Charge Transport on Ultrashort Length and Time Scales

848. WE-Heraeus-Seminar

8 - 11 February 2026

at the Physikzentrum Bad Honnef, Germany

WILHELM UND ELSE
HERAEUS-STIFTUNG

Introduction

The Wilhelm und Else Heraeus-Stiftung is a private foundation that supports research and education in science with an emphasis on physics. It is recognized as Germany's most important private institution funding physics. Some of the activities of the foundation are carried out in close cooperation with the German Physical Society (Deutsche Physikalische Gesellschaft). For detailed information see https://www.we-heraeus-stiftung.de

Aims and scope of the 848. WE-Heraeus-Seminar:

The objective of this seminar is to unite experts and methodologies for imaging light-matter interactions on length scales that are subject to quantum effects with techniques that probe such interactions in time domains of femtoseconds or faster. A particular focus will be on the interaction of photons with electrons, and how their behavior can be manipulated. Another important field are interfaces where electromagnetic radiation can invoke strong quantum-mechanical effects. Examples for this are superconductivity, field emission, circularly polarized luminescence and exciton diffusion. Understanding these effects requires highly specialized techniques that overcome the particular challenges inherent to studying charge carrier motion with femto- or attosecond time resolution and at the atomic scale. The seminar will detail how advances in electron microscopy, intense and ultrashort lightsources, X-ray lasers and diffractometers as well as new computational tools such as theoretical spectroscopy and machine learning models are exploited to achieve this level of spatial and temporal control. With these methods, it is now possible to gain a greatly more detailed understanding of the central light-matter interactions in device applications such as solar cells, 3D printers, quantum computers, light-emitting diodes, lasers, photodetectors and sensors. By bringing together experts from physics, chemistry, and materials science, the seminar aims to identify how the advances in computational strategies, time resolution and spatial control can be unified for a joint effort to excel in the above-mentioned applications. This will be realized through a combination of 10 distinguished keynote lectures and 16 contributed talks. Each day will conclude with a panel discussion featuring speakers from the keynote lectures to summarize major discussion points, provide expert commentary, and inspire further dialogue. An important non-scientific topic will be the future of open data policies and how the enormous amount of scientific data generated world-wide can be shared and accessed in a synergistic and productive way to enable new developments.

Introduction

Scientific Organizers:

Prof. Dr. Christian Klinke	University of Rostock, Germany
Prof. Dr. Marcus Scheele	University of Tübingen, Germany

Administrative Organization:

Dr. Stefan Jorda
Nadine Mock

Wilhelm und Else Heraeus-Stiftung
Kurt-Blaum-Platz 1
63450 Hanau, Germany

Phone +49 6181 92325-20
Fax +49 6181 92325-15
E-mail mock@we-heraeus-stiftung.de
Internet: www.we-heraeus-stiftung.de

Introduction

Venue:

Physikzentrum
Hauptstrasse 5
53604 Bad Honnef, Germany

Conference Phone +49 2224 9010-120

Phone +49 2224 9010-113 or -114 or -117
Fax +49 2224 9010-130
E-mail gomer@pbh.de
Internetwww.pbh.de

Taxi Phone +49 2224 2222

Registration:

Nadine Mock (WE Heraeus Foundation)
at the Physikzentrum, reception office
Sunday (17:00 h – 21:00 h) and Monday morning

Program

Program

Sunday, 8 February 2026

17:00 - 21:00	Registration
18:00 - 20:00	*BUFFET SUPPER and informal get-together*

Program

Monday, 9 February 2026

07:30 - 09:00	*BREAKFAST*	
09:00 - 9:45	Cherie Kagan	**Colloidal Quantum Dot Assemblies and Devices: Charge and Energy Transport and Transfer**
9:45 - 10:05	Pannan Kyesmen	**Colloidal quasi-2D Cs2AgBiBr6 double perovskite nanosheets: synthesis and application as high-performance photodetectors**
10:05 – 10:25	Heyou Zhang	**Photoswitchable Nanoparticle Arrays for All-Optical Logic Gate**
10:25 - 10:45	*COFFEE BREAK*	
10:45 - 11:30	Jannika Lauth	**Strongly Confined Systems and Fast Laser Pulses – A Match Made in Heaven (Optical and Electronic Properties of Flat Quantum Dots)**
11:30 - 12:15	Eleftherios Goulielmakis	**Probing correlated materials with sub-cycle optical pulses**
12:15 - 12:30	*CONFERENCE PHOTO (in front of the main entrance)*	
12:30 - 14:00	*LUNCH*	
14:00 - 14:45	Claus Ropers	**Ultrafast Electron Microscopy**

Program

Monday, 9 February 2026

14:45 – 15:05	Praful Kumar	**A Generalised Framework for Light Induced Insulator-to-Metal Phase Transitions**
15:05 - 15:25	Kasra Amini	**High-brightness, high-throughput, ultrashort keV and MeV electrons for femtochemistry studies in photoexcited matter**
15:25 - 15:45	Manish Garg	**Single Molecule Electronics**
15:45 - 16:05	*COFFEE BREAK*	
16:05 - 17:15	Panel Discussion 1:	**The future of ultra-small and ultra-fast devices (All available keynote speakers.)**
17:15 - 17:30	Stefan Jorda	**About the Wilhelm and Else Heraeus Foundation**
18:00 - 19:30	*HERAEUS-DINNER at the Physikzentrum* *(cold and warm buffet with complimentary drinks)*	
19:30 - 21:00	**Poster Session 1**	

Program

Tuesday, 10 February 2026

07:30 - 09:00	*BREAKFAST*	
09:00 - 9:45	Chris Murray	**Assembly of Nanocrystal-Based Materials and Devices**
9:45 - 10:05	Ata Bozkurt	**Inter-Particle ion migration of caesium lead mixed-halide perovskite superlattices**
10:05 - 10:25	Ronja Piehler	**Carrier Diffusion vs. Waveguiding effects in different layered quasi two-dimensional MAPbI-Perovskites**
10:25 - 10:45	*COFFEE BREAK*	
10:45 - 11:30	Isabelle Staude	**Interaction of 2D semiconductors with optically resonant nanostructures**
11:30 - 11:50	Dariia Matulka	**The Electronic Spectrum in Few-Layer Quasi-2D Crystals**
11:50 - 12:35	Stefan Mathias	**Unraveling charge transport in 2D quantum materials on ultrashort time- and lengthscales using time-resolved momentum microscopy**
12:35 - 14:00	*LUNCH*	
14:00 - 14:45	Claudia Draxl	**Many-body approaches to excitation dynamics in solids**
14:45 - 15:05	Jara Vliem	**The influence of surface state bands on the optical properties of 2D Bi2Se3 nanoplatelets**

Program

Tuesday, 10 February 2026

15:05 - 15:50	Bridget Murphy	**Structure and dynamics at liquid interfaces**
15:50 - 16:10	*COFFEE BREAK*	
16:10 - 17:15	Panel Discussion 2:	**Open Data** **(Claudia Draxl and Bridget Murphy)**
18:00 - 19:30	*DINNER*	
19:30 - 21:00	**Poster Session 2**	

Program

Wednesday, 11 February 2026

07:30 - 09:00	*BREAKFAST*	
09:00 - 09:45	Sascha Feldmann	**Tracking charge, spin and light polarization in space & time in emerging semiconductors**
09:45 - 10:05	Fedor Lipilin	**Natural van der Waals aluminosilicate for electronic applications**
10:05 - 10:50	Andres Castellanos-Gomez	**Controlling structure and transport in 2D nanomaterials**
10:50 – 11:10	*COFFEE BREAK*	
11:10 - 11:55	Hélène Seiler	**Probing electronic disorder in nanomaterials with coherent two-dimensional spectroscopy**
11:55 - 12:15	Yadu Ram Panthi	**Ultrafast Spectroscopic Insights into Triplet Formation and Thermal Artefacts in Functionalised DPP Derivatives**
12:15 - 12:30	**Poster prize and closing remarks**	
12:30 - 14:00	*LUNCH*	

End of the seminar and departure

Posters

Posters

Abdur Rehman Mushtaq Ahmad	**Photothermal Conversion of ZnSe/CdSe Core–Shell Quantum Dots for Solar-Driven Energy Applications**
Mohamed Ait Oufakir	**Smart Solar Breakthrough: Machine Learning Powers Next-Gen CsSnI3/Si Tandem Cells**
Yidan An	**Balancing carrier transport in interconnection layer for efficient perovskite/organic tandem solar cells**
Mrinmoy Chini	**Photo-Rechargeable Supercapacitance Behavior Studies**
Elshaimaa Darwish	**Stability and Uniformity Engineering in Perovskite Nanoparticles for Enhanced Performance**
Riya Dutta	**Low-Temperature Exciton Dynamics in $MAPbBr_3$ Perovskite Nanoparticles.**
Lars Eckhardt	**Charge transfer in CPL active [2,2]para-cyclophanes**
Ehsan Elahi	**Electrical Transport of Nb-Doped MoS2 Homojunction P–N Diode: Investigating NDR and Avalanche Effect**
Markus Fröhlich	**Disentangling Complex Charge Carrier Dynamics in Confined Transition Metal Dichalcogenides**
Andrey Iljin	**Fast nonlinear optical response of liquid crystals**
Leo Kahlmeyer	**Tailoring the optical properties of infrared emitting flat lead chalogenide quantum dots in 2D quantum confinement**
Dilmehak Kaur	**Mapping the multistep electron transfer process in animal-like Cryptochrome**
Sarah Zulfa Khairunnisa	**Probing Plasmon-Mediated Charge and Energy Dynamics in a Hyperuniform Mesoporous Gold-MOF Platform**

Posters

Marjan Krstić	**A time-domain quantum chemistry for multiscale modeling of light-matter interactions**
Nataliia Kuzyk	**Investigation of Derivatives of Benzothiadiazole and Fluorene for Multifunctional Applications in Organic Electronics.**
Sanaa Lahlali	**Multiscale Investigation of Charge Transport and Defect Dynamics in Eco-Friendly Cu_2SnS_3 Nanomaterials for Photovoltaic Applications**
Rostyslav Lesyuk	**Steady-state and transient photo-physical properties of nanoscaled klockmannite linked to crystal anisotropy**
Haochen Liu	**Helical Perovskite Nanowires with Strong Circularly Polarized Luminescence Self-Assembled from Red-Emitting CsPbI3 Quantum Dots Following Chiral Ligand Exchange**
Mario Martin	**High-Speed photoresponse of CVD-grown lateral TMDC heterostructures with 1D p-n junctions**
Isaac Hervé Nado Betsaleel	**Study of load carrier movement**
Asha Ramesh	**Electrical transport through gold nanoparticle films**
Arslan Rehamt	**Floating gate synaptic memory of Janus WSSe Multilayer for neuromorphic computing**
Fabian Scheidler	**Nanoscale free-electron dynamics in plasmonic nanostructures**
Arghya Sen	**CsMnBr3 Nanocrystal: A Curious Case of Photophysics from Picosecond to Microsecond**
Mrinal Kanti Sikdar	**Plasmonic and Magnetic Properties of Ni-Decorated Cr Microrods**

Posters

Onno Strolka	**Ultrafast Transient Processes in Ultrathin Colloidal Transition Metal Diselenides**
Yagmur Tanis	**Accelerating Materials Discovery: A High-Throughput, AI-Driven Workflow for Photocatalyst Optimization**
Janosch Unseld	**Ultra-violet to shortwave-infrared transient absorption spectral features of flat PbSe quantum dots in strong confinement**
Julian Wendel	**Dead Layer Characterization of the CONUS+ HPGe Neutrino Detector**

Abstracts of Talks

(in alphabetical order)

Ultrafast electron diffraction imaging of photoinduced non-thermal lattice disorder in polycrystalline aluminium

Kasra Amini

Max-Born-Institut, Max-Born-Straße 2A, 12489 Berlin, Germany

Since the earliest ultrafast electron diffraction (UED) studies of metals [1,2], photoexcited lattice dynamics in aluminium have served as a benchmark system for understanding energy flow following electronic excitation. The two distinct regimes of thermal and non-thermal lattice disorder depend on excitation fluence and timescale [3], yet how energy is redistributed within the lattice within the non-thermal regime, and how short-range and long-range lattice motion participate in this process, remains incompletely understood.

Here, we investigate ultrafast non-thermal lattice dynamics in a photoexcited polycrystalline aluminium thin film using UED [4,5] which vary with momentum transfer, q. Pump-probe measurements of Bragg and diffuse scattering reveal a prompt increase in mean-square displacement, reflecting rapid electron-phonon energy transfer. In contrast, the subsequent relaxation dynamics depend strongly on diffraction order: lower-order reflections relax rapidly, while higher-order reflections exhibit slower or near-plateau behaviour, indicating multiple q-dependent lattice equilibration pathways.

Residual analysis of the mean-square displacement reveals coherent lattice oscillations. Power spectral density analysis identifies a fundamental mode at 0.192 THz, corresponding to the acoustic breathing (A_{1g}) mode of aluminium, together with higher harmonics consistent with coherent phonon excitation. These observations support a mode-selective, non-thermal lattice response [3] and highlight the importance of resolving lattice dynamics in reciprocal space [6].

Crucially, these results were enabled by normalizing the diffraction signal to the primary unscattered electron beam rather than to a low-order Bragg reflection, as commonly employed in UED. Direct electron detection provides near-unlimited dynamic range, enables detection of the unscattered beam, and improves the signal-to-noise ratio by approximately an order of magnitude, allowing weak high-q scattering signals to be resolved. Measurements were performed at 40 kHz repetition rate, which is a factor of 40-100 higher than typical UED experiments, permitting the use of low bunch charges (~100 electrons per pulse) and temporally uncompressed electron pulses (~300 fs) [7]. This combination of high repetition rate, robust normalization, and direct detection enables high-sensitivity studies of subtle non-thermal lattice dynamics that are inaccessible with diffraction-averaged or low-throughput approaches.

[1] G. Mourou and S. Williamson, *Appl. Phys. Lett.* **41**, 44–45 (1982).
[2] B. Siwick *et al.*, *Science* **302**, 1382 (2003).
[3] L. Waldecker *et al.*, *Phys. Rev. X* **6**, 021003 (2016).
[4] D. Filippetto *et al.*, *Rev. Mod. Phys.* **94**, 045004 (2022).
[5] K. Amini *et al.*, “Structural Dynamics with X-ray and Electron Scattering”, RSC books (2023).
[6] F. R. Diaz and K. Amini, *Submitted for review* (2025).
[7] F. R. Diaz *et al.*, *Struct. Dyn.* **11**, 054302 (2024).

