HL 13: Poster Session I

Time: Monday 17:30–19:30 Location: Poster B

HL 13.1 Mon 17:30 Poster B

Transmission Electron Diffraction on a really free-standing heterostructure and analysis of the resulting Moiré pattern — •Marlene Adrian, Arne Senftleben, Silvio Morgenstern, and Thomas Baumert — University of Kassel, Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), D - 34132 Kassel

The combination of various 2D layered materials in multilayer heterostructures arises great interest in the current science. Due to the large variety of electronic properties of the group of 2D layered materials the combination opens a new pathway towards ultrasmall electronic devices.

In this contribution we present a full mathematical description of multilayer heterostructure samples and their diffraction images including a proposal of a consistent assignment of the superstructure diffraction spots. A 27 nm thick MoS2-graphite heterostructure was produced and fully analysed with the methods presented. Additionally, the ultrafast lattice dynamics after optical excitation of the sample will be discussed.

HL 13.2 Mon 17:30 Poster B

First Principles Phase Diagram Calculations for the 2D TMD systems MoS_2-MoTe_2 and WS_2-WTe_2. — •Benjamin Burton — Materials Measurement Laboratory, National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899, USA

First Principles Phase Diagram Calculations were performed for the 2D Transition Metal Dichalcogenide Systems MoS_2-MoTe_2 and WS_2-WTe_2. These FPPD calculations were performed with the ATAT system using VASP calculated formation energies for $MS_{2-2x}Te_{2x}$ supercells (M=Mo or W) as input. For both of these systems, very surprising results were obtained: (1) although all calculated formation energies for systems with 16 or fewer anion sites were positive, suggesting a miscibility gap, entropy stabilized intermediate phases were predicted in $Mo(S,Te)_2$; (2) although one expects immiscibility to be greater on the S-rich sides of these diagrams (because S^{2-} is a smaller ion than Te^{2-}) it is much greater on the Te-rich sides.This surprising asymmetry is understood as reflecting a preponderance of lower-energy metastable ordered states on the S-rich sides of the systems.

The calculated phase diagrams are for bulk systems, but results for monolayers of $Mo(S,Te)_2$ on a saphire substrate [Al-terminated, (0001) face] will also be discussed.

HL 13.3 Mon 17:30 Poster B

Anderson localization and magnetization in graphene quantum dots — •Abdulmenaf Altintas and Alev devrim Guclu — Izmir Institute of Technology, Izmir, Turkey

We theoretically try to understand the effects of vacancy related disorders and electron-electron interactions on Anderson type localization and the magnetic properties of hexagonal armchair graphene quantum dots. Our model is based on mean-field Hubbard model. Removing p_z orbital induce local magnetic puddle in vacancy related region. Disorders leads to localization of electronic states when they are introduced randomly. Localization length decreases with breaking of sub lattice symmetry.

HL 13.4 Mon 17:30 Poster B

Strain tuning of CVD grown MoS_2 monolayers — •Anna F. Blob[1], Iris Niehues[1], Valentino Jadriŝko[2], Borna Radatović[2], Marko Kralj[2], Steffen Michaelis de Vasconcellos[1], and Rudolf Bratschitsch[1] — [1]Physikalisches Insitut, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institute of Physics, Zagreb, Croatia

Single layers of transition metal dichalcogenides are a new class of 2D materials. Mechanical straining makes it possible to change their fundamental optical transitions [1]. We apply reversible uniaxial tensile strain to CVD grown MoS_2 monolayers by bending a flexible polycarbonate substrate on which the ultrathin semiconductor is placed. To avoid slippage of the MoS_2 monolayer, it is covered with a PDMS layer. Absorption spectra of the atomically thin semiconductor are measured for increasing and decreasing strain levels. The energetic shifts of the exciton resonances are determined to be $-42\,\mathrm{meV/\%}$ and $-43\,\mathrm{meV/\%}$ for the A and B exciton, respectively. These gauge factors are in excellent agreement with those derived from monolayers exfoliated from naturally occuring molybdenite crystals.

[1] R. Schmidt, I. Niehues, R. Schneider, M. Drüppel, T. Deilmann, M. Rohlfing, S. Michaelis de Vasconcellos, A. Castellanos-Gomez, and R. Bratschitsch, Reversible uniaxial strain tuning in atomically thin WSe_2 in: 2D Materials 3, 021011 (2016)

HL 13.5 Mon 17:30 Poster B

Hysteresis in Graphene Nanoribbon Field-Effect Transistors — •Alexander Tries[1,2,3], Nils Richter[1,3], Zongping Chen[2], Akimitsu Narita[2], Klaus Müllen[2,4], Hai I. Wang[2], Mischa Bonn[2], and Mathias Kläui[1,3] — [1]Institut für Physik, Johannes Gutenberg Universität, Mainz, Germany — [2]Max Planck Institute for Polymer Research, Mainz, Germany — [3]Graduate School of Excellence Materials Science in Mainz, Mainz, Germany — [4]Institut für Physikalische Chemie, Johannes Gutenberg-Universität, Mainz, Germany

Hysteresis in carbon based Field-Effect Transistors (FET) such as Graphene FETs or Carbon Nanotube FETs is a known feature that impacts the device performance [1,2]. In this work, we show that also atomically perfect Graphene Nanoribbons (GNR) exhibit a hysteresis behavior while measuring transfer curves. We perform a systematic study on armchair GNRs with a width of 5 and 9 carbon atoms (aGNR5 and aGNR9) using GNR-FET devices. Temperature and gate sweep rate dependent measurements reveal charge carrier trapping as a main cause of the hysteresis. From the measurements, we are able to extract the density and energy of the trap states that result in the hysteresis[3].

[1] Kim et al., Nano Letters 3, 193-198 (2003)
[2] Singh et al., Journal of Applied Physics 122, 195305 (2017)
[3] Tries et al., Manuscript in preparation (2018)

HL 13.6 Mon 17:30 Poster B

The Hofstadter Butterfly under periodic driving — •Martin Wackerl and John Schliemann — Institut für Theoretische Physik, Universität Regensburg

The focus is on externally driven graphene which is additonally in a magnetic field where the external driving is put into practice by polarized light. The Hofstadter buttery problem is treated in a rigerous manner. Then we generalize it to the case with a periodic driving, realized by linear and circular polarized light. We show some representative numerical results for different frequencies, intensities and polarizations. Finally, the topological properties of the Floquet-Hofstadter problem is characterized with Chern numbers. We compare the ground state Chern numbers for different frequencies and intensities. This work gives an analytical as well as a numerical approach to the above formulated system.

HL 13.7 Mon 17:30 Poster B

Valley polarization dynamics of interlayer excitons in dichalcogenide heterostructures in high magnetic fields — •Johannes Holler[1], Jonas Zipfel[1], Mariana Ballotin[2], Anatolie Mitioglu[2], Michael Kempf[1], Philipp Nagler[1], Fabian Mooshammer[1], Alexey Chernikov[1], Peter Christianen[2], Christian Schüller[1], and Tobias Korn[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]High Field Magnet Laboratory (HFML EMFL), Radboud University Nijmegen, Netherlands

In the recent years, research on two-dimensional materials has been a rapidly expanding field. Among these materials, a promising class are the transition-metal dichalcogenides (TMDCs). Besides very interesting physics of monolayers, such as spin-valley locking, these TMDCs can be combined to heterostructures, revealing new excitonic properties.

Here, we study $MoSe_2$-WSe_2 heterostructures, which create a staggered band alignment so that optically excited electron-hole pairs are spatially separated, leading to the formation of interlayer excitons (IEXs). In magnetic fields of up to 30 Tesla, we observe a giant valley-selective splitting in low-temperature photoluminescence measurements and a resulting near-unity valley polarization. Furthermore, we probe the valley dynamics of the IEX in dependence of the magnetic field. We are able to observe the build-up of the valley polarization

after unpolarized excitation, revealing different dynamics and lifetimes for the different valleys.

HL 13.8 Mon 17:30 Poster B

Influence of oxygen and water on the stability and optical properties of monolayer MoS_2 — •Christian Tessarek, Oleg Gridenco, Kathrin Sebald, Stephan Figge, Jürgen Gutowski, and Martin Eickhoff — Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee 1, D-28359 Bremen, Germany

2D materials such as graphene, BN and transition metal dichalcogenides (TMDs) are promising candidates for further miniaturization of (opto-)electronic devices. Monolayer MoS_2, a member of the TMD family, is a semiconductor with a direct band gap of 1.9 eV and thus suitable for transistor, photovoltaic and light emitting applications. Its large surface-to-volume ratio and chemical activity enables strong interaction with the environment essential for highly sensitive optical sensors. In this context it is necessary to understand the influence of the environment on the optical properties of MoS_2.

In this study, thin layers are prepared by exfoliation of bulk MoS_2. Raman spectroscopy is used to identify the number of layers and photoluminescence measurements are performed to investigate the influence of different gases and liquids on the optical properties of mono- and multilayer MoS_2. A strong enhancement of the photoluminescence intensity is achieved by exposing MoS_2 to oxygen and water. It is found that MoS_2 is more stable in oxygen compared to water. Degradation mechanism are analyzed by Raman spectroscopy.

HL 13.9 Mon 17:30 Poster B

Drag Experiments in Double Bilayer Graphene — Matthias Troiber[1], Kenji Watanabe[2], Takashi Taniguchi[2], Dieter Weiss[1], and •Jonathan Eroms[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany — [2]National Institute for Materials Science, Tsukuba, Japan

We present experimental results on longitudinal and transverse drag in double bilayer graphene heterostructures. The graphene sheets were separated by a few nm thick hexagonal boron nitride (hBN) layer and were embedded into hBN using the van der Waals stacking technique. The density in both layers was controlled by a back and top gate, respectively. Drag measurements were performed at temperatures up to $T = 100$ K and both at $B = 0$ and in the quantum Hall regime. Similar to [1], at $B = 0$ we observe a sign inversion of the drag voltages close to simultaneous charge neutrality in both layers. In the quantum Hall regime at elevated temperatures, we observe pronounced signatures in the drag signal at integer filling factors in either layer, despite the fact that in transport the QHE features are only barely visible. Also, at constant combined filling factor similar features appear in the drag signal. The results can be mostly interpreted within the Oppen-Simon-Stern theory [2], and we will discuss possible reasons for remaining discrepancies.

[1] J. I. A. Li, *et al.*, Phys. Rev. Lett. **117**, 046802 (2016).

[2] F. von Oppen, S. H. Simon, and A. Stern, Phys. Rev. Lett. **87**, 106803 (2001).

HL 13.10 Mon 17:30 Poster B

Optical properties the Ferromagnetic CrI_3 monolayer — •Claudia Cardoso[1], David Soriano[1], and Joaquín Fernández-Rossier[1,2] — [1]International Iberian Nanotechnology Laboratory (INL), Braga, Portugal — [2]Departamento de Física Aplicada, Universidad de Alicant, Spain

The recent reports of ferromagnetic order in two dimensional crystals sign the beginning of a new chapter in the field of 2D materials. Bulk CrI_3 is a layered van der Waals ferromagnet and, in its monolayer form, a 2D ferromagnet. Distinct from the Wannier-Mott excitons which dominate the optical response in 2D van der Waals semiconductors, the recently reported absorption photoluminescence measurements on CrI_3 were explained in terms of ligand-field, charge-transfer and parity-forbidden $d-d$ transition characteristic of Cr^{3+} complexes.

The aim of the present work is to go beyond phenomenological models, and study the ferromagnetic CrI_3 monolayer optical properties from first principles. On the one hand, it is possible to describe the properties of a magnetic system in terms of effective single spin Hamiltonians, yet the determination of the different parameters requires experimental input. On the other hand, Density Functional Theory (DFT) provides an accurate description of the ground state electronic properties, however it does not describe low energy spin excitations. By combining these two approaches we derive the effective spin Hamiltonian starting from an atomistic DFT description. This method allows us to interpret the experimental findings and identify the origin of the transitions in the recently reported photoluminescence measurements.

HL 13.11 Mon 17:30 Poster B

Impact of non-resonant terahertz excitation on excitons in $MoSe_2$ monolayer — •Tommaso Venanzi[1,2], Stephan Winnerl[1], Alexej Pashkin[1], Manfred Helm[1,2], and Harald Schneider[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany

We have studied the interaction of excitons in $MoSe_2$ monolayers with high terahertz electric fields by means of THz pump - optical probe spectroscopy. The experiment has been performed with the free electron laser at the Helmholtz-Zentrum Dresden-Rossendorf synchronized to a mode-locked Ti:Sapphire laser. Various frequencies in the range of 3 - 30 THz have been selected for non-resonant pumping of the $MoSe_2$ monolayer, while the probe beam (748 nm) is resonant with the exciton. During the time overlap between the picosecond THz and NIR pulses, we observe a significant reflectivity increase at the exciton resonance. We discuss free carrier absorption, excitonic dynamical Franz-Keldysh effect and AC Stark effect as possible scenarios for this non-resonant interaction.

