A Lindblad master equation capable of describing hybrid quantum systems in the ultra-strong coupling regime

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Abstract

Light-matter interaction between confined electromagnetic fields formed in cavities and quantum emitters is of great interest because it allows to change the fundamental properties of the hybrid systems constituents. This topic has been already widely investigated for different types of systems ranging from cold atoms in optical cavities [1,2] to superconducting qubit-oscillator circuits [3]. However, despite a large theoretical effort devoted to considering light-matter interaction in different regimes, the so-called ultra-strong coupling regime [4] still presents significant challenges for theoretical treatments and prevents the use of many common approximations. In the present work, we propose a model that can describe such systems to any level of accuracy for an arbitrary electromagnetic environment. We extend an approach developed in our group for few-mode quantization of arbitrary systems [5] to the case of large light-matter coupling constants and/or ultrabroad-bandwidth resonances and show that even such systems can be treated using a Lindblad master equation where decay operators act only on the photonic degrees of freedom. We also provide a comparison with state-of-the-art master equation approaches, which show quite noticeable disagreement with our model for the considered problems.

Figures

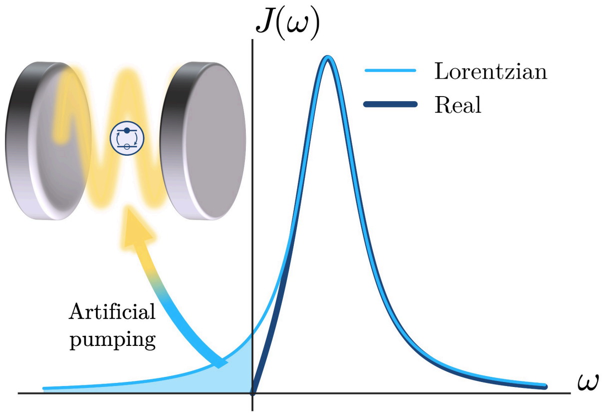

Figure 1: A realistic spectral density at zero temperature and its Lorentz approximation, corresponding to the Lindblad master equation. The spectral tail at negative frequencies causes the artificial pumping of the hybrid quantum system.

References

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