Electric field induced Inter-Particle ion migration of caesium lead mixed-halide perovskite superlattices

Ata Bozkurt,[1] Jonas L. Hiller,[1] Robert Thalwitzer,[1] Mario Martin,[1] Ivan Musil,[2] Martin Eberle,[1] Jonas Haas,[2] Jannik C. Meyer,[2] Marcus Scheele[1]

[1] Institute of Physical and Theoretical Chemistry, University of Tübingen, Auf der Morgenstelle 18, 72076 Tübingen, Germany

[2] Institute of Applied Physics, University of Tübingen, Auf der Morgenstelle 10, 72076, Tübingen, Germany; NMI Natural and Medical Sciences Institute at the University of Tübingen, Markwiesenstraße 55, 72770 Reutlingen, Germany

Abstract

Colloidal lead mixed- halide perovskite nanocrystals combine outstanding optical properties with vulnerability to ionic instability due to field-driven ion migration complicating device integration. While these processes are established for single nanocrystals and films, their role in ordered assemblies is less explored. By precisely positioning individual superlattices between micrometre-sized capacitor plates, we examine the response $CsPbBr_2Cl$ nanocrystal superlattices, synthesised using a two-layer phase diffusion assemble, to strong external electric fields. Using spatially resolved optical microscopy, energy-dispersive X-ray analysis and in-situ mass spectrometry, alongside finite-element simulations of the field distribution, we observe pronounced, spatially dependent PL shifts that correlate with non-uniform halide redistribution. In-situ mass spectroscopy detects bromide sublimation, indicating combined inter- and intra- particle halide diffusion, and irreversible PL changes. These results show how external electric fields affect the structural and compositional integrity of $CsPbBr_2Cl$ superlattices and underscore the necessity of improved structural and compositional stabilization strategies for future optoelectronic applications.

Controlling Structure and Transport in 2D Nanomaterials

Andres Castellanos-Gomez,

Instituto de Ciencia de Materiales de Madrid (ICMM–CSIC). Madrid. Spain.

Two-dimensional (2D) materials offer a unique platform where structure, electronic transport and functionality can be coupled and tuned with exceptional precision. However, harnessing this potential relies critically on the ability to control both the stacking configuration in van der Waals heterostructures and the mechanical state of the material. In this seminar, I will discuss how deterministic fabrication strategies and engineered strain fields enable control over structural order and transport properties in 2D nanomaterials.

I will first present advanced high-throughput deterministic stacking techniques used to assemble artificial heterostructures with well-defined interfaces. These approaches allow the formation of electronic devices based entirely on van der Waals materials, while also enabling systematic exploration of interfacial interactions and their impact on charge transport.

In the second part, I will focus on strain engineering as a powerful degree of freedom to modulate transport in 2D systems. By exploiting both substrate-induced and dynamically controlled strain (through bending or exploiting thermal expansion mismatch) we demonstrate reversible tuning of phase transitions, charge density wave states, and superconductivity. These methods reveal how mechanical deformation can serve as a continuous and purely physical parameter to access new electronic regimes.

Many-body approaches to excitation dynamics in solids

Claudia Draxl

Physics Department and CSMB, Humboldt-Universität zu Berlin, Berlin, Germany

Understanding and controling excitation dynamics is essential for a many phenomena observed in a variety of high-resolution experimental probes. Tackling competing many-body interactions and extending current *ab initio* methodology to the time domain, thereby accounting for electronic and vibrational degrees of freedom, is a timely issue. Many-body perturbation theory (MBPT) is the state-of-the-art methodology: The *GW* approach provides single quasi-particle energies, incorporating electron-electron interactions and electron-vibrational coupling (EVC). The Bethe-Salpeter equation (BSE) is the method of choice for computing optical and core-level excitations to capture excitonic effects. Moreover, spin-orbit coupling (SOC) can give rise to exciting phenomena in the response of matter to light. Treating all these interactions on equal footing allows us to achieve in-depth understanding of complex processes and excellent agreement with experiment, which will be demonstrated by selected examples [1], also in the interpreation of ultrafast processes happening in time-resolved experiments [2,3]. To tackle pump-probe spectroscopy and excitation dynamics from a theory point of view, requires a major step beyond, incorporating time as another variable. Our all-electron BSE formalism, treating optical and core spectra on equal footing, allows us to describe resonant inelastic x-ray scattering (RIXS) [4] as well as pump-probe spectroscopy [5]. Finally, I will show how the BSE together with EVC matrix elements can be used to treat exciton-phonon coupling and thus geometry relaxation in the excited state [6], giving us access to photoluminescence and exciton dynamics.

References

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Tracking charge, spin and light polarization in space & time in emerging semiconductors

Prof. Dr. Sascha Feldmann

Tenure-Track Assistant Professor in Physical Chemistry & Head of the Laboratory for Energy Materials, Ecole Polytechnique Fédérale de Lausanne

Solution-processable semiconductors such as halide perovskites and certain molecules are promising for next-generation spin-optoelectronic applications [1]. Yet, we don't fully understand what mechanisms govern charge, spin and light polarization in such emerging energy materials, and even less how these are affected by chirality [2].
In this talk, I will give an overview of our recent efforts to understand the spin-optoelectronic performance of these materials through time-, space- and polarization-resolved spectroscopy and microscopy, and how these insights may enhance the performance of solar cells and other energy conversion applications.
For investigating halide perovskite films, we pushed broadband circular dichroism to diffraction-limited spatial and 15 fs time resolution for creating a spin cinematography technique to witness the ultrafast formation of spin domains due to local symmetry breaking and spin-momentum locking [3].
I will then briefly explain the fundamentals and artefacts involved in measuring circularly polarized luminescence reliably and introduce an open-access methodology and code to do so [4]. Finally, I will show our most recent development of a transient sensitive broadband full Stokes-vector spectroscopy with unprecedented time- and polarization resolution to track the emergence of chiral light emission [5].

[1] *Nature Reviews Materials* **8**, 365 (2023).
[2] *Nature Reviews Chemistry* **9**, 208 (2025).
[3] *Nature Materials* **22**, 977 (2023).
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[5] *Nature* **643**, 675 (2025).

Background Information:

The Feldmann Lab at EPFL develops and employs ultrafast magneto-chiroptical spectroscopy to understand the next generation of soft semiconductors. The overarching goal is to maximize energy efficiency for a sustainable future by unlocking applications ranging from flexible light-weight solar cells & displays all the way to entirely new applications in quantum information processing.

Sascha studied Chemistry at Heidelberg University (Germany) and completed his PhD in Physics at the University of Cambridge (UK) in 2020, where he continued to work as an independent EPSRC Doctoral Prize Fellow. In July 2022, Sascha started his own group at Harvard University through a Rowland Fellowship. Since 2024 he is a tenure-track assistant professor and head of the Laboratory for Energy Materials at EPFL, while also remaining affiliated as SCR member of Winthrop House at Harvard.

Single Molecule Energetics

Manish Garg

Max Planck Institute for Solid State Research, Heisenbergstr. 1, 70569 Stuttgart, Germany

The intermolecular electronic energy transfer (EET) and electron transport (ET) in donor-acceptor molecular systems are two ubiquitous phenomena in many photophysical processes (such as photosynthesis). Following light absorption in a light-harvesting molecular complex or a photovoltaic system, electronic energy needs to move from one molecule to the next in order to reach the reaction centre. The EET can proceed via classical electron hopping from one molecule to the next one, akin to funnelling OR via quantum electronic coherences between the involved electronic levels of the molecules. Experiments performed in the bulk phase have led to contradicting conclusions to the underlying mechanism of EET and ET. The role of vibronic coupling is poorly understood. Quantum coherent energy/electron transport is difficult to probe in lossy molecular systems in the bulk phase.

In my talk, I am going to show how we have addressed this challenge at the single molecule level by utilizing an ultrafast scanning tunnelling microscope (STM), which has recently enabled *first direct filming of electronic motion* in molecules with sub-Angstrom (spatial) and attosecond (temporal) resolutions, simultaneously [1-6]. Prototypical donor (Platinum phthalocyanine) and acceptor (Zinc phthalocyanine) molecules were arranged next to each other in the STM and energy transfer dynamics between them was investigated by time-resolving the laser-induced tunneling currents. A wavelike energy transfer between the molecules was measured, which originates from the quantum coherence (beating) between the involved excitons in the process. Various parameters influencing the energy transfer dynamics, such as, dipole-dipole coupling and intermolecular distance between the molecules were systematically investigated. Coherent energy transfer between the molecules scales exponentially with the separation between the molecules and strong shifting of the exctionic peaks is observed at shorter intermolecular distances, owing to the dipole-dipole coupling.

References

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Probing correlated materials with sub-cycle optical pulses

E. Goulielmakis
[1]Institut für Physik, Universität Rostock; Albert-Einstein-Strasse 23-24, 18059 Rostock, Germany

Over the last decade, optical waveform synthesis has made it possible to generate phase-stable, single-cycle light transients and to use them as a timing ruler for electron motion, launching key capabilities of attosecond science [1,2]. An essential question is whether these tools can also offer new insight and new methodology for correlated materials, where many central phenomena are traditionally treated as much slower and therefore addressed with longer, less controlled pulses.

We will discuss how single-cycle pulses enable a phase-resolved probing concept that combines a super-octave (visible-to-NIR) sub-cycle probe transient with broadband detection to follow-in real time- the emergence of non-equilibrium phases in correlated solids. Using VO_2 as a case study, the approach separates the prompt electronic response from the slower structural rearrangement and tracks how electronic thermalization develops as metallic regions form [3]. The measurements indicate that bond-selective, strongly anharmonic V-V motion is launched on a few-femtosecond time scale and acts as a gate connecting the initial electronic displacement to the structural conversion. We will also discuss how these ideas can be ported to numerus more types of correlated materials,

References

[1] A. Wirth et al., Science 334, 195-200 (2011).
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Colloidal Quantum Dot Assemblies and Devices: Charge and Energy Transport and Transfer

C. R. Kagan[1]

[1]*University of Pennsylvania, Philadelphia, PA USA*

Colloidal semiconductor quantum dots (QDs) are prized for their size-dependent electronic and optical properties, with bandgaps tunable from the UV to the infrared, and as solution-processable building blocks of “artificial” solid-state materials [1–3]. Here, I will describe chemical treatments, namely ligand exchange, doping, and cation exchange, that are used to tailor interparticle distance [4] and composition to add impurities [5], control stoichiometry [6–8], or make entirely new compounds [9,10]. Electrical and cw, ultrafast, and spatially resolved optical spectroscopies are used to show that these treatments allow the design of QD assemblies with tailored carrier energy, type, concentration, mobility, and lifetime, which we have used to create n- and p-type thin films in building optoelectronic and electronic devices and circuits [11–15]. By exploiting the differential chemical and thermal addressability of QD assemblies and bulk materials, we create 3D QD superparticles structured on the 100s of nanometer to micron length scales with geometries that yield circularly polarized luminescence.

References

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A Generalised Framework for Light Induced Insulator-to-Metal Phase Transitions

P. Kumar[1], S. Mandal[1], H. Y. Kim[1], Z. Pi[1], J. Xu[2], D. Chen[2], D. Kazenwadel[3], P. Baum[3], S. Meng[2] and E. Goulielmakis[1]

[1] *Institut für Physik, Universität Rostock, Germany*
[2] *Institute of Physics, Chinese Academy of Sciences, Beijing, China*
[3] *Fachbereich Physik, Universität Konstanz, Konstanz, Germany*

Photoinduced insulator-to-metal transitions (IMT) in strongly correlated materials are central to ultrafast physics and emerging photonic technologies, yet the underlying phase transition mechanism—structural reorganization, electronic redistribution, or their interplay—remains contentious. Ultrafast spectroscopies (reflectivity, transmission, photoemission, and XUV absorption) provide femtosecond temporal resolution and are sensitive to both electronic and lattice dynamics, but they yield mutually inconsistent transition timescales and thus contradictory insights into the mechanism. In contrast, structural probes such as time-resolved X-ray diffraction, electron diffraction, and X-ray scattering capture atomic rearrangements but have limited temporal resolution and reduced sensitivity to electronic response, preventing a unified understanding of how electronic and atomic motions interconnect during metallization.

To address this issue, we utilize single-cycle optical pulses generated in a light-field synthesiser[1], capable of performing phase-resolved spectroscopy, to probe the light-induced IMT in the prototypical correlated material monoclinic vanadium dioxide (M1-VO_2)[2]. Our 2.4 fs pulse duration captures electron dynamics with exceptional temporal fidelity, and its broad bandwidth enables spectral discrimination spanning more than an octave. Our measurements of light-induced reflectivity change reveal two sequential events: lattice conversion from M1-VO_2 to photoexcited rutile (R*-VO_2), followed by thermalization and relaxation dynamics intrinsic to the emergent metallic state. A shift in the plasma frequency, universal to conducting phases upon laser excitation, unambiguously marks R*-VO_2 formation throughout the process. We therefore isolate structural and electronic contributions[3] and demonstrate that population transfer between the two phases occurs in discreet bursts synchronized to the underlying anharmonic lattice motion, which we also retrieve. This work lays the foundation for real-time tracking of IMT in correlated matter and opens prospects for controlling them on their native timescale.

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Colloidal quasi-2D $Cs_2AgBiBr_6$ double perovskite nanosheets: synthesis and application as high-performance photodetectors

Pannan I. Kyesmen[1], Eugen Klein[1], Brindhu Malani S[1], Rostyslav Lesyuk[1], and Christian Klinke[*12]

[1]Institute of Physics, University of Rostock, Albert-Einstein-Str. 23-24, 18059 Rostock, Germany
[2]Department Life, Light & Matter, University of Rostock, Albert-Einstein-Strasse 25, 18059 Rostock, Germany.

