HL 3: Poster Session I

Topics:
- 2D semiconductors and van der Waals heterostructures
- Optical properties
- Quantum transport and quantum Hall effect
- THz and MIR physics in semiconductors

Time: Monday 10:00–13:00 Location: P

HL 3.1 Mon 10:00 P

Biopolymer-templated TiO2 SERS sensors — •Qing Chen[1,2], Marie Betker[1,4,5], Constantin Harder[1,3], Calvin Brett[1,5], Matthias Schwartzkopf[1], Nils Ulrich[7], Maria Eugenia Toimil Molares[7], Christina Trautmann[7], Daniel Söderberg[4,5], Christian Weindl[3], Volker Körstgens[3], Peter Müller-Buschbaum[3,6], Mingming Ma[2], and Roth Stephan[1] — [1]DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]USTC, 230026 Hefei, China — [3]TUM, James-Franck Straße 1, 85748 Garching, Germany — [4]KTH, Teknikringen 56-58, 100 44 Stockholm, Sweden — [5]WWSC, Teknikringen 52-56, 100 44 Stockholm, Sweden — [6]MLZ, TUM, Lichtenbergstraße 1, Garching 85748, Germany — [7]GSI Helmholtz Center, Planckstrße 1, Darmstadt 64291, Germany

Titanium dioxide (TiO2) is an excellent candidate for semiconductor metal oxide-based Surface enhanced Raman scattering (SERS) substrate. We report a novel strategy of the cellulose nanofibril (CNF) - assisted assembly of TiO2/CNF thin-films with a hierarchical three-dimensional network and crystallinity as a SERS substrate. TiO2/CNF thin-films are obtained through the combined action of surface templating and thermal annealing. A high enhancement factor in terms of semiconductor SERS substrates for 4-mercaptobenzoic acid of 1.79 * 106 is obtained in the TiO2/CNF thin-films on ITO substrate with a thickness of 10 nm after thermal annealing. Our approach realizes the improvement of SERS sensitivity of semiconductor metal oxide nanomaterials through a cooperative modulation of the biotemplate morphology and the TiO2 crystalline state.

HL 3.2 Mon 10:00 P

Quantum Theory of Exciton-Plasmon Coupling in Two-Dimensional Semiconductors functionalized with Metal Nanoparticles — •Lara Greten, Robert Salzwedel, Malte Selig, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Monolayers of transition metal dichalcogenides (TMDCs) exhibit tigthly bound excitons with large optical amplitudes, originating from a reduced screening of the Coulomb interaction due to the reduced dimensionaly of these ultrathin materials. The latter gives also rise to a high sensivity of such excitons to their environment.

Contrary, the optical response of metal nano-particles is dominated by plasmons which are collective electron oscillations. They facilitate an impressive amplification of the electric near-field and allow to manipulate the electric field on dimensions below the diffraction limit.

In the presented work, we consider theoretically exciton-plasmon coupling in a hybrid structure of a TMDC layer supported by a single metal nano-particle or a two-dimensional array. For this purpose, we develop a Maxwell-Bloch theory where the excitons are described within the Heisenberg equation of motion framework and the metal nano-particles are treated in classical Mie theory.

Our studies reveal new "plexcitonic" eigenstates of the hybrid system. Furthermore, the results confirm that the configuration allows to reach the strong coupling limit which features a Rabi splitting of tens of meV.

HL 3.3 Mon 10:00 P

Near-field terahertz spectroscopy of flakes of 2D materials — •Ahmad-Reza Etemadi, Sebastian Matschy, Ahana Bhattacharya, and Martin Mittendorff — Department of physics, University of Duisburg-Essen, 47057 Duisburg, Germany

THz spectroscopy is a powerful tool to investigate the carrier dynamics in many materials. Unfortunately, gaining access to the THz conductivities of small samples, e.g. flakes of 2D materials, is rather difficult, as the THz spot size is much larger than the structure of interest. Direct detection in the near-field improves the spatial resolution and can be done by placing the sample directly on top of an electro-optic crystal. A near-infrared (NIR) beam is exploited to probe the THz field in the vicinity of the flake. The spatial resolution of the experiment is mostly determined by the NIR beam size in the electro-optic crystal and the diffraction of the THz beam by the sample. Here we analyze the potential performance of such a THz near-field microscope and present the current stage of our instrument.

