

Fano Profiles in the Resonance Fluorescence spectrum of the Emitter Coupled to Phonons

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Abstract

We present a theory of resonance fluorescence (RF) on a weakly excited emitter coupled to phonons, which perturb the emitter's fundamental transition energy. We show that moderately strong exciton-phonon coupling leads to a Fano-like profile near the resonant energy, which is due to interplay of a narrow inelastic scattering line (stemming from noise-induced transient dynamics) and a broad phonon sideband (PSB). In the weak-coupling limit, the spectrum becomes an exact Fano feature, where resonant light scattering is entirely suppressed. The amplitude of a narrow Fano feature grows linearly with temperature, whereas its width depends solely on the exciton dephasing time.

It has been established that the absorption, emission, or four-wave mixing spectrum consists of a narrow central line and a broad PSB. For RF under pulsed excitation, a similar structure is predicted for the spectrum. However, our studies of RF under cw excitation with white noise show that fluctuation-induced transient dynamics results in non-elastic scattering, manifested by a broadened line at transition frequency.

Here we use a two-level independent boson model of an emitter coupled to longitudinal acoustic (LA) phonons via a deformation potential. We solve the Lindblad equation for the evolution of our system. Then, to compute the RF spectrum, we use the Lax theorem for the two-point autocorrelation function. As the detuning is decreased, the overall scattering intensity grows (and therefore the PSB increases), whereas the narrow feature evolves from a mostly absorptive shape to a spectral dip around the transition frequency.