The search for non-toxic lead-free halide perovskites that can compete with the lead-based counterparts has led to the emergence of double perovskites as potential candidates. Among many options, $Cs_2AgBiBr_6$ stands out as one of the most suitable eco-friendly materials for numerous optoelectronic applications. In this study, quasi-2D $Cs_2AgBiBr_6$ nanosheets (NSs) were prepared via the low-temperature injection colloidal synthesis and used to fabricate high-performance photodetectors in a transport-layer-free architecture. The reaction temperature and ligands played vital roles in the structural purity, shape, and size of the synthesized $Cs_2AgBiBr_6$ NSs. The fabricated NSs disclosed lateral sizes of up to 1.4 µm and are only a few nanometers thick. The high-performance photodetectors fabricated using the $Cs_2AgBiBr_6$ NSs yielded a high detectivity (D) of 1.15×10^{12} Jones, responsivity (R) of 121 mA/W, a notable on-off ratio of 2.39×10^4, and a fast rise and decay time of 857 and 829 µs, respectively. The device demonstrates remarkable stability. Basically, it sustains its entire photocurrent after storage in ambient conditions for 80 days. This work showcases a pathway for the colloidal synthesis of quasi-2D $Cs_2AgBiBr_6$ lead-free double perovskite NSs with suitable properties for high-performance photodetection and other optoelectronic applications.

Keywords: Double perovskites, quasi-2D nanosheets, colloidal synthesis, photodetection, detectivity, and response time

Strongly Confined Systems and Fast Laser Pulses – A Match Made in Heaven (Optical and Electronic Properties of Flat Quantum Dots)

Jannika Lauth
University of Tübingen, Institute of Physical and Theoretical Chemistry,
Auf der Morgenstelle 18, 72076 Tübingen, Germany
University of Hannover, Institute of Physical Chemistry and Electrochemistry
Callinstr. 3a / Laboratory for Nano- and Quantum Engineering, Schneiderberg 39,
30167 Hannover, Germany

We characterize light-matter interactions with a highly accurate stopwatch – by light itself! Following the generation, fate and recombination of excited states in materials is one of the key features in driving and explaining photophysical processes and being able to accurately describe photoexcited charge carrier interactions, e.g. in two-dimensional nanomaterial systems like flat lead chalcogenide quantum dots[1], [2], [3] and colloidal transition metal dichalcogenide nanoplatelets and nanosheets.[4], [5], [6]

In my talk I will touch on recent examples in which we combine our unique wet-chemistry – spectroscopy feedback loop to unravel photoexcitation-induced dynamics in highly diverse systems for innovative photonics.

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Natural van der Waals aluminosilicate for electronic applications

F. Lipilin[1], A. Söll[1], K. J. Sarkar[1], K. Meganathan[1], B. Wu[1], J. Luxa[1] and Z. Sofer[1]

[1] *Department of Inorganic Chemistry, University of Chemistry and Technology Prague, Technická 5, 166 28 Prague 6, Czech Republic*

Low-dimensional structures attract significant attention and represent a broad field of scientific research. Nonetheless, current research tends to focus on synthesized compounds or doped solid solutions and often overlooks the potential of naturally occurring minerals.

Exfoliated van der Waals (vdW) natural compounds can provide high-quality structures with desirable properties [1], as well as thermal stability and resistance to oxidation. In this study, we explored and mechanically exfoliated kyanite, a high-pressure polymorph of Al_2SiO_5 [2] as a dielectric material for electronic applications. We employed rigorous bulk analysis alongside field-effect transistor (FET) and Metal–Insulator–Metal (MIM) structures to probe the specific electronic characteristics of the exfoliated flakes. Among the Al_2SiO_5 polymorphs, kyanite has the largest band gap of 5.80 eV and an optical dielectric constant of 3.135 [3]. In terms of these parameters, it is comparable to widely used hexagonal boron nitride (h-BN) but exceeds h-BN in the static dielectric out-of-plane constant, which reaches 9.01 [4]. Overall, the findings of this study demonstrate the considerable potential of kyanite in 2D electronics as a gate dielectric for FETs and as an h-BN alternative in optoelectronic devices.

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The Electronic Spectrum in Few-Layer Quasi-2D Crystals

D. Matulka, B. Lukiyanets

Lviv Polytechnic National University, Bandery St. 12, 79-013 Lviv, Ukraine
e-mail: dariya.v.matulka@lpnu.ua

The study of the kinetics of quasi-2D crystals (e.g. graphene, transition metal chalcogenides and A_3B_6 semiconductors) requires us to abandon the idea that carriers are particles and to consider their quantum mechanical nature instead.

This is due to the nanoscale regions in such crystals and the relationship between the nanoscale region size d, the carrier's de Broglie wavelength λ and the coherence length. These factors give rise to the discreteness of the carrier spectrum. Therefore, analysing the carrier spectrum is highly relevant in the quantum-mechanical description of carrier kinetics in a crystal.

The technological capability to obtain few-layer fragments of quasi-2D crystals has become an ideal means of achieving electronic and optical properties that are atypical of bulk materials.

The present study describes a generalised model of few-layer fragments based on the Kronig-Penney potential, representing them as a sequence of wells and barriers to provide a flexible tool for modelling electronic states in diverse nanostructured materials. The electronic spectrum of mono- and bilayer structures is investigated, with a particular focus on the behaviour of the lowest states depending on the geometric parameters of these structures. The observed changes to the spectrum are consistent with theoretical and experimental results reported in the literature for specific few-layer quasi-2D crystals.

Our research shows that changes in the electronic spectrum during the transition to few-layers are caused by quantum confinement effects due to reduced dimensionality. We also demonstrate that varying the width of the wells is the most effective way to modify the properties of both mono- and bilayer films. However, this effect is more pronounced in a monolayer. This indicates that the optical width of a monolayer's band gap can be more easily controlled.

Understanding the spectra of mono- and bilayer structures enables us to select optimal parameters for their use in energy conversion and storage materials, such as supercapacitors, photodetectors and next-generation solar cells. It also allows us to draw conclusions about the influence of dimension on the kinetic properties of fewlayer quasi-2D crystals.

Assembly of Nanocrystal-Based Materials and Devices

Christopher B. Murray

[1]University of Pennsylvania, Philadelphia PA, USA

The advances in the multiscale organization of ensembles of monodisperse colloidal nanocrystals (NCs) with controlled composition, size, and shape now represent a new strategy for low-cost flexible fabrication. These NCs, acting as 'artificial atoms' with tunable electronic, optical, and magnetic properties, pave the way for the development of a new periodic assembly with unique transport and optoelectronic properties. Monodisperse NCs are ideal building blocks for incorporation into new thin films, micro-resonators, and integrated devices. In this talk, I will briefly outline the current state of the art in synthesis, purification, and integration of single-phase NCs and core-shell (heterostructures and heterodimer) NCs, emphasizing the design of semiconductor building blocks, rare-earth-based phosphors, and magnetic NCs with tunable shapes. I will then describe how these tailored NCs can be assembled into single-component, binary, and ternary NC superlattices, providing a scalable route to the production of soft metamaterials. The scalability of this process paves the way for large-scale applications. Examples of assembly for magnetic and thermoelectric applications will be briefly shared. Newer directions in engineering structural changes that can be reversed by increasing the temperature or modulating the optical properties of NC assemblies will be shared. It is possible to control the formation and phase transformations in NC superlattices by adjusting the thermal energy of a NC dispersion, thereby exerting precise control over nanocrystal assembly. The modular assembly of these NCs enables the enhancement of desirable features of the underlying quantum phenomena through photonic feedback. Strategies for emulsion-based assembly that enable continuous production and tuning of stimuli-responsive, tunable photonic resonators from dense NC 'supraparticles' will be discussed. Progress in the optical characterization of supraparticles and their potential as whispering-gallery-mode resonators, with a low lasing threshold, will be discussed.

Ultrafast Spectroscopic Insights into Triplet Formation in Functionalised DPP Derivatives – Applicable for Optoelectronics

Yadu Ram Panthi[1], Muhammed Arshad Thottappali[1], Miroslav Menšík[1], Tuhin Khan[1], Jiří Pfleger[1]

[1] *Institute of Macromolecular Chemistry, CAS, Prague, Czech Republic*

Spectroscopic investigation of thiophene-diketopyrrolopyrrole (TDPP) derivatives functionalized with benzoxazole (R-BOX) and dicyanothiophene (R-TCN) groups using femtosecond transient absorption spectroscopy reveals important excited-state dynamics in solution and thin-film.[1] In chloroform, R-BOX exhibited strong fluorescence and direct relaxation to the ground state, whereas R-TCN demonstrated vibronic and structural relaxation, followed by efficient intersystem crossing with triplet yield of ~20%. Thin films of both derivatives showed significantly faster singlet decay compared to solution. Long-lived spectral features initially suggestive of triplet formation were, upon detailed thermal analysis, attributed to laser-induced heating artefacts. The findings underline the influence of molecular rigidity and substituent effects on excited-state relaxation pathways and emphasize the necessity of accounting for thermal contributions in ultrafast spectroscopy. These results offer important insights for the rational design of organic materials for optoelectronics devices such as OFETS, Memristors, photovoltaic and OLEDs applications.

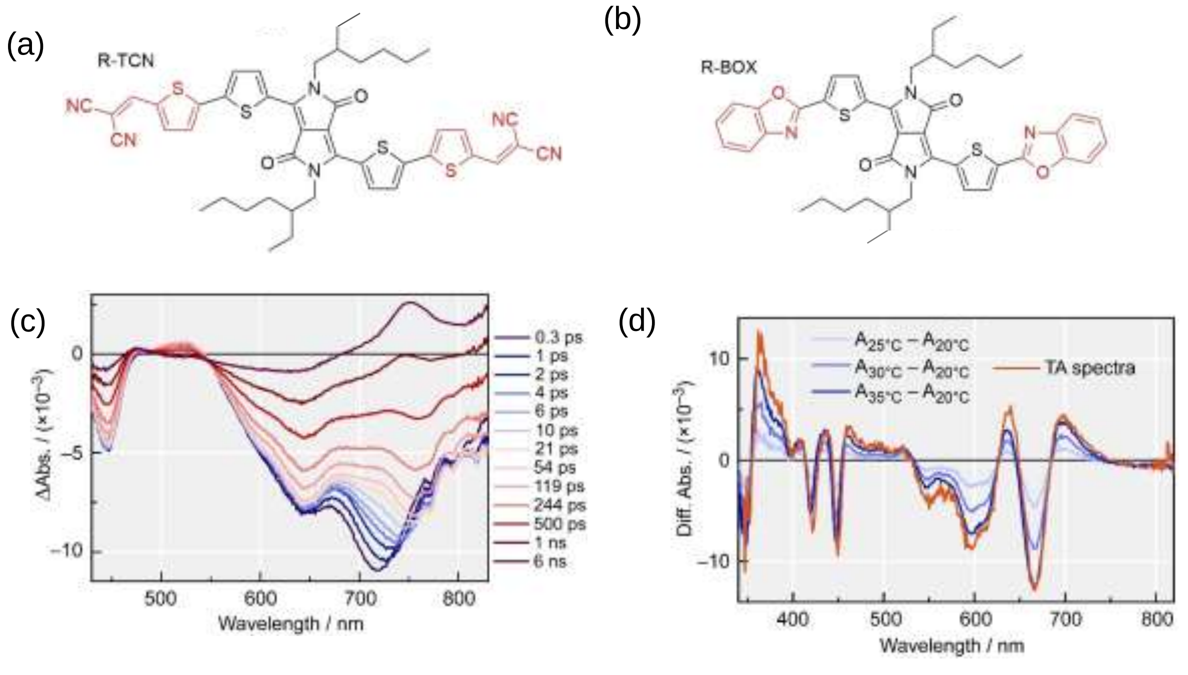

Figure: Chemical structure of the thiophene-diketopyrrolopyrrole-derivative a) R-TCN, and b) R-BOX. c) Spectral evolution of R-TCN. d) Differential spectra in steady state absorption spectra of R-BOX thin film at different temperatures.

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Tracking Exciton Diffusion and Polariton Propagation in $MAPbBr_3$ Perovskite Sheets

R. Piehler[1], E. Klein[1], R. Lesyuk[1,2], C. Klinke[1,3]

[1]University of Rostock Institute of Physics, Rostock, Germany
[2] Pidstryhach Institute for Applied Problems of Mechanics and Mathematics of NAS of Ukraine, Leviv, Ukraine
[3] University of Rostock Department Life Light & Matter, Germany

In optoelectronic applications, metal halide perovskites (MHPs) are compelling materials due to their highly tunable and intensely competitive optical properties. Colloidal synthesis enables the controlled formation of various morphologies of MHP nanocrystals, all with different carrier properties and, hence, other possibilities of carrier migration. A fluorescence imaging microscope (FLIM) for time- and space-resolved measurements of the carrier migration was employed to quantify the charge carriers' migration process upon photoexcitation.

We characterized the diffusion behavior of excitons in mixed-*n*-layered micrometer-sized methylammonium lead tribromide perovskite ($MAPbBr_3$) sheets, where so-called funnels act as quasi-traps leading to a subdiffusive behavior. [1]

In pure bulk $MAPbBr_3$ sheets, we found exciton-polaritons (EPs), which are quasi-particles forming combined states of light and matter. Because of their two-dimensional structure, these perovskite sheets are self-hybridized, allowing polaritons to form at room temperature without external cavities. [2] Since EPs propagate much faster and farther than normal excitons, they enable advanced, fast, and efficient information processing. These findings provide a better understanding of optoelectronic processes in perovskites relevant for future applications.

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Ultrafast Electron Microscopy

Claus Ropers

Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany
University of Göttingen, Germany
e-mail: claus.ropers@mpinat.mpg.de

Providing the most detailed views of atomic-scale structure and composition, Transmission Electron Microscopy (TEM) serves as an indispensable tool for structural biology and materials science. The combination of electron microscopy with pulsed electrical or optical stimuli allows for the study of transient phenomena, involving magnetization dynamics, strain evolution and structural phase transformations. Ultrafast transmission electron microscopy (UTEM) is a pump-probe technique, which tracks non-equilibrium processes with simultaneous femtosecond temporal and nanometer to atomic-scale spatial resolutions.

This talk will introduce UTEM based on laser-triggered field emitters, and will provide application examples, such as the real-space imaging of structural phase transitions [1] and the coherent mapping of optical fields [2]. Beyond time-resolved imaging, ultrafast TEMs also serve as testbeds for free-electron quantum physics, facilitating the study of electron-electron [3,4] as well as electron-photon [5] correlations and entanglements [6].

