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Time-delayed four-wave mixing: the interplay between laser field fluctuations and the atomic memory time

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Coherent signals induced by fundamentally incoherent phenomena through a four-wave mixing process are among the most intriguing and subtle effects in nonlinear spectroscopy. These effects were initially observed by Bloembergen and his co-workers in the form of pressure-induced extra resonances in four-wave mixing (PIER 4) [1]. Using standard perturbative techniques based on the optical Bloch equations, they suggested that these collision induced resonances were the result of a "destruction of the destructive interference" existent between two alternate time-ordered pathways. Subsequently, Prior et al. [2] realized that fluctuations in the incident radiation fields could play essentially the same role as the collisionally induced dephasing. In practice, of course, both collisional dephasing and field fluctuations are present in a typical atomic vapor pulsed four-wave mixing experiment. If the timescales governing these two effects approach one another, one can expect to gain valuable new insights into this fascinating process of "incoherently" inducing a coherent signal[3,4].

We explore theoretically the phase conjugate signal generated by a fluctuating radiation field via a four-mixing process in an atomic vapor undergoing dephasing collisions. The incident radiation field is taken to be well detuned from the atomic resonance and modeled as a two mode laser field whose mode amplitudes obey jointly circular Gaussian statistics, while the dephasing collisions are treated as a Markovian process. A fully analytical expression for the phase conjugate signal is obtained which contains contributions from several possible time-ordered pathways. We show that by varying the amount of decoherence introduced by dephasing collisions, relative to that provoked by the laser field fluctuations and the inhomogeneous broadening, one can manipulate the relative strengths of the various contributing time-ordered pathways. This possibility gives one a rather powerful tool to study the cross-correlations between modes in a fluctuating multi-mode laser field.

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