Emergent functionality in quantum plasmonics

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Enhancing complexity in interacting systems could give rise to emergent behavior with phase transitions and chaos as striking examples. It is interesting to ask on what level of complexity such emergent behavior arises in quantum systems. Here we demonstrate that already for two interacting quantum systems coupled to the environment a new functionality of the system emerges, i.e., single-photon spontaneous down conversion occurs in a plasmon-exciton hybrid system with almost unity efficiency. In strongly coupled quantum systems, pure dephasing mechanisms acting on one constituent of the hybrid system break symmetry and enable optical transitions, which are forbidden in the uncoupled system. Here we employ this concept to a localized plasmon ultrastrongly coupled to an exciton, which is exposed to an ultrafast pure dephasing process, and demonstrate single-photon induced parametric down-conversion. Fast pure dephasing of the exciton enables photon pair generation as the dominating energy relaxation pathway for the excited system. Note that here the pure dephasing via the interaction with the environment, which is in general seen as a detrimental effect, is key to enable the desired functionality.