HL 31: Focus Session: Young Semiconductor Forum Poster

The young semiconductor forum gives a platform for post-docs at all career stages to present themselves and their scientific ideas. It consists of an oral session with invited talks and immediately afterwards, a poster session, where further participants present a poster about their work and/or scientific vita. With this format, we hope to attract both postdocs and senior researchers and decision makers to join this forum: for postdocs, to give them a platform to present themselves, and for professors, to meet the next generation of scientists.

This part is the poster session.

Organized by Alexander Holleitner and the AGyouLeaP (Susanne Liese, Alexander Schlaich, and Christoph Kastl)

Time: Wednesday 12:15–13:00 Location: H13

HL 31.1 Wed 12:15 H13

Exploring Auto-Oscillations in Semiconductor Electron-Nuclear Spin System — •Alex Greilich, Nataliia E. Kopteva, Vladimir L. Korenev, and Manfred Bayer — Experimentelle Physik 2a, TU Dortmund University, Dortmund, Germany

We demonstrate self-sustained auto-oscillations in a dissipative electron-nuclear spin system (ENSS) in semiconductors, where spontaneous breaking of translational symmetry in time produces robust limit-cycle dynamics across a broad range of parameters, including laser power, temperature, and magnetic field. These periodic oscillations exhibit coherence times extending to hours, reflecting ideal "time atom" ordering within the auto-oscillatory system.

Additionally, we uncover synchronization within excited subsystems without additional modulation, identifying its microscopic origins. Under periodic driving, modulation of parameters such as excitation power and pump polarization yields parametric resonances, signaling a transition to discrete auto-oscillatory behavior. Key phenomena include frequency entrainment, Arnold tongues, bifurcation jets, and a devil's staircase, showcasing the ENSS's versatility in exploring nonlinear dynamics, with broad implications for both fundamental physics and semiconductor applications.

HL 31.2 Wed 12:15 H13

Reducing waste through substrate reuse: a pathway to cost-effective iii-v optoelectronics — •radouane ennadir — 3IT, Sherbrooke University, Sherbrooke, QC, Canada

III-V materials, such as Gallium Arsenide (GaAs), are widely used in optoelectronic devices due to their superior electronic and optical properties. However, the high cost of III-V substrates, primarily made from Ge or other expensive materials, represents a significant barrier to the widespread adoption of these technologies.

Our research focuses on reducing waste in the production of III-V optoelectronics through the reuse of Germanium (Ge) substrates. In this study, we propose a novel approach to mitigate substrate waste by reusing Ge substrates in the fabrication of III-V optoelectronics. By carefully optimizing the recycling process, including substrate cleaning, surface treatment, and the integration of new III-V layers, we aim to significantly reduce material costs without compromising device performance. This approach not only enhances the sustainability of optoelectronic manufacturing but also provides a cost-effective pathway to large-scale production of III-V-based devices. The findings of this study contribute to both environmental sustainability and economic viability in the growing field of optoelectronics, opening up new opportunities for the development of advanced, cost-effective optoelectronic devices.

HL 31.3 Wed 12:15 H13

1D exciton confinement in monolayer $MoSe_2$ near ferroelectric domain walls in periodically poled $LiNBo_3$ — •Pedro Soubelet, Yao Tong, Asier Astaburuaga Hernandez, Andreas V. Stier, and Jonathan J. Finley — Walter Schottky Institut and TUM School of Natural Sciences, Technische Universität München, Am Coulombwall 4, 85748 Garching, Germany

Monolayer transition metal dichalcogenides are an emergent platform for exploring and engineering quantum phenomena in condensed matter. Due to their atomic thickness, the excitonic response is highly influenced by the dielectric environment. In this work, we explore the optical properties and exciton kinetics of monolayer thick $MoSe_2$ straddling domain wall boundaries in ferroelectric periodically poled $LiNbO_3$ (PPLN). Spatially resolved photoluminescence (PL) experiments reveal sorting of neutral and charged excitons across the boundary. Our results reveal evidence for extremely large in-plane electric fields ($\simeq$4000 kV/cm) at the domain wall (DW), whose effect is manifested in the routing of free charges and trions towards oppositely poled domains, resulting in a nonintuitive spatial PL intensity pattern. In a second step, we engineer the PPLN substrate and the 2D heterostructure to exploit the non-uniform in-plane electric field exerted by the DW to confine neutral excitons in a 1D dipolar gas. Reducing the dimensionality holds an excellent potential for unlocking strong exciton-exciton interaction regimes, enabling exploration of exotic quantum phases of matter and designing advanced optoelectronic devices.

