

Non-Gaussian framework for multimode spin-boson models in the strong coupling regime

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We investigate the energy landscape of a multimode optical cavity containing a nonuniform tweezer array, governed by an effective Hamiltonian featuring spin-phonon-photon interactions. This setup reveals how site-dependent couplings influence collective phenomena, including multi-stage superradiant phase transitions and the self-organisation of atoms into the antinodes of the cavity standing wave. To effectively describe the system in the strong coupling limit, we employ a dressing transformation that partially decouples the Hamiltonian, allowing us to utilize a non-Gaussian variational framework. This method serves as a generalization of the Lang-Firsov transformation for multimode bosonic interactions and can be broadly applied to a wide variety of multimode spin-boson models.

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