Electrical control of interlayer excitons in 2D van der Waals heterostructures

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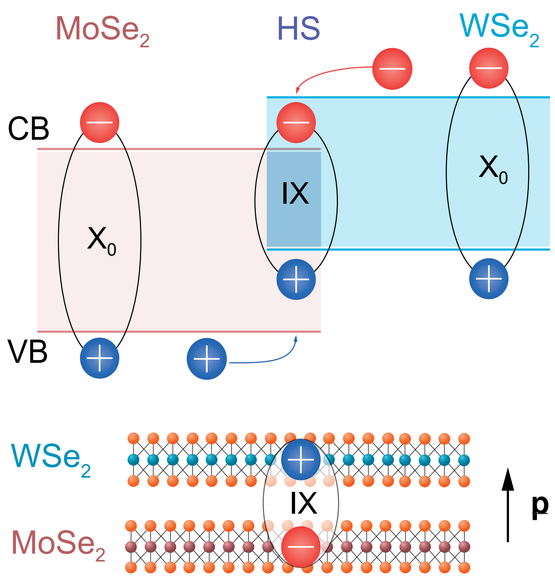
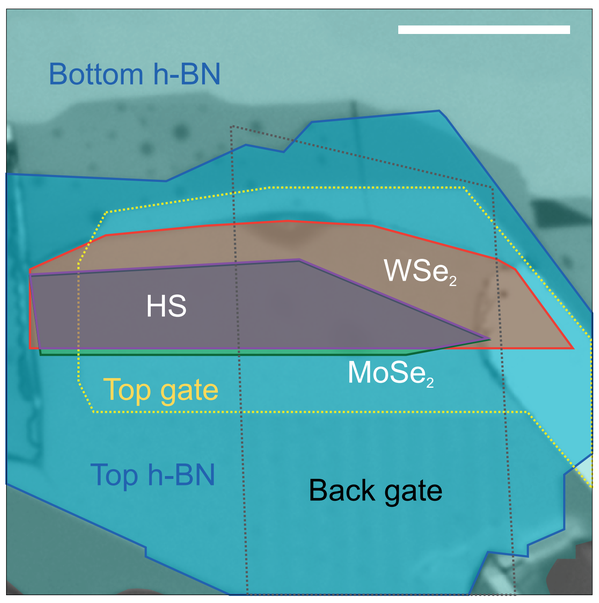
Introduction

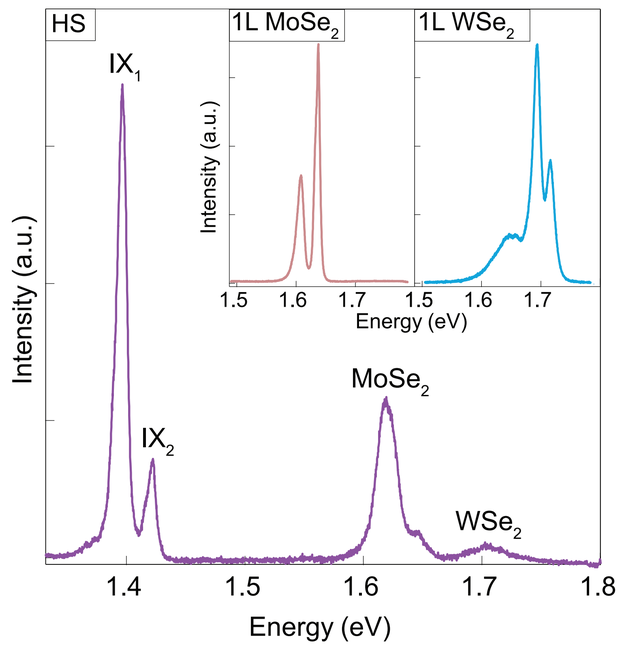
Long-lived interlayer excitons in van der Waals heterostructures (HS) based on transition metal dichalcogenides and unique spin-valley physics makes them promising for next-generation photonic and valleytronic devices. While the emission characteristics of interlayer excitons have been studied, efficient manipulation of their valley-state, a necessary requirement for information encoding, is still lacking. Here, we demonstrate comprehensive electrical control of interlayer excitons in a $MoSe_2/WSe_2$ heterostructure. An ultra-clean interface allows us to resolve two separate interlayer transitions with opposite helicities under circularly polarized excitation, either preserving or reversing the polarization of incoming light. By electrically controlling their relative intensities, we realize a **polarization switch** with tuneable emission intensity and wavelength.