HL 13.12 Mon 17:30 Poster B

ultrafast Auger-mediated hole trapping and coherent phonon dynamics in CdSe/CdS core/shell colloidal semiconductor nanoplatelets — •shuo dong[1,2], jie lian[3], yinthai chan[3,4], and zhiheng loh[1] — [1]Division of Chemistry and Biological Chemistry, and Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, 21 Nanyang Link, Singapore 637371, Singapore — [2]Fritz Haber Institut of the Max Planck Society, Faradayweg 4-6, 14195 Berlin, Germany — [3]Institute of Materials Research & Engineering A*STAR, 3 Research Link, Singapore 117602, Singapore — [4]Department of Chemistry, National University of Singapore, 3 Science Drive 3, Singapore 117543, Singapore

The narrow absorption and photoluminescence emission spectra of atomically flat, quasi-two-dimensional, colloidal semiconductor nanoplatelets (NPLs), which originate from the atomically precise thickness, have motivated increasing research interest. Here, we report the use of ultrafast transient absorption spectroscopy to study the early-time carrier dynamics of CdSe/CdS core/shell NPLs. By selective monitoring the excitonic transitions, fluence-dependent measurements reveal a sub-picosecond Auger-mediated hole trapping process. The low-frequency oscillatory features observed in the first-moment time traces can be assigned to the hitherto undetected coherent acoustic phonons (5 and 20 cm-1). The elementary carrier and phonon dynamics of colloidal semiconductor NPLs observed herein could potentially influence their optoelectronic properties.

HL 13.13 Mon 17:30 Poster B

The influence of field effect doping on the optical properties of a MoS_2 monolayer — •Shun Okano[1], Apoorva Sharma[1], Mahfujure Rahaman[1], Akira Nishimura[2], Nicole Köhler[3], Kenji Ikushima[2], and Dietrich R.T. Zahn[1] — [1]Semiconductor Physics, Chemnitz University of Technology, D-09107 Chemnitz — [2]Department of Applied Physics, Tokyo University of Agriculture and Technology, Tokyo 184-8588, Japan — [3]Zentrum für Mikrotechnologien, Chemnitz University of Technology, D-09107 Chemnitz

Since the discovery of graphene, 2D materials are in the centre of attention in the scientific community. Within the 2D material family MoS_2 possesses semiconducting properties with a band gap unlike graphene, which is a conductor. This makes MoS_2 a suitable candidate for various device applications such as transistors etc. Furthermore, K.F. Mak et al. reported a novel property of modulating the light absorption for a monolayer of MoS_2 with field effect doping [1]. However, a detailed optical spectroscopic analysis of this material is still lacking. Here we present the results obtained from microscopic imaging spectroscopic ellipsometry and a thorough analysis of the results. The study was conducted on mechanical exfoliated MoS_2 flakes stamped on highly doped p-type silicon substrate with a thermally grown 375 nm thick silicon dioxide layer. To induce field effect doping in the MoS_2, gold electrodes were patterned with e-beam lithography technique. From the results obtained the modulation of the optical properties can be correlated to the change in carrier concentration. [1] Mak,K. F.,Nature materials 12.3(2013):207-211.

HL 13.14 Mon 17:30 Poster B

Single-photon emitters in hBN — •Johann Preuss, Osvaldo del Pozo-Zamudio, Robert Schmidt, Philipp Tonndorf, Johannes Kern, Steffen Michaelis de Vasconcellos, and Rudolf Bratschitsch — Physikalisches Institut und Center for Nanotechnology, Westfälische Wilhelms-Universität Münster, Deutschland

Single photon emitters (SPEs) have gained increased attention due to their application in quantum technologies, such as quantum computation and communication. Solid-state SPEs are promising due to their high stability and scalability in addition to the excellent optical properties. Recently, the 2D semiconductors WSe2 and WS2 have been shown to host SPEs [1,2,3]. Hexagonal boron nitride (hBN), a van der Waals insulator, exhibits ultrabright and narrowband single photon emission also at room temperature [4]. We investigate the optical properties of single localized emitters in hBN using photoluminescence spectroscopy.

[1] Tonndorf et al., Optica 2, 347-352, 2015 [2] Maragkou, Nature Materials 14, 564, 2015 [3] Palacios-Berraquero et al., Nature Comm 7, 12978, 2016 [4] Tran et al., Nature Nanotech 11, 37-42, 2016

HL 13.15 Mon 17:30 Poster B

Electroluminescence in strain-reduced MoSe2 monolayer p-n-junctions — •Georg Winkens[1], Jhih-Sian Tu[1], Thomas Grap[2], Joachim Knoch[2,3], Detlev Grützmacher[1], and Beata Kardynal[1,3] — [1]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, Germany — [2]Institute of Semiconductor Electronics, RWTH Aachen University — [3]JARA - Fundamentals of Future Information Technology, RWTH Aachen University, Germany

P-n junctions are one of the fundamental elements of modern semiconductor devices, such as diodes, LEDs, transistors and photodetectors. Doping needed to form p-n junctions in monolayers of transition metal dichalcogenides (TMD MLs) is proving difficult, while strong interest in this class of material has been fueled by their unique properties which could lead to new applications. The strong spin-orbit interaction combined with favourable optical selection rules makes them extremely interesting for opto-spintronics and valleytronics. A shift of the electrochemical potential in TMD MLs can be achieved by the use of local gating instead of dopants, allowing very flexible manipulation of doping levels and thus fabrication of complex devices. In this presentation we will compare two alternative designs of devices based on local gating, both aiming at eliminating strain from the TMD monolayers in the patterned devices. While one relies on preparing van der Waals heterostructures, the second makes use of substrates with buried tungsten gates. We will compare the two designs by characterizing MoSe2 ML light emitting diodes.

HL 13.16 Mon 17:30 Poster B

Determination of the crystal orientation of monolayer transition metal dichalcogenides and transition metal dichalcogenide heterostructures. — •Michael Kempf, Johannes Holler, Philipp Nagler, Christian Schüller, and Tobias Korn — Universität Regensburg, 93053 Regensburg Germany

We investigate the crystal orientation of monolayer transition metal dichalcogenides (TMDC) and especially the relative crystal orientation of single layer TMDC heterostructures. This difference is of special interest for interlayer effects, for example the formation and recombination of interlayer excitons, and can be determined by using polarized second harmonic generation (SHG) measurements. The heterostructure samples are fashioned through mechanical exfoliation of monolayer $MoSe_2$ and WSe_2 and stepwise transfer onto a SiO_2 substrate. We perform scanning SHG measurements of our structures with sub-μm resolution and defined polarization. For a 0° and 60° orientation difference of the monolayers in a heterostructure we observe a constructive and destructive interference of the SHG intensity, respectively.

HL 13.17 Mon 17:30 Poster B

Resonant Raman scattering on few layer $MoSe_2$ — •Sebastian Meier, Philipp Nagler, Andreas Hecht, Tobias Korn, and Christian Schüller — Universität Regensburg, 93040 Regensburg, Germany

We perform resonant Raman scattering to look for electronic scattering mechanisms in $MoSe_2$. Our samples are prepared by mechanical exfoliation and transferred to a Si/SiO_2 substrate. Using a Ti:Sapphire laser, we can tune the excitation energy across the whole region of excitonic transitions at the K and K' points in $MoSe_2$. This allows us to record the detailed resonance behaviour of known phonon modes as well as to look for new peaks in the low-energy region. Such measurements were done for room temperature and at $T = 4\,\mathrm{K}$.

For both temperatures, a new peak is observed on few-layer samples, which we can not explain by phonon scattering. It is located at very low wavenumbers and appears only at extremely resonant excitation. We then investigate the properties of this peak by changing the electrostatic environment of our samples.

HL 13.18 Mon 17:30 Poster B

The impact of the substrate material on the optical properties of 2D WSe_2 monolayers — •Jan Kuhnert[1], Lorenz Maximilian Schneider[1], Sina Lippert[1], Simon Schmitt[1], Obafunso Ajayi[2], Dylan Renaud[1], Young Duck Kim[2,3], Wolfram Heimbrodt[1], James C. Hone[2], and Arash Rahimi-Iman[1] — [1]Department of Physics and Material Sciences Center, Philipps-Universit'at Marburg, 35032 Marburg , Germany — [2]Department of Mechanical Engineering, Columbia University, 10027 New York, USA — [3]Department of Physics and Center for Humanities and Sciences, Kyung Hee University, 02447 Seoul, Republic of Korea

Layered transition-metal dichalcogenides have attracted great interest in the last few years due to their outstanding optical properties caused by the direct band gap located at the K-point in the brillouin zone. Due to the monolayer thickness, the direct environment plays a crucial role concerning the excitonic and therefor the optical properties of these materials. Our study focuses on optical measurements performed on WSe_2 monolayers on three different substrates. Raman, time-integrated photoluminescence (TIPL) and time-resolved photoluminescence (TRPL) reveal influences of an additionally introduced intermediate hexagonal boron nitride (hBN) layer between substrate and the monolayer on the power-dependent time-evolution of the photoluminescence signal.

HL 13.19 Mon 17:30 Poster B

Synthesis and characterization of graphite oxide based ink for printed transistors — •Tessy Theres Baby[1], Abhinav Chandresh[1,2], Surya Abhishek Singaraju[1], Ben Breitung[1], and Horst Hahn[1,3] — [1]Institute for Nanotechnology, Karlsruhe Institute of Technology (KIT), D-76344 Eggenstein-Leopoldshafen, Germany — [2]Christian-Albrechts-University of Kiel, Kaiserstrasse 2, 24143 Kiel, Germany — [3]KIT-TUD Joint Research Laboratory Nanomaterials, Institute of Materials Science, TU Darmstadt, Petersenstr. 32, 64287 Darmstadt, Germany

Graphene, the one atom thick layer of carbon, is ideally suited for numerous electronic applications on account of its high conductivity, carrier concentration and extraordinary mobility (15,000 cm2 V-1s-1). However, the absence of an electronic band gap has been an impediment in realizing graphene based devices. Therefore, the aim of this work is to synthesize graphite oxide/graphene oxide (GO) with tunable electronic properties at variable temperatures. We have followed the well know Hummer's method to synthesize good quality GO. Acid functionalization has been carried out to obtain stable dispersions with tailored morphology. Finally, in the course of fabricating field-effect devices, a printable (ink-jet) grade of nanoink consisting of GO has been prepared. In order to preserve the electronic properties, no surfactants or additives have been added. Relatively low temperature was used to process the devices. Electrochemically-gated field-effect transistors using composite solid polymer electrolytes have been characterized systematically. Fabricated devices showed p-type behavior.

HL 13.20 Mon 17:30 Poster B

Mechanical exfoliation of MoS2 monolayer flakes — •Yuhao Zhang, Eicke Icking, and Stefan Linden — Physikalisches Institut, Nussallee 12, Universit at Bonn , 53115 Bonn, Germany

Transition metal dichalcogenide (TMDC) monolayers have attracted considerable interest in recent years. Here we report on the mechanical exfoliation and all-dry viscoelastic stamping [1] of MoS2 monolayer and few-layer flakes onto different substrates. The optical properties of these layers are characterized by differential reflectance and transmittance spectroscopy. Additional electron energy loss spectroscopy experiments are currently being carried out.

[1] Castellanos-Gomez A. et al. . Deterministic transfer of twodimensional materials by all-dry viscoelastic stamping. 2D Mater. 1, 011002 (2014).

HL 13.21 Mon 17:30 Poster B

Spatially resolved photoluminescence of mono- and bi-

layer molybdenum ditelluride — •Matthias Kunz[1], Sophia Helmrich[1], Robert Schneider[2], Alexander W. Achtstein[1], Ashish Arora[2], Bastian Herzog[1], Steffen Michaelis de Vasconcellos[2], Mirco Kolarczik[1], Oliver Schöps[1], Rudolf Bratschitsch[2], Nina Owschimikow[1], and Ulrike Woggon[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Germany — [2]Physikalisches Institut, Westfälische Wilhelms-Universität Münster, Germany

We study the photoluminescence of a mechanically exfoliated molybdenum ditelluride ($MoTe_2$) flake in the spatial crossover region from monolayer (ML) to bilayer (BL) at low temperatures. To repeatedly address identical locations on the flake, we develop a camera-piezo feedback loop and confirm the reproducibility of the data obtained in different runs. In contrast to other transition metal dichalcogenides (TMD) materials, the $MoTe_2$ BL shows a strong luminescence comparable in intensity to the ML. The peak energy of the BL exciton is red-shifted by about 35 meV with respect to the ML, but displays a shift to larger energies at close distances to the ML/BL border. With edge effects thus influencing the peak positions, our results underline the importance of correct positioning of the excitation spot on TMD flakes.

HL 13.22 Mon 17:30 Poster B

Manipulation of the Environmental Interaction and Optical and Electrical Properties of Single-Layer MoS_2 Transistors — •Philip Klement[1], Christina Steinke[2], Tim Wehling[2], Sangam Chatterjee[1], and Martin Eickhoff[1,3] — [1]Institute of Experimental Physics I, Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Institute for Theoretical Physics and Center for Computational Material Sciences, University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany — [3]Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany

The optical and electrical properties of two-dimensional transition metal dichalcogenides such as MoS_2 exhibit a high sensitivity to their dielectric environment due to their large surface-to-volume ratio and the presence of active surface sites. Further, they offer the possibility of manipulating the Coulomb interaction by electrostatic screening through gaseous species or external electric gating. We studied the underlying interaction mechanism by a variation of the Fermi level and its influence on the adsorption and desorption behavior of oxygen. Photoluminescence and photo-induced channel current measurements show a strong variation of the electrical and optical properties of single-layer MoS_2. A reversible charge carrier transfer between O_2 and MoS_2 is confirmed, and is very sensitive to the density of free carriers. This concept is supported by theoretical calculations.

