Exciton Coupled to Fermi-Sea Polarizations In Semiconductor Quantum Wells and Transition-Metal Dichalcogenides

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Optical spectra associated with excitons in the presence of a Fermi sea (FS) in bulk or semiconductor quantum wells have been a subject of great interest for decades. Depending on the doping concentration, the Coulomb interaction between the photocreated exciton and the FS electrons can lead to various exotic complexes that come from the dressing of the exciton by Fermi-sea excitations, in the form of FS electron-hole pairs. At low doping, a bound state can emerge from the interaction of a trion and a FS hole, known as Suris tetron. [1,2] When the FS contains just one electron, this 4-particle complex reduces to the conventional X^- trion because there is no other hole state for the FS hole to scatter into to possibly form a bound state with the trion through repeated interactions.

Recently, we have developed a theory to study the exciton and its interaction with doped electrons in semiconductor quantum wells and found an interesting cross-over behavior of trion-hole complex and exciton polaron[3]. We show that an exciton-single-pair complex can exist by only keeping single electron-hole pair excitations in the Fermi sea. This 4-body complex behaves like a Fermi-sea hole weakly bound to a trion for $k_F a_x << 1$, where k_F is the Fermi wave-vector and a_x the exciton Bohr radius. The oscillator strength of photo-absorption associated with this trion-hole bound state increases as k_F increases. As k_F continues to increase, the feature of trion-hole bound state becomes unrecognizable, while the exciton state dressed by scattered electron-hole pairs (which can be interpreted as an exciton-polaron) becomes more pronounced. The evolution of the excitation spectra of these 4-particle coupled states (one exciton and one Fermi-sea electron-hole pair) as k_F increases reveals the cross-over from trion-hole resonance to exciton-polaron resonance, which is associated with the internal reconfiguration of the 4-body complex in the presence of the Fermi sea.

The same theoretical formalism has been extended to double quantum wells under electric field and to monolayer transition-metal dichalgogenides (TMDs) with the addition of spin-valley effects and suitable quasi-2D dielectric screening . The comparison of our theretical predictions with available experimental data (including reflance and photoluminecence pectra) will be presented.

References

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