HL 31.4 Wed 12:15 H13

Probing strong electron-phonon coupling in graphene by resonance Raman spectroscopy with infrared excitation energy — •Simone Sotgiu[1,2], Tommaso Venanzi[1], Lorenzo Graziotto[1], Francesco Macheda[1], Taoufiq Quaj[2], Elena Stellino[1], Bernd Beschoten[2], Christoph Stampfer[2], Francesco Mauri[1], and Leonetta Baldassarre[1] — [1]Department of Physics, Sapienza University of Rome, Rome, Italy — [2]JARA-FIT and 2nd Institute of Physics, RWTH Aachen University, Aachen, Germany

Resonance Raman spectroscopy (RRS) has been a key asset to study the interplay between electronic and vibrational properties of graphene. We report on RRS measurements with an excitation photon energy down to 1.17 eV on mono (MLG) and bilayer (BLG) graphene, to study how low-energy carriers interact with lattice vibrations. Thanks to the excitation energy close to the Dirac point, we unveil in the MLG a giant increase of the intensity ratio between the double-resonant 2D and 2D* Raman peaks with respect to graphite [1]. In BLG, the low excitation energy hampers some of the resonant Raman processes giving rise to the 2D peak. Consequently, the subfeatures composing the 2D mode are spectrally more separated with respect to visible excitations. We compare experimental measurements on BLG with ab initio theoretical calculations and we trace back such modifications on the joint effects of probing the electronic dispersion close to the band splitting and enhancement of electron-phonon matrix elements [2]. [1] T. Venanzi et al., Phys. Rev. Lett. 2023, 130, 256901 [2] L. Graziotto et al., Nano Lett. 2024, 24, 1867

HL 31.5 Wed 12:15 H13

Effects of atomistic fluctuations on the excitonic fine-structure in alloyed colloidal quantum Dots — •Anne Nadine Tewonoue Djota, Surender Kumar, and Gabriel Bester — Institute of physical chemistry and physics, University of Hamburg

The electron-hole exchange interaction in the presence of spin-orbit coupling leads for an atomistic calculation to a small energy splitting of the excitonic state known in this context as the fine structure splitting (FSS). Although this splitting is typically small, it has large consequences for the optical properties. For instance, the photoluminescence originates from these few states and is governed by the splitting (giving rise to temperature dependence) and polarization of these low energy excitonic states. So far most of the theoretical modeling has assumed that high symmetry structures lead to a simple dark-bright splitting with a large degeneracy of the excitonic states. In this work, we show based on atomistic calculations, that even globally perfectly symmetric structures (i.e., as far as an atomistic construction permits a "spherical" quantum dot) show a qualitatively different FSS as soon as alloying is introduced. The alloying effect is significantly stronger than any global shape anisotropy where the symmetry is broken for instance by geometrical elongation of the quantum dot. On the other hand, al-

loying a quantum dot through processes such as cation exchange is inherently random. As a result, different random alloy configurations with the same size and composition can exhibit significantly different FSS.

HL 31.6 Wed 12:15 H13

Resistance standards from artifact wire coils to graphene quantum Hall resistance — •Yefei Yin[1], Mattias Kruskopf[1], Stephan Bauer[1], Teresa Tschirner[1], Klaus Pierz[1], Frank Hohls[1], Rolf J. Haug[2], and Hans W. Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover, Germany

Historically, resistance standards were made by physical artifact wire coils before 1990 and quantum resistors based on GaAs heterostructures after 1990. However, conventional GaAs quantum Hall resistance (QHR) standards with the quantized resistance $R_H = h/2e^2$ are operating under high magnetic flux densities B > 10 T, limited currents I < 50 μA, and low temperatures T < 1.5 K, which significantly hinder the dissemination of primary resistance standards. In this work, we developed practical primary QHR standards based on n- and p-type epitaxial graphene. This study first systematically demonstrated that p-type epitaxial graphene can also be used for primary resistance standards, as accurate (10^{-9} accuracy) as GaAs and n-type graphene counterparts for realizing the SI unit ohm in quantum metrology. [1] The n-type graphene QHR standards achieved the world best performance so far with a 10^{-9} accuracy under relaxed conditions (B = 4.5 T, I = 232.5 μA, T = 4.2 K) simultaneously. [2-3] Our graphene QHR standards have been utilized in the national metrology institutes in European countries. [1] Appl. Phys. Lett., 125, 064001 (2024). [2] Adv. Phys. Res. 1, 2200015 (2022). [3] Phys. Rev. Applied, 2024

HL 31.7 Wed 12:15 H13

Hybridized excitons in 2D van der Waals materials — •Andreas Stier — Walter Schottky Institut und TUM School of Natural Sciences, TU München, Garching, Deutschland

I will review our recent progress on magneto optical spectroscopy of atomically thin materials in magnetic fields up to 91 T with an emphasis on the spin-valley physics of neutral and charged excitons.