HL 13.23 Mon 17:30 Poster B

Ultrafast Coulomb-induced intervalley coupling in monolayer WS_2 — Robert Schmidt[1], Gunnar Berghäuser[2], •Robert Schneider[1], Malte Selig[3], Philipp Tonndorf[1], Ermin Malic[2], Andreas Knorr[3], Steffen Michaelis de Vasconcellos[1], and Rudolf Bratschitsch[1] — [1]Institute of Physics and Center for Nanotechnology, University of Münster, 48149 Münster, Germany — [2]Department for Applied Physics, Chalmers University of Technology, SE-41296, Gothenburg, Sweden — [3]Department for Theoretical Physics, Technical University Berlin, 10623 Berlin, Germany

Monolayers of semiconducting transition metal dichalcogenides are promising for information processing due to the presence of two valleys, which are located at the K and K' point of the Brillouin zone and separately addressable by circularly polarized light of different helicity. We perform ultrafast, spectrally and polarization-resolved pump-probe measurements on single mechanically exfoliated WS_2 monolayers to elucidate the underlying coupling between the two valleys. Together with microscopic theory, we demonstrate that the strong signal, which is observed in the unpumped valley, is due to Coulomb-induced intervalley coupling [1]. This interaction explains the different degree of valley polarization obtained with ultrafast pump-probe measurements compared to photoluminescence studies.

[1] R. Schmidt et al.,"Ultrafast Coulomb-induced intervalley coupling in atomically thin WS2", Nano Lett. 16, 2945-2950, (2016)

HL 13.24 Mon 17:30 Poster B

Optimization of charge injection into few layered Indium Selenide for high performance logic devices — •Vivek Koladi Mootheri, Phanish Chava, Himani Arora, and Artur Erbe — Helmholtz Zentrum Dresden Rossendorf, Dresden, Germany.

Two-dimensional materials provide the ideal physical basis for field effect devices based on alternative materials and architectures, owing to the absence of interfacial dangling bonds. Indium Selenide (InSe) falls under the III-VI semiconducting layered chalcogenide group of the two-dimensional materials family. Its properties such as high mobility and direct band gap in few layered exfoliated flakes provide a basis for exploring its potential for future electronic/optoelectronic devices. However, the intrinsic superior electronic properties of InSe have not been completely utilized due to inefficient charge injection into the material from the source and drain electrodes. This project thus focuses on optimizing the charge injection with the help of different contacting techniques on few layered InSe flakes. Here we demonstrate the use of few layered graphene to contact hexagonal Boron Nitride (hBN) encapsulated InSe flake and also realize implanted contacts by a focused ion beam. This work hence provides a comparative study of the various contacting approaches used, identifying the most beneficial approach.

HL 13.25 Mon 17:30 Poster B

Dielectrically Defined Lateral Heterojunctions in Transition Metal Dichalcogenide Monolayers — •Sven Borghardt[1], Leo Yu[2], Archana Raja[3], Jhih-Sian Tu[1], Detlev Grützmacher[1], Tony F. Heinz[2,4], and Beata E. Kardynal[1] — [1]Peter Grünberg Institute 9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Department of Applied Physics, Stanford University, Stanford, CA 94305, USA — [3]Kavli Energy Nanoscience Institute, University of California, Berkeley, CA 94720 — [4]SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA

Heterojunctions (HJs), i.e. the interfaces of two semiconductors with unequal band gaps, are the backbone of established semiconductor technology. Recently, we have demonstrated that both the electronic and optical band gaps of transition metal dichalcogenide monolayers (TMD-MLs) can be manipulated through externally induced dielectric screening. However, to the present date, little is known about exciton dynamics in dielectrically induced lateral HJs.

In order to shed light on exciton dynamics in dielectrically defined lateral HJs, we have prepared TMD-MLs encapsulated with nanopatterned hexagonal boron nitride sheets. Photoluminescence and reflectance measurements with μm-resolution are performed to probe an ensemble of dielectrically defined HJs, with the temperature, charge level and pattern layout as tunable parameters. From these ensemble measurements, we expect to obtain insights into both exciton diffusion and lateral exciton confinement processes in dielectrically induced HJs, paving the way towards well-engineered dielectrically defined devices.

HL 13.26 Mon 17:30 Poster B

Effective passivation of ultra-thin layers of InSe to enhance electrical properties — •Himani Arora[1,2], Younghun Jung[3], Sanghoon Chae[3], Daniel Rhodes[3], Ghidewon Arefe[3], Takashi Taniguchi[4], James Hone[3], and Artur Erbe[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany — [3]Department of Mechanical Engineering, Columbia University, New York, NY, 10027, USA — [4]Advanced Materials Laboratory, National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044, Japan

We report electrical properties of ultrathin layers of Indium Selenide (InSe), a member of the III-VI chalcogenides family, which has shown a mobility two orders of magnitude higher than MoS2, alongside better stability than black phosphorus.

InSe has light electron effective mass and high mobility enabling its usage for fast, high performance electronics. State-of-the-art InSe transistors reported so far, consist of 6 nm thick InSe flake contacted using graphene edge contacts and reaching a mobility of 1500 cm2V-1s-1 at RT in top-gate configuration. However, InSe being an air-sensitive material loses its conductance over time, resulting the transistor to become unfunctional.

In this study, we report an InSe-based transistor fully encapsulated in h-BN layers which enhanced its electrical properties compared to an un-encapsulated device. The transistor reached a high Hall mobility at RT, while retaining its performance for a long period of time.

HL 13.27 Mon 17:30 Poster B

Momentum-resolved hole and exciton dynamics in WSe_2 — •Patrick Xian, Michele Puppin, Christopher Nicholson, Martin Wolf, Laurenz Rettig, and Ralph Ernstorfer — Fritz-Haber-Institut der Max-Planck-Gesellschaft

Time-resolved ARPES (trARPES) is a unique tool for direct tracking of electronic dynamics in momentum space. We used a 500 kHz XUV source to photoemit electrons from the valence and conduction bands of WSe_2 following optical excitation of A excitons. We uncover the momentum dependence of various aspects of the excited state dynamics, in particular signatures of a bright to dark exciton transition. We extract bright exciton lifetimes with an optical Bloch equation model. The momentum dependence of the hole dynamics is retrieved by a global fitting algorithm that extracts the time dependence of 2D band structure parameters. Finally, we condensed our analysis pipeline into an open-source software package for trARPES data handling from 2D background removal to band position detection to multidimensional data visualization. Its Python implementation and support for Igor data formats invite public contribution and adoption.

HL 13.28 Mon 17:30 Poster B

Intermediate band solar cells - Characterization of transition metal doped indium sulfide — •Ron Hildebrandt[1], Tanja Jawinski[2], Leonard Wägele[2], Holger von Wenckstern[1], Roland Scheer[2], and Marius Grundmann[1] — [1]Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Linnéstraße 5, 04103 Leipzig, Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Von-Dankelmann-Platz 3, 06120 Halle, Germany

The Shockley-Queisser limit for solar cell efficiency of 33.7% is based on a trade-off between generated photocurrent and photovoltage [1]. Intermediate band (IB) solar cells are proposed to overcome this trade-off by an additional two step photon absorption via states within the band gap [2]. Those states may be realized by quantum dots, band anti-crossing in highly mismatched alloys or deep level impurities.

In this work we present a deep level impurity approach for IB solar cells. The heterostructure is p-$ZnCo_2O_4$/i-In_2S_3/n-ZnO:Al with Au contacts on each side. The transition metal doped In_2S_3 absorber material is deposited by thermal co-evaporation. $ZnCo_2O_4$ is deposited by pulsed laser deposition and ZnO:Al by HF-sputtering.

The devices were characterized by current voltage, thermal admittance spectroscopy, photocurrent and transmission measurements, as well as atomic force microscopy. The solar cells showed rectification of 3.5 orders of magnitude and a clear photovoltaic response.

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HL 13.29 Mon 17:30 Poster B

Thin films made of Cu_2ZnSnS_4 nanocrystal inks for solar cells — •Karen P. Stroh, Ismael Gerardo Pérez Marín, Yasir A. Altowairqi, Marek Szablewski, and Douglas P. Halliday — Centre for Materials Physics, University of Durham, United Kingdom

Thin film solar cells based on nanocrystal inks, which make use of earth-abundant elements and may be fully printable, are a promising approach to sustainable, low-cost, and high-efficiency photovoltaic devices. The quaternary chalcogenide Cu_2ZnSnS_4 (CZTS) nanoparticles investigated are synthesised by a solution-based hot injection method. Being redispersed they form an ink, which is then used to deposit thin films via spin coating.

The influence of the temperature as well as the duration of the sintering process on the film properties is investigated, alongside with a characterisation of the nanocrystals used. The broader objective of the study is to enhance grain-growth and to achieve better uniformity throughout the films regarding composition, phase, and structure. This is substantial for limiting recombination losses and carrier scattering at grain boundaries and for enlarging the fraction of absorber layer material which effectively contributes to the generation of current. Opto-electronic properties, chemical composition, and structure of the synthesised nanoparticles as well as the resulting films are analysed by use of UV-visible spectroscopy, XRD, Raman, and SEM measurements.

HL 13.30 Mon 17:30 Poster B

polymer solar cells using an AgAl alloy anode — Xiangkun Jia[1,2] and •Xiaohong Chen[1] — [1]Engineering Research Center for Nanophotonics and Advanced Instrument, Ministry of Education, and Department of Physics, East China Normal University, Shanghai 200062, China. — [2]Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute for Applied Physics, Technische Universität Dresden, Nöthnitzer Str. 61, 01187 Dresden, Germany.

In this work, we improve the performance and air stability of inverted polymer solar cells (PSCs) using a combination of a LiF-modified ITO cathode and a MoO3/AgAl alloy anode. The power conversion efficiency (PCE) of PSCs with the AgAl contact reaches 9.4%, which is higher than that of the cells with a Ag (8.8%) or Al electrode (7.6%). This improvement is primarily attributed to the formation of thin AlOx at MoO3/AgAl interface, preventing the Ag diffusion and improving the hole tunneling probability and built-in potential across the active layer in the cells. The PCE of AgAl-based PSCs is further increased to up to 10.3% through the incorporation of an ultrathin LiF-modified ITO, due to an improvement in electron collection. These devices exhibit a superior stability as compared to the cells with Ag and Al contacts. The PCE of the AgAl-based cells without encapsulation remains 78% of its original value after the cells were aged for 380 days in air.

HL 13.31 Mon 17:30 Poster B

High-throughput calculations for the identification of novel materials for tandem cells — •Hossein Mirhosseini, Ramya Kormath Raghupathy, Hendrik Wiebeler, and Thomas D. Kühne — Department of Chemistry, University of Paderborn, Paderborn, Germany

One straightforward way to considerably enhance the efficiency of the solar cells is the realization of multi-junction solar cells such as tandem cells: the efficiency of a two sub-cells tandem can be raised up to 42% [1]. In this work, high-throughput ab-initio calculations were employed to identify the most promising absorber and p-type transparent conducting materials (TCMs) for future tandem cells [2]. Non-toxic semiconductors with hole effective masses smaller than 1 and band gaps larger than 1 eV (for absorber) and 1.7 eV (for TCMs) were considered here. The dopability and extrinsic dopants were investigated to determine the performance of the selected compounds.

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HL 13.32 Mon 17:30 Poster B

Ab initio study of binary pnictides and halides for the identification of transparent p-type conducting materials — •Hendrik Wiebeler, Kormath Raghupathy Ramya, Hossein Mirhosseini, and Thomas D. Kühne — Department of Chemistry, University Paderborn, Germany

Transparent conducting materials (TCMs) have received attention owing to their wide range of applications from solar cells to transparent electronics[1]. Transparent conducting oxides (TCOs) have been predominantly commercialized as n-type TCMs. In contrast to this, the performance of p-type TCOs is not satisfactory, due to the nature of their valence bands. Hence, in this work, ab initio calculations were employed to identify high-performance p-type semiconductors[2]. Materials having wide band gaps (E_g) and low hole effective masses (m_h) are promising p-type TCMs. Therefore, non-toxic and non-expensive binary semiconductors with $E_g > 1.7$ eV and $m_h < 1$ were considered. The role of intrinsic and extrinsic point defects was explored to determine the p-type performance.

