Microcavity-engineered plasmonic resonances for strong light-matter interaction

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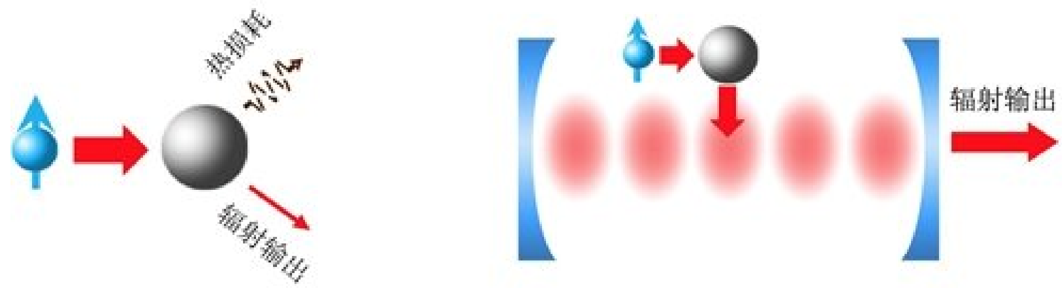

Figure 1. Left. A quantum emitter interacting with a metallic nanostructure in the vacuum. Right. A quantum emitter interacting with a microcavity-engineered metallic nanostructure. Credit: Peking University

Achieving strong light-matter interaction at the quantum level has always been a central task in quantum physics since the emergence of quantum information and quantum control. However, the scale mismatch between the quantum emitters (nanometers) and photons (micrometers) makes the task challenging. Metallic nanostructures resolve the mismatch by squeezing the light into nanoscale volume, but their severe dissipations make quantum controls unlikely. Now, a group led by Xiao Yun-Feng at Peking University (China) has theoretically demonstrated that the strong light-matter interaction at quantum level can be achieved using microcavity-engineered metallic nanostructures. This result has been published in a recent issue of *Physical Review Letters*.

Strong coupling is fundamental to implementing quantum gates in quantum computers and also crucial to increasing the signal-to-noise ratio in sensing applications. To realize strong coupling, the coherent interaction strength should exceed the system dissipation rates. Although the metallic nanostructures provide high interaction rate, the dissipations intrinsic to metals are usually even stronger. As a result, strong coupling in metallic nanostructures has only been realized in extreme experimental conditions.

In this work, the researchers report that the dissipation can be suppressed by engineering the electromagnetic environment of metallic nanostructures. An optical microcavity provides a non-trivial electromagnetic environment which substantially broadens the radiative output channel of the metallic nanostructures, guiding the energy out from the dissipative region and thus suppressing the dissipations. With such an interface, energy and information can be guided out from the single quantum emitter at both high speed and high efficiency.

"Theoretical model shows that microcavities-engineered metallic structures can boost the radiation efficiency of a quantum emitter by 40 times and the radiation output rate by 50 times, compared to metallic nanostructures in the vacuum", said Peng Pai, who was an undergraduate at Peking University and now is a Ph.D. student at Massachusetts Institute of Technology. Importantly, reversible energy exchange between the photon and the quantum emitter at THz rate can be achieved, manifesting the strong light-matter interaction at the quantum level.

"Our approach to reducing the dissipations is not restricted by the scale, shape, and material of the metallic nanostructures," said Professor Xiao. "In combination with previous approaches, it is promising to build the state-of-the-art light-matter interface at nanoscale using microcavity-engineered metallic nanostructures, providing a new platform for the study of quantum plasmonics, quantum information processing, precise sensing and advanced spectroscopy."

More information: Pai Peng et al. Enhancing Coherent Light-Matter Interactions through Microcavity-Engineered Plasmonic Resonances, *Physical Review Letters* (2017). DOI: 10.1103/PhysRevLett.119.233901

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