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2D MATERIALS

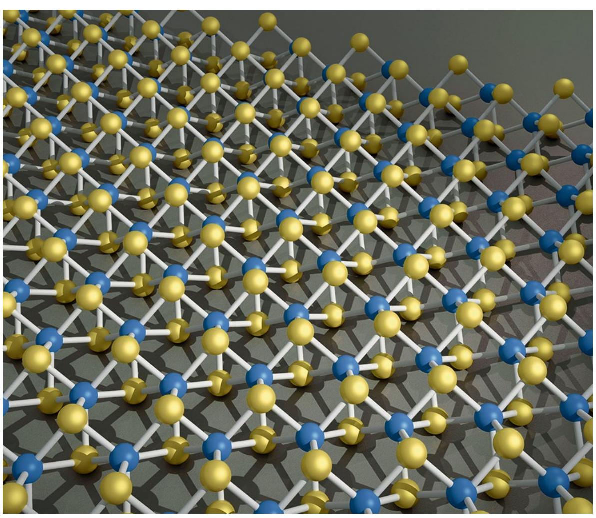
Valleytronics with a twist

> our work is an important step in realizing materials for valley-based optoelectronics

Interlayer excitons in twisted bilayers of WSe_2 have a high degree of valley polarization and long lifetimes, as Hongkun Park, Mikhail Lukin and colleagues report in *Physical Review Letters*.

Electrons and holes in 2D materials tend to reside in energetically favourable momentum states known as valleys. This endows them with a so-called valley degree of freedom, which in principle can be exploited to encode and process information in ways that go beyond conventional charge-based electronics.

Transition metal dichalcogenides (TMDs) have drawn particular attention in this field of valleytronics because, by shining circularly polarized light on them, one can selectively create excitons (bound electron–hole pairs) in one of two valley states. "These valley-selective excitons could play the role of zeros and ones in next-generation optoelectronic and information processing devices," explains Giovanni Scuri, co-first author of the paper. "Unfortunately, excitons in TMD monolayers tend to be short-lived and rapidly jump between the valleys, causing the stored information to be either quickly deleted or scrambled: realizing long-lived valley-selective excitons is a major challenge in the field."



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In natural, aligned bilayers of TMDs interlayer excitons, consisting of an electron and a hole hosted in different layers, have long lifetimes but suffer from rapid valley mixing. The researchers fabricated WSe_2 bilayers with a twist angle between the two layers, a strategy that is emerging as a powerful tool for property engineering. The devices were encapsulated in hexagonal boron nitride to avoid contamination and equipped with top and bottom graphene gates to enable independent control of doping and vertical electric fields. "In this engineered material system, the interlayer excitons can store the valley information for times that are orders of magnitude longer than for excitons in a single TMD layer," comments Trond Andersen, co-first author of the paper. "Moreover, this valley storage can be switched on and off simply by applying a voltage to the device: as such, our work is an important step in realizing materials for valley-based optoelectronics." A key effect of the twisting is that it changes the alignment between the valleys in the two layers in momentum space so that it is difficult for interlayer excitons in a given valley to hop to a different valley.

The new findings open up new opportunities for tuneable chiral photonics and electrically switchable valleytronic devices. "One exciting direction is to couple our system to functional structures that can enable routing of the information: this task can be achieved, for example, by integrating twisted TMDs with optical or plasmonic metasurfaces," concludes Park. "The valley storage time is currently limited by the exciton lifetime rather than by the valley scattering time, so another appealing direction is to incorporate our system in a cavity to extend the exciton lifetime. Finally, we are actively exploring twisted TMD bilayers as a platform for creating arrays of valley-selective quantum emitters, which could be used to realize solid-state quantum simulators."

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ORIGINAL ARTICLE Scuri, G. et al. Electrically tunable valley dynamics in twisted WSe_2/WSe_2 bilayers. *Phys. Rev. Lett.* **124**, 217403 (2020)