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HL 13.33 Mon 17:30 Poster B

Suppression of interference effects in electroreflectance spectroscopy on $Cu(In,Ga)(S,Se)_2$ solar cell buffer layers — •J. Seeger[1], U. Piesch[1], O. Kiowski[3], D. Hariskos[3], W. Witte[3], M. Powalla[2,3], P. Eraerds[4], R. Lechner[4], T. Dalibor[4], H. Kalt[1], and M. Hetterich[2] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]Light Technology Institute, KIT, 76131 Karlsruhe, Germany — [3]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), 70563 Stuttgart, Germany — [4]AVANCIS GmbH, 81739 München, Germany

$Cu(In,Ga)(S,Se)_2$ thin-film solar cells are a great alternative to the widely spread silicon technology. One approach to further improve them is to find alternative materials for the commonly used CdS buffer layer. CIGS solar cells with different buffer materials are investigated utilizing electroreflectance spectroscopy (ER). While ER can readily be applied to absorber layers [1], the investigation of buffer layers is often quite challenging. One reason for this is the low thickness of the buffer layer, which leads to a weak signal. Therefore, occurring interference effects in the layer stack can have a strong influence on the ER spectra. Measuring scattered instead of specularly reflected light can reduce such interference effects [2]. Another approach is the reduction

of the ZnO window layer thickness by etching it partially away. Results for both techniques will be discussed in this contribution.
[1] C. Huber *et al.*, Phys. Rev. B 92, 075201, 2015.
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HL 13.34 Mon 17:30 Poster B

In Situ TEM Studies of Rear Contact Formation of Aluminium with Multi-Crystalline Silicon — •Christoph Flathmann, Tobias Meyer, and Michael Seibt — IV. Physikalisches Institut der Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

For various reasons, the rear contact of a solar cell is a crucial part concerning energy conversion efficiency. The most important requirements are a low resistance ohmic contact and a smooth as well as highly reflective interface, for both minority carriers and photons. In order to create such contacts for multi-crystalline silicon (mc-Si) solar cells, aluminium (Al) is alloyed to the back of the cells. Hence, a heavily Al doped p^+-region and thus a back-surface field (BSF), which increases cell efficiency, is created. However, rear contacts suffer from flaws due to non-uniform alloying and crystal defects, such as grain boundaries.

To thoroughly investigate the alloying process, cross-section lamellas for transmission electron microscopy (TEM), mimicking the rear of a solar cell, are either prepared employing a focused ion beam or conventionally. Subsequently, the samples are heated and *in situ* studied by TEM. High resolution and analytical TEM are utilized for analysing structure and chemical composition, respectively. Particular attention is paid to the effect of grain boundaries on the alloying characteristics and the evolution of {113} defects in the silicon during BSF formation.

HL 13.35 Mon 17:30 Poster B

Investigation of $Pr_{1-x}Ca_xMnO_3$-$SrTi_{1-y}Nb_yO_3$ Interfaces Using Electron Beam Induced Voltage (EBIV) — •Tobias Westphal[1], Patrick Peretzki[1], Tobias Meyer[1], Birte Kressdorf[2], Christian Jooss[2], and Michael Seibt[1] — [1]4th Physical Institute, Georg-August-Universität Göttingen, 37077 Göttingen, Germany — [2]Institute of Material Physics, Georg-August-Universität Göttingen, 37077 Göttingen, Germany

P-n heterojunctions consisting of the p-doped manganite $Pr_{1-x}Ca_xMnO_3$ (PCMO) and the n-doped titanite $SrTi_{1-y}Nb_yO_3$ (STNO), both perovskite-structured, have been investigated with Electron Beam Induced Current (EBIC). To further study the photovoltaic properties of this system, the Electron Beam Induced Voltage (EBIV) technique is used in this work. The standard form for EBIV models predicts a behaviour logarithmic to the EBIC, which is useful for measuring the nanometer scale diffusion length of minority charge carriers in this system.

To investigate the interface of PCMO-STNO, both a wedge shaped lamella and a cleaved cross section are prepared to perform cross-section measurements. Focused Ion Beam is used for lamella preparation and cleaning the cleaved edge. The temperature dependence of EBIV is measured in the range from 80 K to 300 K especially in the regime of the charge ordering temperature of PCMO ($T_{CO} \approx 230$ K). Beam current dependent measurements at $T \approx 300$ K are performed as well. Results show the important role of measurement time limits due to an emerging capacitance in the measure circuit at low temperature.

HL 13.36 Mon 17:30 Poster B

The environmental stability of PbS quantum dot solar cells — •David Becker-Koch — Universität Heidelberg, Kirchhoff-Institut für Physik, Heidelberg

Colloidal inorganic nanocrystal quantum dots (QDs) are excellent solution-processed candidates for third-generation photovoltaics. Due to the quantum-confinement effect their absorption and emission spectra can be readily tuned over the entire visible-NIR spectrum by controlling their compositions and dimensions from synthesis. The state-of-the-art power conversion efficiency of single-junction solid-state QD solar cells reaches 11.6%, which together with their near-IR absorbing capabilities makes them of great interest for a myriad of applications. While the efficiencies are being improved constantly by intensive research, the Achilles heel of these devices seems to be their environmental instability. So far only limited research has been done to study the fundamental causes and mechanisms leading to the environmental instability in devices based on nanocrystal quantum dots.

We investigate the effects of oxygen, humidity, light and their combinations on the performance of high efficiency lead(II)-sulfide (PbS) solar cells. We find that while individual degradation factors cause device instabilities, the combination of exposure to oxygen, humidity and light may result in a recovery of the performance of the device after a short initial degradation phase.

HL 13.37 Mon 17:30 Poster B

Computational Screening of Ternary Selenides for Water Splitting — •Estefanía Garijo, Mohnish Pandey, and Karsten Wedel Jacobsen — Computational Atomic-scale Materials Design (CAMD), Department of Physics, Technical University of Denmark, DK-2800 Kogens Lyngby, Denmark

Photoelectrochemical water splitting is one of the possible solutions for efficient production of sustainable fuels. However, a suitable large band-gap photoabsorber that matches silicon in the so-called tandem cell has not been identified yet. Here, we present a large survey of ternary selenides in the stoichiometry $ABSe_3$, with A and B metal atoms. In our screening study, key properties, such as stability, photoabsorption, carrier mobility and defects are evaluated step-wise, so that the resulting computationally expensive descriptors are only evaluated for those candidates that have been identified as promising in previous, less expensive steps.

HL 13.38 Mon 17:30 Poster B

Theoretical analysis of optical properties of Cu2ZnSn(S,Se)4 solar absorbers. — •Sergii Zamulko[1], Kristian Berland[1], and Clas Persson[1,2] — [1]Centre for Materials Science and Nanotechnology, University of Oslo, P. O. Box 1048 Blindern, NO-0316 Oslo, Norway — [2]Department of Materials Science and Engineering, Royal Institute of Technology, Brinellvägen 23, SE-100 44 Stockholm, Sweden

Kesterite Cu2ZnSn(SxSe1-x)4 are attracting much attention for application in thin film solar cells, as they consist of earth-abundant elements and operate in a favorable size of band-gap. In this work, we study the dielectric functions of this compound for different alloy composition $0 < x < 1$. Results of ellipsometry measurements are compared with density functional theory (DFT) calculations. The calculations were performed at three levels of theory, using a generalized gradient approximation (GGA), meta-GGA - both relying on on-site +Ud Coloumb correction - and a hybrid functional approach. Furthermore, using a recently developed k.p interpolation scheme, we show that a dense Brillouin zone sampling is needed to accurately account for the shape of the dielectric function. Comparing experimental and theoretical data with enhanced numerical accuracy sheds light on how the critical points in the real part of dielectric function shifts as a function of sulfur content.

HL 13.39 Mon 17:30 Poster B

Charge Carriers Dynamics in Kesterite: From Ultra-fast Trapping via Localized Transport to Surface Recombination — •Hannes Hempel, Rainer Eichberger, and Thomas Unold — Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Hahn-Meitner Platz 1, 14109 Berlin

Kesterite solar cells materials are known to exhibit band tails originating from potential fluctuations and defect bands. We investigate how these tails affect the dynamics of photo-excited charge carrier by applying transient absorption and time resolved THz spectroscopy to coevaporated Cu2ZnSnSe4 thin films. We find that 100 fs after excitation with 1.5 eV photons the carriers form a hot Boltzmann distribution in the band states. Within 2 ps they thermalize to lattice temperature and reach simultaneously band edge and tail states. Afterwards the carriers are distributed in bands, tails and defects and exhibit in average a localized mobility with a DC-value of 100 cm2/Vs. Their transport can be described by a sequence of trapping and detrapping between extended band and localized tail states.

HL 13.40 Mon 17:30 Poster B

In-Silico Homovalent Screening of Hybrid Halide Perovskite Materials for Tandem Solar Cells — •Manaswita Kar and Thomas Körzdörfer — AG Computational Chemistry, University of Potsdam, Institute of Chemistry, Karl-Liebknecht Straße 24-25, D-14476 Potsdam-Golm

Solar cells based on hybrid organic-inorganic lead-halide perovskites are among the most promising emerging photovoltaic materials of the past decade. Within only a very short research time span, record efficiencies were achieved with solar cells based on methylammonium lead iodide ($CH_3NH_3PbI_3$). The presence of Pb in the currently most efficient perovskite solar cells has raised questions over the possible toxicity of these devices and the extent of their environmental impact. Therefore, a lot of research has been devoted to finding alternative per-

ovskite materials with similar or even better optoelectronic properties. A flipside strategy to improve the efficiency of thin-film solar cells is to build efficient tandem cells by combining materials with specifically tailored band-gaps.

As a first step, geometrical and electronic structure of 48 candidate structures (combination of 12 metals, and 4 halogens) are calculated in 3 different phases, namely, orthorhombic, tetragonal, and cubic using semilocal (PBE) with relativistic corrections. The band gap of these materials are then screened using hybrid functional (HSE), to get candidates in the band-gap range of 1 eV and 1.9 eV. In the next step, the stability of these materials are tested using Quasi-harmonic approximation, in order to find their room-temperature stable phase.

HL 13.41 Mon 17:30 Poster B

Morphology control of methylammonium bismuth iodide films for photovoltaics — •Christian Fettkenhauer, Martina Pantaler, Irina Anusca, and Doru C. Lupascu — Institute for Materials Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Universitätsstraße 15, 45141 Essen, Germany

Recently, perovskite solar cells have attracted much attention due to the high achievable efficiencies using abundant hybrid organic-inorganic perovskite absorber materials. The benchmark perovskite absorber is methylammonium lead iodide (MAPI). In this material lead causes serious discussion about potential environmental hazards. Bismuth derived materials like $MA_3Bi_2I_9$ (MBI) might be a less poisenous alternative to MAPI. Although MBI has already been known since the 1960ies its suitability as absorber material has just recently been evaluated. The current power conversion efficiency (PCE) record is 1.64 %. One of the reasons for the lower performance compared to MAPI based solar cells are the anisotropic charge carrier transport properties. Thus, one of the approaches to further increase the PCE is the controlled growth of MBI thin films with a-b planes perpendicular to the substrate. In this work we compare different vapor- and solution processed MBI films with respect to their crystal growth direction, optical absorption, and morphology of the resulting films aiming for further efficiency improvement of MBI based solar cells.

HL 13.42 Mon 17:30 Poster B

Insights into lead-free double perovskite Cs2AgBiBr6 thin films for photovoltaic application — •Martina Pantaler[1], Svetlana Syrotinskaya[2], Selina Olthof[3], Alexsander Schmitz[4], Christian Fettkenhauer[1], Irina Anusca[1], Niels Benson[2], Gard Bacher[4], Roland Schmechel[2], and Doru C. Lupascu[1] — [1]Institute for Materials Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen Universitätsstraße 15, 45141 Essen — [2]Institute of Technology for Nanostructures and Technology (NST), University of Duisburg-Essen, Bismarckstraße 81, 47057 Duisburg — [3]Department of Chemistry, University of Cologne, Luxemburger Straße 116, 50939 Köln — [4]Department of Electrical Engineering and Information Technology, University of Duisburg-Essen, Bismarckstrasse 81 BA, 47057 Duisburg

The double perovskites are a promising lead free alternative to MAPbI3 based perovskite solar cell. Promising photovoltaic properties are long carrier recombination lifetime, good stability against air and moisture, low effective carrier masses, and band gap around 2 eV. We investigate double perovskite thin films and the possibility of solar cell fabrication. We prepared thin films on different substrates using spin-coating. Their crystalline structure, chemical composition, and morphology can be investigated using XPS, XRD, and SEM. Measuring time-resolved photoluminescence we got better insights into the charge carrier lifetime of double perovskite thin film. Finally we determined the valance band energy using ultraviolet photoelectron spectroscopy. Inverted (p-i-n) planar solar cell achieves PCE of 0,42%.

HL 13.43 Mon 17:30 Poster B

A2BX4 Absorber as thin films for photovoltaic application — •Irina Anusca, Christian Fettkenhauer, Martina Pantaler, and Doru C. Lupascu — Institute for Material Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Universitätsstraße 15, 45141 Essen

Two-dimensional (2D) organic inorganic perovskites A2BX4 (A= CnH2n+1NH3, B = Cu, Mn, X = Cl, Br, I) can serve as photoabsorber for lead free perovskite solar cells [1-3]. The perovskite layer is the most crucial factor for the high performance of solar cells. The controlled synthesis of materials as thin films (the process deposition) is a fundamental step for good crystallization. We prepare different series of Cu and Mn based 2D-perovskites by mixing different CnH2n+1 organic ammonium cation (alkyl and aromatic) and X halide ions. Film processing steps are discussed. The quality of the obtained films is examined combining the effect of solvents (nature and concentration) with the nature of the deposition process. Both X-ray diffraction (XRD) spectroscopy and scanning electron microscopy (SEM) were used to study film crystallinity and surface morphology.

