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Multimode-cavity picture of non-Markovian waveguide QED

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We introduce a picture to describe and intrepret waveguide-QED problems in the non-Markovian regime of long photonic retardation times resulting in delayed coherent feedback. The framework is based on an intuitive spatial decomposition of the waveguide into blocks. Among these, the block directly coupled to the atoms embodies an effective lossy multimode cavity leaking into the rest of the waveguide, in turn embodying an effective white-noise bath. The dynamics can be approximated by retaining only a finite number of cavity modes which grows with the time delay. This description captures the atomic as well as the field's dynamics, even with many excitations, in both emission and scattering processes. As an application, we show that the recently identified non-Markovian steady states can be understood by retaining very few or even only one cavity modes.

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