Exploration of electromagnetically induced absorption with circular polarised lasers in a degenerate two-level system

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In previous works [1,2] we have analysed with a three-beam heterodyne interferometer the response of a caesium atomic beam under the action two laser beams of orthogonal polarisations driving and probing two different degenerate two-level transitions, thus inducing on the system either electromagnetically induced transparency (EIT) or electromagnetically induced absorption (EIA). The joint effect of using copropagating laser beams and an orthogonally propagating atomic beam was crucial to dramatically reduce the Doppler broadening of the measured signals. In this way it was possible to measure absorption and dispersion signals for either the probe or the coupling laser with linewidths of the order of 20 kHz. These measurements confirmed the theoretical interpretation for the emergence of EIA in a degenerate two-level systems: spontaneous transfer of coherence.

The simplest system in which spontaneous transfer of coherence can arise is the so-called N-system. In this system two degenerate ground levels are coupled with two degenerate excited levels through the action of a fixed frequency coupling laser. Furthermore one of the two ground levels is coupled with one of the two excited ones via a probe laser while the other cross transition between the other ground level and the other excited level is forbidden by selection rules.

Within the Zeeman sublevels of a degenerate two-level system this configuration can be easily realised with a linearly polarised coupling laser and a circularly polarised probe laser. However this experimental configuration does not allow an easy separation between collinear propagating laser of the same frequency. For this reason most of the measurements of EIA performed so far used either linearly polarised lasers of orthogonal polarisation or introduced an angle between probe and coupling laser, thus degrading the linewidth of the measured signals. The theoretical description involves in this case a much more complicate fauna of sublevels than in the simple N system but agreement has been found between the theoretical calculations performed so far and the measured signals, at least in the low intensity regime of the probe laser. Another less explored possibility is that of using circularly polarised laser of orthogonal polarisation. For this last configuration exact calculations have been recently performed in the group of Arlene Wilson-Gordon.

Here we present the corresponding measurements obtained with a modified version of our heterodyne interferometer. The measurement were obtained in the 6s $^2S_{1/2}$ F=4 → 6p $^2P_{3/2}$ F=5 transition of the caesium D_2 line. As it is the case for double linear polarisation the probe absorption signals showed electromagnetically induced absorption. However, the amplitude of the induced absorption peak over the broader regular absorption signal resulted much lower than the measured one for the double linear case. This may be due to the fact that in the double circular case no compact N subsystems can be easily built between the sublevels. The resulting spectra are therefore similar to those measured in open two-level systems.

In addition to the measured absorption signals we present dispersion signals measured either in the presence of electromagnetically induced absorption or in the presence of electromagnetically induced transparency - i.e. on the F=3 → F=2 line - for both the coupling and the probe laser. On the basis of the measured dispersion signals, the possible applications for the future generation of gravitational wave detection of non-linear media obtainable through the use coherently prepared gases under electromagnetically induced transparency or absorption conditions are discussed.

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References

1. L. Spani Molella, R.-H. Rinkleff, and K. Danzmann, “Role of the coupling laser in electromagnetically induced transparency”, Phys. Rev. A **72**, 041802(R) 1-4 (2005).
2. L. Spani Molella, R.-H. Rinkleff, and K. Danzmann, “Spectral measurement if the caesium D_2 line with a tunable heterodyne interferometer”, Spectrochim. Acta A **63**, 987-993 (2006).