Keywords: layered 2D perovskite, solvent engineering, photoabsorber

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HL 13.44 Mon 17:30 Poster B

Photoluminescence of Methylammonium Lead Iodide Perovskites in Terms of Stoichiometric Ratios — •Fabian Meier, Sebastian Reichert, Alexander Wagenpfahl, and Carsten Deibel — Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

Understanding recombination mechanisms of electrical charge carriers is of tremendous importance for understanding the extraordinary power conversion efficiencies, which increased from 4 % up to almost 23 %. We investigate thin films of methylammionium lead iodide perovskite in terms of their stoichiometric ratio of methylammonium iodide and lead iodide. The perovskites are deposited on top of PTAA transport layers on ITO coated glass. By confocal photoluminescence measurements we determine radiative recombination of electric charges as function of time and spatial location. We discuss our results in terms of illumination intensity as well as temperature dependence and compare it to the energetically resolved emission spectra. We furthermore interpret our results in terms of tail states and their impact on the performance of solar cells.

HL 13.45 Mon 17:30 Poster B

Electromodulation Spectroscopy on Organic-Inorganic Perovskite Solar Cells — •Alice Magin[1], Fabian Ruf[1], Moritz Schultes[2], Erik Ahlswede[2], Jonas Schwenzer[3], Heinz Kalt[1], and Michael Hetterich[3] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), 70563 Stuttgart, Germany — [3]Light Technology Institute, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

Organic-inorganic perovskites are promising candidates for low-cost solar cells, showing power-conversion efficiencies above 20% [1] and band-gap tunability. Many fundamental material properties of both methylammonium lead iodide and mixed-cation lead mixed-halide compounds have already been studied, e.g. phase transitions [2] and charge-carrier transport [3]. We investigate the electronic structure of solution-processed perovskite solar cells using temperature-dependent electromodulation spectroscopy in order to determine the energetic position of optical transitions. The temperature dependence reflects the phase transition from the orthorhombic to the tetragonal phase. Comparison with absorption measurements allows estimating the nature of the observed resonances. [1] M. A. Green et al., Prog. Photovolt: Res. Appl. 2017, 25:3-13. [2] A. Poglitsch et al., J. Chem. Phys. 87, 6373 (1987). [3] I. Grill et al., ACS Appl. Mater. Interfaces, 2017, 9 (43), pp 37655-37661.

HL 13.46 Mon 17:30 Poster B

Spectroscopic Characterisation of Trap States in Perovskite Solar Cells — •Sebastian Reichert, Fabian Meier, Alexander Wagenpfahl, and Carsten Deibel — Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

Perovskite solar cells constitute an intensely studied topic in photovoltaics caused by their fast improvement in power conversion efficiency. Investigation of perovskite solar cells has been challenging due to the richness of physical processes occuring on similar time scales. Recently, significant attention has been paid to the capacitance properties in dependence of frequency and applied voltage. Capacitance spectroscopy can be used to infer underlying physical mechanisms such as the charge carrier loss mediated by trap states within the active layer. We present the analysis of methyl ammonium lead iodide solar cells by impedance spectroscopy, capacitance–voltage measurements and deep level transient spectroscopy. These techniques offer access

to many electronic processes and allow to understand the influence of trap states on the device performance.

HL 13.47 Mon 17:30 Poster B

Optimization and Characterization of Perovskite Thin-Films — •Sandhya Tammireddy, Fabian Meier, Alexander Wagenpfahl, and Carsten Deibel — Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

In the past few years, organo-metal trihalide perovskite solar cells have been attracting tremendous interest because of their unique properties in photovoltaic applications such as high mobilities and long lifetimes of charge carriers. In order to obtain high power conversion efficiencies in perovskite solar cells it is essential to fabricate high quality thin-films with controlled morphology and crystallinity. We produce methyl ammonium lead iodide solar cells by optimizing the absorber layer using solvent engineering techniques. Subsequently, we characterize our thin-films by measuring the time dependent photoluminescence. The decay of the photoluminescence signal allows us to determine the dominant charge carrier loss mechanisms in order to understand recombination in hybrid perovskites.

HL 13.48 Mon 17:30 Poster B

Analyzing optical properties of methylammonium lead bromide using photoluminescence spectroscopy — •Lukas Falk, Paul Fassl, and Yana Vaynzof — Kirchhoff-Institute for Physics / Centre for Advanced Materials, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Organometal halide perovskites drew a lot of research attention over the last years due to their intriguing material properties which make them suitable active layers in both photovoltaic (PVs) and light-emitting diodes (LEDs).

We employ photoluminescence spectroscopy to investigate the optical properties of methylammonium lead bromide ($MAPbBr_3$) layers that are commonly used either as emissive layers in perovskite LEDs or as the active layer of a front cell in tandem perovskite PVs. We find that subtle variations in layer processing result in variations of the optical properties and subsequently variations in the performance of the devices. We also investigate the effect of exposure to oxygen on the photoluminescence quantum efficiency of the layers and compare the results to those obtained for methylammonium lead iodide ($MAPbI_3$).

HL 13.49 Mon 17:30 Poster B

High Performance Planar Perovskite Solar Cells by ZnO Electron Transport Layer Engineering — •qingzhi an[1,2], paul fassl[1,2], yvonne jasmin hofstetter[1,2], david becker koch[1,2], alexandra bausch[1,2], paul hopkinson[1,2], and yana vaynzof[1,2] — [1]kirchhoff institute for pyhsics,heidelberg,germany — [2]centre for advanced materials,heidelberg,germany

Due to the many advantageous properties of ZnO, such as high electron mobility and low processing temperatures, it is commonly used as an electron extraction layer in organic photovoltaic devices. However, it has been reported that ZnO cannot be successfully utilized in perovskite photovoltaics due to surface hydroxide groups induced instabilities in the perovskite layers. In this work, we modify the bulk ZnO layer by incorporating Cs or Li dopants and the surface of ZnO layer by depositing a self-assembled monolayer and demonstrate that this combined approach leads to significant improvements in the performance of planar MAPBI3 perovskite solar cells. A maximum power conversion efficiency of 18% is achieved accompanied by a reduction in hysteresis and a significant enhancement of the device stability.[1] Our work shows that ZnO can serve as a practical alternative to TiO2 in standard perovskite solar cells with low fabrication temperatures.

[1] Q. An, P. Fassl, Y. J. Hofstetter, D. Becker-Koch, A. Bausch, P. E. Hopkinson and Y. Vaynzof, "High Performance Planar Perovskite Solar Cells by ZnO Electron Transport Layer Engineering" Nano Energy 39, 400 (2017).

HL 13.50 Mon 17:30 Poster B

A chain is as strong as its weakest link – Stability study of $MAPbI_3$ under light and temperature — •Philippe Holzhey[1,2] and Michael Saliba[2] — [1]Fachbereich Physik, Freie Universität Berlin, D-14195 Berlin, Germany — [2]Laboratory of Photonics and Interfaces, Institute of Chemical Sciences and Engineering, École Polytechnique Fédérale de Lausanne, Lausanne CH-1015, Switzerland

The stability of perovskite solar cells has been considered poor compared to other solar cells. One reason for this is thought to be the volatile organic methylammonium (MA) cation. At the same time, small amounts of MA are used for practically all highest performing solar cells with efficiencies beyond 21%. These compositions have also shown some of the best reported stabilities indicating that MA might not be as unstable as previously assumed. This raises the question whether excluding MA for the sake of stability has been concluded prematurely. Here, we use weakest link devices, i.e. $MAPbI_3$, to study the stability under light and different temperatures.

HL 13.51 Mon 17:30 Poster B

Cause Study of the Low Fill Factor of Squaraine Based Solar Cells by Steady-State Methods — •Oliver Kolloge[1], Dorothea Scheunemann[1], Matthias Schulz[2], Arne Lützen[2], and Manuela Schiek[1] — [1]Energy and Semiconductor Research Laboratory, Institute of Physics, University of Oldenburg, D-26111 Oldenburg, Germany — [2]Kekulé Institute for Organic Chemistry and Biochemistry, University of Bonn, Gerhard-Domagk-Str.1, D-53121 Bonn, Germany

Organic solar cells whose active layer consists of a model squaraine donor blended with a fullerene acceptor are particularly interesting because they show absorption within the deep-red combined with a high open circuit voltage. Unfortunately, these devices suffer from a low fill factor [1]. To gain deeper understanding of the limiting factors we utilize steady-state current-voltage measurements to assess the electronic quality factor of devices with varying layer thickness by a recently described method [2]. In addition, we investigate the wavelength dependence of the loss mechanisms by voltage- and white-light-biased external quantum efficiency measurements.

[1] Scheunemann et al., Appl. Phys. Lett. 111 (2017) 183502.
[2] Kaienburg et al., Phys. Rev. Appl. 6 (2016) 024001.

HL 13.52 Mon 17:30 Poster B

Applicability and limitations of hopping-based transport theories — •Sebastian Hutsch and Frank Ortmann — Center for Advancing Electronics Dresden, Technische Universität Dresden, 01062 Dresden, Germany

Many theories have been developed to describe charge transport in organic semiconductors, which is a complex task due to the strong electron-phonon coupling. Two of the most commonly used approaches use hopping-rates based on the classical Marcus theory and on the more advanced Levich-Jortner theory, which distinguishes classical and quantum mechanical contributions of the phonons. In this work, based on ab-initio material parameters, we test the applicability of both theories for a broad range of established organic crystals. The variety of materials allows us to assess the accuracy of both methods and to introduce a classification. The physical reasons for the different behaviour is analyzed and suggestions for an improved method are given.

HL 13.53 Mon 17:30 Poster B

In situ transport measurements in organic field effect transistors with $F_{16}CuPc$ — •Mareike Dunz, Karsten Rott, Jan Schmalhorst, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Organic semiconductors are widely used in OLED and organic photovoltaic systems. However, organic field effect transistors cannot yet compete with silicon based technology due to their low charge carrier mobility. Fluorinated copper phtalocyanine ($F_{16}CuPc$) is reported to be one of the rare air-stable n-channel organic semiconductors that can be considered for transistor applications [1].

We prepared organic field effect transistors with thermally evaporated $F_{16}CuPc$ on oxidized silicon substrates in a bottom contact configuration. Electrical in situ measurements allow for the detection of a thickness dependent source-drain current during the evaporation of the organic molecules. We found a maximum of the source-drain current around a thickness of 20 nm. Subsequent temperature dependent measurements of the electron mobility in the range from $-150\,^{\circ}C$ to $150\,^{\circ}C$ reveal charge transport via the hopping mechanism. At room temperature, the electron mobility is determined to lie around $2 - 8 \cdot 10^{-3}\,cm^2/Vs$, depending on the applied gate voltage. Furthermore, we show how those transistors react when exposing them to gases like oxygen.

[1] Z. Bao et al., J. Am. Chem. Soc. 7863(23), 207 (1998)

HL 13.54 Mon 17:30 Poster B

Charge Transfer at the Interface of Indoline Dye/ZnO Solar Cells — •Nico Hofeditz[1], Ingo Meyenburg[1], Raffael Ruess[2],

Derck Schlettwein[2], and Wolfram Heimbrodt[1] — [1]Department of Physics and Material Sciences Center, Philipps-University Marburg, Renthof 5, 35032 Marburg, Germany — [2]Institute of Applied Physics, Justus-Liebig-University Gießen, Heinrich-Buff-Ring 16, 35392 Gießen, Germany

Dye-sensitized solar cells containing mesoporous ZnO and the indoline dyes D131 and DN216 have been prepared either with an iodide/triiodide or with a cobalt-based redox electrolyte with different concentrations of 4-tert-butylpyridine (TBP). The TBP additive reduces the acidity of the cobalt redox electrolyte. An important process in high efficient dye-sensitized solar cells is an optimized electron transfer, i.e., the electron injection yield from the dye into the conduction band of the ZnO at the organic-inorganic interface. We studied the photoluminescence intensity as well as the decay time of the dyes by varying the applied voltage. We were able to reveal the electron transfer times from the excited dye by analyzing the photoluminescence transients of the excitons after femtosecond excitation and applying kinetic model calculations. We will compare both dyes and show that the level alignment and the number of anchoring groups have a strong influence on the charge transfer. Furthermore, we discuss in our contribution the influence of cell aging as well as the influence of dye aggregation on the charge transfer times, i.e., electron injection efficiency.

HL 13.55 Mon 17:30 Poster B

Graphite Oxide Obtained From Bamboo as Possible Selective Contact For Solar Cells — Jhon Jairo Prias-Barragan[1], •Katherine Gross[1], Jose D Perea[3], Nial Kilallea[3], Wolfgang Heiss[3], Christoph Brabec[3], Hernando Ariza-Calderon[1], and Pedro Prieto[2] — [1]IIs, Universidad del Quindío, Colombia — [2]cenm, Department of Physics, Universidad del Valle, Colombia — [3]i-MEET, FAU, Germany

The effect of the carbonization temperature (TCA) on the optoelectronic response of Graphene Oxide (GO) multilayers obtained from bamboo tar (BPA) was investigated. RAMAN, XRD and FTIR spectra indicate that increased TCA increases graphite conversion and reduces oxygen coverage. Decreased oxygen content from 17% to 4% tunes the Bandgap energy from 0.30 to 0.11 eV. Implicit solvation model COSMO was used to visualize the surface charge density; here we could observe that by increasing the oxygen content the electron acceptor and donor abilities increase in the material, showing the electron-hole pair density distributions by multifunctional oxide presence. The optoelectronic response investigated via UV-VIS, PL-Vis-NIR and PL-MIR measurements have shed light on the mechanism involved in light absorption processes. UV-VIS spectra show a broadband light absorption from 200 nm until 1100 nm. Interestingly, increasing TCA results in a blue-shift of the absorption. Broadening and blue-shift in the absorbance spectrum could be correlated with the large size distribution of the graphitic nano-crystals. This study suggests that GO-BPA can be appropriate as selective contact in OPV.