HL 3.4 Mon 10:00 P

Optical properties of various crystalline phases of WO_3 — •Felix Bernhardt and Simone Sanna — Institut für Theoretische Physik and Center for Materials Research, Justus- Liebig-Universität Gießen, 35392 Gießen, Germany

Tungsten trioxide (WO_3) is a semiconductor suitable for a wide variety of applications. Due to multiple, temperature-driven phase transitions and an electronic band gap within the optical spectrum [1], it is employed in a multitude of devices, ranging from smart windows [3] to gas sensors [5]. In this work, we investigate the monoclinic (stable at room temperature), the triclinic and orthorhombic phases of WO3 from first principles. Furthermore, we compare them with a hypothetical, simpler cubic configuration, which is often employed to approximate the real structures in theoretical studies.

Ground state properties such as lattice parameters and electronic structures are calculated within density functional theory (DFT). The optical response is modeled within the Bethe-Salpeter equation and time-dependent DFT using a long-range corrected kernel. Our results are in excellent agreement with previous theoretical investigations [1,4] as well as experiments [2,6]. The cubic phase fails to correctly reproduce the dielectric function of the real crystals.

[1] M Mansouri et al, Turk. Journal of Phys. 41(238) (2017) [2] B Loopstra et al, Acta Cryst. 25(1420) (1968) [3] L Liang et al, Sci. Rep. 3(1936) (2013) [4] F Wang et al, Journal Of Phys. Chem. 115(8345) (2011) [5] N. Yamazoe et al, Catalysis Surveys from Asia 7(63-75) (2003) [6] M Vargas et al, Journal of Applied Phys. 115(2014)

HL 3.5 Mon 10:00 P

Theoretical investigations of (non linear) optical properties of [RSi(CH2SnPh)3E3] molecules and molecular crystals on the path to understanding white light generation using molecules containing adamantane-like cores. — •Ferdinand Ziese[1], Irán Rojas-León[2], Christof Dues[1], Stefanie Dehnen[2], and Simone Sanna[1] — [1]Solid State Spectroscopy, Institut für Theoretische Physik Heinrich-Buff-Ring 16, 35392 Gießen — [2]The Dehnen Group, Hans-Meerwein-Straße 4, 35032 Marburg

Recent studies have demonstrated white light generation from molecular clusters with adamantane-like cores and different ligands [1,2]. The mechanism leading to the white light emission is currently under discussion. In order to understand the intertwinement between atomic and electronic structure and optical response, we have modeled the structural, electronic, and (nonlinear) optical properties from first principles. Isolated molecules and molecular crystals with formula unit [RSi(CH2SnPh)3E3], where R=Ph, Tol, and E=S, Se, Te. Both the chemistry of the ligands and of the cluster core have an heavy impact on the optical response of the material. The investigations presented append current and past investigations on the path towards understanding white light generation using molecules containing adamantane-like cores.

[1] N. W. Rosemann, J. P. Eußner, A. Beyer, S. W. Koch, K. Volz, S. Dehnen, S. Chatterjee, Science 2016, 352, 301

[2] N. W. Rosemann, J. P. Eußner, E. Dornsiepen, S. Chatterjee, S. Dehnen, J. Am. Chem. Soc. 2016, 138, 16224.

HL 3.6 Mon 10:00 P

How to Trace Structural Dynamics in Lead Halide Perovskites Using THz Kerr Effect Spectroscopy — •Maximilian Frenzel[1], Marie Cherasse[1,2], Leona Nest[1], Martin Wolf[1], and Sebastian F. Maehrlein[1] — [1]Fritz Haber Institute of the Max

Planck Society, Faradayweg 4-6, 14195 Berlin, Germany — [2]LSI, CEA/DRF/IRAMIS, CNRS, Ecole polytechnique, Institut Polytechnique de Paris, 91120 Palaiseau, France

The origin of the surprising optoelectronic performance of lead halide perovskite (LHP) semiconductors is still debated. It has been suggested that their highly polar and anharmonic lattice might beneficially govern their optoelectronic properties in the form of dynamic charge carrier screening. To study the LHP's ultrafast lattice polarization when subjected to a transient electric field we employ THz Kerr Effect (TKE) spectroscopy. In particular, we investigate the responses in the organic-inorganic hybrid semiconductor $MAPbBr_3$ and its fully inorganic counterpart $CsPbBr_3$. By comparing our obtained signals to four-wave mixing simulations, we find that it is crucial to account for dispersion and optical anisotropy, as certain features may be misidentified for molecular relaxation dynamics or quasi-particle oscillations. Finally, we show that strong THz fields nonlinearly excite Raman active phonons in both materials, corresponding to distortions of the inorganic lattice. We hope that these findings lead to a more complete understanding of the ultrafast lattice response to transient local fields and its contributions to charge carrier screening.