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Probing electronic disorder in nanomaterials with coherent two-dimensional spectroscopy

T. Kawde[1], P. Trofimov[1], M. Russo[1], A. Trenczek[1], and H. Seiler[1]

[1]*Freie Universität Berlin, Berlin, Germany*

Static inhomogeneities and dynamical fluctuations are inherent to nanomaterials and understanding their impact on electronic properties is highly relevant for applications. Coherent spectroscopy two-dimensional (2D) is a powerful tool to separate static and dynamic sources of disorder. Here we introduce a 2D spectroscopy setup to investigate excitons and polaritons in van der Waals 2D materials and heterostructures, which are often only 10-100 μm in size and spatially heterogeneous. The 2D spectrometer is integrated with a confocal back focal plane imaging setup, featuring high magnification, spatial and angle resolution, while maintaining a time resolution of $\sim$15 fs. We demonstrate the approach on an exfoliated WSe_2 monolayer, resolving A-exciton lineshape dynamics. The data reveal <100 fs homogeneous linewidth broadening, indicating that dynamical fluctuations of the exciton-energy proceed on the femtosecond timescale. These measurements provide insight into dephasing mechanisms such as excitation-induced dephasing, which set fundamental limits to coherent control and quantum-optical applications.

Interaction of 2D semiconductors with optically resonant nanostructures

Z. Fedorova[1,2] **and I. Staude**[1,2]

[1]Institute of Solid State Physics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena, Germany
[2]Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University, Albert-Einstein-Str. 15, 07745 Jena, Germany

*corresponding author: isabelle.staude@uni-jena.de

Two-dimensional transition metal dichalcogenides (2D TMDs) are highly promising atomically thin semiconductor materials for photonic applications due to their direct bandgap in the monolayer phase, strong photoluminescence, pronounced excitonic effects, high nonlinearity, and unique valley properties with potential for classical and quantum information processing. Their two-dimensional nature facilitates effective integration into nanophotonic architectures, while their exceptional optical properties and tunability make them ideal for compact, fast, and functional optoelectronic devices. The development of hybrid nanostructures based on 2D TMDs is a rapidly evolving field, with applications ranging from light-emitting metasurfaces and tunable lenses to ultrafast wavefront shaping and holography. Advancing these applications requires novel fabrication strategies for integrating 2D TMDs with resonant photonic nanostructures. In this talk, we present our recent advances in optically resonant hybrid nanostructures based on 2D-TMDs for optoelectronics. Our work includes integrating 2D-TMDs with dielectric metasurfaces for tunable nanophotonics [1], investigation of the influence of resonant plasmonic nanoparticles on optically accessing the valley degree of freedom in 2D-TMDs [2], nanopatterning techniques preserving optical properties, and large-scale encapsulation strategies. We discuss fabrication challenges, optical performance, and prospects for next-generation photonic applications.

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Optical properties of 2D Bi_2Se_3 nanoplatelets

J. F. Vliem[1], S. Ataberk Cayan[2], R. Reho[1], A. R. Botello-Méndez[1], P. Geiregat[2], Z. Zanolli[1], D. Vanmaekelbergh[1], A. Baserga[3], R. Kumar[3], G. Cerullo[3]

1 Utrecht University, Debye institute of nanomaterials science, Utrecht, The Netherlands 2 University of Ghent, Physics and Chemistry of Nanostructures Group (PCN), Ghent, Belgium 3 National Laboratory for Ultrafast and Ultraintense Optical Science, Istituto Nazionale per la Fisica della Materia, Dipartimento di Fisica, Politecnico, Milan, Italy

Three-dimensional bismuth selenide (Bi_2Se_3), a layered topological insulator, has an insulating bulk and gapless surface states characterized by spin-momentum locking. Upon reducing the crystal thickness below 7 quintuple layers, these surface states hybridize which results in the opening of a gap. The original gapless surface states of 3D Bi_2Se_3 become part of the 2D band structure by forming regions with a high surface contribution[1]. Using pump-probe spectroscopy on 2D Bi_2Se_3 nanoplatelets, we investigated the effect of these surface state regions on the dynamics of photogenerated carriers. We observe a few-picosecond delay in carrier recombination when exciting surface state transitions, which is attributed to carrier accumulation in the valleys of the Rashba-shaped valence band and in higher-lying surface states of the conduction band. Furthermore, coherent oscillations reveal strong electron-phonon coupling to the A_{1g}^1 and A_{1g}^2 optical phonon modes and a ~0.4 THz acoustic mode. Fourier analysis demonstrates that the A_{1g}^1 mode couples most strongly to a bulk electronic transition near 1.97 eV[2]. These results show that the distinction between surface state bands and bulk bands is important in explaining the optical properties of 2D Bi_2Se_3.

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All-Optical Logic Operation Mediated by Photochromic Molecules

Heyou Zhang 1, Pankaj Dharpure 2, Paul Mulvaney 3, Mukundan Thelakkat 2, and Jürgen Köhler* 1

1. Spectroscopy of soft Matter, University of Bayreuth, 95440 Bayreuth, Germany

2. Applied functional Materials, University of Bayreuth, 95440 Bayreuth, Germany

3. ARC Centre of Excellence in Exciton Science, School of Chemistry, University of Melbourne, Parkville, VIC 3010, Australia

Recent advancements in nanophotonics have significantly enhanced optical data storage and logic operation by enabling dynamic control of light emission. A key challenge in this field is achieving precise manipulation of material emission properties enabling optical communication.

To address this challenge, we introduce photochromic molecules, diarylethene (DAE), whose emission properties are modulated optically by light illumination. Their on/off emission states are interpreted as 1/0 in logic operation. Surface-Templated Electrophoretic Deposition (STEPD) is used to fabricate arrays of DAE molecules, creating well-ordered arrays, enabling selective optical addressing of individual bits to modulate their emission states at a micrometer scale.[1] Furthermore, a photonic logic AND gate is demonstrated by a proof-of-principle experiment, where two variants of DAE molecules are optically linked. The presence or absence of photons of particular wavelengths that represent the logic variables.[2]

Our research explores binary data processing capabilities through optically monitoring photochromic molecules. These findings demonstrate the feasibility of continuous recording, opening new possibilities for advanced optical memory devices and logic gates in optoelectronic systems.

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Abstracts of Posters

(in alphabetical order)

Photothermal Conversion of ZnSe/CdSe Core–Shell Quantum Dots for Solar-Driven Energy Applications

Abdur Rehman Mushtaq Ahmad[1], Syed Abdul Basit Shah[1], Vanni Lughi[1]

[1] Dipartimento di Ingegneria e Architettura (DIA), Università degli Studi di Trieste, Italy

Semiconductor quantum dots (QDs) with engineered band structures are promising materials for light-to-heat energy conversion. In this work, ZnSe/CdSe core–shell QDs were studied to evaluate their photothermal performance under solar-simulated irradiation. The heterostructure design provides tunable band alignment between the ZnSe core and CdSe shell, enabling controlled non-radiative recombination that leads to heat generation [1]. Structural and optical characterizations, including TEM, UV–Vis absorption, and steady-state photoluminescence, confirmed the formation of well-defined nanocrystals with strong visible absorption. Preliminary photothermal measurements demonstrated a measurable temperature rise in aqueous dispersions of the QDs under one-sun equivalent illumination, indicating effective conversion of absorbed photon energy into heat [2]. These findings highlight the potential of II–VI core–shell quantum dots as solution-processable photothermal materials for solar-driven evaporation, purification, and energy-harvesting applications. Further optimization of shell thickness and surface chemistry is expected to enhance their photothermal efficiency.

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Smart Solar Breakthrough: Machine Learning Powers Next-Gen CsSnI3/Si Tandem Cells

M.A.Oufakir [1,2] **and Y. Chrafih**[1]**and O. Aitmellal**[2]

[1]Faculty of Science, Mohammed V University in Rabat, Morocco
[2] National Center for Energy, Sciences and Nuclear Techniques, Material Sciences Unit, Rabat, 10001, Morocco

Tandem solar cells enhance the absorption of photons by utilizing materials that have different band gaps, allowing them to exceed the efficiency limits set by standard single-junction cells. In these configurations, the upper cell captures high-energy photons, whereas lower-energy photons are transmitted to the lower cell for additional conversion. This research presents a computational study of a two-terminal tandem solar cell that merges a lead-free CsSnI3 top cell with a silicon bottom cell. The examination was carried out using SCAPS-1D simulations, which were improved with machine learning techniques to fine-tune device parameters like layer thickness and doping levels to achieve current matching and minimize losses from recombination. The CsSnI3 absorber was meticulously adjusted to improve charge carrier behavior and optimize optical absorption, while the silicon sub-cell was modeled based on the filtered light spectrum from the top cell. The optimized tandem configuration reached a PCE of 29.68%, featuring a Voc of 1.675 V, a Jsc of 20. 47 mA/cm², and a FF of 86.53%. These findings suggest the potential of machine learning-enhanced design in the development of high efficiency, lead-free perovskite/silicon tandem solar cells. This methodology not only achieves impressive efficiency but also promotes sustainable and cost-effective photovoltaic technologies for future solar energy advancements.

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Balancing carrier transport in interconnection layer for efficient perovskite/organic tandem solar cells

Yidan An[1] **and Hin-Lap Yip**[1, *]

[1]Department of Materials Science and Engineering, City University of Hong Kong, Kowloon, Hong Kong 999077, China

While individual perovskite and organic solar cells have demonstrated remarkable performance, achieving similar success in high-efficiency perovskite/organic tandem solar cells (TSCs) remains a challenge, predominantly due to large voltage deficits and severe non-radiative recombination. Here, we identified that imbalanced carrier transport, particularly inadequate hole transport in the organic subcell significantly limits the overall performance of perovskite/organic TSCs. To mitigate this, we implemented a p-type self-assembled monolayer (SAM) anchored to MoO_3, which converted the inherently n-doping MoO_3 to a p-type surface. This doping-type alteration enhances hole transport through drift-diffusion instead of quantum tunneling, facilitating a more balanced carrier transport and significantly suppressing non-radiative recombination at the interconnection layer (ICL), as shown in Figure 1. The resulting perovskite/organic TSCs achieved an impressive power conversion efficiency (PCE) of 25.75%, with an open-circuit voltage of 2.182 eV. Our findings elucidate critical limiting mechanisms from a carrier transport perspective and present a successful method for optimizing carrier dynamics in the ICL.

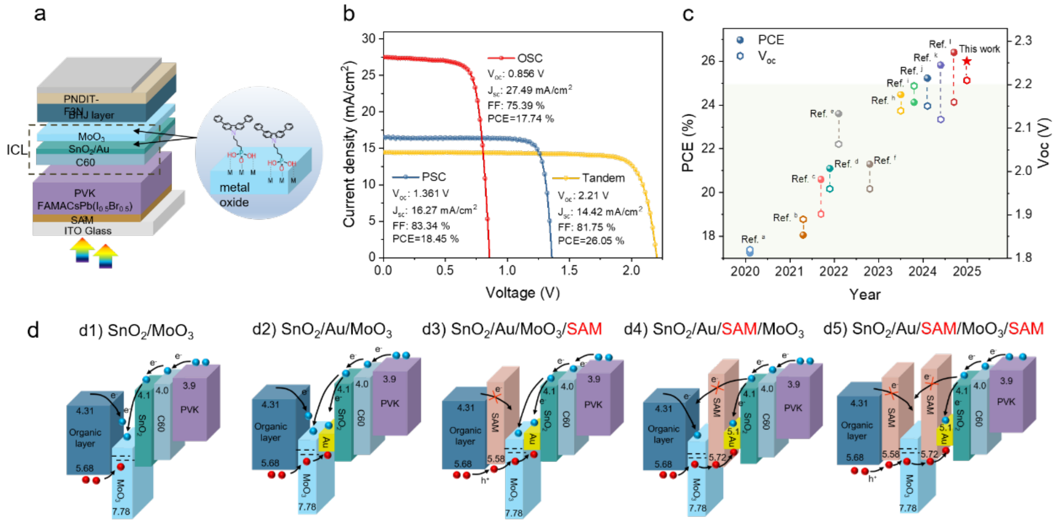

Figure 1. Perovskite/organic tandem solar cell performance and different ICL on the influence of carrier transport dynamics.

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Photo-Rechargeable Supercapacitance Behavior Studies

Mrinmoy Kumar Chini
Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh
201310, India

Abstract: Quantum well-structured two-dimensional (2D) hybrid halide perovskites (HPs) have unique opto-electronic properties such as mixed electronic-ionic conductivity, tunable band gap, high absorption coefficient, high charge carrier mobility, and good operational stability due to relatively slower ion kinetics.[1–3] These properties enable them as a promising candidate for photo-rechargeable energy storage systems such as supercapacitors. Their external quantum efficiencies originate from the spatial charge confinement due to the presence of bulky organic cations in 2D HPs. However, the phase impurity, and structural defects limit the supercapacitor applications. In this context, 2D HPs supercapacitors offer the potential of excellent energy storage devices that can capture and store solar energy directly. Our aim is to fabricate 2D HPs integrated devices to store energy as well as recharge themselves for the design of light-weight and self-sufficient applications such as portable and wearable electronics, Internet of Things (IoT) devices, etc.[3]

We have thus investigated $Arg_2MA_2Sn_3Cl_{10}$ (2D HPs) (n = 3) as our super capacitor material.[2] It shows promising results and good operational stability due to relatively slower ion kinetics. All the electrochemical cell characterizations are performed using CV and GCD techniques under dark and light condition. From GCD, calculated specific capacitance values under dark and light condition are 49.38 F/g, and 57.81 F/g at 0.1A/g current density, respectively. The achieved energy (ED) and power density (PD) from GCD under light are 20.55 Wh/Kg and 80 W/Kg at 0.1 A/g current density. Thus, HPs supercapacitors showed photo-rechargeable response. The ion kinetics in the perovskite active layer contributes to the capacitive mechanism more from pseudo capacitance and EDLC compared to diffusion-controlled charge storage. Therefore, ion migration in the perovskite active layer can be used to manipulate the total charge storage and the charging/discharging response time in perovskite-based supercapacitors. In summary, there is a huge scope of improving the supercapacitive performance by changing the composition of 2D HPs as electrode materials alongside other parameters and investigating the relatively unexplored 2D hybrid HPs as electrode materials for photo-rechargeable energy storage devices.