HL 13.56 Mon 17:30 Poster B

Optimization of the Base Electrode in Organic Permeable Base Transistors — •Yang Li, Felix Dollinger, Markus P. Klinger, Axel Fischer, Hans Kleemann, and Karl Leo — Dresden Integrated Center for Applied Physics and Photonic Materials(IAPP), Dresden, Germany

Flexible electronics are a hot topic in the field of electronics. Organic semiconductors represent one way to realize flexible transistors. Organic permeable base transistors (OPBT) are a special thin-film transistor architecture having an extremely short channel length, down to 100 nanometers, achieved by a vertical geometry. OPBT devices consist of a base electrode permeable for electrons. With an applied voltage, the base can either block or transmit the electrons traveling from the emitting electrode. The short channel length allows for a current density above 10 A/cm^2 at a relatively low voltage (1 V). This device can also achieve an on/off ratio as high as 10^6. These devices are suited for applications in the high-frequency regime above 10 MHz.

The state-of-the-art fabrication process of these devices had been published previously, but still, the reproducibility needs to be improved. The crucial part is the thin oxide layer around the base electrode. The oxide layer is fabricated by directly oxidizing the base aluminum electrode. We studied the performance of the devices under different oxidants. The result shows that the performance of the transistor is highly related to the quality of the oxide layer around the base. The detailed influence of different oxidants and annealing temperatures will be shown on the poster.

HL 13.57 Mon 17:30 Poster B

EPR spectroscopic signatures of C_{60} and C_{70} fullerene cations — •René Wieczorek, Svetlana Kucher, Sven Berlekamp, and Wolfgang Harneit — Fachbereich Physik, Universität Osnabrück, Deutschland

Due to their relatively high reactivity, spectroscopic data are scarce for fullerene cations in condensed matter. Especially EPR parameters seem to depend greatly on the choosen method of cation preparation.

Nevertheless, there is a growing interest in charged fullerene species within several research fields. For organic solar cells, the role of oxidized fullerene derivatives as possible intermediates in charge carrier transport has been discussed. Correspondingly, magnetic resonance methods (EPR, EDMR) rely on precise spectroscopic signatures to identify the different species taking part in such processes. Similarly, the potential application of endohedral group-V fullerenes, either as qubits or as molecular probes for magnetic fields, requires identification of competing spin carrying derivatives, namely C_{60} and C_{70} cations or anions.

We therefore use a reported protocol, oxidation of fullerenes by means of iron(III)-exchanged zeolite NaY, to conduct a systematic study of fullerene cations using EPR spectroscopy. We report on pulsed and cw measurements at different frequency bands (X-, Q-, and W-band). Consequences of our findings for the different research fields are discussed.

HL 13.58 Mon 17:30 Poster B

Electric-field-induced Molecular Modifications in Organic Semiconductors: Studies in Frequency and Time Domain — •Debkumar Rana, Patrice Donfack, Javid Shirdel, Vladislav Jovanov, Veit Wagner, and Arnulf Materny — Physics and Life Sciences, Jacobs University Bremen, Campus Ring 1, 28759 Bremen

Recently, the field of organic electronics has seen an impressive progress, which was pushed forward due to the attractive application potential of the organic semiconductors. Thin film transistors, diodes, solar cells etc. based on polymers like Poly(3-hexylthiophene) (P3HT) show advantages due to their wide range of variability, mechanical properties, ease of fabrication, and, related to this, low costs.

The performance of organic electronics has been improved greatly, but still a more detailed understanding of the elementary processes is required. For this, we have studied the influence of external electric fields on the vibrational/vibronic and excitonic properties of Poly(3-hexylthiophene) (P3HT)-based semiconductor systems using Raman spectroscopy as well as femtosecond time-resolved spectroscopy. Changes in the Raman spectra (line broadenings and shifts) yield information about the coupling of vibrations to the electric fields. The influence on the life time of excitons after excitation with a femtosecond laser pulse gives insights into the field-dependence of relaxation and decay channels. First experimental results will be presented and discussed.

HL 13.59 Mon 17:30 Poster B

Formation Dynamics of Charge-Transfer States at the Pentacene/Perfluoropentacene Interface — •Melanie Fey[1], Robin Carl Döring[1], Andre Rinn[2], Tobias Breuer[2], Gregor Witte[2], and Sangam Chatterjee[1] — [1]Institute of Experimental Physics I, Justus-Liebig University Giessen, Heinrich-Buff-Ring 16, D-35392 Gießen, Germany — [2]Faculty of Physics and Materials Science Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany

Model crystalline molecular donor-acceptor heterostructures allow systematic investigations of the charge-carrier dynamics at the internal interfaces. Here, we investigate the charge-transfer (CT) exciton dynamics in different intermixed and layered heterostructures of pentacene (PEN) and perfluoropentacene (PFP). We study the formation of interfacial CT states by comparing low-temperature photoluminescence excitation spectroscopy and linear absorption spectroscopy measurements. We find that an excitation at the lowest-energy bright exciton resonance of PEN directly leads to emission at the CT exciton energies while no such contribution is observed for the lowest bright exciton energy of PFP. The corresponding linear absorption spectra, however, reveal significant oscillator strength for both resonances. Our results thus indicate firstly, that PEN is the main contributor to the formation of CT excitons in PEN-PFP heterosystems and, secondly reveals limitations of a description of CT exciton states relying on the robustness of the frontier molecular orbitals at the hetero interface.

HL 13.60 Mon 17:30 Poster B

Determination of Trap Distribution in Polymer-based Diodes

with Complementary Techniques — •Michael Bretschneider, Christopher Wöpke, Clemens Göhler, Alexander Wagenpfahl, and Carsten Deibel — Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

The understanding of transport phenomena inside polymer-based diodes is one key point of improving organic optoelectronic devices. The interplay between traps and charge carriers inside these diodes has a strong impact on the charge carrier mobility and thus determines the device performance. We investigate three different polymer-based (P3HT, PCDTBT, MDMO-PPV) diodes with the Thermally Stimulated Current (TSC) method. We present the density of occupied traps distribution with fractional TSC and compare the results with temperature dependent J_{SC}–V_{OC} measurements for complementary investigation. We discuss the interplay of traps with mobile charge carriers in order to gain deeper insight into charge transport in disordered organic diodes.

HL 13.61 Mon 17:30 Poster B

Degradation mechanism in high performance PffBT4T-2OD:PC71BM organic devices — •Joshua Kress and Andreas Weu — Centre for Advanced Materials, Heidelberg, Deutschland

Although in recent years significant progress has been made in improving the performance of organic photovoltaic devices, their environmental stability remains a limiting factor preventing their integration in industrial applications. We investigate the degradation mechanisms of high performance photovoltaic devices based on PffBT4T-2OD:PC71BM which result in record power conversion efficiencies of 11%. To identify the contribution of the deterioration of charge transport during degradation to the photovoltaic performance loss, the active layers of the photovoltaic devices have been investigated in bottom-gate/top-contact field effect transistors (OFETs) which have been degraded under identical conditions to complete photovoltaic devices. The studies are combined with x-ray photoemission spectroscopy (XPS), photothermal deflection spectroscopy (PDS) and transient absorption spectroscopy (TA). We compare the effects of exposure to nitrogen or oxygen with and without light and find that exposure to oxygen alone (in dark) results in a similar degradation of the photovoltaic performance as that caused by exposure to light (in inert atmosphere). Despite this, the effect on charge transport is very different and is a consequence of oxygen induced p-doping of the active layer. This highlights the importance of identifying the individual causes of degradation introduced by the various environmental factors in order to be able to develop relevant mitigation strategies.

HL 13.62 Mon 17:30 Poster B

Charge storage in β-$FeSi_2$ nanoparticle — •fangfei li[1], martin geller[1], hans orthner[2], hartmut wiggers[2], and axel lorke[1] — [1]Experimental Physics and CENIDE, University of Duisburg-Essen, Germany — [2]Institute for Combustion and Gas Dynamics and CENIDE, University of Duisburg-Essen, Germany

The development of portable electronic devices drives the increasing demand for electrochemical energy storage with high energy density. Among various energy storage devices, supercapacitors provide a promising solution to fast charging and discharging.

Normally, supercapacitors work with liquid or solid electrolytes. Here, we present a non-toxic, environmentally friendly and cost-effective capacitor that works in gaseous atmosphere, such as water vapor. Unlike traditional parallel double plate capacitors, an interdigitated capacitor structure is employed. The active material, i.e., β-$FeSi_2$ nanoparticles are spin-coated onto the gold interdigitated structure, which is lithographically defined on SiO_2 substrate.

Compared to the bare electrodes without β-$FeSi_2$ nanoparticles, the β-$FeSi_2$ nanoparticles-coated capacitor exhibits an up to 3−4 orders of magnitude increased capacitance. Also, the capacitance of β-$FeSi_2$ capacitor that runs under dry air is negligible, compared with a capacitor that is operated in humid atmosphere. In this work, the charging and discharging mechanism is studied with cyclic voltammetry, X-ray photoelectron spectroscopy and capacitance-voltage measurement. Also, the possibility of working under other gaseous atmosphere, such as acetone, is explored.

HL 13.63 Mon 17:30 Poster B

Functional nanostructuring with nanoporous alumina membranes as templates for advanced energy conversion and storage — •Huaping Zhao, Yang Xu, Yan Mi, Rui Xu, Long Liu, Yaoguo Fang, Min Zhou, and Yong Lei — Institut für Physik & IMN MacroNano (ZIK), Technische Universität Ilmenau, 98693, Ilmenau, Germany

Nanostructures have drawn great attentions for functional device applications. Among the various techniques developed for fabricating arrayed nanostructures of functional materials, nanostructuring technique with nanoporous alumina membranes as templates becomes more attractive owing to the superior geometrical characteristics and low-cost. Herein, we summarize our recent progress about functional nanostructuring based on perfectly-ordered nanoporous alumina membranes to prepare perfectly-ordered nanostructure arrays of functional materials toward constructing high-performance energy conversion and storage devices. By employing the perfectly-ordered nanoporous alumina membranes as templates, arrayed nanostructures in the form of nanoparticle, nanorod, nanotube and nanopore have been synthesized over large area. These as-obtained nanostructure arrays have large specific surface area, high regularity, large-scale implementation, and tunable nanoscale features. All these advanced features enable them to be of great advantage for the performance improvement of energy conversion and storage devices, including photoelectrochemical water splitting cells, supercapacitors, and sodium-ion batteries, etc.

HL 13.64 Mon 17:30 Poster B

Solution-Based Layers of Nickel Oxide for Applications in Electrochromic Windows — •Florian Eberheim, Christian Lupó, and Derck Schlettwein — IAP, JLU Giessen, Germany

Electrochromic windows are of interest in light-managing devices like smart windows or smart mirrors. The aim of this work consist in the preparation of an electrochromic ion storage anode which is compatible to other device constituents. Nickel oxide can serve for this purpose with properties complementary to tungsten oxide as cathode. Because of the thermal sensitivity of intercalated tungsten oxide layers the production temperature of the nickel oxide layers should be sufficiently low. In this project nickel oxide is produced at $230°C$ by an internal combustion reaction with urea as fuel. For this synthesis nickel nitrate hexahydrate, urea and a solvent were mixed. Ethanol, acetone, H_2O, methanol, 1-Propanol or DMSO where used as solvents. The nickel oxide layer is made by spin-coating this solution onto the substrate (FTO on glass) and heating on a hot-plate. Non-stoichiometric NiO is formed with a considerable concentration of Ni^{3+} centers, leading to a dark-brown color. These layers were characterized by SEM and studied by cyclic voltammetry in contact to a Li^+-containing organic electrolyte. Upon reduction and Li^+-intercalation the layers became widely transparent as desired for compatibility with tungsten oxide. The ion-capacity and the reversibility of this reaction was determined dependent on preparation conditions and film thickness. It was shown that ethanol as solvent led to layers with the highest ion capacity and the largest change in coloration.

HL 13.65 Mon 17:30 Poster B

Orbital Angular Momentum sorting of light emitted by exciton polariton vortices — •Marius Kahlert[1], Bernd Berger[1], Daniel Schmidt[1], Marc Assmann[1], Martin Kamp[2], Christian Schneider[2], Sven Höfling[2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Technische Physik, Physikalisches Institut, Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Germany

The nonlinear interaction of exciton polariton vortices is a subject of remarkable interest among the rich phenomenology of microcavity exciton polaritons. We generate exciton polariton vortices using light beams carrying orbital angular momentum (OAM) and demonstrate a method for monitoring the time dynamics of the exciton polariton vortex decay. Here the sample emission runs through a custom optical transformation, which translates the helical phase of OAM modes into a linear gradient and in principle enables a simultaneuos detection of all OAM modes. Finally the OAM sorted signal is resolved in time using a streak camera, granting insight into the decay dynamics of exciton polariton vortices.

