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Reversible Population Dynamics at the Nanoscale for a Quantum Emitter Near a WSe_2 Monolayer †

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Abstract: The interaction of quantum emitters with photonic antennas created by nanoscale structures may lead to several interesting phenomena with many important potential applications in current and future technology. There are two distinct regimes of light–matter interaction between a quantum emitter and its modified photonic environment, the weak coupling regime and the strong coupling regime, where the quantum emitter has a completely different spontaneous emission response. In the weak coupling regime, an initially excited quantum emitter shows an exponential spontaneous emission dynamic (Markovian response), but the spontaneous decay rate can be markedly different from the free-space vacuum, and can be either enhanced or suppressed due to the Purcell effect. In the strong coupling regime, there is a coherent exchange of energy between the quantum emitter and its modified nanophotonic environment, which manifests itself in non-exponential spontaneous emission dynamics (non-Markovian response). We investigate the spontaneous emission dynamics of a two-level quantum emitter in proximity to an atomically thin tungsten diselenide (WSe_2) layer at various distances of the emitter from the layer and various free-space decay rates of the emitter. Depending on the distance and the decay rate value, our studies cover the range of the weak to strong coupling regime of the light–matter interaction between the quantum emitter and the electromagnetic continuum modified by the WSe_2 layer. We find that the decay dynamics is Markovian under weak coupling conditions, and it becomes strongly non-Markovian, characterized by oscillatory population emitter dynamics, on the top of the overall population decay, as well as population trapping in the emitter. Besides population evolution, we also discuss the non-Markovian spontaneous emission dynamics using a widely used non-Markovianity measure.

Keywords: quantum emitter; two-dimensional material; transition-metal dichalcogenide; Purcell effect; spontaneous emission; non-Markovianity measure

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