Long-lived direct and indirect interlayer excitons in van der Waals heterostructures

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Ensembles of indirect or interlayer excitons (IXs) are intriguing systems to explore classical and quantum phases of interacting bosonic ensembles. IXs are composite bosons that feature enlarged lifetimes due to the reduced overlap of the electron-hole wave functions resulting in dense IX ensembles thermalized to the lattice temperature. Besides IX ensemble in III-V heterostructures [1,2], transition metal dichalcogenides exhibit superior potential for studying interacting IX ensembles due to a strong light matter interaction together with a large exciton binding energy in these 2D materials [3]. Hetero-bilayers from these materials have a type II band alignment driving an efficient charge transfer between the two layers that results in the formation of spatially separated electron hole pairs or interlayer excitons.

We report the observation of a doublet structure in the low-temperature photoluminescence of interlayer excitons in heterostructures consisting of monolayer MoSe2 and WSe2. Both peaks exhibit long photoluminescence lifetimes of several tens of nanoseconds up to 100 ns verifying the interlayer nature of the excitons. The energy and line width of both peaks show unusual temperature and power dependences. While the low-energy peak dominates the spectra at low power and low temperatures, the high-energy peak dominates for high power and temperature. We explain the findings by two kinds of interlayer excitons being either indirect or quasi-direct in reciprocal space. Our results provide fundamental insights into long-lived interlayer states in van der Waals heterostructures with possible bosonic many-body interactions [4].

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References

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