HL 13.66 Mon 17:30 Poster B

Time-resolved dielectric function tensor of *m*-plane ZnO studied by femtosecond spectroscopic ellipsometry — •Oliver Herrfurth[1], Steffen Richter[1], Mateusz Rębarz[2], Miroslav Kloz[2], Shirly Espinoza[2], Jakob Andreasson[2,3], Marius Grundmann[1], and Rüdiger Schmidt-Grund[1] — [1]Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Linnéstraße 5, 04103 Leipzig — [2]ELI Beamlines, Institute of Physics, Czech Academy of Science, Na Slovance 2, 182 21 Prague, Czech Republic —

[3]Condensed Matter Physics, Department of Physics, Chalmers University of Technology, Gothenburg, Sweden

We report on femtosecond time-resolved spectroscopic ellipsometry measurements on a *m*-plane oriented ZnO single crystal. Our recently developed technique relies on a pump-probe scheme employing an amplified Ti:Sa laser (6 mJ,35 fs). Its third harmonic is used as pump pulse and its fundamental wavelength is used to create a supercontinuum white light probe by focussing onto CaF_2. This method allows to probe a spectral range from 340 nm to 1000 nm with a single shot. The time resolution is estimated as 170 fs. We determine the complex dielectric function tensor from measurements parallel and perpendicular to the crystal's optic axis using a transfer matrix algorithm. A crucial point is the depth-dependence of the model parameters imposed by the finite, temporally varying penetration depth of the pump and probe beam. The relaxation dynamics of the excited charge carriers are observed. In particular, the resonances of excitons and exciton-phonon complexes are suppressed and spectrally shifted.

HL 13.67 Mon 17:30 Poster B

3D stabilization of an optical μ-absorption spectrometer — •Jurek Lange and Sangam Chatterjee — Institute of Experimental Physics I, Justus-Liebig-University Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany

Spectroscopy of microscopic or even nanoscopic particles requires extreme mechanical stability to enable significantly long exposure times; e.g., even small changes in the ambient temperature can result in sample drifts, which blur or even distort the measurements.

Here, we actively stabilize a home-built optical microscope equipped with a 3D nanopositioner to measure optical transmission in sample areas of less than 1 μm^2 (0.65 NA). A permanent feedback loop is implemented to rectify the thermal drift in the measuring algorithm. It is based on a live image analysis on multi-dimensional Fourier transform analysis and corrects both the focus and shifts with in the focal plane. The reliability of the approach is verified by stabilizing the optical system using a 1951 USAF target in for 35-hour measurement. The sample drift was reduced from 12 μm to 0.4 μm for while the ambient temperature randomly changed between 19 and 21 °C.

HL 13.68 Mon 17:30 Poster B

White-light and second-harmonic generation in various SnS-based cluster molecules — •Nils Mengel[1,3], Eike Dornsiepen[2], Florian Dobener[3], Nils Rosemann[4], Stefanie Dehnen[2], and Sangam Chatterjee[3] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]Department of Chemistry and Material Sciences Center, Philipps-Universität Marburg, Hans-Meerweinstraße, D-35043 Marburg, Germany — [3]Institute of Experimental Physics I, Justus-Liebig-University Giessen, Heinrich-Buff-Ring 16, D-35392 Gießen, Germany — [4]Department of Chemistry, Lund University, Naturvetarvägen 14, SE-22362, Lund, Sweden

Light sources providing a broad spectral range and well defined beam parameters are needed for numerous scientific experiments and technical applications. Lasers usually offer the advantageous beam properties but have a very small spectral width. To enhance the spectral bandwidth, high-harmonic or supercontinuum generations are commonly used. These require high-power lasers or highly nonlinear optical materials.

Powders containing SnS-based cluster molecules offer very strong nonlinear properties. They enable low-etendue, directional broadband supercontinua even when irradiated with a continuous-wave laser diode. Here, we present the nonlinear optical response of various powder compositions aiming to achieve a better understanding of the underlying processes responsible for the white light generation.

HL 13.69 Mon 17:30 Poster B

Phonon-assisted luminescence in hexagonal boron nitride — •Claudio Attaccalite[1,2] and Elena Cannuccia[2] — [1]CINaM UMR 7325, Aix-Marseille University - CNRS, Marseille, France — [2]Universita Tor Vergata, Roma, Italy

We study luminescence in hexagonal-boron nitride by combining Green's function theory with Williams-Lax theory to simulate phonon replica in the optical spectra. Our results explain recent experiments on h-BN, and point out the role of phonons in the optical response of this material.

HL 13.70 Mon 17:30 Poster B

Exciton-assisted transversal magneto-optical Kerr effect in CdMnTe/CdMgTe quantum well structures — •Lars Klompmaker[1], Felix Spitzer[1], Olga Borovkova[2], Vladimir I. Belotelov[2,4], Ilya A. Akimov[1,3], Alexander N. Poddubny[3,6], Victor F. Sapega[3], Maciej Wiater[5], Tomasz Wojtowicz[5], Grzegorz Karczewski[5], Dmitri Yakovlev[1,3], and Manfred Bayer[1,3] — [1]Experimentelle Physik 2, TU Dortmund University, D-44221 Dortmund, Germany — [2]Russian Quantum Center, Skolkovo, Russia — [3]Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [4]M.V. Lomonosov Moscow State University, Moscow, Russia — [5]Institute of Physics, Polish Academy of Sciences, PL-02668 Warsaw, Poland — [6]ITMO University, 197101 St. Petersburg, Russia

We studied the influence of excitons in a CdMnTe/CdMgTe quantum well (QW) structure on the transverse magneto-optic Kerr effect (TMOKE) using a Fourier imaging setup, which allows the measurement of the reflected light's intensity as a function of its energy and angular distribution at the same time. Induced by the giant Zeeman splitting of excitons in diluted magnetic semiconductors, we see a two-order enhancement of the TMOKE in the spectral region of the excitonic resonances. We are able to separate between contributions from heavy and light hole exciton states in the TMOKE's spectral dependence with up to 2% effect at an incidence angle of about 20°.

HL 13.71 Mon 17:30 Poster B

Telecom wavelengths photonic crystal cavities: Simulation and Fabrication — •Lucas Rickert, Andrei Kors, Kerstin Fuchs, Johann Peter Reithmaier, and Mohamed Benyoucef — Institute of Nanostructure Technologies and Analytics (INA), CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Telecom wavelengths InP-based photonic crystal (PhCs) cavities with embedded quantum dots (QDs) show interesting properties caused by the interaction between the atom-like behaviour of the QD and the degree of confinement of a spectrally and spatially suited cavity mode, leading to possible applications for long-distance quantum communication and quantum information processing.

This work focuses on the study of the influence of geometrical parameters on the quality factor enhancement, light out-coupling and the mode profiles of PhC cavities. Suitable PhC are designed using finite difference time domain (FDTD) simulations. The InP-based L3 PhC cavities are fabricated using electron beam lithography followed by reactive ion etching and wet etching of an underlying sacrificial layer resulting in free standing InP membranes containing QDs. The optical properties of the PhC cavities are examined via low temperature micro-photoluminescence spectroscopy (μ-PL) and exhibit sharp mode profiles at the telecom C-Band and enhanced exciton-biexciton single dot emission confirmed by excitation power dependent PL measurements. Temperature detuning experiments show a weak coupling behaviour.

HL 13.72 Mon 17:30 Poster B

Calculation of zero-field splitting for defects in semiconductors: reaching all-electron accuracy with pseudopotentials — •Timur Biktagirov, Wolf Gero Schmidt, and Uwe Gerstmann — Universität Paderborn, 33098 Paderborn, Germany

Spin centres in semiconducting materials are promising candidates for quantum information processing, photonics and sensing at ambient conditions. For successful quantum applications, a spin centre has to be addressed on a single-defect level. For high-spin ($S > 1/2$) centres, one of the key spectroscopic fingerprints is the zero-field splitting (ZFS) parameter addressable by electron paramagnetic resonance (EPR), which describes the interactions between the unpaired electrons. Here, we report on DFT based calculations of the spin-spin contribution to ZFS tensor being implemented in the GIPAW module of Quantum ESPRESSO package [1]. We use a single-determinant approach proposed by Rayson and Briddon [2,3], and extend it by adding a projector augmented wave (PAW) [4] reconstruction which has not been implemented before. We benchmark our approach against well-established all-electron method for a series of diatomic radicals, and defects in diamond and silicon carbide.

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HL 13.73 Mon 17:30 Poster B

Active frequency stabilization of frequency doubled

AlGaInP-VECSELs — •Hoy-My Phung[1], Roman Bek[1], Hermann Kahle[1], Michael Böhm[2], Kevin Schmidt[2], Oliver Sawodny[2], Michael Jetter[1], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, research centers IQST and SCoPE, Universität Stuttgart, Allmandring 3 — [2]Institut für Systemdynamik, Universität Stuttgart, Waldburgstr. 17/19

In recent years, vertical external-cavity surface-emitting lasers (VECSELs) based on the material system AlGaInP have shown outstanding performance for high continuous-wave output power and excellent beam quality in the red spectral range. Furthermore, second harmonic generation to the ultraviolet spectral range enables new applications for AlGaInP-VECSELs such as UV spectroscopy or interference lithography. To achieve laser emission in the ultraviolet spectral range we insert a beta barium borate (BBO) crystal in a v-shaped cavity. A birefringent filter and an etalon are used for tunable single-frequency operation. However, the linewidth of non-stabilized lasers or short-term stability is often not sufficient for the above-mentioned applications and many precision measurements. Based on the side-of-fringe locking technique, we develop a control system to actively stabilize the frequency of the laser. The fundamental frequency is locked to a reference Fabry-Pérot cavity. The position of the flat end mirror is controlled by a piezo actuator in order to compensate for disturbances due to mechanical vibrations. These are measured by acceleration sensors and characterized by amplitude and frequency.

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Spacer thickness effects on the optical properties of double vertically stacked InP/AlGaInP quantum dots laser structures — •Hatam Mahmudlu, Zhihua Huang, Michael Zimmer, Stefan Hepp, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen and Research Center ScoPE and IQST, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Quantum dots (QDs) as gain medium for semiconductor lasers are attractive for many applications. This is due to the promising lower threshold, higher material gain and the enhanced opportunity for tuning the gain spectral width and the emission wavelength. In the present work, we investigate the effects of the spacer thickness between the double vertically stacked QD layers on the optical properties and lasing performance of the self-assembled InP/AlGaInP QD edge emitting lasers. A numerical model is developed to determine the electron and hole coupling between the QD layers. The QD lasers with varying spacer layer thicknesses were grown by metal-organic vapor-phase epitaxy (MOVPE). The optical properties are carried out by photoluminescence (PL), electroluminescence (EL), and time-resolved measurements. Meanwhile, the laser performance is compared by characterizing the optical gain, internal optical losses, threshold current, and output power, respectively. Our work provides a guideline to determine the optimized spacer layer thickness for the vertically stacked QD lasers.

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Design and fabrication towards red-emitting AlGaInP based electrically pumped VECSELs — •Michael Zimmer, Zhihua Huang, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart

Electrically pumped external cavity surface emitting lasers (EP-VECSELs) are a new generation of light sources for a wide field of applications, benefiting by the advantage of combining the excellent beam quality of optically pumped VECSELs and the compact size of VCSELs. However, a major challenge in the realization of EP-VECSELs, especially for the short wavelength regime, is to achieve a homogeneous charge carrier distribution within the active region to support the fundamental mode and high power laser output.

In this work, a red-emitting AlGaInP based EP-VECSEL structure is investigated with an electro-thermal numerical model based on the finite element method (FEM). These simulations gave us design proposal where we can achieve a uniform current density distribution. This proposed structure of an EP-VECSEL is grown by metal-organic-vapor-phase-epitaxy (MOVPE) on a GaAs substrate. In this contribution, the fabrication of a flip-chip process is presented and experimentally studied. We are successful to remove the GaAs substrate by wet chemical etching while keeping the heavy doped GaAs contact layer faultless. A fast, smooth and deep mesa etching for GaAs/AlGaAs/AlGaInP materials is also achieved by inductively coupled plasma (ICP) etching.

HL 13.76 Mon 17:30 Poster B

Optical properties of highly excited CuI based microwire cavities — •Evgeny Krüger[1], Marcel Wille[1], Steffen Blaurock[1], Vitaly Zviagin[1], Rafael Deichsel[1], Gabriele Benndorf[1], Volker Gottschalch[2], Harald Krautscheid[2], Rüdiger Schmidt-Grund[1], and Marius Grundmann[1] — [1]Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Linnéstr. 5, Leipzig — [2]Universität Leipzig, Institut für Anorganische Chemie, Johannisallee 29, Leipzig

We present the first experimental results for lasing in cuprous iodide (CuI) microwire cavities. The microwires with diameter of (2 – 20) μm were grown by vapor-phase transport method in a three-zone furnace with a linear temperature profile between (250 – 450)°C. The microwire crystal structure, chemical composition as well as morphology were evaluated using X-ray diffraction, energy dispersive X-ray spectroscopy and scanning electron microscopy, respectively. The observed excitonic photoluminescence emission lines as well as formation of gain under high optical excitation indicate high optical quality of the investigated microwires. The analysis of the spectral mode positions suggests that the microwires with a triangular cross-section act as whispering-gallery type resonators. Time-resolved micro-photoluminescence studies reveal the dynamics of the laser process on the picosecond time scale.