HL 3.7 Mon 10:00 P

single-photon emission and coherence properties of quantum emitters in WSe_2 monolayers — Martin von Helversen[1], •Bárbara Rosa[1], Chirag Palekar[1], Carlos Antón-Solanas[2], Christian Schneider[3], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [2]Institute of Physics,Carl von Ossietzky University, Oldenburg, Germany — [3]Institute of Physics, University of Oldenburg, Oldenburg, Germany

Two-dimensional van der Waals monolayers have arisen as a new platform for exploring optical, electronic, and structural properties of semiconducting materials. Among several unique features of transition-metal dichalcogenides, the ability of manipulating one or few atomiclayers play an important role in providing a potential two-level single photon emitters (SPEs) by engineering of strain [1,2] or defects [2]. In this work, we explore the quantum properties of SPEs in strained WSe2monolayers [1]. By conducting off- and quasi-resonant optical excitation at cryogenic temperatures, we identify emitters with linewidth sas low as 70 /*mu*eV. Furthermore, throughout second order autocorrelation measurements we observe a multi-photon suppression by achieving $g^{(2)}(0) = 0.05(5)$. Lastly, we investigate the first order of coherence in SPEs WSe_2 when performing scanning Michelson interferometer experiments.

[1] L. N. Tripathi, et al.ACS Photonics8, 5, 1919-1926 (2018).
[2] K. Parto et al.Nat Commun.12, 3585 (2021).

HL 3.8 Mon 10:00 P

Magnetotunneling Spectroscopy of Double Quantum Wells in GaAs/AlGaAs Heterostructures — •Maximilian Mischke[1], Gunnar Schneider[1], Werner Dietsche[2], and Rolf Johann Haug[1] — [1]Leibniz Universität Hannover, Institut für Festkörperphysik — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart

In order to investigate the influence of a parallel magnetic field on bilayer phenomena, we performed magnetotunneling measurements on GaAs/AlGaAs double quantum wells. Therefore, the tunneling current between the two quantum wells is measured dependent on applied bias voltage, electron densities in the individual wells and a magnetic field oriented parallel to the 2D layers. We observe a systematic dependence of the tunneling resonance on the energetic difference of the two wells due to imbalanced densities. The applied bias compensates the mismatch. The parallel magnetic field introduces an additional term to the wave vector of the electrons, leading to a shift of the Fermi circles of the two quantum wells against each other [1]. This shift has an influence on the tunneling resonance since 2D-2D-tunneling requires not only energy conservation but also conservation of momentum [2]. The results of the measurements allow for a mapping of the Fermi contours of the two quantum wells [3,4].

[1] G.S. Boebinger et al, Phys. Rev. B 43, 12673 (1991)
[2] J.P. Eisenstein et al, Appl. Phys. Lett. 58, 1497 (1991)
[3] J.P. Eisenstein et al, Phys. Rev. B 44, 6511 (1991)
[4] T. Ihn et al, Phys. Rev. B 54, R2315 (1996)

HL 3.9 Mon 10:00 P

Back Focal Plane Imaging of Interlayer Excitons in $WSe_2/MoSe_2$ Heterostructures — •Lukas Sigl[1], Mirco Troue[1], Mauro Brotons-Gisbert[2], Brian Gerardot[2], Ursula Wurstbauer[3], and Alexander Holleitner[1] — [1]TU Munich, Germany — [2]Heriot-Watt University, United Kingdom — [3]University of Münster, Germany

Transition metal dichalcogenide monolayers exhibit strong light-matter interactions, which promotes them as ideal candidates for novel 2D optoelectronic applications. A vertical stacking into van der Waals heterostacks leads to the formation of long-lived interlayer excitons in adjacent layers.

We experimentally determine the transition dipole orientation of interlayer excitons in $WSe_2/MoSe_2$ heterobilayers at a base temperature of 1.7 K. The far-field photoluminescence is observed in the back focal plane of a microscope objective, such that the angular emission pattern can be resolved. An analytical model, based on source terms and transfer matrices, provides an accurate description of the dipole radiation from the heterobilayers. The obtained dipole orientation gives insight into the nature of interlayer exciton transitions and coincides with theoretical calculations for the ground state configurations in R- and H-type heterobilayers.