Key Words: Energy storage devices; halide perovskites; photo-rechargeable; Supercapacitors; Two-dimensional

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Title of contribution: “Stability and Uniformity Engineering in Perovskite Nanoparticles for Enhanced Performance”

Elshaimaa Darwish

Elshaimaa Darwish: Materials for Electronics and Energy Technology (i-MEET), Friedrich-Alexander-Universität Erlangen-Nürnberg, Martensstraße 7, 91058 Erlangen, Germany

Abstract:

Lead halide perovskite nanoparticles possess exceptional optical and electronic properties, yet their practical implementation remains limited by instability and non-uniformity at the nanoscale. In this work, we present a set of simple and scalable room-temperature strategies—based on compositional tuning, doping, and polymer-assisted synthesis—to engineer perovskite nanoparticles with improved stability, size uniformity, and enhanced luminescence. These approaches strengthen surface passivation, mitigate degradation pathways, and enable better control over the structural features that govern optical and electronic behavior. Across multiple perovskite compositions, the developed methods yield nanoparticles with higher quantum yields, improved photophysical responses, and more uniform emissive characteristics. In addition, selected materials were successfully integrated as down-shifting layers on silicon-based devices, demonstrating that nanoscale engineering directly translates into enhanced light-management performance at the device level. By advancing practical and accessible routes for producing robust perovskite nanoparticles, this work contributes to a deeper understanding of how nanoscale structure and chemical environment influence optical and electronic properties. These insights are relevant for applications ranging from light emission to energy conversion, and complement ongoing efforts to unravel charge transport and light–matter interactions on ultrashort length and time scales.

Low-Temperature Exciton Dynamics in $MAPbBr_3$ Perovskite Nanoplatelets.

Riya Dutta, Eugen Klein, Rostyslav Lesyuk, Christian Klinke.

Institute of Physics, University of Rostock, Albert-Einstein-Straße 23, 18059 Rostock

Abstract: We investigate how defects influence exciton emission and polaron behavior in the perovskite $MAPbBr_3$ nanoparticles. At room temperature, we observe a single emission peak at 535 nm, while at lower temperatures two red-shifted peaks appear at a sharp peak around 560 nm and a broad peak near 585 nm. These emissions are attributed to defect assisted excitons and polaron. We also observe a continuously evolving, yet reversible, transition between these emission states. In addition, we find that film morphology strongly affects exciton distribution, likely through energy funneling toward low-energy defect sites. These results deepen our understanding of exciton dynamics in $MAPbBr_3$ and support the development of improved optoelectronic materials and devices.

Charge transfer in CPL active [2,2]para-cyclophanes

L. Eckhardt[1], **A. Loleit**[2], **J. L. Hiller**[1], **H.F. Bettinger**[2] **and M. Scheele**[1]

[1]IPTC, Auf der Morgenstelle 18, Tübingen, Germany
[2] Institut für organische Chemie, Auf der Morgenstelle 18, Tübingen, Germany

Circularly polarized luminescence (CPL) is the differential emission of left- and right-handed circularly polarized photons [1]. Materials which exhibit CPL promise applications in 3D displays, quantum computing or cryptography []. However, the structure property relationship of CPL emitters remains somewhat elusive. Here, two organic chromophores based on a rigid [2,2]para-cyclophane scaffold were investigated. The dissymmetry factors, defined as $g_{lum} = 2\Delta I(\lambda)/I(\lambda)$ [1], were determined using a rotatable quarter-wave plate coupled with a linear polarizer. The carbonyl-substituted derivative exhibits a remarkably high g_{lum} of $+2.5 \times 10^{-2}$ / -2.6×10^{-2}, being among the highest values reported for cyclophane CPL emitters but suffers from a low quantum yield. In contrast, the thioketone analogue exhibits lower CPL with a g_{lum} of $\pm 6 \times 10^{-3}$ but features dual emission. Those results are put in perspective by solvent-dependent studies (e.g. Lippert-Mataga analysis), which provide insight into the role of charge transfer and specific solute-solvent interactions in shaping the chiral and achiral emission behaviour. These results show how solvent studies can provide further insight into the mechanisms of photoluminescence and emphasize the role of [2,2]para-cyclophanes as model system.

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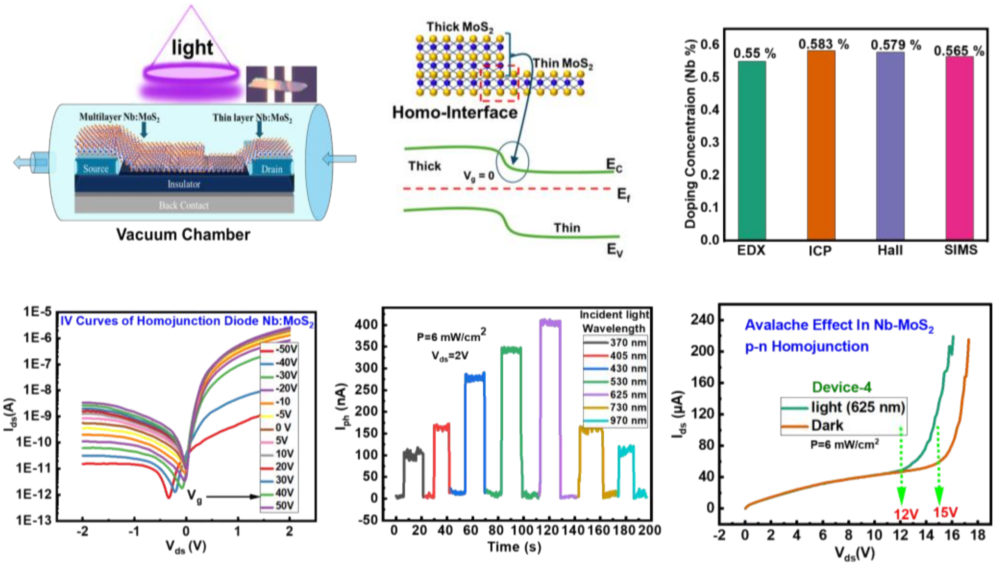
Electrical Transport of Nb-Doped MoS_2 Homojunction P–N Diode: Investigating NDR and Avalanche Effect

Ehsan Elahi[1], **Umer Ahsan**[1]

[1]*Department of Inorganic Chemistry, UCT Prague, Czech Republic*

2D transition metal dichalcogenides (TMDCs) are promising candidates for next generation nanoelectronics and optoelectronics. Yet, controlling layer number, stacking angle, and interfacial quality in van der Waals (vdW) heterostructures remains challenging, often limiting device performance and reproducibility. Homojunctions formed within a single 2D material can circumvent these issues, but their reliable fabrication and systematic exploration of exotic quantum phenomena remain elusive. Here, we report the fabrication and characterization of a thickness-modulated lateral p–n homojunction from a single flake of Nb-doped MoS_2. This configuration suppresses interface traps without external interface engineering, enabling excellent and highly stable device performance. The diodes exhibit strong rectifying behavior with a rectification ratio of ≈10^4 and a remarkably low ideality factor ($\eta = 1.23$). Notably, we observe field-dependent negative differential resistance (NDR) at low temperatures, offering unique prospects for unconventional electronic applications. The devices also achieve high photoresponsivity (1.09×10^3 A W^{-1}), external quantum efficiency (2.16×10^5 %), and detectivity (7.5×10^{10} Jones). Furthermore, electrical breakdown studies reveal avalanche multiplication at relatively low voltages, enabling high-performance avalanche photodetectors. Overall, our results demonstrate a simple yet robust approach for probing carrier multiplication in 2D homojunction p–n diodes, underlining the broad potential of TMDCs in advanced optoelectronic and quantum device applications [1].



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Disentangling Complex Charge Carrier Dynamics in Confined Transition Metal Dichalcogenides

Markus Fröhlich,[a] Surender Kumar,[b] Timo Braun,[a] Marco Kögel,[c] Onno Strolka,[a,e] Jannik C. Meyer,[c,d] Caterina Cocchi,[b] Jannika Lauth[a,e]

[a]Institute of Physical and Theoretical Chemistry, Eberhard Karls University of Tübingen, 72076 Tübingen, Germany. [b]Institut für Festkörpertheorie und -Optik, Friedrich-Schiller-Universität Jena, 07743 Jena, DE. [c]NMI Natural and Medical Sciences Institute at the University of Tübingen, 72770 Reutlingen, DE. [d]University of Tübingen, Institute of Applied Physics, 72076 Tübingen, DE. [e]Leibniz University of Hannover, Cluster of Excellence PhoenixD (Photonics, Optics and Engineering - Innovation Across Disciplines), 30167 Hannover, DE.

Transition metal dichalcogenides (TMDs) are a widely used two-dimensional material platform for investigating optoelectronic processes under confinement. Their high exciton binding energies allow studying exciton dynamics at room temperature. [1] Continued progress in colloidal synthesis of these van der Waals materials enables selective preparation of semiconducting[2] and predominantly monolayered[3,4] nanosheets. Adjusting precursor concentration and injection timing allows precise control over both lateral size (tunable between 3.7 and 21.2 nm)[5,6] and elemental composition to yield ternary alloys of the formular $Mo_{1-x}W_xS_2$.[4,7] Extensive characterization by HR-TEM, STEM, steady-state absorption, and Raman spectroscopy[4] support the interpretation of femtosecond transient absorption (TA) data. Applying global analysis to TA spectra enables separation of the complex decay pathways consisting of ultrafast trapping (250–900 fs), band-gap renormalization (red shift, 10–30 ps), and charge-carrier recombination (2ns–5 µs) in colloidal TMDs.[8] We observe a clear dependence on size and composition, with smaller NPLs and higher molybdenum content exhibiting faster non-radiative decay (265 fs vs. 741 fs, along with a prolonged ~2ns component for larger MoS_2 and WS_2 NSs associated with radiative recombination). These results are supported by DFT calculations, which indicate that under stronger confinement mid-gap transitions in MoS_2 and WS_2 become increasingly localized at the edges.[5] By establishing a fundamental understanding of the excited-state dynamics in TMDs, we aim to chemically enhance their photoluminescence efficiency, offering a scalable route toward photoluminescent colloidal TMDs.

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Fast nonlinear optical response of liquid crystals

A. Iljin [1,2]

[1] Institute of Physics, National Academy of Sciences of Ukraine, Kyiv, Ukraine
[2] Max Planck Institute for the Science of Light, Erlangen, Germany

Liquid crystals (LC) gained their fame and acquired ubiquity in modern optoelectronic and photonic technologies due to their large birefringence and strong responsiveness to external fields. Realignment of the LC director with the associated reorientation of the optical axis has been the principal mechanism engaged in the vast majority of applications. The elastic forces of LC medium, however, spread vastly outside the control area effectively decreasing real resolution and making the nonlinear optical response substantially nonlocal and concealing the recorded optical information. Wherein, as far as holography needs are concerned, a strict one-to-one correspondence between the light intensity and refractive index modulation is required. Moreover, since the response times are roughly proportional to the square of the characteristic dimensions of the affected region, these collective effects remarkably slow down the optical response.

The phenomenological model of Light-Induced Order Modification (LIOM) is presented that accounts for the changes of the refractive indices of an LC layer emerging due to the photo-induced changes of the LC order parameter [1]. Excitation with light of a molecule sitting in a liquid crystal medium results in abrupt changes of its intermolecular interaction potential with the closest neighbors, greatly affecting the orientational ordering of the latter. The model was successfully employed to explain the experimentally observed large optical nonlinearities being extremely fast as for LC systems.

The LIOM-type mechanism does not depend on the cell thickness and furnishes really fine resolution. It works for the whole range of light wavelengths and, since the optical read-out is spectrally independent from the pumping, such a mechanism could be useful for fast control of optical signals of very high intensity, for instance, in the IR range and beyond.

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Tailoring the optical properties of infrared emitting flat lead chalogenide quantum dots in 2D quantum confinement

Leo Kahlmeyer [a], Leon Biesterfeld [a,b,c], Jannika Lauth [a,b,c]

a – Institut für Physikalische und Theoretische Chemie, Universität Tübingen, Auf der Morgenstelle 18, D-72076 Tübingen, Germany.

b – Exzellenzcluster PhoenixD (Photonics, Optics, and Engineering – Innovation Across Disciplines), D-30167 Hannover, Germany.

c – Institute für Physikalische Chemie und Elektrochemie, Leibniz Universität Hannover, Callinstr. 3A, D-30167 Hannover, Germany.

By utilizing wet-chemical synthesis of two-dimensional (2D) lead chalcogenides PbX (X=S, Se, Te), highly emissive semiconductors for the infrared region are obtained with narrow size distribution.[1-3] The thereby yielded nanocrystals can be synthetically tuned towards desired lateral sizes and therefore band gap energies, due to their strong degree of quantum confinement, resulting in precisely tailored emission wavelengths. In the process, a promising novel material class has been discovered in the form of PbSe flat quantum dots (fQDs), with dimensions of 6 x 5 x 0.8 nm³.[4] These fQDs have reached up to 61 % quantum yield within the telecommunication band region between 860 – 1550 nm, which is of severe interest for fiber optics and thus device integration. To increase the applicability for higher excitation energies, as well as to enhance the stability, CdSe has been utilized due to its negligible lattice mismatch, via cation exchange method, to protect the the PbSe fQD core. The resulting heterostructure shows efficient radiative recombination, even at high excitation energies and increased quantum yield at those. Hereby, another step towards integration and application of optically active nanomaterials is synthetically pursued, alluding to the readiness of optical communication.