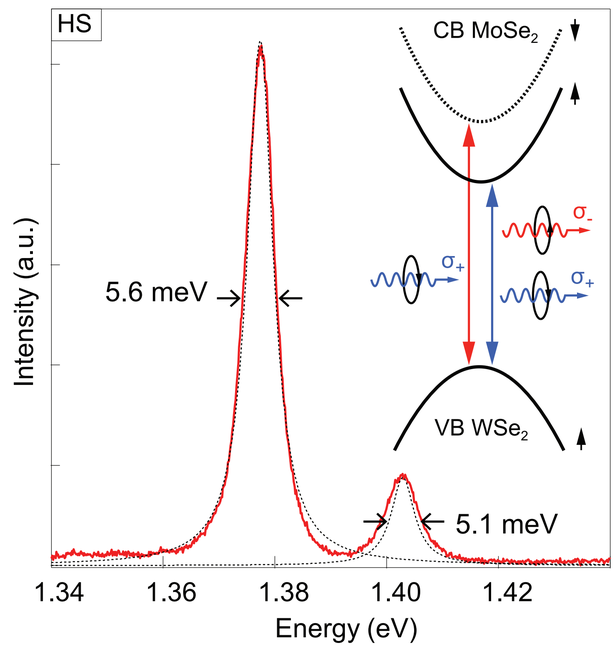
Band allignement of $MoSe_2/WSe_2$



Optical image of the device



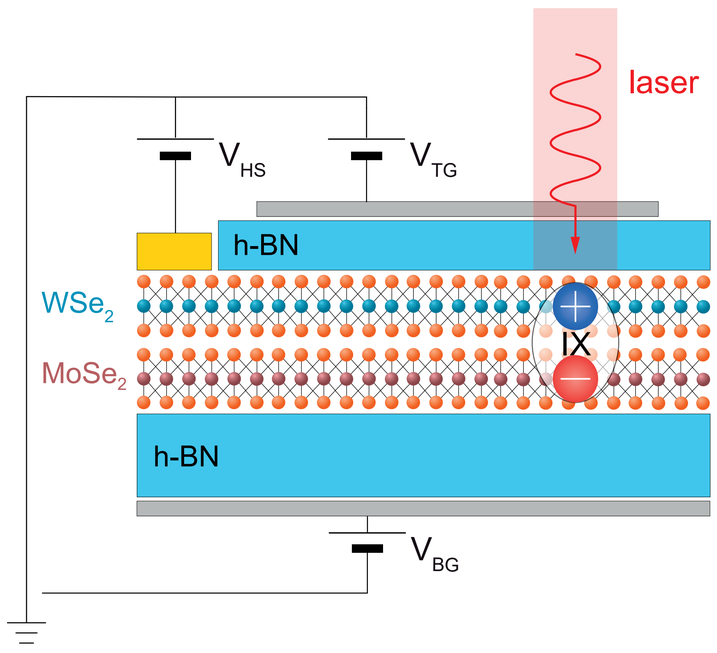
PL spectra from the heterostructure



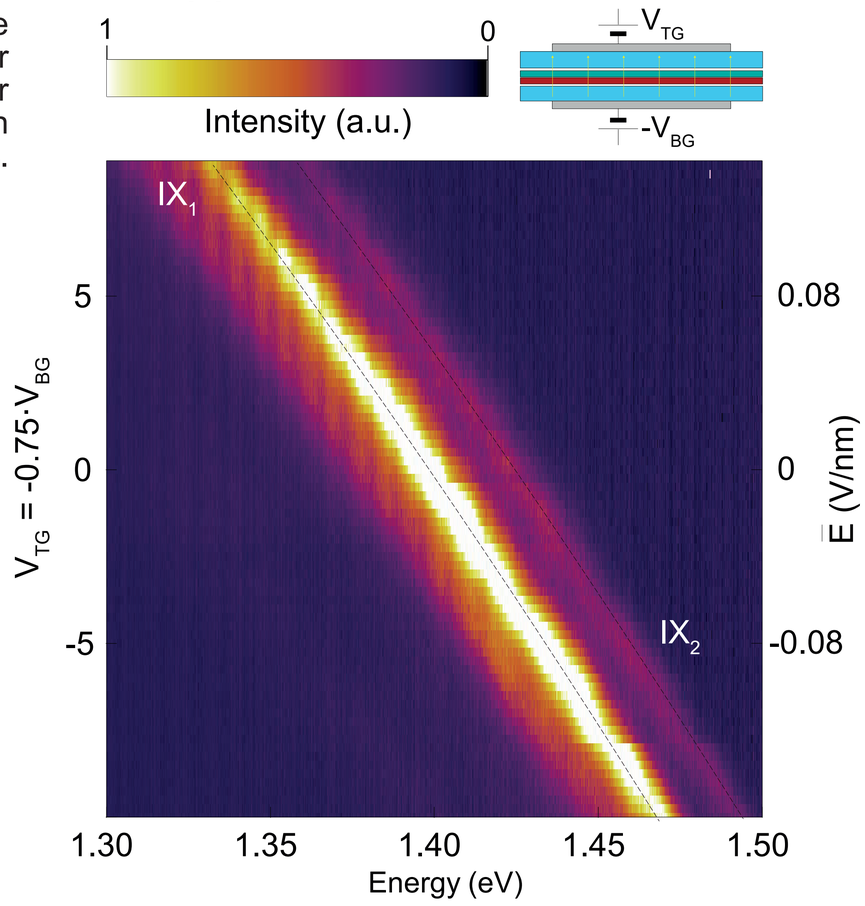
IX doublet with spin-triplet transition

Device structure

