Contribution ID: **73** Type: **Oral Presentation**

Computational study of nonlinear spectroscopy including saturated absorption and four wave mixing in two and multi-level atoms

Tuesday, 12 July 2016 15:40 (20 minutes)

Abstract content
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We report on the study of two and multi-level atoms interacting with multiple laser beams. The semi-classical approach is used to describe the system in which the atoms are treated quantum mechanically via the density matrix operator, while the laser beams are treated classically using Maxwell's equations.
We present results of a two level atom interacting with single and multiple laser beams and demonstrate Rabi oscillations between the levels. The effects of laser modulation on the dynamics of the atom (atomic populations and coherence) are examined by solving the optical Bloch equations. Plots of the density matrix elements as a function of time are presented for various parameters such as laser intensity, detuning, modulation etc. In addition phase-space plots and Fourier analysis of the density matrix elements are provided.
The atomic polarization, estimated from the coherence terms of the density matrix elements, is used in the numerical solution of Maxwell's equations to determine the behavior of the laser beams as they propagate through the atomic ensemble. The effects, of saturation and hole-burning, are demonstrated in the case of two counter propagating beams with one strong beam and the other being very weak.
The above work is extended to include four-wave-mixing in four level atoms in a diamond configuration. Two counter propagating beams of different wavelengths drive the atoms from a ground state|1> to an excited state |3> via an intermediate state |2>. The atoms then decay back to the ground state via another intermediate state |4> resulting in the generation of two additional correlated photon beams. The intermediate state |4> has a substructure allowing for an uncertainty in the precise decay path. The characteristics of these additional photons are studied.

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Session Classification: Parallel Track B