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Engineered plasmonic resonances with Fabry-Perot optical microcavities

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Optical cavities play a crucial role in confining light in both the time and frequency domains, serving as essential components in fundamental and applied studies. Higher quality factor (Q) and smaller mode volume (V) are sought-after characteristics, as the Purcell factor is directly proportional to Q/V. Dielectric microcavities possess an ultra-high Q but a relatively large V, whereas plasmonic nanocavities have an ultra-small V but suffer from significant Ohmic loss. Hybrid microcavities combine the high Q of dielectric microcavities with the subwavelength confinement of plasmonic nanocavities [1-5]. Theoretical studies predicted improved coherent radiation and reduced incoherent dissipation [3]. Experiments have also demonstrated their abilities in boosting single quantum dot emission, single-particle detection, and ultra-sensitive photothermal detection. Moreover, in a recent report using a leaky Fabry-Perot (FP) cavity, the linewidth of the hybrid microcavity is compressed and matched to that of excitons to realize strong coupling, which dramatically relaxes the harsh requirement for single-exciton strong coupling, thus significantly improving the success rate [5].

In the paper titled "Reshaping plasmon modes by film interference" [1], the authors take advantage of the constructive and destructive modes in FP cavities and investigate how they can engineer the LSPR. When a metal nanoparticle is positioned at the anti-node of the cavity field, the constructive mode reshapes the LSPR with a 58% reduction in linewidth and a 3.6-fold enhancement in radiation. In contrast, when the destructive mode coherently cancels the scattering of a metal nanoparticle, the scattering spectrum exhibits double peaks, each of which has significantly narrower linewidth. In either case, the modes of the hybrid microcavity possess lower loss and higher radiation compared to the stand-alone LSPR. Such an FP-reshaped hybrid mode is paramount for paving the way toward low-loss plasmonic photonics and practical applications.

This study introduces a direct approach to engineering and regulating the dissipation of LSPRs with the constructive/destructive FP cavity modes. Though the discussions have been focused on the spectral dimension, the local density of states that are simultaneously regulated may attract more attention to the light-matter interaction community. With the FP-reshaped cavity fields, the realization of room-temperature single-exciton strong coupling can be much more efficient, further advancing the development of room-temperature quantum devices.

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