HL 3.10 Mon 10:00 P

Terahertz spectroscopy on nanograined Bismuth Telluride pellets — •Ahana Bhattacharya[1], Jeongwoo Han[1], Sepideh Izadi[3,4], Sarah Salloum[2], Stephan Schulz[2], Gabi Schierning[3], and Martin Mittendorff[1] — [1]Department of Physics, University of Duisburg-Essen,47057, Duisburg, Germany — [2]Department of Chemistry, University of Duisburg-Essen, 45141, Essen, Germany — [3]Department of Physics, Experimental Physics, Bielefeld University, 33615, Bielefeld, Germany — [4]Leibniz IFW Dresden, Institute for Metallic Materials, 01069, Dresden, Germany

Topological insulators (TI) host surface carriers with a very high mobility. However, the transport properties of extended crystals are dominated by bulk carriers which outnumber the surface carriers by orders of magnitude. One way to overcome the domination of bulk carriers is to use compacted TI nanoparticles. Bismuth Telluride nanoparticles which are compacted by hot pressing to nanograined bulk samples with a high surface to volume ratio are studied and analyzed.

THz time-domain spectroscopy is used as a tool to elucidate the contribution of surface and bulk carriers to the transport properties. While this is not possible with dc measurements, this can be achieved by measuring the reflection as a function of the frequency. Charge carriers with a high mobility lead to a pronounced frequency dependence of the conductivity, and thus the reflection, while low mobility carriers lead to a rather flat response. Analyzing the experimental results at various temperatures allows us to understand the role of surface and bulk carriers

HL 3.11 Mon 10:00 P

Electrical Investigation of Thin $ZrSe_3$-Films — •Lars Thole[1], Sonja Locmelis[2], Christopher Belke[1], Peter Behrens[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Institut für Anorganische Chemie, Leibniz Universität Hannover, 30167 Hannover, Germany

In recent years, 2D materials have garnered a lot of attention. Particularly graphene and transition metal dichalcogenides have been researched extensively [1]. However, there is a continuous interest in different groups of 2D materials because of their potential for new physics. Among these, the transition metal trichalcogenides (TMTC) include a lot of materials showing extraordinary properties [2].

We want to present our research on the TMTC zirconium triselenide ($ZrSe_3$) which we synthesized by a chemical transport method, exfoliated into thin flakes and then contacted by using e-beam lithography. It was possible to determine characteristics similar to that of the bulk material, even in thin layers down to 9 nm. Temperature dependent measurements give a value of about 0.6 eV for the band gap. Looking at the case of infinite thickness by comparing samples with different thicknesses a mean free path for the bulk material was determined. Thin flakes showed a degradation behavior under ambient condition which was investigated in more detail, showing a growth over several weeks. Furthermore, thin-film transistors show n-type doping when operated with a gate voltage.

[1] A. K. Geim, I. V. Grigorieva, Nature, 499, 419-425 (2013).
[2] J. O. Island et al., 2D Materials, 4, 0220033 (2017).

HL 3.12 Mon 10:00 P

Polarization resolved photoluminescence study of interlayer excitons in a twisted van-der-Waals heterostructure — •Johannes Michl[1], Sergey Tarasenko[2], Frederik Lohof[3],

Christopher Gies[3], Martin von Helversen[4], Renee Sailus[5], Sefaattin Tongay[5], Takashi Taniguchi[6], Kenji Watanabe[6], Tobias Heindel[4], Stephan Reitzenstein[3], Tatiana Shubina[2], Sven Höfling[1], Carlos Anton-Solanas[1,7], and Christian Schneider[7] — [1]Technische Physik, Universität Würzburg — [2]Ioffe Institute, St. Petersburg — [3]Institute for Theoretical Physics, University of Bremen — [4]Institute of Solid-State Physics, Technische Universität Berlin — [5]Arizona State University — [6]National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan — [7]Institute of Physics, Carl von Ossietzky University Oldenburg

Two-dimensional monolayers of transition metal dichalcogenides (TMDCs) offer a wide range of possibilities for investigation due to their unique optical properties, resulting from the exotic valley physics and the strong Coulomb interaction. By stacking two different TMDCs with a twist angle, a van der Waals heterostructure is formed that exhibits a spatially periodical Moiré potentials.

We discuss polarization resolved photoluminescence experiments performed on interlayer excitons in a slightly twisted MoSe2/WSe2 heterobilayer. In detail, we focus on the polarization properties of our sample: Our results highlight the observation of a significant degree of circular polarization of excitons, which can be manipulated with an externally applied magnetic field.

