TMD excitons coupled to integrated photonic cavities: weak and strong-coupling regimes

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The integration of active photonic materials such as III-V or III-nitride semiconductors onto complementary metal-oxide semiconductor and dielectric photonic circuits has faced longstanding challenges. In this context, the ease of exfoliation and transfer of van der Waals materials onto nearly any material platform has fostered the development of integrated photonic devices based thereon. The use of van der Waals materials as integrated nonlinear devices began more than ten years ago, when graphene was exploited for fabricating modulators and photodetectors. More recently, the advent of transition metal dichalcogenides (TMDs) has further enriched this field. Indeed, their broken-inversion symmetry and strong spin-orbit interactions result in a unique combination of valley and spin degrees of freedom. Furthermore, monolayer TMDs host not only bright excitons that display very large binding energies and oscillator strengths, but also dark and charged excitons (i.e. trions). TMD-based heterostructures show an even larger plethora of excitonic species, including interlayer dipolar excitons, Moiré excitons, etc… rendering them particularly interesting for light-matter coupling studies, going from the weak-coupling regime to the strong-coupling regime.

TMD excitons have been mainly coupled to vertical microcavities made up of dielectric distributed Bragg reflectors and/or metallic mirrors. These vertical structures have enabled to showcase fundamental polaritonic phenomena thanks to the coupling of bright excitons and vertical-cavity modes, including polariton lasing, polariton-polariton nonlinearities and parametric scattering. While these effects had been previously demonstrated in more mature materials such as GaAs, the richness of excitonic species in TMDs enabled to demonstrate the achievement of additional polaritonic species, such as trion-polaritons, Moiré-polaritons and dipolar polaritons, modifying thereby the nature and strength of polariton-polariton interactions.

In this work we take advantage of the weak interlayer van der Waals forces to transfer TMD monolayers and heterobilayers onto dielectric in-plane photonic waveguides and cavities, and study the interaction of different excitonic species with the in-plane photonic modes, engineered thanks to the underlying patterned dielectrics. In particular, we will illustrate how one and the same photonic structure can couple differently to distinct excitonic species.

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