Coherently Controllable Photonic Structures with Zero Absorption

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Resonant enhancement of the refractive index with vanishing absorption in coherently driven multilevel systems was a subject of intense recent theoretical and experimental studies (see [1-2] and the references there in). In this work we show an attractive possibility for coherent modulation of the refractive index in space and/or in time maintaining zero absorption.

To illustrate an idea we consider a three level ladder system with populated intermediate state and equal strengths and widths of the 1-2 and 3-2 transitions. The remarkable property of this system is that the probe field tuned to one half of atomic transition frequency $\omega_{31}$ experiences neither absorption nor gain independently on the intermediate level position. On the other hand, spatial or temporal modulation of this level position on the scale of the optical linewidth would result in corresponding modulation of refractive index from the minimum resonantly decreased to the maximum resonantly enhanced value. Temporal modulation could be provided with a rate much smaller than the frequency of the atomic transitions by applying a time varying electric or magnetic field via the dc-Stark or Zeeman effects. Spatial modulation may be provided by the AC-Stark effect, by applying a strong far-off resonant laser to create a standing wave. The Bragg scattering condition can be easily met providing efficient and coherently controllable (in particular, optically switchable) photonic structures.

The strength and width of the upper atomic transition 3-2 can be tuned by application of a strong control field at the adjacent to 3-2 transition forming a far-detuned lambda system at twophoton resonance which behaves as a two-level system with controllable properties. We discuss possible implementation of such system in the rare-earth doped crystals with excited state absorption.

Fig 1. (a) Energy diagram of the three-level ladder system. (b) Normalized real part of susceptibility of the probe field plotted as a function of the displacement of the intermediate level. Imaginary part of susceptibility is identically equal to zero.