HL 3.13 Mon 10:00 P

Magnetotransport Measurements on Folded Twisted Bilayer Graphene-Hexagonal Boron Nitride Heterostructure — •Bei Zheng[1], Lina Bockhorn[1], Christopher Belke[1], Sung Ju Hong[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Division of Science Education, Kangwon National University, Chuncheon, 24341, Republic of Korea

The transport properties of bilayer graphene are strongly depended on rotational mismatch between the two graphene sheets, owing to the energy band modulation from the corresponding Moiré superlattice [1,2]. Here, we focused on the magnetotransport characteristics of folded twisted bilayer graphene (fTBG) which was obtained by mechanical exfoliation and it's heterostructure stacking with hexagonal boron nitride (hBN). The typical Landau fan diagrams from our hBN/fTBG/hBN sample were observed and the corresponding quantum Hall effect was investigated. Additional to the charge neutrality point (CNP), a local resistance peak which is independent of the perpendicular applied magnetic field was also distinguished. This could be attributed to the folded edge [1] that induces strong gauge fields [3] and exhibits different charge carrier densities.

[1] H. Schmidt et al., Nat. Commun. 5, 5742 (2014)
[2] J. C. Rode et al., 2D Mater. 3, 035005 (2016)
[3] D. Rainis et al., Phys. Rev. B 83, 265404 (2011).

HL 3.14 Mon 10:00 P

An ultra-sensitive cavity absorption microscope for hyperspectral imaging of 2D materials — Manuel Nutz[1], •Ines Amersdorffer[1], Florian Sigger[1], Theodor Hänsch[2], Alexander Högele[2], Christoph Kastl[3], and Thomas Hümmer[1] — [1]Qlibri project, Faculty of Physics, Ludwig-Maximilians-Universität Munich, Germany — [2]Faculty of Physics, Ludwig-Maximilians-Universität Munich, Germany — [3]Walter Schottky Institute and Physics Department, TU Munich, Garching, Germany

We use a tunable high-finesse optical micro-cavity as a versatile and powerful tool to measure absorption in transition metal dichalcogenides (TMDs) down to the parts-per-million level. Our scanning-cavity imaging technique [1,2], where a microscopic mirror is scanned across a larger mirror that hosts the sample, allows to collect absorption images of 2D materials with unprecedented sensitivity, spatially resolved with 2*m resolution and in real time. Our approach can be extended to allow for spectrally resolved measurements and reveals polarization-dependent absorption, implanted defects, crystal foldings, and bubbles. Furthermore, we present our progress to extend this absorption measurements to cryogenic temperatures. [1] Mader et al., Nat Commun 6, 7249 (2015) [2] Hümmer et al., Nat Commun 7, 12155 (2016)

HL 3.15 Mon 10:00 P

Detection of correlated noise in quantum rings — C. Riha[1], S. S. Buchholz[1], O. Chiatti[1], A. D. Wieck[2], D. Reuter[3], and •S. F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany — [3]Optoelektronische Materialien und Bauelemente, Universität Paderborn, 33098 Paderborn, Germany

Cross-correlated noise measurements in equilibrium at a bath temperature of $T_{bath} = 4.2$ K are performed in etched AlxGa1-xAs/GaAs-based quantum rings [1], which are of interest to the study of mode control and heat flow at the nanoscale and in quantum systems [2]. The measured white noise exceeds the thermal noise expected from the measured electron temperature T_e and the electrical resistance R. This excess noise is neither observed if one arm of a quantum ring is depleted of electrons nor in 1D-constrictions that have a length and width comparable to the quantum rings. Also, it decreases as T_{bath} increases and vanishes for $T_{bath} > 12$ K. A model is presented that suggests that the excess noise originates from the correlation of noise sources, mediated by phase-coherent propagation of electrons. The noise measurements at $T_{bath} = 4.2$ K allow the estimation of a correlation coefficient from the excess noise.

[1] C. Riha *et al.*, Appl. Phys. Lett. **117**, 063102 (2020)
[2] S. S. Buchholz *et al.*, Phys. Rev. B **85**, 235301 (2012); C. Kreisbeck *et al.*, Phys. Rev. B **82**, 165329 (2010); C. Riha *et al.*, Appl. Phys. Lett. **106**, 083102 (2015)

HL 3.16 Mon 10:00 P

Improving the Visibility of Graphene on III-V semiconductors — •Timo Kruck, A.D. Wieck, and Arne Ludwig — Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum

In a first step towards working with graphene on III-V semiconductors the visibility of graphene will be analyzed and improved with an optical microscope in the NIR range.

