Institut für Festkörperphysik

Abteilung Atomare und Molekulare Strukturen

Vortrag

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“Nanophotonics and Cavity QED Using Atomically Thin Materials“

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Abstract

2D semiconductors are ideally suited as active materials for the solid-state cavity QED system, since they host rich excitonic photo-physics and can be assembled into heterostructures via the van der Waals bonding. However, the integration of 2D semiconductors to quasi 0D nanocavities while preserving *pristine* excitonic properties and high cavity Q-factors remains a challenge. Most commonly, non-encapsulated monolayers are stacked directly on top of prefabricated photonic structures. In this case, the disorder from the substrate strongly perturbs the excitonic properties. Meanwhile, perforating photonic structures in 2D semiconductors results in complex effects and limits the cavity Q-factor ~10^3.

Our hybrid nanocavity solves the problems by making unperforated 2D flakes a functional part of the cavity dielectric structure. As such, the *pristine* excitonic properties and the large overlap to the cavity mode are achieved simultaneously. Our approaches provide cavity Q-factors routinely over 10^4 and some reach the ultra-high value over 10^5 [1]. In such a good platform, we find that the free exciton in monolayer MoS_2 operates in a nonlocal regime of light-matter interaction, arising from the phonon-limited exciton mobility which extends over the cavity photonic mode volume [1]. Moreover, we observe a phononic hybridization between the lattice and nanomechanical degrees of freedom, and this coupling exhibits an unexpected selectivity to the neutral exciton [2]. These works reveal the significant impact of phonon processes in the light-matter interaction of 2D materials, and enable the control of these processes using phononic technologies.

Compared to traditional emitters dominated by zero-phonon emission, the charged boron vacancy V_B^- in hBN is a unique emitter that has a weak zero-phonon line, emission instead being dominated by phonon-induced processes [3]. This indicates that V_B^- is intrinsically sensitive to, and interacts with local deformations induced by phonon modes. We probe the phonon processes in the V_B^- emission and construct a model for which the light-matter coupling is induced by the phonons. Our model accounts well for the experiment, establishing the strong interplay between different photon (V_B^- emission, cavity photonic) and phonon (V_B^- phonon, cavity mechanical) modes as an emitter-optomechanical system [4]. Such multi-modal couplings provide new paradigms to interface spin defects, photons and phonons in condensed matter systems.