Cascade atom in high-Q cavity: the spectrum for non-Markovian decay

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The spontaneous emission spectrum for a three-level cascade configuration atom in a single mode high-Q cavity coupled to a zero temperature reservoir of continuum external modes is determined from the atom–cavity mode master equation using the quantum regression theorem [1]. Initially the atom is in its upper state and the cavity mode empty of photons. Following Glauber [2], the spectrum is defined via the response of a detector atom. Spectra are calculated for the detector located inside the cavity (case A), outside the cavity end mirror (case B - end emission), or placed to record emission sideways from the cavity (case C) (see Fig. 1). The spectra for case A and case B are found to be essentially the same. In all the cases the predicted lineshapes are free of instrumental effects and only due to cavity decay. Spectra are obtained for intermediate and strong coupling regime situations (where both atomic transitions are resonant with the cavity frequency), for cases of non-zero cavity detuning, and for cases where the two atomic transition frequencies differ. The spectral features for cases B(A) and C are qualitatively similar, with six spectral peaks for resonance cases and eight for detuned cases. These general features of the spectra can be understood via the dressed atom model [3]. However, case B and C spectra differ in detail, with the latter exhibiting a deep spectral hole at the cavity frequency due to quantum interference effects (see Fig. 2). The spectra are qualitatively different from the two-level atom case and are still to be confirmed in experiments.

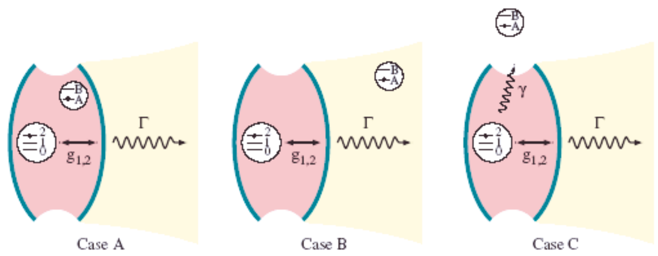

Figure 1: The cascade atom in a high-Q cavity with the detector atom in various locations. In case *A* the detector atom is inside the cavity, in case *B* it is outside the cavity output mirror and positioned to detect end emission and in case *C* it is outside the cavity positioned to detect side emission.

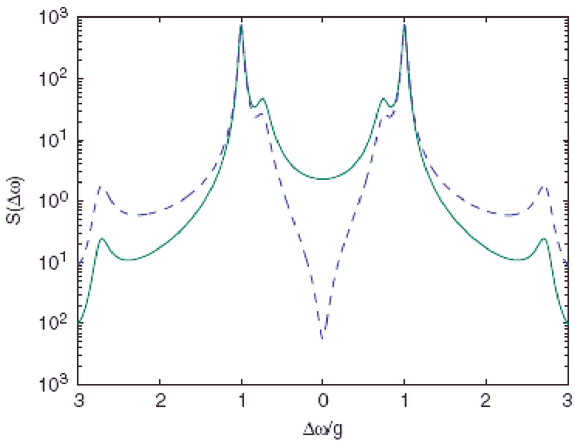

Figure 2: Cascade atom in high-Q cavity. SE spectra $S(\omega)$ versus spectral detuning from cavity frequency $\Delta\omega = (\omega - \omega_c)$. The case of resonance is shown, where each transition is resonant with the cavity frequency, $\delta = \bar{\delta} = 0$. The coupling constants are $g_1 = g_2 = 1$ and the detector coupling constants are $\mu = R_1 = R_2 = 1$. The cavity decay is $\Gamma = 0.1$. The solid line is for case $A(B)$-end emission and the dashed line is for case C-side emission.

References

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