Kerr and Higher Order Nonlinearities in Gaseous Atomic Systems

Andal Narayanan and Abheera Hazra

Raman Research Institute, Sadashivnagar, Bangalore - 560 080, INDIA

Dilute samples of gaseous alkali systems have become a prototype testing ground for coherent light-matter interactions. The phenomenon of Coherent Population Trapping (CPT) and the associated vanishing of linear susceptibility resulting in Induced Transparency (EIT), enables the study of coherent, nonlinear interactions of light with matter, at very low light levels. Specifically, Kerr-type nonlinearity has been predicted and seen in such systems [1,2]. This is a coherent nonlinear effect seen in a typical N system irradiated with three laser fields. Usually the higher order nonlinearity is seen in a field which is also showing the EIT effect. In this paper, we show the presence of Kerr and other higher order nonlinear effects in a laser beam which does not directly take part in the two-photon EIT transparency. This is shown in an N system and also in Zeeman degenerate systems. We show explicitly that the cross-phase modulation (XPM) of the medium, due to the other lasers under EIT conditions, is primarily responsible for generation of higher order effects. Our N-type system is around the D2 line of ^{87}Rb connecting the hyperfine levels of $5\,S_{1/2}$ to levels in the $5\,P_{3/2}$ manifold. Zeeman degenerate transitions are studied using a pair of levels of these manifolds.

We observe ultra narrow absorption and transparency resonances in these systems which are higher order nonlinear resonances. A systematic study of the contrast of these resonances with detuning and intensity has been undertaken and the results of the N system are compared with those of Zeeman degenerate systems. We find the Zeeman degenerate system to be a rich source of symmetries giving rise to higher order transparency effects which are absent in N systems.

The coherent nature of these effects may find possible applications in entanglement swapping schemes when extended to low light levels.

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[1] H. Schmidt, A. Imamoglu, Optics Letters **21**, 1936 (1996).

[2] H. Kang, Y. Zhu, Phys. Rev. Lett. **91**, 093601 (2003).