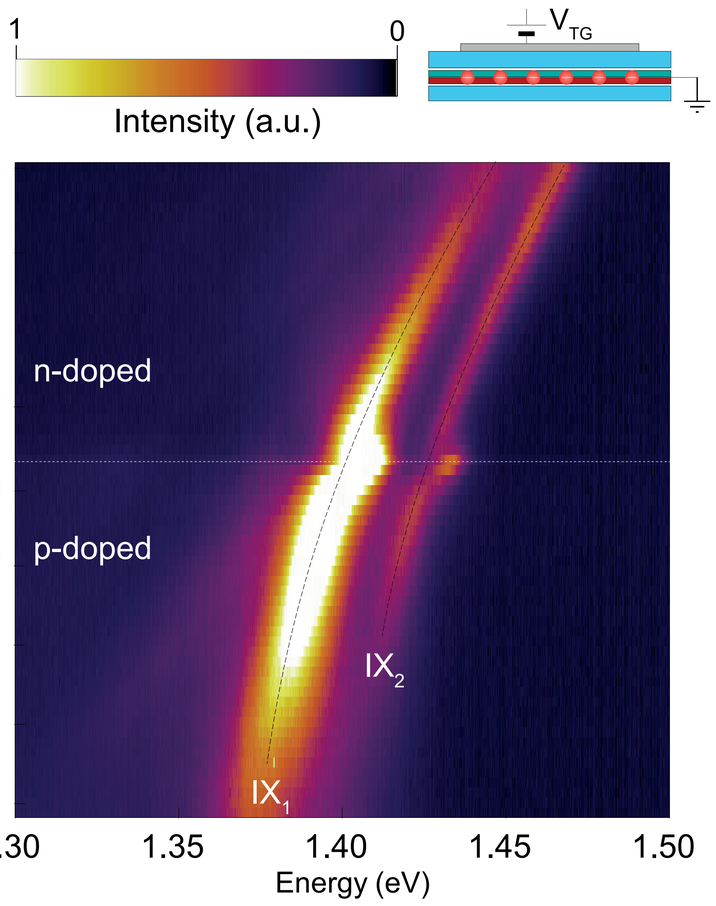
The hBN-encapsulated, double-gated heterostructure allows for precise and indipendent control of the carrier concentration and the electric field. We excite interlayer excitons with a 647 nm CW laser and detect the emission due to photoluminescence (PL) while operating the gates.