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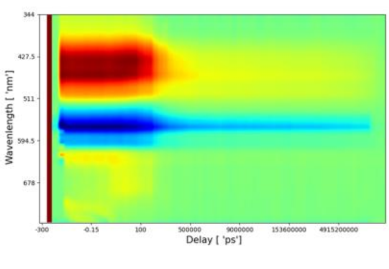
Mapping the multistep electron transfer process in animal-like Cryptochrome

Dilmehak Kaur[1] , Rachel Jack[2], Gabriel Zoldak[1], Gustavo Vives[3], and Krishna Khakurel[2]

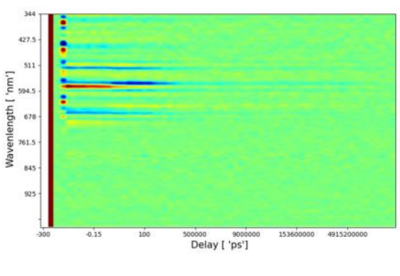
[1]*Department of Biophysics, Pavol Jozef Safarik University, Kosice, Slovakia*
[2] *ELI Beamlines, Prague, Czech Republic*
[3]*Laboratory of Biomolecular Recognition, Institute of Biotechnology of the Czech Academy of Sciences, Vestec, Czech Republic*

Nature exhibits a rich class of proteins which shows response to light. Upon photoexcitation these proteins show a myriad of processes which is yet to be completely understood. Among such proteins are blue-light receptor cryptochromes, a class of flavoproteins, which undergo several structural and electronic transitions at timescales ranging from a few femtosecond to sub-second [1]. Among these processes are the multiple electron transfer that initiates after the photo-reduction of the Flavin Adenine Dinucleotide (FAD) and then propagates across the tryptophan triad in the vicinity of the FAD molecule. Despite huge interest in rendering a fine-stoked detail of the electron transfer process, the radical-pair formation mechanism and being the central subject for magnetoreception, the experimental studies to map these processes across all the timescale is sparse. Here we present preliminary results obtained from ultrafast transient absorption spectroscopy and Femtosecond stimulated Raman spectroscopy performed in the temporal range of femtosecond to 40 ms to probe these processes. The spectral map obtained from these experiments are shown in Fig 1 (a) and (b). The signature of the dynamics across various time-scale can be clearly seen in the spectral maps. The timescales and the relevant process shall be discussed. Future strategies to tune these dynamics shall also be briefly presented.

(a)



(b)



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Probing Plasmon-Mediated Charge and Energy Dynamics in a Hyperuniform Mesoporous Gold-MOF Platform

Sarah Z. Khairunnisa[1, 2], **Olga Guselnikova**[1], **Yunqing Kang**[1], **Pavel S. Postnikov**[3], **Rashid R. Valiev**[3], **Jonathan P. Hill**[1], **Nugraha**[2], **Brian Yuliarto**[2], **Yusuke Yamauchi**[1, 4], **Joel Henzie**[1]

[1]Research Center for Materials Nanoarchitectonics (MANA), National Institute for Materials Science (NIMS), Tsukuba, Japan
[2]Doctoral Program of Nanoscience and Nanotechnology, Graduate School, Institut Teknologi Bandung, Bandung, Indonesia
[3]Research School of Chemistry and Applied Biomedical Sciences, Tomsk Polytechnic University, Tomsk, Russian Federation
[4]School of Chemical Engineering, Australian Institute for Bioengineering and Nanotechnology (AIBN), The University of Queensland, Queensland, Australia

This work explores the complex light-matter interactions within a hybrid platform designed to manipulate electrons and photons at the nanoscale for enhanced sensing. We engineer a disordered hyperuniform mesoporous gold (mAu) film, a structure where long-range order suppresses density fluctuations while short-range disorder generates a high density of plasmonic hotspots. These hotspots are interfaces of intense, localized electromagnetic fields where the interaction with photons leads to the generation of non-equilibrium 'hot' electrons and confined optical modes. We then infiltrate this plasmonic network with a UiO-66-I metal-organic framework (MOF), creating a heterointerface where these quantum-mechanical effects can be harnessed. The MOF acts as a selective charge and energy mediator: its halogen-bonding linkers recruit target molecules, while its high refractive index further confines plasmonic energy and modulates the density of optical states at the interface.

While characterized here through steady-state SERS achieving ultra-sensitive detection ($<10^{-10}$ M), this platform presents a compelling model system for probing fundamental dynamics. The porous, hyperuniform metal network is an ideal architecture for studying plasmon-mediated charge transfer and energy relaxation pathways on femtosecond timescales and across a disordered landscape. We propose that our system provides a foundational structure for interrogating how nanoscale confinement and tailored interfaces can manipulate electron behavior following photoexcitation. Understanding these dynamics through ultrafast spectroscopy and theoretical modeling—key themes of this seminar—is the critical next step to rationally designing advanced optoelectronic devices, including highly efficient sensors, photocatalysts, and quantum light sources.

A time-domain quantum chemistry for multiscale modeling of light-matter interactions

M. Krstić[1] **and M. Poleva**[1] **and C. Rockstuhl**[1,2]

[1]*Institute of Theoretical Solid State Physics, KIT, Karlsruhe, Germany*
[2]*Institute of Nanotechnology, KIT, Karlsruhe, Germany*

A theoretical multiscale framework to describe complex light-matter interactions within photonic devices and molecular materials combining quantum-chemical calculations with Maxwell's scattering simulations based on the T-matrix formalism is presented.[1,2] The framework allows us to efficiently bridge scale sizes from single molecules to macroscopic photonic devices. For individual molecules, the T-matrix is constructed from dynamic polarizabilities and its nonlinear counterpart, a hyper-T-matrix from the first hyperpolarizabilities.[3,4] The workflow is applied to model numerous linear and nonlinear multi-scattering optical response in infrared, visible and ultraviolet spectral domains.[1,4,5,6] We applied it to study optical response from within molecular materials, at interfaces and of complex photonic devices.

However, quantum-chemistry calculations, until now, were performed in the frequency-domain for the finite-size molecular models. Recent developments shift these calculations to the time-domain and full periodic description, allowing us a better understanding of the dynamic processes of electron density of materials upon interacting with the light. This advancement opens a new path to apply our multiscale framework in a full periodic description of materials on all levels, unlocking new possibilities to understand and tune optical response of broader class of materials. Here, we present an initial calculations of molecules and solid state materials in time domain and periodic settings such as of chiral camphorquinone molecule or silicon with comparison to the finite-size frequency-domain calculations as a benchmark.

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MateriaWE-Heraeus-Seminar: Charge Transport on Ultra-short Length and Time Scales

Investigation of Derivatives of Benzothiadiazole and Fluorene for Multifunctional Applications in Organic Electronics.

Nataliia Kuzyk, [1] Khrystyna Ivaniuk, [1] Pavlo Stakhira, [1] Mohamed Abdella, [2] Jurate Simokaitiene, [2] Dmytro Volyniuk, [2] Juozas Vidas Grazulevicius [2]
[1] Lviv Polytechnic National University, Bandera str., 12, Lviv 79013, Ukraine.
[2] Kaunas University of Technology, K. Baršausko g. 59, 51423 Kaunas, Lithuania
e-mail: natalii.i.kuzyk@lpnu.ua

Bulk heterostructure photodetectors based on organic semiconductors, exhibiting sensitivity across a broad spectral range, are distinguished by their environmental sustainability, low fabrication cost, and compatibility with flexible substrates [1]. These attributes render them promising candidates for applications in ultraviolet sensing technologies, in diverse fields including environmental monitoring, defence, medicine, and space communications.

In this study, we investigated the perspectives of derivatives of benzothiadiazole and fluorene(FBT) as functional materials, not only for organic photodetectors (OPDs) but also for organic light-emitting diodes (OLEDs). The synthesised compounds showed deep blue emissions with high photoluminescence quantum yields of up to 67%. Either they demonstrate high hole reaching 10-4 cm²/V·s at an electric field of 106 V/cm. They are investigated as efficient emitters for emissive layers of deep-blue OLEDs exhibiting an external quantum efficiency up to 3.9%. They are tested as efficient hosts of bulk heterostructure photodetectors. In this structure, the synthesised donor material, with the optical bandgap energy of 3.43 eV, and the acceptor C_{70} (Eg = 1.77 eV) serve as UV-sensitive materials that effectively absorb near-ultraviolet light. The developed bulk heterojunction device for ultraviolet detection exhibits a low dark current (~30 nA), high photosensitivity, and operates at a low bias voltage. The photocurrent-to-dark current ratio can reach a maximum value of approximately ~1,67 × 103 at an applied voltage of −0.5 V. Proposed structures demonstrate considerable potential for investigating low-cost, low-voltage UV photodetectors and efficient narrowband emission OLEDs.

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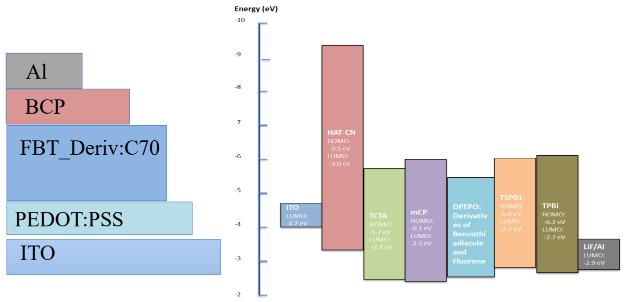
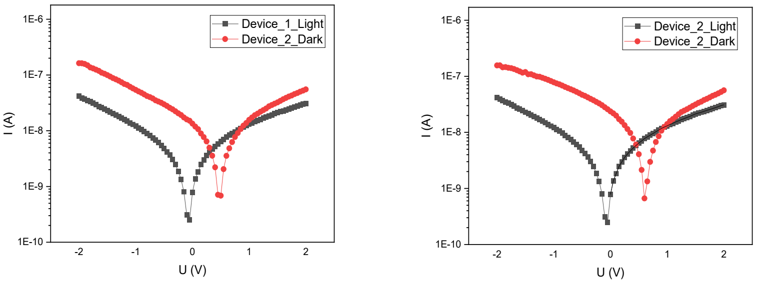
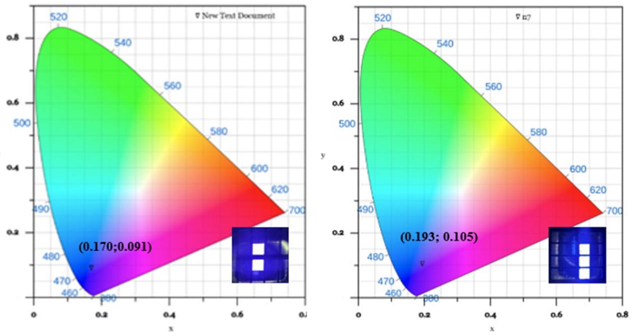
The energy diagrams for the fabricated OPD and OLED`s



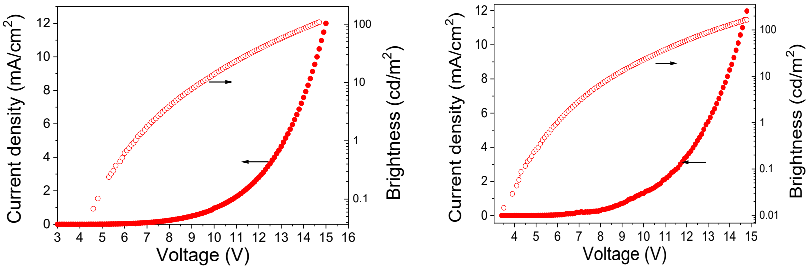
J-V curves in the dark and sun mode



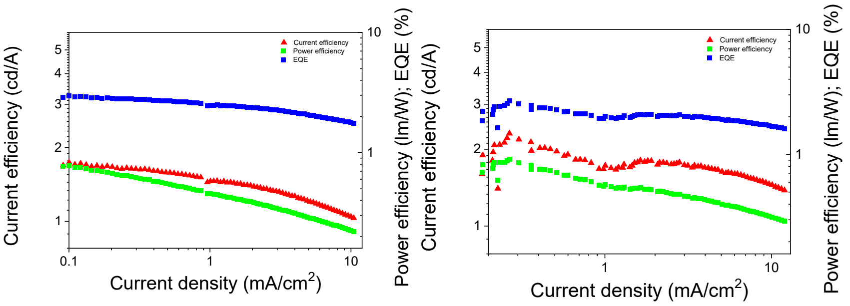
CIE1976 chromaticity coordinates with the corresponding values of OLED`s



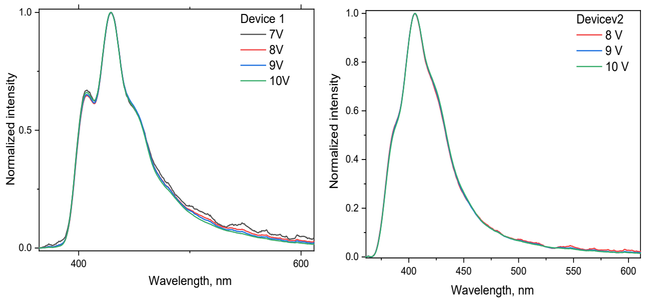
The current density−voltage−luminance curves and external quantum efficiency–current density–current efficiency curves (inside) of fabricated OLED`s



The current efficiency/power efficiency-current density of fabricated OLED`s



Electroluminescence spectra of the OLED at selected applied voltages



Conclusions

Benzothiadiazole and fluorene derivatives show strong potential as multifunctional organic semiconductors for deep-blue OLEDs and UV photodetectors. They deliver high photoluminescence (up to 67%), efficient charge transport (~10^{-4} cm²/V·s), and external quantum efficiencies up to 3.9%. When blended with C_{70}, they enable UV photodetectors with low dark current (~30 nA) and high sensitivity (PC/DC ratio ~1.67 × 10^3 at −0.5 V), supporting low-cost, low-voltage applications in sensing, displays, and communication.

Acknowledgement

This work was supported by the project HORIZON-WIDERA-2023-ACCESS-02-02, HELIOS, Research and Innovation Strategy for Lviv Polytechnic National University, dedicated to White-Emitting Organic Lighting Systems

Funded by the European Union

HELIOS (101155017)

WHITE-EMITTING ORGANIC LIGHTING SYSTEMS

Multiscale Investigation of Charge Transport and Defect Dynamics in Eco-Friendly Cu_2SnS_3 Nanomaterials for Photovoltaic Applications

S. Lahlali[1]

[1]*University Mohamed VI Polytechnic, Ben Guérir, Morocco*

Understanding charge carrier transport across multiple length and time scales is key to improving the performance of next-generation optoelectronic and photovoltaic devices. This contribution focuses on Cu_2SnS_3 (CTS), a sustainable, earth-abundant, and non-toxic semiconductor, as a model system to explore how defects, cation disorder, and interfaces influence charge motion and recombination dynamics. CTS nanostructures are synthesized via a hydrothermal route, enabling fine control of morphology and crystallinity.