Each layer of graphene absorbs a certain fraction of light in a wide spectral range from visible to infrared. This fraction is $\pi\alpha \sim 2.3\%$, where α is the fine-structure constant. This absorption can be enhanced by superimposing it on certain photonic structures. For this purpose, a DBR based on GaAs and AlAs with an antireflection layer was grown on a GaAs substrate with MBE and according reflectance spectra are measured. Graphene has been exfoliated on this structure and is observed with an optical microscope illuminated by a NIR VCSEL. The resulting contrast produced by a different number of layers is analyzed and compared with simulations based on the transfer matrix method (TMM). The TMM simulations are supported by reflectometry to account for deviations of the as-grown structure from the intended structure.

HL 3.17 Mon 10:00 P

Temperature and magnetic field dependent noise measurements in quantum rings — •Birkan Düzel[1], Olivio Chiatti[1], Sven S. Buchholz[1], Andreas D. Wieck[2], Dirk Reuter[3], and Saskia F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany — [3]Optoelektronische Materialien und Bauelemente, Universität Paderborn, 33098 Paderborn, Germany

Phase-coherent transport of electrons and resulting interference effects offer a way to characterize systems. Noise measurements can be used to determine system properties, such as the electron temperature T_e. White noise exceeding the expected thermal noise has been reported in quantum ring structures [1]. The presented model suggests that the excess noise is caused by a correlation of noise sources in quantum rings, because said excess noise can only be observed when two interfering electron pathes exist. This work investigates the dependence of the excess noise in quantum rings on the bath temperature and applied magnetic field. Noise measurements in Al_xGa_xAs/GaAs-based etched quantum rings are performed in equlibrium with bath temperatures ranging from 15 mK to 12 K and magnetic fields ranging from -50 mT to 50 mT. The aim is to quantify the relationship between the phase coherence length of the electrons and the excess noise in the quantum ring structures.

[1] C. Riha *et al.*, Appl. Phys. Lett. **117**, 063102 (2020).

HL 3.18 Mon 10:00 P

Charge transfer in TMDC-graphene heterobilayers with defects — •Daniel Hernangómez-Pérez and Sivan Refaely-Abramson — Weizmann Institute of Science, Rehovot, Israel

Recent experimental and theoretical studies of charge transport in van der Waals heterostructures have revealed a rich arena of electronic

and optical phenomena, that span from tunneling spectroscopy [1] to ultrafast interfacial charge transfer after photoexcitation [2, 3]. We focus here on a theoretical study of charge transfer processes occurring at the interface of XS_2-graphene heterobilayers with isolated chalcogen vacancies (X = Mo, W). We analyze the low-energy subgap features of the defect states in the presence of graphene and propose a perturbation-based theory to describe electronic transport between the defect states mediated by the graphene layer.

[1] N. Papadopoulos, P. Gehring, K. Watanabe et al. Phys. Rev. B 101, 165303 (2020). [2] L. Yuan, T.-F. Chung, A. Kuc et al. Science Advances 4 (2), 10.1126/sciadv.1700324 (2018). [3] S. Aeschlimann, A. Rossi, M. Chávez-Cervantes et al. Science Advances 6 (20), 10.1126/sciadv.aay0761 (2020).

HL 3.19 Mon 10:00 P

A field-effect-transistor based on the carbon allotropes diamond and graphene — •Vasilis Dergianlis, Martin Geller, Dennis Oing, Nicolas Wöhrl, and Axel Lorke — Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany

Graphene is the two-dimensional carbon allotrope that exhibits exceptional mechanical strength and electron mobility. Due to its high conductivity, it is considered as one of the best conductors and can also be used as gate electrode in transistor-type devices. A second important carbon allotrope is diamond, which is a wide-bandgap semiconductor in its bulk form, where by hydrogen termination and exposure to ambient atmosphere, a two dimensional hole gas (2DHG) is formed on its surface.

In this work, we have combined the two aforementioned 2D carbon allotropes together with a thin layer of hexagonal Boron Nitride (h-BN) to a diamond-based FET. The sample consists of chemical vapor deposition-grown diamond, where a hydrogen termination induces a 2DHG on the surface as a conductive layer [1]. Graphene and hBN flakes were exfoliated and, using a dry-transfer method, placed onto the functionalized diamond surface. In this transistor-like structure, the h-BN serves as the gate-dielectric. As graphene is an ambipolar two-dimensional semiconductor itself, it can serve as both the gate electrode and tunable conductive channel. We show FET characterization of the graphene-gated structure with a mobility of $5\,cm^2/V \cdot s$ and carrier density of $p = 3.7 \cdot 10^{12} cm^{-2}$ at a gate voltage of $V_g = -9V$

[1] Oing, D., et al. Diamond and Related Materials **97**, 107450 (2019).

