Quantum Interface and Cooperative Processes in One-Dimensional Atomic Systems

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Ordered atomic arrays trapped in the vicinity of nanoscale waveguides offer original light-matter interfaces, with applications to quantum information and quantum nonlinear optics. We report on our study of the decay dynamics of a single collective atomic excitation coupled to a waveguide in different configurations. The atoms are arranged as a linear array, and only a segment of them is excited to a superradiant mode and emits light into the waveguide. Additional atomic chains placed on one or both sides play a passive role, either reflecting or absorbing this emission, see Fig. 1 (upper image). We show that when varying the geometry, such a one-dimensional atomic system could be able to redirect the emitted light, to directionally reduce or enhance it, and in some cases, to localize it in a cavity formed by the atomic mirrors bounding the system [1,2].

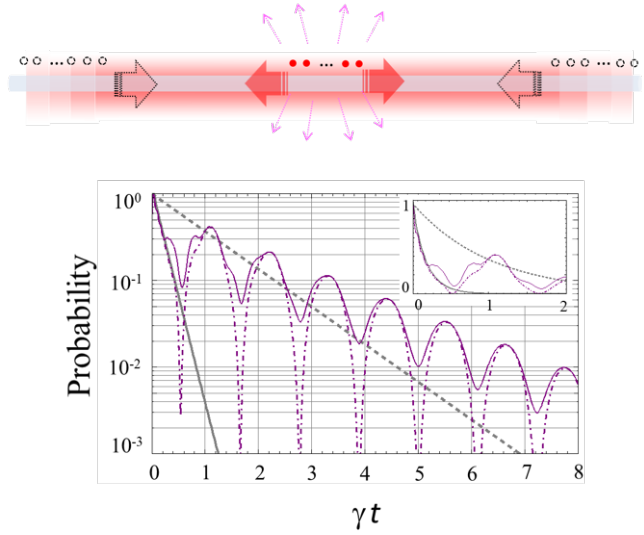

Figure 1: The excitation geometry and the calculation example, see text

In Fig. 1 (lower graph), we show the excitation probabilities calculated for some specific parameters in the case of a long resonator: the decay of the probabilities for the emitter (magenta dash-dotted line) and of the global chain (magenta solid line). Also shown are the cooperative emission of the unperturbed collective emitter (gray) and the single-atom natural, spontaneous decay in free space (gray dashed). The inset in linear scale clarifies the early stage of the decay process. As evident from this graph in the strong-coupling case in cavity QED, the model predicts strong intracavity quantum Rabi oscillations.

We will also discuss other examples of the quantum interface between light and atomic arrays involving a relatively small number of working atoms. This concerns the problem with quantum memories and various demonstrations of cooperative phenomena and light localization assisted by nanostructures.

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References

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