

PHYSIKALISCHES KOLLOQUIUM

Wintersemester 2023/24

Das Kolloquium findet (soweit unten nicht anders angegeben) jeweils montags **jeweils montags um 17:15 Uhr online via Zoom** statt.

(Der jeweilige Link wird noch zur Verfügung gestellt.).

04.12.2023

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Watching ultrafast excitation dynamics in momentum space

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Abstract

The dynamics of quasi-particles in non-equilibrium states of matter reveal the underlying microscopic coupling between electronic, spin and vibrational degrees of freedom. We aim for a quantum-state-resolved picture of coupling on the level of quasi-particle self-energies, which goes beyond established ensemble-average descriptions, and which requires ultrafast momentum-resolving techniques. Electronic and excitonic excitations are measured with time- and angle-resolved photoemission spectroscopy (trARPES). While (tr)ARPES data is traditionally interpreted in a single-particle band-structure picture, we developed approaches to access the key properties of many-body states with multidimensional photoemission spectroscopy. I will exemplify these approaches for excitons in transition metal dichalcogenide semiconductors [1] and van der Waals heterostructures. TrARPES can

reveal all key properties of the excitons like binding energy, exciton-phonon coupling, and the real-space distribution of the many-body wave functions through the Fourier transform of the photoelectrons' momentum distribution. In addition, we investigated the singlet-exciton-fission process in the molecular crystal pentacene and revealed the hybrid-orbital character of the singlet state as well as the disputed mechanism of the fission process [2].

The complementary view of ultrafast phonon dynamics is obtained through femtosecond electron diffraction. The elastic and inelastic scattering signal reveals the temporal evolution of vibrational excitation of the lattice and momentum-resolved information of transient phonon populations generated by electron- and exciton-phonon coupling in inorganic and organic semiconductors [3,4,5].

References

- [1] S. Dong et al., *Direct measurement of key exciton properties: Energy, dynamics, and spatial distribution of the wave function*, [Natural Sciences 1, e10010 \(2021\)](#).
- [2] A. Neef et al., *Orbital-resolved observation of singlet fission*, [Nature 616, 275 \(2023\)](#).
- [3] L. Waldecker et al., *A Momentum-Resolved View on Electron-Phonon Coupling in Multilayer WSe₂*, [Phys. Rev. Lett. 119, 036803 \(2017\)](#).
- [4] H. Seiler et al., *Accessing the anisotropic nonthermal phonon populations in black phosphorus*, [Nano Letters 21, 6171 \(2021\)](#).
- [5] H. Seiler et al., *Nuclear dynamics of singlet exciton fission in pentacene single crystals*, [Science Advances 7 \(26\), eabg0869 \(2021\)](#).

Für die Dozentinnen bzw. Dozenten der Fakultät

Prof. Dr. Assaad, Prof. Dr. Hinrichsen, Prof. Dr. Pflaum und Hr. Kuhr