HL 3.20 Mon 10:00 P

Proximity control of interlayer exciton-phonon hybridization in van der Waals heterostructures — •Marlene Liebich[1], Philipp Merkl[1], Chaw-Keong Yong[1], Isabella Hofmeister[1], Gunnar Berghaeuser[2,3], Ermin Malic[2,3], and Rupert Huber[1] — [1]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Physics, Philipps-Universitaet Marburg, 35037 Marburg, Germany — [3]Department of Physics, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Van der Waals stacking has provided unprecedented flexibility in shaping many-body interactions by controlling electronic quantum confinement, orbital overlap and electron-phonon coupling. We introduce proximity-controlled strong-coupling between Coulomb correlations and lattice dynamics in neighbouring van der Waals materials, creating new electrically neutral hybrid eigenmodes, called excitonic Lyman polarons. Specifically, we explore how the internal orbital $1s$–$2p$ transition of Coulomb-bound electron-hole pairs in monolayer tungsten diselenide resonantly hybridizes with lattice vibrations of a polar capping layer of gypsum. Tuning orbital exciton resonances across the vibrational resonances, we observe distinct anticrossing and polarons with adjustable exciton and phonon compositions. Such proximity-induced hybridization can be further tailored by shaping the spatial wavefunction overlap of excitons and phonons, providing a promising new route towards engineering novel ground states of two-dimensional systems.

HL 3.21 Mon 10:00 P

Implementation of the Bethe-Salpeter Equation in the Spex Code — •Jörn Stöhler[1,2], Dmitrii Nabok[1], Christoph Friedrich[1], and Stefan Blügel[1] — [1]Forschungszentrum Jülich and JARA, Germany — [2]RWTH Aachen University, Germany

The Bethe-Salpeter Equation (BSE) and *GW* approximation are two many-body perturbation theory techniques that together form the state-of-the-art method to include electron-hole interaction in periodic systems. The BSE has proven to be the most accurate tool to compute optical absorption for the valence and core energy region, as well as electron energy loss. In recent developments the BSE has been applied to compute the exciton band dispersion and exciton effective masses, inelastic electron scattering, and many more.

We have implemented the BSE in the SPEX code, a full-potential linearized augmented planewave (FLAPW) code that supports a range of Green function based methods including the GW approximation, optical spectra in the random phase approximation, and more. The BSE is run on top of a one-shot G_0W_0 calculation with SPEX, or directly on top of the underlying density functional theory (DFT) calculations from FLEUR.

Our code has been tested for various bulk, layered and monolayer semiconductors, among them LiF and MoS2, and includes spin-orbit coupling. The results agree with the literature. We also use the crystal symmetries to achieve a significant computational speedup, and maintain good scalability of the code for parallel computing.

HL 3.22 Mon 10:00 P

Excitation-induced quenching and optical amplification in a CDW-phase of a two dimensional material — •Stephan Michael and Hans Christian Schneider — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, P.O. Box 3049, 67653 Kaiserslautern, Germany

The optical excitation of two dimensional materials like transition metal dichalcogenides (TMDs) in connection with their rich electronic phase diagrams offer new ways to manipulate material properties on ultrafast timescales [1,2]. We study theoretically the appearance and the quenching of a CDW phase in a model system of a two dimensional material due to optical excitation with time-dependent interaction matrix elements and screening effects. We describe the excitonic and coherent-phonon effects in the band-dynamics by electron-hole and electron-phonon coupling. The non-equilibrium carrier dynamics includes the optical excitation, the carrier-carrier scattering as well as the carrier-phonon scattering. We discuss how interaction processes affect anomalous expectation values and use projection techniques to illustrate the time-dependent appearance of additional bands. We propose an optical amplification effect in the mid-infrared up to infrared regime with a potential for high-frequency modulation.

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HL 3.23 Mon 10:00 P

Electric field manipulation of the Zeeman splitting in van der Waals heterostructures — •Paulo E. Faria Junior and Jaroslav Fabian — University of Regensburg, Regensburg, Germany

Under external magnetic fields, the interplay of spin and orbital angular momenta drives the Zeeman splitting, often encoded by the effective g-factors. Here, we explore the electric field control of g-factors in transition metal dichalcogenides (TMDCs) van der Waals heterostructures (vdWHs) of $MoSe_2$ and WSe_2. Using a full ab initio approach for the electronic structure and g-factors, we show that external electric fields introduce strong interlayer hybridization with robust signatures in the g-factors of interlayer and intralayer excitons. Furthermore, different interlayer exciton species can be identified by their characteristic dependence with respect to the electric field, an important information to disentangle the optical spectra observed in experiments. In summary, our study provides fundamental insight on the electric field manipulation of g-factors in TMDC-based vdWHs, benchmarking the relevant physics that must be included to investigate moiré excitons. Supported by SFB 1277 and SPP 2244.

