Cavity Quantum Electrodynamics with Individual Perovskite Quantum Dots Coupled to a Fiber Microcavity

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Organic and inorganic lead halide perovskite quantum dots (pQDs) have recently emerged as highly promising nano-emitters due to their outstanding optical properties, including high brightness, tunable optical bandgap, reduced blinking, and easy and low-cost fabrication [1]. These features place them as strong candidates to realize a new generation of optoelectronics devices such as light emitting diodes (LEDs), lasers, photodetectors, or even liquid crystal displays (LCD). At the individual quantum dot level, single photon emission at room temperature [2] and long coherence times at cryogenic temperature [3, 4] have been observed. These features hold great promise for employing pQDs as foundational elements for the efficient generation of single photons in quantum optics and quantum communication applications.

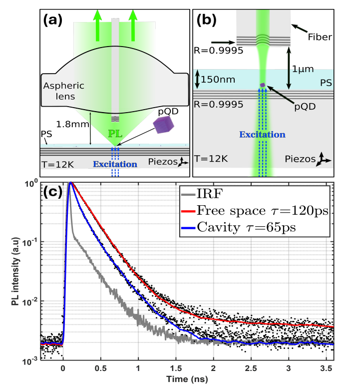

Fig. 1. (a) Free space configuration. (b) Cavity configuration. (c) Time-resolved photoluminescence of a pQD in free space and in cavity.

In this context, the next challenge is to couple single pQDs to an optimized photonic structure to control and boost the nano-emitters spontaneous emission properties using cavity Quantum ElectroDynamics (cQED) effects.

To achieve this goal, we have designed and implemented a reconfigurable open fiber-based microcavity, especially suited for $CsPbBr_3$ pQDs (Figures 1a and 1b). It is based on a highly versatile setup that was previously successfully optimized for single carbon nanotubes [5]. In contrast to more conventional monolithic microcavities, which are designed to ensure spatial and spectral matching with a specific nano-emitter and cannot be modified afterwards, this fiber microcavity is perfectly suited for solution-processed nano-emitters such as pQDs. It is composed of a planar mirror on top of which pQDs are deposited and a movable concave fiber mirror. This geometry enables us to both ensure the spatial and spectral matching for various pQDs and to study the same nano-emitter in free space and in cavity configurations.

By comparing the photoluminescence (PL) lifetime of a single pQD in free space and coupled to the cavity in the Purcell regime (Fig. 1c), we measured Purcell factors up to F_p=3, corresponding to nearly a 2-fold acceleration in PL lifetime. This initial result opens the path to realizing a narrow and efficient single-photon source at the cavity resonance frequency in the weak coupling regime. The reversible coupling of individual pQDs to the cavity presents also a highly interesting tool for exploring light-matter interaction in these promising nano-emitters. In a short-term, one should expect the increase of the photon indistinguishably of the emitted photons thanks to the cavity. In a longer-term perspective, more advanced cQED effects could also be used to realize quantum photonic logic gates.

References

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