

Lossless intensity-dependent dispersion in coherently prepared multi-state atoms using EIT

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Recently, the properties of three-state atoms in the Λ configuration have been studied as the benchmark for describing electromagnetically induced transparency (EIT) and its associated optical nonlinearities. In describing the nonlinearities, much effort has focused on the group velocity seen by a weak probe field under conditions of EIT, which under appropriate conditions can be made extremely small, or even zero¹. Such effects are dramatic examples of cross-phase nonlinearities, i.e. ones where the strong coupling field alters the refractive index profile seen by the probe field.

We recently introduced a new atomic configuration, the Chain Λ atom, which is a multi-state extension of the conventional Λ scheme², and where the probe and coupling fields couple multiple transitions. In figure 1 we present a schematic energy-level diagram showing the allowed couplings. Under these conditions, the probe field experiences an intensity-dependent dispersion (self modulation) without compromising the EIT condition. From this dispersion we may calculate a group velocity (assuming an optically thin sample), and this is presented as a function of probe Rabi frequency (P) in figure 2 for 3, 5, 7 and 9 state Chain Λ atoms.

In this work we will describe Chain Λ atoms, identify realistic conditions for observing Chain Λ atoms, present extended results where propagation effects are taken into account and explore the prospects for using such atoms in novel quantum devices.

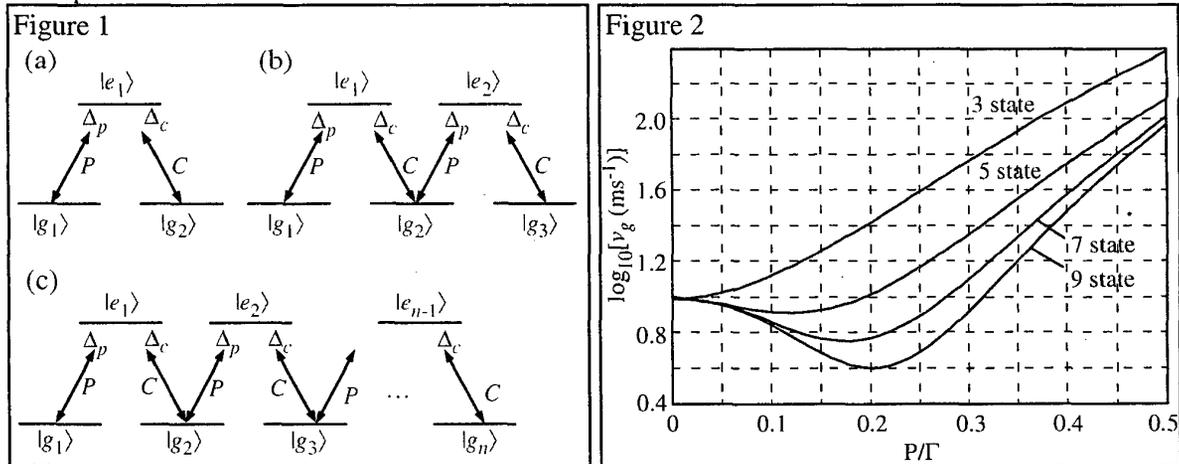


Figure 1: Energy level and coupling diagram for Chain Λ atoms, (a) is the standard three level Λ atom, (b) is the five level, or M atom, (c) is a general atom with n ground states and $n-1$ excited states, the probe field excites all transitions of the form $|g_i\rangle \rightarrow |e_i\rangle$, the coupling field excites all transitions of the form $|g_i\rangle \rightarrow |e_{i-1}\rangle$. Figure 2: Group velocity as a function of normalised probe Rabi frequency for Chain Λ atoms of varying order. Note the qualitatively different behaviour between 3 state and other Chain Λ atoms

¹ A. B. Matsko, O. Kocharovskaya, Y. Rostovtsev, G. R. Welch, A. S. Zibrov, and M. O. Scully, Adv. At., Mol., Opt. Phys. **46**, 191 (2001)

² A. D. Greentree, D. Richards, J. A. Vaccaro, A. V. Durrant, S. R. de Echaniz, D. M. Segal, and J. P. Marangos, Intensity-dependent dispersion under conditions of EIT in coherently prepared multi-state atoms, to appear in Phys. Rev. A and is also at quant-ph/0209067