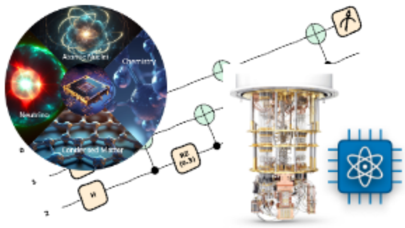

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Time-delayed collective dynamics in waveguide QED and bosonic quantum networks

Friday, November 21, 2025 2:30 PM (25 minutes)

This work introduces a theoretical framework to model the collective dynamics of quantum emitters in highly non-Markovian environments, interacting through the exchange of photons with significant retardations [1]. The formalism consists on a set of coupled delay differential equations for the emitter's polarizations, supplemented by input-output relations that describe the field mediating the interactions. These equations capture the dynamics of both linear (bosonic) and nonlinear (two-level) emitter arrays. It is exact in some limitse.g., bosonic emitters or generic systems with up to one collective excitationand can be integrated to provide accurate results for larger numbers of photons. These equations support a study of collective spontaneous emission of emitter arrays in open waveguide-QED environments. This study uncovers an effect we term cascaded super- and sub-radiance, characterized by light-cone-limited propagation and increasingly correlated photon emission across distant emitters. The collective nature of this dynamics for two-level systems is evident both in the enhancement of collective emission rates, as well as in a superradiant burst with a faster than linear growth. While these effects should be observable in existing circuit QED devices or slight generalizations thereof, the formalism put forward in this work can be extended to model other systems such as network of quantum emitters or the generation of correlated photon states.

[1] arXiv:2505.02642 [quant-ph] (2025)

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