Microscopic theory of phonon-assisted relaxation of quantum dots in photonic crystals

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We consider the role of phonons in modifying the absorption and emission lineshape of a two-level atom (quantum dot) in the “colored” vacuum of a photonic band gap (PBG) material. This is based on a microscopic Hamiltonian describing the radiative and non-radiative processes treated quantum mechanically. Phonon sidebands and broadening of the zero-phonon line in an ordinary electromagnetic reservoir are recaptured using a simple model of optical phonons. Our formalism is then used to treat the non-Markovian dynamics of the same system within the structured electromagnetic density of states of a photonic crystal. We elucidate the extent to which phonon-assisted decay limits the lifetime of a single photon-atom bound state and derive the modified spontaneous emission dynamics due to coupling to the phonon bath. Our model should provide a starting point to describe the control of decoherence and relaxation through external coherent electric fields and multiple quantum dot interactions.