Quantum Coherent Perfect Absorption in Nanoplasmonic Cavities

Ortwin Hess

Trinity College Dublin, The University of Dublin, College Green, Dublin, Ireland

Plasmonic nanoresonators offer the unique ability to confine light to extremely sub-wavelength volumes and strongly enhance local optical fields via resonant surface plasmon modes, thereby constituting exceptional architectures for enhanced light-matter interaction and the exploration of extreme nano-optics for quantum dynamics. In particular, room-temperature strong coupling using single molecules and colloidal quantum dots in nanoplasmonic environments has been realized using ultrathin (□1 nm) nanoplasmonic cavities [1] and scanning probe tips [2]. While ultrafast plasmonic near-field evolution can be exploited to achieve high-speed quantum operations [3], including dynamic bi [4]- and tripartite [5] entanglement in quantum dots, it is vital to explore pathways for improving the temporal robustness of strongly coupled plasmon-emitter states under ambient conditions, with the aim of realizing truly room-temperature-viable quantum nanophotonic devices.

Here, a novel strategy for selective preparation and, conceivably, ‘immortalization’ of selected plasmon-exciton polariton states by means of quantum coherent perfect absorption (qCPA) is discussed. It is shown that under plasmonic nanowire-waveguide driving, the qCPA regime can selectively lock a nanocavity-emitter system in either the upper or lower plasmon-emitter polariton state. Furthermore, in this regime, the intrinsic losses of the nanocavity-emitter device can be precisely compensated for, effectively paving the way towards strongly coupled light-matter states that are robust against decoherence at room temperature. This contrasts sharply with the conventional belief that preserving an individual quantum state requires cryogenic cooling andstrict isolation of the system from environmental influence. In fact, here, dynamic dissipation under ambient conditions is fully embraced, strategically harnessing its interplay with plasmon interference in a specific dressed state to establish the qCPA regime itself. As a novel paradigm for quantum state preparation and preservation in plasmonic cavity quantum electrodynamics (cQED), qCPA offers exciting prospects for innovative and room-temperature-viable quantum nanophotonic technologies.

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