Selective Preparation of Collective States via SUPER Excitation

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The efficient preparation of the superradiant and subradiant states in dipole-coupled quantum emitters is a central challenge, as it provides access to immediately witnessing their signature radiative properties and subsequently enables their applications in quantum information processing. Here, for the first time, we theoretically demonstrate the possibility of deterministic and efficient preparation of collective states of two two-level quantum emitters at deep-subwavelength separation using the Swing-UP of quantum EmitteR population (SUPER) excitation scheme [1]. This ultrashort and unconventional excitation scheme, relying on two red-detuned time-overlapped Gaussian pulses, penetrates the system's electromagnetic environment to achieve near-unity population inversion in targeted pure collective eigenstates, both with and without an optical cavity. By introducing a tunable optical phase, hybrid collective states can also be prepared. Furthermore, our effort to populate collective states in a cavity interface paves the way for efficient preparation of collective states even in the presence of a certain amount of environmental decoherence, making our predictions suitable for solid-state emitters and molecules. In addition, our scheme enables single-photon generation (with an optical cavity), which, in principle, could operate at elevated temperatures. The state-of-the-art and foreseeable developments suggest that our predictions are likely to be realized in the future.

References

[1] J. Kerber, L. Ostermann, V. Remesh, H. Ritsch, and A. Pal, arXiv:2508.19692 (2025).

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