Tailoring photophysics based on hybrid nanostructure: Toward metadevices

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Tuning, manipulating, and activating photophysical processes are extremely important not only in revealing new fundamental mechanism but also in developing novel types of optoelectronic devices. To this end, hybrid nanophotonic structures have been utilized as an attractive strategy for controlling the photophysics, which impacts various applications such as light emitting devices, quantum information processing, photocatalysis activation, tunable photodetection, and energy harvesting devices. In this talk, I will present my research topic and achievement related to photophysics engineering. First, I will discuss the nonlocal control of photophysical processes in organic-nanophotonic hybrid structures using ultrafast time-resolved optical spectroscopy. I will show the experimental observation and theoretical analysis that a metamaterial structure composed of metal-dielectric multilayers can significantly vary charge transfer dynamics in organic semiconductors. Based on this work, I will introduce follow-up studies on controlling the distance dependent charge transfer rate and optical field driven charge transfer dynamics. Next, I will discuss the spectral blue shift of intramolecular charge transfer emission by nonlocal effect of hyperbolic metamaterials and the identification of distance regime where hyperbolic dispersion has practically impact on spontaneous emission rate. Finally, I will present the study on exciton dynamics in 2D MoS_2-hyperbolic metamaterial hybrid structure, in which we have revealed the exact exciton migration mechanism and enhancement of energy transfer efficiency.