Fermi-polarons and polaritons in two dimensional materials

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Cavity-polaritons have emerged as an exciting platform for studying interacting bosons in a driven-dissipative setting. Typically, the experimental realization of exciton-polaritons is based on undoped GaAs quantum wells (QW) embedded in between two monolithic distributed Bragg reflector (DBR) layers. Introduction of a degenerate electron gas either to the QW hosting the excitons or a neighboring layer substantially enriches the physics due to polariton-electron coupling. It has been proposed that such an interacting Bose-Fermi mixture can be used to study polariton-mediated superconductivity in a two dimensional electron gas.

Transition metal dichalcogenide (TMD) monolayers, such as molybdenum diselenide (MoSe2), represent a new class of valley semiconductors exhibiting novel features such as strong Coulomb interactions, finite exciton Berry curvature with novel optical signatures and locking of spin and valley degrees of freedom due to large spin-orbit coupling. In contrast to quantum wells or two-dimensional electron systems in III-V semiconductors, TMD monolayers exhibit an ultra-large exciton binding energy of order 500 meV and strong trion peaks in photoluminescence that are red-shifted from the exciton line by 30 meV. In this talk, I will present cavity spectroscopy of gate-tunable monolayer MoSe2 and show that in the limit of perturbative cavity coupling elementary optical excitations in this system are attractive and repulsive exciton-polarons – excitons dressed by Fermi sea electron-hole pairs. By reducing the cavity length, we reach the strong-coupling limit of cavity-QED and observe polariton formation in both attractive and repulsive branches: this constitutes a new regime of polaron physics where the polariton impurity mass is much smaller than that of the itinerant electrons. Our findings constitute a first step in investigation of a new class of degenerate Bose-Fermi mixtures consisting of polaritons and electrons.