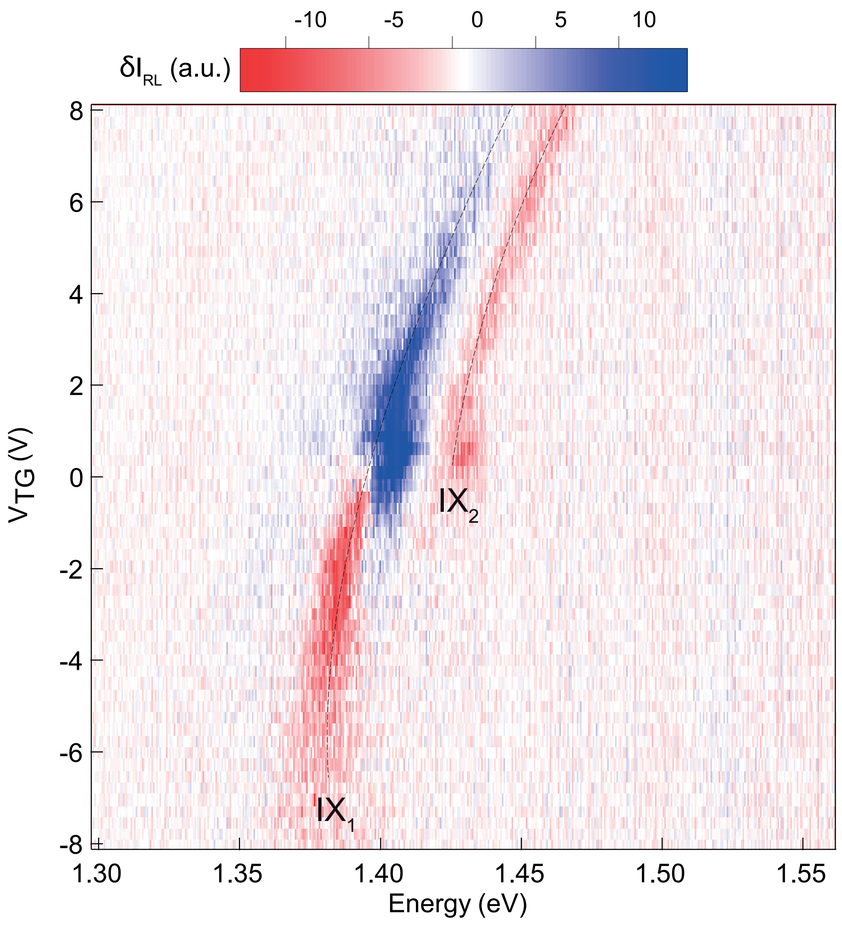
Application of electric field



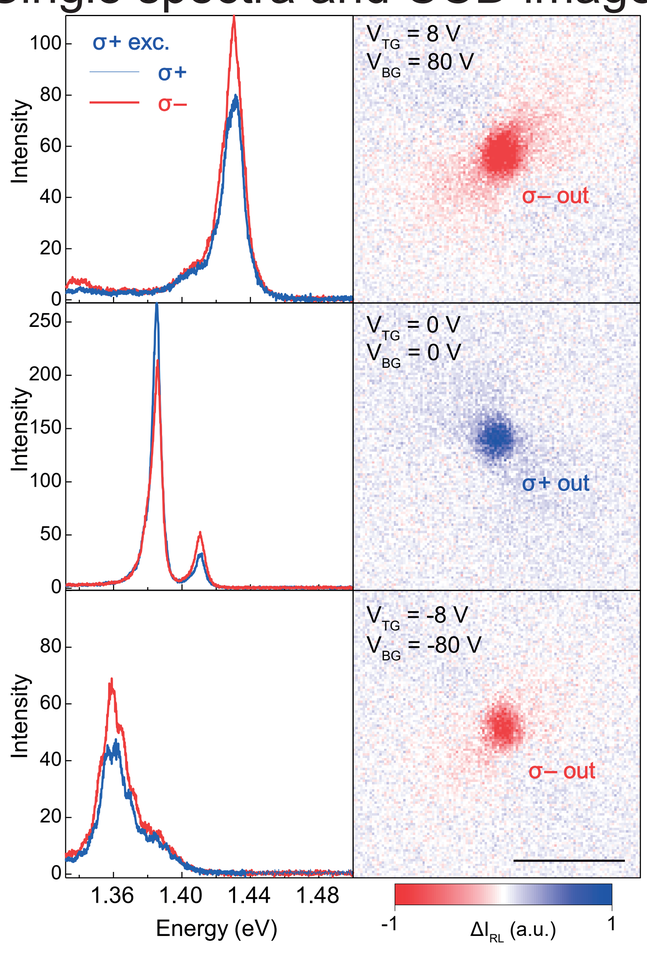
Carrier concentration



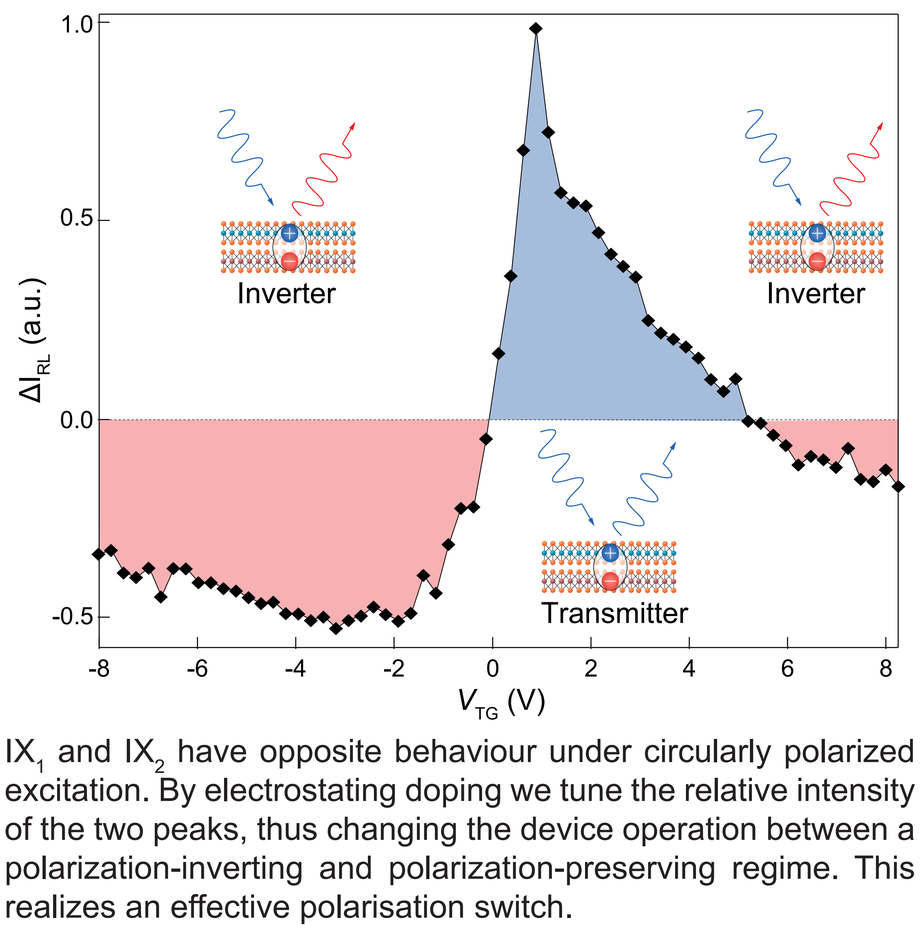
Polarization map



Single spectra and CCD images



Polarization switch



IX_1 and IX_2 have opposite behaviour under circularly polarized excitation. By electrostating doping we tune the relative intensity of the two peaks, thus changing the device operation between a polarization-inverting and polarization-preserving regime. This realizes an effective polarisation switch.

Conclusions

In conclusion, we have demonstrated comprehensive electrical control over the polarization, wavelength and intensity of emission from interlayer excitons in a $WSe_2/MoSe_2$ vdW heterostructure. The ability to integrate all these functions in a single device to fine-tune the emitted radiation is key to practical optoelectronics and could pave the way for novel applications for valleytronic devices. Even more importantly, polarisation conservation or reversal have been demonstrated to be gate-tuneable, enabling for the first time a polarization-inverting action.

References

A. Ciarrocchi*, D. Unuchek* et al. “Control of interlayer excitons in two-dimensional van der Waals heterostructures”, arXiv:1803.06405

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