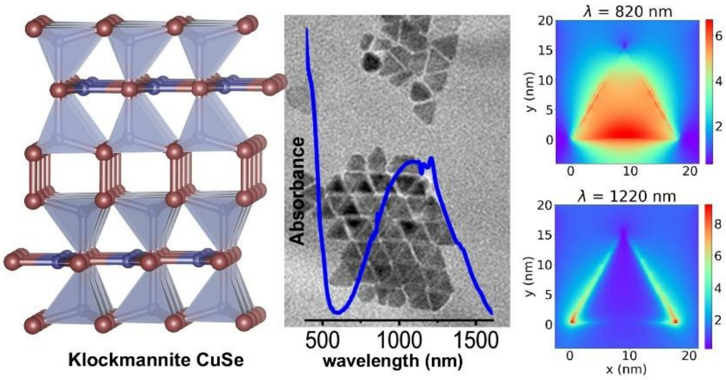
The electrical response is probed through impedance spectroscopy, providing insights into trap-assisted conduction, carrier relaxation times, and interface effects that govern macroscopic transport. To complement experiments, density functional theory (DFT) calculations elucidate defect energetics, charge localization, and electronic band structure, offering an atomistic understanding of the mechanisms observed experimentally.

By correlating steady-state characterization with theoretical modeling, this work bridges the gap between experimental time scales and the ultrafast charge carrier dynamics central to the seminar’s theme. The study outlines pathways to integrate CTS research with femtosecond-resolved spectroscopic techniques, aiming to deepen the understanding of light–matter interactions and charge transport phenomena in complex ternary semiconductors. Ultimately, this multiscale approach supports the design of cost-effective and eco-friendly materials for sustainable energy conversion.

Steady-state and transient photo-physical properties of nanoscaled klockmannite linked to crystal anisotropy

Rostyslav Lesyuk

University of Rostock, Institute of Physics, A. Einstein Str. 23, 18059 Rostock, Germany



Stoichiometric copper chalcogenides such as CuSe in the klockmannite and CuS in the covellite phases are exceptional, quasi-layered, monolithic materials exhibiting both semiconducting and metallic properties in the adjacent visible and near-infrared (NIR) spectral ranges[1,2]. In this contribution, the spectral features of klockmannite in the NIR were analyzed in detail using complex-scale discrete dipole approximation (CSDDA) calculations. These calculations reveal pronounced optical anisotropy and a hyperbolic domain at the boundary of the visible and infrared ranges. The combined effect of propagating and evanescent fields is considered the cause of these modes in the hyperbolic region. Finally, the ultrafast photophysical behavior of the material in the klockmannite phase is investigated, including hot hole cooling, trapping, and coherent phonon generation[3]. The results underscore the important role of crystal anisotropy in the physical properties of nanoscale klockmannite.

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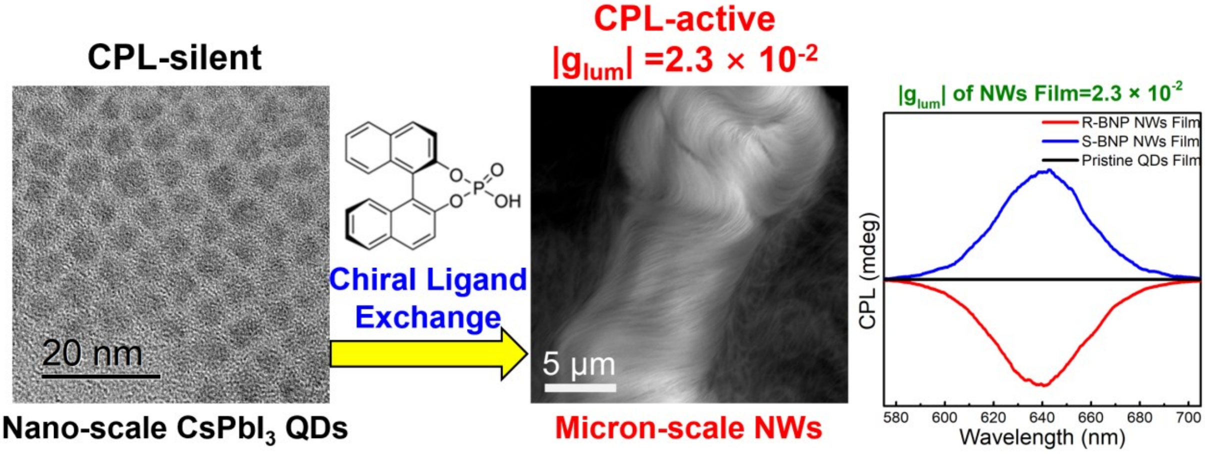
Helical Perovskite Nanowires with Strong Circularly Polarized Luminescence Self-Assembled from Red-Emitting $CsPbI_3$ Quantum Dots Following Chiral Ligand Exchange

Haochen Liu, Arsenii S. Portniagin, Bing Tang, Kunnathodi Vighnesh, Yun Li, Ye Wu, Daniil A. Rusanov, Lingyi Ke, Yunfan Wang, Ding Zhu, Desui Chen, Kwok-Chung Law, Maria V. Babak, Elena Ushakova, Andrey L. Rogach*

City University of Hong Kong, Hong Kong S.A.R. 999077, P. R. China

Email: andrey.rogach@cityu.edu.hk

Circularly polarized luminescence (CPL) from chiral perovskite nanocrystals offers great potential for spin-based optoelectronic devices, but strong CPL in the red emission region remains a challenge. Here, a facile ligand exchange method is demonstrated to induce the self-assembly of red-emitting $CsPbI_3$ quantum dots (QDs) into helical nanowires (NWs) featuring intense CPL. The resulting films exhibit high luminescence dissymmetry factors ($g_{lum} \sim 2.3\times10^{-2}$) centered at around 640 nm emission. These multilayer NW films function effectively as chiral photoluminescence filters with tunable handedness. This scalable strategy advances the design of chiral perovskite nanostructures, with promising applications in spin-LEDs and chiral photonics.



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Unraveling charge transport in 2D quantum materials on ultrashort time- and lengthscales using time-resolved momentum microscopy

S. Mathias
I. Physical Institute, University of Göttingen, Germany

Two-dimensional semiconducting quantum materials and organic semiconductors have emerged as promising materials for next-generation optoelectronics and energy harvesting. At their heart lies the process of exciton formation: when light is absorbed, Coulomb-bound electron-hole pairs, termed excitons, carry and convert energy on nanometer spatial and femtosecond temporal scales. Understanding the very first moments of light–matter interaction, along with subsequent exciton relaxation and energy conversion, is vital for designing devices with new functionality and high efficiency.

To study light-matter interaction and exciton dynamics in such 2D quantum material heterostructures, we have developed a state-of-the-art, photoemission-based experiment [1] that enables us to observe exciton dynamics in space and time, spanning nanometers and femtoseconds. This approach uncovers the characteristic fingerprints of exciton generation, tracks their dynamics of energy transfer and thermalization, and lets us map the elusive dark exciton landscape in 2D semiconductors.

In my talk, I will show how we probe ultrafast light-matter interactions [2] and resolve the formation dynamics of dark interlayer excitons across a variety of 2D quantum materials [3-6]. I will discuss the identification of distinctive photoemission signatures linked to these processes, show how the dark exciton landscape can be mapped, and introduce “photoemission exciton tomography” [5], a new technique that enables tracing ultrafast charge transfer from transition metal dichalcogenides (TMDs) to organic layers in real time [6].

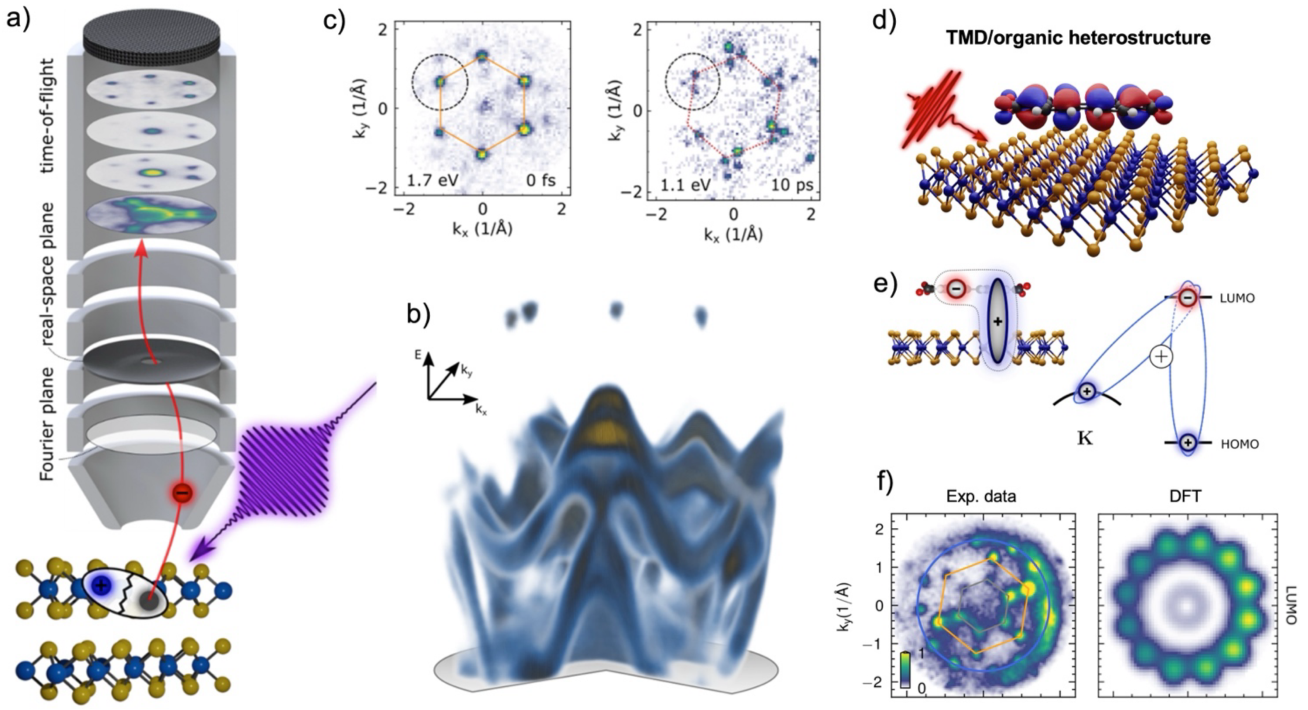

Fig. 1. a) *Scheme of the ultrafast momentum microscopy experiment [1].* ***b)*** *3D electronic structure of WSe_2/MoS_2 with excitonic signals above the valence band maxima [3,4].* ***c)*** *Selected momentum cuts showing the momentum fingerprint of the optically excited A-exciton in WSe_2 (left) and an interlayer exciton in WSe_2/MoS_2 [3].* ***d)*** *Transition metal dichalcogenide – organic semiconductor heterostructure [4].* ***e)*** *Scheme of the hybrid exciton (left) and the involved electronic single-particle states (top of valence band of TMD and HOMO/LUMO of molecular layer).* ***f)*** *Exciton fingerprints from experiment (left) showing bright and dark excitons in the TMD and the signature of the molecular orbital being indicative for the hybrid exciton. Right: DFT calculation of LUMO state of PTCDA for comparison [6].*

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High-Speed photoresponse of CVD-grown lateral TMDC heterostructures with 1D p-n junctions

M. Martin[1], A. Printschler[2], W. Roberts[1], P. Michel[1], M. Hammer[1], M. Eberle[1], J. Hiller[1], M. T. Hossain[2], A. Turchanin[2] and M. Scheele[1]

[1]Institute of Physical and Theoretical Chemistry, Tübingen, Germany
[2] Institute of Physical Chemistry, Jena, Germany

High-speed photodetection is essential for advanced optical communication systems, such as high-bandwidth internet transmission. In recent years, transition metal dichalcogenides (TMDCs) have received significant attention as promising 2D materials for this purpose, leading to a variety of fast photodetectors.

Among different fabrication methods for thin TMDC layers, chemical vapor deposition (CVD) is one of the most well-known large-scale techniques, making it highly suitable for device integration.

CVD techniques have been shown to enable the synthesis of monolayer lateral heterostructures, such as WSe_2–$MoSe_2$, which inherently form one-dimensional p–n junctions[1]. After aligning metal electrodes lithographically to these junctions, Raman and photoluminescence spectroscopy confirm the heterostructures. Optoelectrical measurements reveal an internal electric field via diode behavior and the photovoltaic effect. Fabricated devices have been demonstrated to function as high-speed photodetectors with bandwidths on the order of 200 MHz.

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48e Seminar We-Heraeus

Presenter/ author: NADO BETSALEEL Isaac Hervé

Institute (IMPRO) City: Bangui Country: Central African Republic
Institute (IMPRO) City: Bangui Country: Central African Republic

Theme: Seminar Charge Transport on Ultra- Short Length and time Scales
***Area of Intervention**: Study of load carrier movement*

Titre 48e Seminar We-Haraeus,

Name NADO BETSALEEL Isaac Hervé BP 1542 Bangui institute IMPRO de Bangui

Abstract: of the study of the movement of load carrier

Figure 2: Different goupings when EX EY {0,1} and EXY {(0,0),(0,1),(1,1)}. We denote by pij the probability of the point (i, j) ∈ EXY. In (b) and (c), the probabilities to the
left are the marginals X∗P and Y∗P, respectively, and those to the right are the conditional
laws on the appropriate subset of EXY.

multiples of s1(x) : −xln(x) + (1 − x)ln(x) [57]. Daroczy [25] proposed a similar equation solved by the α-entropy sα(x) : xα +(1− x)α −1. 3

The situation is already quite striking, because Shannon's characterization asks for an infinite number of conditions—certain equations for any set of events and any possible grouping of them—along with strong regularity of the functions H (an infinite family indexed by n), and actually just one set, two different groupings, and measurability of the unknowns are enough to reach the same conclusion. Maybe this would only be a nice mathematical curiosity, if these chain-rule-like functional equations did not accept a much deeper interpretation. Let us define,4 for any probabilistic functional P → f(P), a new functional X.f given by

(X. f)(P) :

in order to rewrite (0.6) as

X∗P(X)f(Y∗P|X x).

x∈EX

0 X.S1[Y]−S1[(X,Y)]+S1[X]

The notation is meant to suggest an action of random variables on probabilistic functionals, and in fact the equality Z.(X.f)
(Z, X). f holds. There is an strong
resemblance between (0.10) and a cocycle equation in group cohomology. Baudot and Bennequin [10] formalized this analogy: it is possible to use the general con structions of homologicalalgebratorecovertheequations(0.10)ascocycleconditions
in an adapted cohomology theory that they called information cohomology. Since the entropy is the their only solution, the argument constitutes an alternative character ization of entropy. This description is not axiomatic, but algebro-geometrical: it has a

ABSTRACT Asha Ramesh:

Charge transport in ligand-stabilized gold nanoparticle assemblies plays a pivotal role in advancing molecular electronics and nanoscale device architectures.This work examines three dithiol linkers: 1,6-hexanedithiol (6D), 1,8-octanedithiol (8D), and 1,10- decanedithiol (10D) to investigate how the length of the molecular ligand affects charge transfer in AuNP films. Using I–V measurements throughout a broad temperature range (6 K to 300 K), electrical characterisation was performed to examine the effects of ligand length on conductivity, activation energy, and tunnelling characteristics. The findings show that films stabilized with shorter ligands have lower activation energies and greater conductivity, which is in line with improved electronic coupling and closer interparticle spacing. A substantial temperature sensitivity is seen by tunnelling decay constants taken from temperature-dependent conductivity graphs, especially below 25 K where quantum tunnelling predominates. These results advance our knowledge of nanoscale charge transport by highlighting the function of energy barriers and ligandmediated electronic coupling in controlling transport pathways in nanoparticle assemblies.

