Physikalisches Kolloquium

Universität Konstanz

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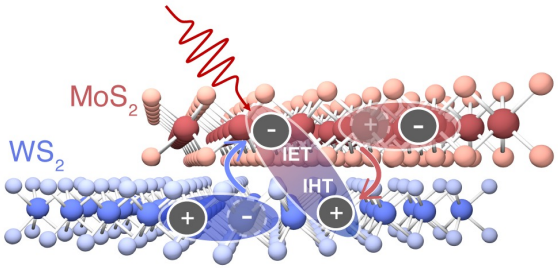
R513
Kaffee/Tee im Anschluss



Ultrafast charge transfer in heterostructures of two-dimensional materials

Heterostructures (HS) of two-dimensional materials offer unlimited possibilities to design new materials for applications to optoelectronics and photonics. In such HS the electronic structure of the individual layers is well retained because of the weak interlayer van der Waals coupling. Nevertheless, new physical properties and functionalities arise beyond those of their constituent blocks, depending on the type and the stacking sequence of layers. In this presentation we use high time resolution ultrafast transient absorption (TA) and two-dimensional electronic spectroscopy (2DES) to resolve the interlayer charge scattering processes in HS.

We first study a $WSe_2/MoSe_2$ HS, which displays type II band alignment with a staggered gap, where the valence band maximum and the conduction band minimum are in the same layer. By two-colour pump-probe spectroscopy, we selectively photogenerate intralayer excitons in $MoSe_2$ and observe hole injection in WSe_2 on the sub-picosecond timescale, leading to the formation of interlayer excitons (ILX). The temperature dependence of the build-up and decay of interlayer excitons provide insights into the layer coupling mechanisms [1]. By tuning into the ILX emission band, we observe a signal which grows in on a 400 fs timescale, significantly slower than the interlayer charge transfer process. This suggests that photoexcited carriers are not instantaneously converted into the ILX following interlayer scattering, but that rather an intermediate scattering processes take place We then perform 2DES, a method with both high frequency and temporal resolution, on a large-area W_S2/MoS_2 HS where we unambiguously time resolve both interlayer hole and electron transfer with 34 $\pm$ 14 and 69 $\pm$ 9 fs time constants, respectively [2]. We simultaneously resolve additional optoelectronic processes including band gap renormalization and intralayer exciton coupling.

Finally, we investigate a graphene/WS_2 HS where, for excitation well below the bandgap of WS_2, we observe the characteristic signal of the A and B excitons of WS_2, indicating ultrafast charge transfer from graphene to the semiconductor [3]. The nonlinear excitation fluence dependence of the TA signal reveals that the underlying mechanism is hot electron/hole transfer, whereby a tail the hot Fermi-Dirac carrier distribution in graphene tunnels through the Schottky barrier. Hot electron transfer is promising for the development of broadband and efficient low-dimensional photodetectors.

[1] Z. Wang et al., Nano Lett. **21**, 2165–2173 (2021).

[2] V. Policht *et al.*, Nano Lett. **21**, 4738–4743 (2021).

[3] C. Trovatello et al., npj 2D Mater Appl **6**, 24 (2022).