[1] M. Wille et al., Appl. Phys. Lett. 111, 031105 (2017)

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Radio-frequency studies of self-mode-locking in a single-section quantum dot laser: experiment and simulation — •Christoph Weber[1], Paolo Bardella[2], Lorenzo Luigi Columbo[2], Mariangela Gioannini[2], and Stefan Breuer[1] — [1]Institut für angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

Self-mode-locked single-section semiconductor lasers (SCLs) with active gain materials based on quantum wells [1], quantum dashes [2] or quantum dots [3], are compact photonic sources that generate optical frequency combs. We experimentally find and numerically study a transition from unlocked multi-modal emission to self-mode-locked emission of a single-section quantum dot based SCL depending on the injected gain current. This transition is characterized by a significantly reduced beat note line-width in the radio-frequency spectrum and a reduction of the integrated relative intensity noise. Experiments and simulations are in good qualitative and quantitative agreement. [1] Sato et al., Electron. Lett. 37 (2001),763. [2] Panapakkam et al., IEEE J. Quantum Electron. 52 (2016),1. [3] Liu et al., Opt. Letts. 33 (2008), 1702. [4] Bardella et al., Opt. Express 25 (2017), 26234.

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Experimental investigations on the gain and dispersion properties of mode-locked semiconductor lasers — •Stefan Heppe[1], Christoph Weber[1], Paolo Bardella[2], Lorenzo Luigi Columbo[2], Mariangela Gioannini[2], and Stefan Breuer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

Optical frequency combs generated by monolithic mode-locked (ML) semiconductor lasers (SCLs) in the near-infrared wavelength region are ideal sources in time critical applications such as optical communication. Since the phase difference between adjacent modes is fixed over time, ultra-short optical pulses can be emitted but due to group delay dispersion (GDD) inside the laser cavity the pulses are in most cases not Fourier-limited and it is even possible to have ML operation without any pulses in the laser output [Bardella et al, Opt. Expr. 25 (2017), 26234]. To obtain ultra-short pulses, a precise knowledge of the GDD and the gain properties of the laser material is necessary. In this work, we use a method employing a Fourier-transform spectrometer [Hofstetter, Faist, IEEE Phot. Techn. Letts. 11 (1999), 1372; Villares et al, Optica 3 (2016), 152] to measure the wavelength dependent gain and GDD in ML SCLs with different active materials and emission wavelengths.

HL 13.79 Mon 17:30 Poster B

Experimental studies of gain and absorption properties of passively mode-locked semiconductor lasers — •Stefan

Heppe[1], Christoph Weber[1], Julien Javaloyes[2], Andreas Klehr[3], Andrea Knigge[3], and Stefan Breuer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Departamendto de Fisica, Universitat de les Illes Balears, 07122 Palma de Mallorca, Spain — [3]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

Passively mode-locked multi-section semiconductor lasers are attractive photonic sources for optical telecommunications, as they can generate ultrashort pulses at high repetition rates. In order to derive new laser geometries, gain and absorption properties need to be accessed. In this work, the gain and absorption spectra of a 1 mm long monolithic multi-section QW laser with a 0.1 mm long absorber section and an emission wavelength of 1070 nm are investigated in dependence on injected gain current and applied absorber reverse bias voltage, by using a Czerny-Turner spectrometer and a photon counting technique. By analyzing the modulation depth of the Fabry-Perot modes in the subthreshold amplified spontaneous emission spectrum, the wavelength dependent gain and absorption of the laser can be determined by the differential Hakki-Paoli method proposed in [Stolarz et al., IEEE Photon. J. 3 (2011), 1067]. This method allows to measure gain and absorption properties in the processed two- or multi-section laser devices.

HL 13.80 Mon 17:30 Poster B

Repetition rate tuning range analysis of passively mode-locked quantum-well semiconductor lasers subject to optical self-feedback: simulation and experiment — •Dominik Auth[1], Christoph Weber[1], Andreas Klehr[2], Andrea Knigge[2], and Stefan Breuer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

Compact monolithic passively mode-locked (PML) semiconductor lasers (SCLs) with multi-GHz repetition rates (RR) emitting at wavelengths of around 1070 nm are attractive ultrafast sources for seeding ytterbium doped fiber amplifiers and for photonic communication at high data rates. In this work, the pulse RR tuning range of PML multi quantum-well (QW) SCLs subject to single cavity optical feedback (OFB) is investigated. A stochastic time-domain model [Drzewietzki et al., Opt. Expr. 21 (2013), 16142] is applied to predict the RR tuning range and timing jitter (TJ) reduction in QW SCLs subject to very long OFB lengths up to 73 m. Furthermore, the obtained RR tuning range predictions for different OFB lengths and the TJ reduction are proven experimentally by studying 3 mm long PML QW SCLs with different absorber lengths and subject to long OFB. The limits of the RR tuning range are also confirmed experimentally.

HL 13.81 Mon 17:30 Poster B

Optical frequency comb stabilization of a self-mode-locked quantum dot laser by optical time-delayed self-feedback — •Sebastian Stutz[1], Dominik Auth[1], Christoph Weber[1], Oleg Nikiforov[1], Luke F. Lester[2], Thomas Walther[1], and Stefan Breuer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Bradley Department of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA

Optical frequency combs generated by self-mode-locked semiconductor lasers based on quantum dot (QD) gain material are ideal sources for application in high data rate optical communication, demanding tunable and stable comb-line spacing in the range of 40 GHz. In this work, the impact of fine-delay tunable dual-cavity optical feedback (DC-OFB) on the mode spacing and the optical frequency comb stability generated by a 1 mm long self-mode-locked single-section QD laser emitting at 1255 nm is studied experimentally and by simulation. The linewidth of the laser mode-beating frequency of 40.67 GHz amounts to 1.4 MHz in the of free running case. By fine-delay tuning of both optical feedback lengths, we find a comb-line spacing tuning range of 70 MHz. The beat note linewidth decreases to 2 kHz for well-adjusted optical feedback cavities. Simulation results based on a stochastic time-domain model [Drzewietzki et al., Opt. Expr. 21 (2013), 16142] reproduce the experimentally observed trends with good qualitative and quantitative agreement.

HL 13.82 Mon 17:30 Poster B

Temperature-control based fiber optical self-feedback configuration for passively mode-locked semiconductor lasers — •Sebastian Stutz[1], Dominik Auth[1], Christoph Weber[1], Oleg Nikiforov[1], Luke F. Lester[2], Thomas Walther[1], and Stefan Breuer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Bradley Department of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA

Passively mode-locked (PML) semiconductor lasers (SCLs) generating short optical pulse widths and high pulse repetition rates (RR) are promising compact sources for future time-critical applications. Since the pulse train of PML SCLs can exhibit considerable timing jitter (TJ), experimental concepts to improve the TJ are demanded. A dual-cavity optical self-feedback concept to improve the pulse train stability and control the RR has recently been reported [Nikiforov et al., Opt. Expr. 24, 14301 (2016)]. In this contribution, we present experimental results obtained by an all optical time-delayed feedback configuration where a highly-precise temperature controlled optical fiber delay is employed for the first time. By substantially reducing environmental influences including acoustic noise, temperature instabilities and vibrations, we are able to achieve a substantially improved pulse train stability.

HL 13.83 Mon 17:30 Poster B

Timing stability and repetition rate tuning analysis of a passively mode-locked quantum-well semiconductor laser subject to dual-cavity optical self-feedback — •Dominik Auth[1], Christoph Weber[1], Andreas Klehr[2], Andrea Knigge[2], and Stefan Breuer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

Monolithic passively mode-locked (PML) semiconductor lasers (SCLs) offer pulse repetition rates (RR) in the Multi-GHz range and picosecond-short optical pulses. Their pulse train timing stability, however, is considerable lower as compared to fiber-based pulsed lasers. All-optical self-feedback (OFB) configurations are elegant concepts without using any additional sources for external time reference and they allow to improve the timing stability and control the RR frequency, both of which are important in photonic communication applications. In this work, we study the influence of OFB by fine-delay controlled dual optical cavities on the pulse RR and the timing jitter (TJ) of a multi quantum-well (QW) SCL emitting at 1070 nm. A 3 mm long PML QW SCL with a saturable absorber length of 10% of the total cavity length is studied. We quantify the timing stability improvement by radio-frequency, temporal and optical domain analysis and in dependence on the OFB strengths as well as the feedback delays. We report on single digit Gigahertz RR control while simultaneously ensuring a substantial TJ reduction.

HL 13.84 Mon 17:30 Poster B

Intensity noise of a two-state quantum dot laser — •Robert Pawlus[1], Lorenzo L. Columbo[2], Paolo Bardella[2], Stefan Breuer[1], and Mariangela Gioannini[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Dipartimento di Elettronica, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

We study experimentally and by numerical simulations the intensity noise behavior of an InAs/InGaAs quantum dot (QD) laser emitting simultaneously at the ground-state (GS) and the excited-state (ES) wavelengths. Experimentally, a reduction in power fluctuations up to 4 dB is found when GS and ES emit simultaneously as compared to the case of single GS or ES emission. This stability is also studied by spectrally resolved GS and ES time-signal analysis. By means of numerical simulations we explain this phenomenon and qualitatively reproduce its trend with the laser biasing conditions. The coupling of GS and ES emissions trough the common carrier reservoir is identified as the underlying physical mechanism leading to a quasi anti-phase dynamics.

HL 13.85 Mon 17:30 Poster B

Performance and Dynamics of Three-Section Tapered Mode-Locked Lasers — •Stefan Meinecke[1], Lukas Drzewietzki[2], Christoph Weber[2], Benjamin Lingnau[1], Stefan Breuer[2], and Kathy Lüdge[1] — [1]Institut für Theoretische Physik, Technische Universtität Berlin, Berlin, Germany — [2]Institut für Angewandte Physik, Technische Universtität Darmstadt, Darmstadt, Germany

Passively mode-locked semiconductor lasers are inexpensive sources of short optical pulses with high repetition rates. They find applications in high-capacity optical interconnects and high-precision metrology, where stable pulse trains with small amplitude and timing jitter are required. Optimizing the design of monolithic mode-locked semiconductor lasers for such demands has therefore become of major interest.

Combining a traveling-wave model for the electric field propagation with microscopically based quantum-dot (QD) charge-carrier rate equations, we investigate the performance and dynamics of monolithically integrated multi-section QD mode-locked lasers. In this work, we focus on a three section device with two short straight sections at one end, which can be individually biased, and a long tapered gain section at the pulse emission facet.

Our simulations nicely reproduce experimental results and furthermore enable us to predict device geometry for stable operating regimes that exhibit short and high power pulses with low timing jitter. We especially study the influence of the position and length of saturable absorber and the taper angle of the long gain section.

HL 13.86 Mon 17:30 Poster B

Characterization of high-efficiency AlGaInP VECSELs in a gain chip holder with optimized heat flow — •Alexander Peschken[1], Hermann Kahle[2], Roman Bek[1], Cherry May Mateo[3], Uwe Brauch[3], Marwan Abdou Ahmed[3], Michael Jetter[1], Thomas Graf[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, SCoPE, IQST, Univ. Stuttgart, Germany — [2]Tampere Univ. of Technology, Finland — [3]Institut für Strahlwerkzeuge, SCoPE, Univ. Stuttgart, Germany

Vertical external-cavity surface-emitting lasers (VECSELs) provide in principle power scalability at constant beam quality and vast wavelength flexibility. However, due to the limited charge-carrier confinement in AlGaInP-based VECSELs, an optimized heat extraction is essential in order to enable power scalability. Unfortunately, the substrate and the distributed Bragg reflector in such VECSELs show a low thermal conductivity. Hence, an additional intra-cavity heat spreader is inevitable to overcome occurring temperature problems. A modified chip holder with mechanically improved thermal contact between gain element and heat spreader showed already a doubling of the maximum output power compared to the standard one. However, recent thermal and laser measurements have shown that the heat transfer out of the heat spreader is still hampered by bottlenecks at the transitions between different parts of the gain chip holder, limiting the power scaling ability. A new chip-holder was designed to overcome these thermal problems. Its design as well as results of AlGaInP VECSELs emitting at 665 nm will be presented.

HL 13.87 Mon 17:30 Poster B

Probing the (opto)electronic properties of functional materials by scanning near-field optical microscopy — •Jinhui Zhong[1,2], Bin Ren[2], and Christoph Lienau[1] — [1]Institute of Physics and Center of Interface Science, Carl von Ossietzky University, 26111 Oldenburg, Germany — [2]College of Chemistry and Chemical Engineering, Xiamen University, Xiamen 361005, China

Scanning near-field optical microscopy (SNOM) is a powerful tool that allows for nanoscale physical and chemical analysis. In this contribution, we first demonstrated the use of tip-enhanced Raman spectroscopy (TERS) for atomic- and molecular-level characterization of heterogeneous catalyst. With plasmon-enhanced Raman scattering effect, TERS provides simultaneous topographical and chemical information at the nano/atomic scale. We show that TERS can chemically and spatially probe the site-specific chemical (electronic and catalytic) and physical (plasmonic) properties of an atomically well-defined Pd(submonolayer)/Au(111) bimetallic model catalyst at 3 nm resolution in real space using phenyl isocyanide as a probe molecule. We observe a weakened NC bond and enhanced reactivity of phenyl isocyanide adsorbed at the Pd step edge compared with that at the Pd terrace. Density functional theory corroborates these observations by revealing a higher d-band electronic profile for the low-coordinated Pd step edge atoms.

We further discuss the combination of SNOM with ultrafast spectroscopy to study the nanoscale exciton properties of 2D heterostructures.