Graz Advanced School of Science

PHYSICS COLLOQUIUM OF THE UNIVERSITY OF GRAZ AND
THE GRAZ UNIVERSITY OF TECHNOLOGY

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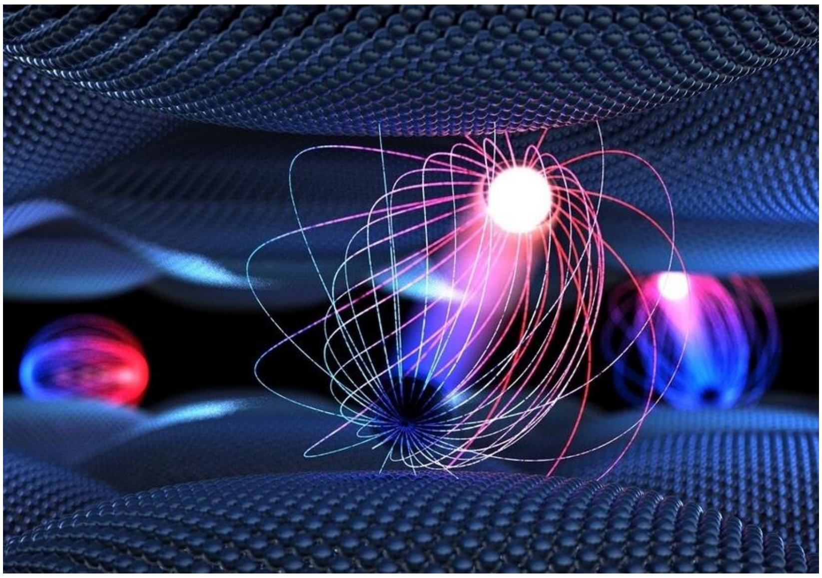
Formation of moiré interlayer excitons in space and time

Abstract:

Transition metal dichalcogenides (TMDs) are an exciting model system to study ultrafast energy dissipation pathways, and to create and tailor new emergent quantum phases [1,2]. The versatility of TMDs results from the confinement of optical excitations in two-dimensions and the concomitant strong Coulomb interaction that leads to excitonic quasiparticles with binding energies in the range of several 100 meV. In TMD stacks consisting of at least two layers, the interlayer interaction can be precisely controlled by manipulating the twist angle: The misalignment of the crystallographic directions leads to a momentum mismatch between the high symmetry points of the hexagonal Brillouin zones. This strongly impacts the interlayer wavefunction hybridization, and, moreover, adds an additional moiré potential. Crucially, in this emergent energy landscape, dark intra- and interlayer excitons dominate the energy dissipation pathways. While these dark excitonic features are hard to access in all-optical experiments, time-resolved momentum microscopy [3] can provide unprecedented insight on these quasiparticles [4].

In my talk, I will present the ultrafast formation dynamics of dark interlayer excitons in twisted WSe_2/MoS_2 heterostructures in space and time. First, I will report on the identification of a hallmark signature of the moiré superlattice that is imprinted onto the momentum-resolved interlayer exciton photoemission signal. With this data, we reconstruct the electronic part of the exciton wavefunction, and relate its extension to the moiré wavelength of the heterostructure. Second, I will show that interlayer excitons are effectively formed via exciton-phonon scattering, and subsequent interlayer tunneling at the interlayer hybridized Σ_W valleys on the sub-50 fs timescale.



Schematic of twisted layers of WSe_2 (top) and MoS_2 (bottom). Following optical excitation, a multitude of optically “dark” excitons form between the layers. These “dark” excitons are electron-hole pairs bound by Coulomb interaction (light and dark spheres connected by field lines), which cannot be directly observed using visible light. One of the most interesting quasiparticles is the "moiré interlayer exciton" – shown in the middle of the image - in which the hole is located in one layer and the electron in the other. The formation of these excitons on the femtosecond time scale and the influence of the Moiré potential are investigated using femtosecond photoemission momentum microscopy [4].

References

[1] Wang *et al.*, Rev. Mod. Phys. **90**, 021001 (2018).
[2] Wilson *et al.*, Nature **599**, 383 (2021).
[3] Keunecke *et al*., Rev. Sci. Ins. **91**, 063905 (2020).
[4] Schmitt *et al*., Nature 608, 499 (2022).

Date: Tuesday, November 22, 2022, 16:15

Location: Lecture Hall 05.01, Institute of Physics, University of Graz, Universitaetsplatz 5

Host: P. Puschnig – Institute of Physics – Theoretical Solid State Physics