HL 3.24 Mon 10:00 P

InGaAs Based Resonant Tunnelling Diodes By GSMBE — •Begum Yavas Aydin, Sven Höfling, Fauzia Jabeen, and Lukas Worschech — Technische Physik, University of Würzburg, Am Hubland, D-97074 Würzburg, Germany

Resonant Tunneling Diodes (RTD) are promising devices for various applications such as GHz to THz oscillators and high sensitivity photon detectors due to their ultra-high frequency, ultra-high-speed, and low power. High current density (JP) and high peak-to-valley current ratio (PVCR) are required for high-speed RTDs. To obtain high current densities and PVCR, structural parameter's dependence on barrier thickness, the spacer thickness of emitter and collector play key role.

InGaAs-based RTDs are grown by gas sources molecular beam epitaxy (GSMBE). High current density can be achieved by a thin barrier with a high electron transmission [1]. Peak current density reached 75 kA/cm2 with 1.5 nm thin AlAs barriers. Three RTD samples differing

in In0.53Ga0.47As collector spacer thickness of 5, 10, and 25 nm are grown. The highest JP of 500 kA/cm2 with PVCR 5.7 is achieved at room temperature for a 1.5 nm thin AlAs barrier and an asymmetric spacer layer.

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[2] Kanaya, H., et al. J. of Infrared, Millimeter, Terahertz Waves 35.5 (2014)

HL 3.25 Mon 10:00 P

Nonlinear THz spectroscopy at TeraFERMI — •Johannes Schmidt, Paola Di Pietro, and Andrea Perucchi — Elettra - Sincrotrone Trieste S.C.p.A., S.S. 14 km - 163,5 in Area Science Park, I-34149 Basovizza, Trieste, Italy

TeraFERMI is a THz beamline at the Free-electron laser (FEL) FERMI. After passing the undulator of the FEL the electron bunches are refocused on a thin slab and generate coherent transition radiation (CTR) as THz pulses with a spectral range of typically 0.1 to 6 THz. TeraFERMI provides strong single-cycle pulses with MV/cm electric peak fields or magnetic peak fields up to 1 T, which is in combination with the low repetition rate of 50 Hz an ideal source for nonlinear spectroscopy in many sciences from biology to physics. The short ps THz-pulses are phase-envelope stable with a low temporal jitter of about 66 fs (rms) and is therefore perfect for THz-pump probe experiments with different probe colors. Up to now, we focused on THz-pump NIR-probe and fluence-dependent THz spectroscopy. Thereby is the radial polarization of the beam a specialty of the CTR THz-beam and allows for longitudinal spectroscopy. Here, we report about the latest technological advances of TeraFERMI as well as first pilot experiments.

HL 3.26 Mon 10:00 P

Quantum anomalous Hall effect in Bernal-stacked bilayer graphene — Fabian Geisenhof[1], Felix Winterer[1], Anna Seiler[2], Jakob Lenz[1], Tianyi Xu[3], Fan Zhang[3] und •Thomas Weitz[2] — [1]Department of Physics, Ludwig-Maximilians-Universität München, Germany — [2]Department of Physics, University of Texas at Dallas, USA — [3]1st Physical Institute, University of Göttingen, Germany

The anomalous quantum Hall effect is a peculiar state of matter that has been observed in only very few materials systems including artificially engineered Moiré heterostructures [1]. However, the special bandstructure of naturally occurring bilayer graphene, has also been predicted to host an interaction-driven quantum anomalous Hall insulating phase at zero magnetic field [2], which has escaped previous experimental observation. Here, based on advanced sample design of near-field imaging, suspension and dual-gating, we show clear signatures of this quantum anomalous Hall insulating phase in ultra-clean bilayer graphene [3]. Besides the simplicity, diversity, and robustness of the system, the quantum anomalous Hall phase is also distinct from previously observed ones, since it is the first phase that does not only exhibit quantized charge Hall conductance at zero magnetic field, but also spin, valley and spin-valley anomalous quantum Hall effects as well as out-of-plane ferroelectricity.

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