Correlated Interlayer excitons in Atomically Thin van der Waals Semiconductor Heterostructures

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Atomically thin van der Waals (vdW) semiconductor heterostructures based on transition metal dichalcogenides (TMDs) are an electrically tunable platform for developing coherent on-chip optoelectronic devices. In these systems, interlayer excitons (IEs) form out-of-plane dipoles and exhibit long lifetimes due to the spatial separation of electrons and holes. Their bosonic nature and strong dipolar interactions make IEs ideal candidates for studying Bose-Einstein condensation in two-dimensional (2D) materials. In this talk, we discuss creating high densities of controllable excitons, an essential step in studying the phase diagram of dipolar exciton gases in atomically thin $MoSe_2/WSe_2$ heterostructures. Using electrostatic gating, we modulate the vertical electric fields, creating a quasi-1D trap for diffusive IEs and enabling control over the diffusion profile and local IE densities. By electrically modulating the density, we demonstrate linewidth broadening at the Mott density, which is independent of the local electrostatic profile. Employing these heterostructure as light emitting diode across the vdW interface, we also demonstrate photon emission from the IEs formed by electrically driven carrier injection. We observe a threshold in the electroluminescence of interlayer excitons as we increase the applied forward bias with balanced electron and hole injection. We characterize the nature of this transition further by performing second-order correlation function measurements. Strong photon number correlations have been observed near the IE emission threshold, indicating correlations among IEs in this regime. We unveil the novel phenomenon of steady-state cooperative electroluminescence from incoherently injected, electrically generated IEs. These results expand our understanding of non-equilibrium phases of matter and have the potential to advance the development of optoelectronic devices for future classical and quantum technologies.