In monolayer (ML) semiconductors, magneto-absorption spectroscopy revealed the diamagnetic shifts of the exciton Rydberg states, which allowed the first direct experimental measure of the reduced mass and binding energy. Surprisingly, investigating the photoluminescence, we observe the emergence of a new excitonic peak, which we discuss in the framework of the theoretically predicted linear dispersing exciton branch originating from intervalley exchange interactions.

For heterostructures (HS) of a 2D semiconductor with graphene, we find a new multi-step proximity effect due to band folding in the HS, where we show that the spin-valley physics can be used to quantify interlayer hybridization. In HS from ML MoSe2 and the layered antiferromagnetic (AFM) semiconductor CrSBr, we show the formation of new exciton states depending on the twist angle. These excitons exhibit clear signatures of proximity coupling to the magnetic state of the AFM layer, such as hysteretic response to in- and out of plane B fields. We discuss these results in the framework of Ising-type spin-orbit proximity coupling.

HL 31.8 Wed 12:15 H13

Shaped pulses enable robust coherent control of quantum dots: perspectives for quantum technologies — •Vikas Remesh — Institute für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria

Shaped laser pulses have been remarkably effective in investigating and controlling various light-matter interactions in a broad area of research. In quantum technologies, the techniques to shape complex spatiotemporal waveforms have found renewed interest, for instance in coherent control of quantum dots [1]. In this talk, I will navigate through the impact of pulse shaping techniques in nanospectroscopy and how it enabled efficient preparation schemes in quantum dots, based on our recent works [2], including the pioneering off-resonant coherent control of quantum dots, compact plug-and-play method of exciting multiple quantum dots and accessing dark excitons in quantum dots for advanced entanglement generation. Afterwards, I will conclude with my vision on the future scope of nanophotonics-assisted-quantum technology roadmap. [1] Photonic Quantum Technologies: Science and Applications 1, 53 (2023) [2] Nano Letters 22, 6567 (2022), Materials for Quantum Technology 3, 025006 (2023), APL Photonics 8, 101301 (2023), npj Quantum Information 10, 17 (2024), Advanced Quantum Technologies, 2300352 (2024), arXiv:2409.13981, arXiv:2406.07097, arXiv:2404.10708

HL 31.9 Wed 12:15 H13

First-Principles Investigation of NV Centers in Silicon Carbide Polytypes — •Timur Biktagirov, Uwe Gerstmann, and Wolf Gero Schmidt — Universität Paderborn, Paderborn, Germany

Optically addressable spin defects in semiconductors offer versatile platforms for quantum applications, including computing, communication, and sensing. Among these, nitrogen-vacancy (NV) centers in silicon carbide (SiC) polytypes have emerged as a promising class of quantum defects, analogous to the NV center in diamond. In contrast to diamond, SiC is a technologically mature material with large-scale production capabilities, advanced doping techniques, and compatibility with CMOS fabrication methods. Additionally, the emission wavelengths of NV centers in SiC lie in the near-infrared range, making them particularly suitable for applications in single-photon emission. In this work, we discuss recent advancements in the ab initio investigation of NV centers in the 4H, 6H, and 3C polytypes of SiC. Simulating the magneto-optical properties of these spin centers, which are crucial for quantum applications, requires a detailed and accurate description of both the host material and the embedded defect. Accordingly, we demonstrate how supercell density functional theory (DFT) and recent implementations based on DFT can be employed to model key properties, including intra-defect optical transition energies, electron-electron and electron-nuclear spin interactions, and electron-phonon coupling. These theoretical insights provide a foundation for optimizing NV centers in SiC for next-generation quantum technologies.

HL 31.10 Wed 12:15 H13

Transport properties of quantum dots for single-electron pumps — •Johannes C. Bayer, Thomas Gerster, Dario Maradan, Frank Hohls, and Hans W. Schumacher — Physikalisch-Technische Bundesanstalt, 31668 Braunschweig, Germany

A single-electron pump (SEP) is a device emitting a well-defined number of n electrons per cycle of an external drive. With driving frequency f and elementary charge e, this results in a current of $I = nef$. Since the revision of the SI system, the elementary charge e hereby is an exact value, so that SEPs provide a suitable basis for a quantum current standard. The accuracy of this current is directly related to erroneous cycles, where the emitted number of electrons deviates from n. Our SEP devices are based on electrostatically defined quantum dots in GaAs/AlGaAs two-dimensional electron gases. In such devices, the tunnel barriers as well as the energy levels are controllable via gate voltages. Based on multiple quantum dot devices we here investigate relations between transport properties and SEP operation characteristics.