Probing Zeeman coherence with four-wave mixing

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Potential applications in optical communication and quantum information processing as well as fundamental aspects of atom-light interactions are generating widespread interest in coherent atomic media. To effectively control the properties of such media the spectral and temporal non-linear processes occurring in them must be understood, since light-induced long-lived coherence significantly enhances the nonlinear susceptibility in the vicinity of the Raman transition. Our investigation of nearly degenerate wave mixing in Rb vapours with coherence between Zeeman states illustrates the rich potential this approach offers for understanding the processes involved in generating the atomic nonlinearities that enhance the four-wave mixing.

Two acousto-optic modulators are used to produce mutually coherent drive and probe beams with a small tunable frequency offset δ from an extended-cavity diode laser. We use homodyne and heterodyne methods to separate the frequencies of the co-propagating drive and probe laser fields and components resulting from the four-wave mixing (FWM) processes. In both methods, the signal from a photodiode monitoring the transmitted fields is sent to a radio frequency spectrum analyzer.

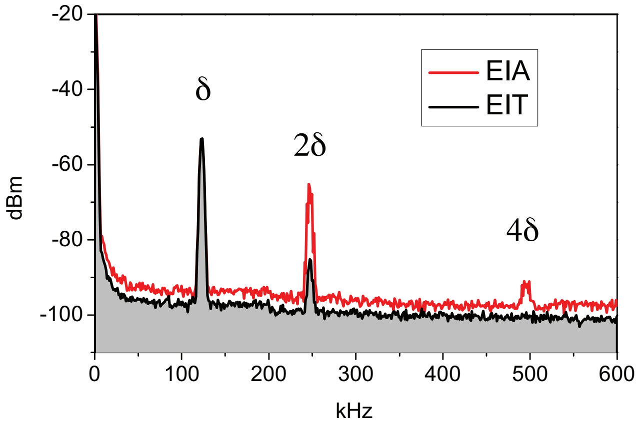

Fig. 1: Four-wave mixing spectra obtained for drive and probe fields separated by $\delta \simeq 125$ kHz.

Fig. 1 shows FWM spectra in Rb vapour taken under conditions of electromagnetically induced transparency (EIT) [1] and electromagnetically induced absorption (EIA) [2] using the homodyne detection method. Beating of the drive and probe fields generates a strong signal at δ and occurs even for off-resonant radiation, while the signal at 2δ requires FWM to have occurred. The 2δ signal can arise, for example, as a result of the new wave at $2\nu_D - \nu_P$ beating with the probe wave at ν_P.

The spectra demonstrate that the four-wave mixing is more efficient in the EIA medium under otherwise similar experimental conditions. This observation is consistent with the values of the Kerr coefficients measured directly in both cases, where higher values are found in EIA media.

We have shown that two mutually coherent, co-propagating waves with a small detuning δ may produce up to ten new mutually coherent co-propagating optical waves in Rb vapour. Our study could extend the physical basis of the efficient control of wave mixing in coherently driven atomic media [3].

References

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[2] A. M. Akulshin, S. Barreiro, A. Lezama, Phys. Rev. A **57**, 2996 (1998).
[3] A. M. Akulshin, A. I. Sidorov, R. J. McLean and P. Hannaford, arXiv:0910.5024 (2009).