Floating gate synaptic memory of Janus WSSe Multilayer for neuromorphic computing

Arslan Rehmat[1], **Ehsan Elahi**[1], **Umer Ahsan**[1], **Zdeněk Sofer**[1]

[1]Department of Inorganic Chemistry, University of Chemistry and Technology, Prague
Technická 5, Prague, 616628, Czech Republic

Janus materials are an emerging class of two-dimensional systems characterized by two chemically distinct surfaces, enabling novel multifunctional properties for electronics, optoelectronics, and memory devices. In parallel, neuromorphic computing based on floating-gate transistor architectures is gaining momentum as a hardware platform to emulate brain-like synaptic functions for artificial intelligence technologies (AIT).

In this work, we report an emerging non-volatile memory design based on Au/hBN/WSSe and Gr/hBN/WSSe heterostructures fabricated on the same WSSe channel. Gold and graphene are employed as floating-gate materials, while hexagonal boron nitride (h-BN) serves as an efficient tunneling dielectric. A direct comparison under identical measurement conditions reveals distinct performance characteristics for the two floating-gate configurations. The Au-based device exhibits a current ON/OFF ratio of approximately 10^5, while the graphene floating-gate device shows an ON/OFF ratio of about 10^3. Notably, the Gr/hBN/WSSe memory demonstrates a larger and more stable memory window ($\Delta V \approx 65$ V) compared to the Au-based device ($\Delta V \approx 51$ V).

Furthermore, the graphene floating-gate device displays robust endurance exceeding 10^5 program/erase cycles and long-term retention up to 10^6 s, along with gate-dependent multilevel states suitable for synaptic weight modulation. To evaluate system-level applicability, artificial neural network (ANN) simulations based on MNIST and Fashion-MNIST datasets were performed, achieving classification accuracies of 87% and 78%, respectively. These results demonstrate that WSSe-based floating-gate synaptic transistors can effectively support ANN learning, highlighting their potential for next-generation neuromorphic memory and computing platforms.

Nanoscale free-electron dynamics in plasmonic nanostructures

Fabian Scheidler, Jessica Meier and Bert Hecht

Nano-Optics Biophotonics Group, Experimental Physics 5, University of Würzburg,
Am Hubland, 97074 Würzburg, Germany

Intense laser pulses give rise to strong-field phenomena, where the external electromagnetic field exceeds the binding field of electrons in matter [1]. In atomic gases this results in high-harmonic generation which is typically described by a three-step recollision model involving laser-induced ionization, free acceleration, and recombination. At sharp metallic nanotips, a similar process leads to a nonlinear photocurrent driven by multiphoton and strong-field photoemission [2], which has been applied for high quality pulsed electron beam sources, e.g. for ultrafast electron microscopy [3].

Plasmonic nanoantennas fabricated by focused helium ion beam milling from monocrystalline gold microplatelets provide large field enhancements stemming from both an asymmetric nanotip-shaped gap and plasmonic hotspots [4]. Such structures have been shown to yield a geometry-dependent photocurrent across small gaps when driven by a femtosecond Ti:Sa laser in the visible to infrared spectral regime.

Our goal is to employ nanoantenna systems as local electron sources with designed plasmonic near fields for electron control. To describe the free-electron dynamics, we develop a semi-classical simulation scheme to analyze free-electron motion as well as the resulting nonlinear photocurrent in static and dynamically driven near fields.

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$CsMnBr_3$ Nanocrystal: A Curious Case of Photophysics from Picosecond to Microsecond

Dr. Arghya Sen[1], Prof. Christian Klinke[1]

[1]Institute of Physics, University of Rostock, Albert-Einstein-Straße 23
18059 Rostock

Abstract:

The growing imperative to eliminate toxic lead has catalyzed intense interest in lead-free alternatives. Among them, purely Mn-based one-dimensional (1D) perovskites, $CsMnX_3$ (X = Cl, Br, and I), have emerged as particularly promising candidates. Ongoing research continues to explore their synthetic tunability and the optical phenomena arising from their unique structural motifs. Conventionally, the broad red photoluminescence (PL) of $CsMnBr_3$ nanocrystals (NCs) is attributed to spin-forbidden d–d transitions of Mn^{2+} ions, a mechanism that typically manifests in millisecond-scale PL lifetimes. Surprisingly, recent reports have revealed ultrafast picosecond radiative lifetimes, presented a compelling inconsistency and stimulated active debate in the community. In this presentation, I will highlight the excited-state dynamics of these NCs. By correlating structural features with their photophysical signatures, this work seeks the simultaneous origin of the short (picosecond) and long (microsecond) lifetime. Further, detailed time-resolved PL spectroscopy reveals two separate excited state processes are contributing to the room temperature. Ultimately, this investigation will offer a crucial framework for engineering next-generation, lead-free luminescent systems with customizable photophysical behavior.

Plasmonic and Magnetic Properties of Ni-Decorated Cr Microrods

M. K. Sikdar[1,2], G. Ghorai[2], K. Ghosh[2], P. K. Sahoo[2]

[1]Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23–24, 18059 Rostock

[2]School of Physical Sciences, National Institute of Science Education and Research, An OCC of Homi Bhabha National Institute, Jatni 752050, Odisha, India

Nanostructures made from non-noble transition metals that combine a broad plasmonic response with intrinsic magnetic order are an attractive route toward low-cost, thermally robust magneto-plasmonic materials. This work focuses on the synthesis of Ni decorated chromium Cr microrods produced by thermally driven solid-state dewetting of Cr/Ni bilayer thin films and studying their plasmonic and magnetic properties. Cathodoluminesce study reveal three spatially localized emissions centered in the UV–visible–IR regions. The Ni nanoparticle decorated Cr microrods also exhibit substantial ferromagnetism at room temperature. Such coexistence of sizable magnetic ordering and plasmonic resonances enable genuine magneto-plasmonic functionality beyond noble metals.

Ultrafast Transient Processes in Ultrathin Colloidal Transition Metal Diselenides

O. Strolka[1,2], M. Fröhlich[1], T. Braun[1], and J. Lauth[1,2]

[1]Institute of Physical and Theoretical Chemistry, Eberhard Karl University Tübingen, Tübingen, Germany; [2]Cluster of Excellence PhoenixD, Hannover, Germany

Transient Absorption Spectroscopy (TAS) allows for the precise tracking of changes in absorption (ΔA) on timescales ranging from femtoseconds to nanoseconds and up to microseconds. One crucial aspect in interpreting the observed ΔA is the correct attribution to photophysical processes, which can be used to fit the measured data.

Transition metal dichalcogenides (TMDCs) are layered materials of the form MX_2 (M = Mo, W; X = S, Se, Te) which possess a direct band gap in monolayers and strong spin-orbit coupling.[1,2] A reduced Coulomb screening of excitons in ultrathin TMDCs results in large binding energies with values of ~500 meV at room temperature.[3] As a result of these interesting photophysics, a wide range of applications including sensors, nanoelectronics, energy harvesting, catalysis, superconductors and spintronics have been proposed. [3-9] A critical step toward the realization of these applications is the scalable production of processable quantities of 2D semiconductor monolayers.

We use colloidal bottom-up synthesis methods for obtaining $MoSe_2$ and WSe_2, which we have established for different TMDCs to yield processable inks,[5-9] and characterize them via TEM, XRD, XPS and Raman spectroscopy. From the inks we then perform femtosecond transient absorption and potential modulated absorption spectroscopy to determine the optical and electronic properties of the material experimentally. In these materials, the main contributing transient processes are the bleach of steady state signals and band gap renormalisation,[10-11] which are difficult to disentangle due to their overlapping spectral and temporal ranges. Here we present our newest findings, which aim to disentangle contributing processes and underlying band structures.

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Accelerating Materials Discovery: A High-Throughput, AI-Driven Workflow for Photocatalyst Optimization

Yağmur Tanış, Dr. Olga Guselnikova

Institute of Applied Physics, TU Wien, Wiedner Hauptstraße 8-10, 1040 Wien, Austria

Conventional recycling methods often struggle with molecular contaminants in post-consumer plastics, frequently leading to downcycling or landfilling rather than sustainable recovery. Photocatalysis offers a powerful, light-driven solution for decontaminating materials at the molecular level, thereby enabling true bottle-to-bottle sustainable reuse within a circular economy framework. However, the discovery of optimal photocatalytic materials is historically hindered by the slow pace of traditional trial-and-error experimental approaches.

The proposed solution consists of a two-stage optimization loop. In the first stage, the AI model identifies and suggests promising new catalyst materials for synthesis. In the second stage, the model optimizes reaction parameters, such as pH and dosage, to maximize performance. We applied this methodology to a model system featuring Au@g-C_3N_4 for the degradation of Methylene Blue (MB). While g-C_3N_4 absorbs in the UV range, the introduction of gold nanoparticles (AuNPs) enables plasmonic absorption (~513 nm), aligning with the peak solar spectrum.

Through this iterative "Test -> Analyze -> Predict" workflow, preliminary experimental cycles have already demonstrated a significant increase in reaction efficiency compared to initial benchmarks. Current findings highlight strong performance at a loading of 1 wt% Au, a catalyst dosage of 0.15 g/L, and a pH level of 11. These results, quantified via UV-Vis spectroscopy and Apparent Quantum Yield (AQY) calculations, demonstrate that AI-guided methodologies can drastically reduce the time required to develop high-performance materials. The project is currently in its second guided cycle, and these iterative processes will continue to further refine the catalyst formulations and converge on an optimized solution for industrial reuse.

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Ultra-violet to shortwave-infrared transient absorption spectral features of flat PbSe quantum dots in strong confinement

J. Unseld[1], L. Biesterfeld[1], Prof. Dr. Jannika Lauth[1]
[1] IPTC, Tübingen, Germany

The direct wet-chemical synthesis of two-dimensional (2D) lead selenide (PbSe) flat quantum dots (fQDs) yields bright materials with strong excitonic contribution at room temperature. [1,2] These highly confined 2D nanocrystals exhibit photoluminescence (PL) in the near-infrared (900 – 1550 nm) with a PL quantum yield of up to 60 %. [1] Their highly efficient PL at fiber-optics-relevant telecommunication wavelengths renders colloidal lead chalcogenide 2D semiconductors intriguing materials for future solution-processable components for fiber optic applications. However, their (time-resolved) absorption characteristics have not been thoroughly investigated up to now, as their excitonic absorbance is rather weakly expressed in conventional steady-state absorbance measurements. Here, we investigate the photophysics and charge carrier dynamics in PbSe fQDs (8.3 × 4.9 nm^2) by femtosecond broadband transient absorption spectroscopy (TAS). Careful spectral tuning of the photoexcitation wavelength allows for probing of the elusive ground state bleach of the first excitonic transition. By probing the full energy range (350 – 2400 nm), we can assign the $1P_{\mathrm{e,h}} – 1P_{\mathrm{h,e}}$ - exciton at 660 nm shifted *via* biexcitonic interaction,[3] the ground state bleach of the $1S_{\mathrm{e,h}} – 1S_{\mathrm{h,e}}$ – exciton at 1450 nm and excited state absorption from the $1S_{\mathrm{e,h}} – 1P_{\mathrm{e,h}}$ - transition at 2300 nm. [4] By fitting, charge carrier dynamics such as intraband relaxation ($\tau_{intraband}$ ~ ps) [4] and radiative recombination ($\tau_{radiative}$ ~ µs) [1a] were found. Furthermore, multiexcitonic contribution to the decay was found ($\tau_{multiexc.}$ ~ 20 – 240 ps).[5] Our results advance the understanding of near-infrared emissive highly confined 2D PbSe fQDs for the first time and will help to implement them in future applications.

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848. WE-Heraeus-Seminar: Charge Transport on Ultra-short Length and Time Scales

Dead Layer Characterization of the CONUS+ HPGe Neutrino Detector

Julian Wendel[1,2]

[1]Max Planck Institute for Nuclear Physics (MPIK), Heidelberg, Germany
[2]Heidelberg University, Heidelberg, Germany

The CONUS+ experiment aims to detect coherent elastic neutrino–nucleus scattering (CEνNS) of reactor antineutrinos using high-purity germanium (HPGe) detectors. CEνNS was first theoretically proposed by Freedman [1] and is characterized by a comparatively large cross section while producing extremely low-energy nuclear recoils. This makes a precise understanding of the detector response essential. CONUS+ has been operational since late 2023 at the Leibstadt Nuclear Power Plant in Switzerland and employs four p-type point-contact HPGe detectors optimized for sub-keV energy thresholds [2].

This contribution presents the current status of my master's thesis, which focuses on the measurement and characterization of the detector dead layer. The dead layer directly affects the effective active volume and the energy response at low recoil energies and therefore constitutes an important systematic uncertainty for CEνNS analyses. Surface effects and dead-layer properties in p-type point-contact HPGe detectors are known to have a significant impact on low-energy measurements and charge collection [3]. A precise determination of this parameter is thus crucial for improving the accuracy of signal predictions and background modeling in CONUS+.

The CONUS collaboration has already reported first experimental constraints on CEνNS using reactor antineutrinos [4]. While the analysis presented here is still at an early stage, first quantitative results are expected by the time of the seminar and will then be presented if available. This work contributes to a refined understanding of the detector response and supports the long-term goal of enhancing the sensitivity and precision of low-energy neutrino measurements in the CONUS+ experiment.

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