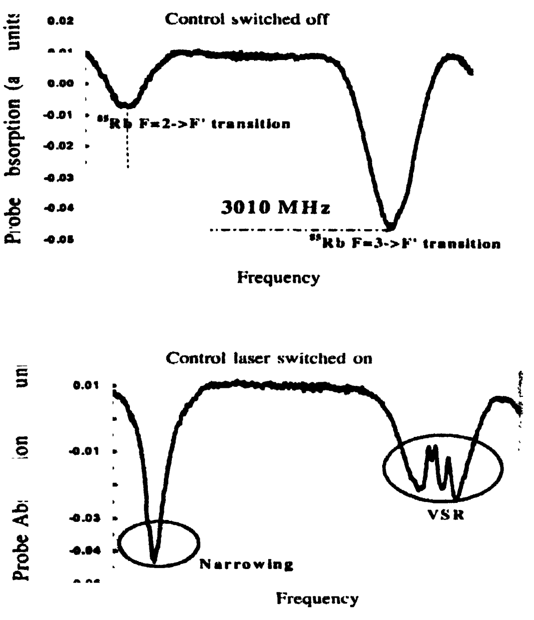

Figure 6. Probe absorption spectra with and without pump laser.

Theoretically calculated separation between the Doppler broadened transitions of ^{85}Rb $F = 2 \rightarrow F' = 1,2,3$ and $F = 3 \rightarrow F' = 2,3,4$ is 3010 MHz (Figure 6). This information was used to calibrate the ramp voltage used to tune the laser frequency to the frequency scale. The frequency calibrated ramp voltage was used to measure the separation between the hyperfine like transitions in the VSR experiment and the separation between the satellite transmission dips on either side of the EIT in the second set of experiments.

Home built single detector using HR8101 Silicon photodiode is used for laser locking set-up. Commercial CCD camera (Samsung) detects the fluorescence. A Wavemeter (Coherent, Wavemaster) is employed for approximate wavelength readout. Yokogawa DL1620 Digital Storage Oscilloscope is used for data recording.

3. Conclusion

We have observed crossover free hyperfine like transitions and call them velocity selective resonances (VSR). The Velocity Selective Resonances can be manipulated by shifting the lock points of the control laser. The peak height and width of the VSRs change by changing the pump power. For the double Λ-type system, we get a pair of satellite dips displaced symmetrically from the central electromagnetically induced transperancy (EIT). For a pure Λ-type system when the difference in the pump and probe frequencies exactly match the lower atomic hyperfine separation, we get a centrally located EIT on the Doppler background.

References

[1] M Xiao, Y Li, S Jin and J Banacloche *Phys. Rev. Lett.* 74 (1995)

[2] S E Harris, J E Field and A Imamoglu *Phys. Rev. Lett.* 64 (1990)

[3] V Wong, R W Boyd, C R Stroud, R S Vennink and A N Marino *Phys. Rev.* **A68** 012502 (2003)

[4] S Chakrabarti, A Pradhan, A Bandyopadhyay, A Ray, B Ray, N Kar and P N Ghosh *Chem. Phys. Lett.* **399** 120 (2004)