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Complexity and Topology in Quantum Matter

Julius-Maximilians-UNIVERSITÄT WÜRZBURG

TECHNISCHE UNIVERSITÄT DRESDEN

Sixth QMA Retreat

31 Mar – 02 Apr 2025

MONDAY, March 31

	Arrival	
12:00–13:30	Lunch	
13:30–14:00	Welcome	*Maximillian Ünzelmann*
14:00–15:30	**Nonlinear THz field driven dynamics in conducting systems**	***Sergey Kovalev*** TU Dortmund
15:30–16:00	Coffee Break & Check-In	
16:00–18:30	**Workshops** • Complex Content – Captivatingly Presented	***Roland Wengenmayr***
	• Publishing in Nature Portfolio Journals	***Silvia Conti***
	• Effective Presentation – Talks and Posters with Confidence	***Alexander Schiller***
18:30–20:00	Dinner	
20:00–21:00	Ice Breaker	

TUESDAY, April 01

07:00–08:30	Breakfast	
08:30–12:00	Social activity • Excursion to ZEISS • City tour (English)	
12:00–13:30	Lunch	
13:30–15:00	**Diagrammatic approach to frustrated quantum spin systems**	***Björn Sbierski*** The University of Tübingen
15:00–15:30	Group Photo Session	
15:30–16:00	Coffee Break	
16:00–17:40	**Session 1: Student talks**	
16:00–16:20	Topological insulator surface states in a magnetic field	***Shyam Sundar Yadav*** JMU Würzburg

16:20–16:40	Nuclear introduction, use of radioactive decay for insights in periodically polarized $LiNbO_3$	***Hannes Gürlich*** TU Dresden
16:40–17:00	Klein tunneling Diode effect in Dirac p-n junction of zerogap HgTe quantum wells	***Shoubnik Mandal*** JMU Würzburg
17:00–17:20	Time-resolved Uni-directional Propagation Of Exciton-Polariton Condensates In a Kagome Edge Mode	***Christian G. Mayer*** JMU Würzburg
17:20–17:40	$PbCuTe_2O_6$ is not just a quantum spin liquid candidate: structural insights	***Alexander Mistonov*** TU Dresden
17:40–18:00	**Poster Preparation**	
18:00–19:30	**Dinner**	
19:30	**Poster Session** **Link to Youtube with Poster Pitches**	

WEDNESDAY, April 02

07:00–09:00	**Breakfast**	
09:00–10:30	**Session 2: Student talks**	
09:00–09:20	Fracton gauge theories from internal space MDMA	***Alessio Caddeo*** JMU Würzburg
09:20–09:40	Phonon-mediated un3w2conventional superconductivity on the surface of Weyl semimetals	***Kristian Mæland*** JMU Würzburg
09:40–10:00	Influence of effective mass on the Coherence properties of exciton-polariton condensates	***Siddhartha Dam*** JMU Würzburg
10:00–10:20	Transport properties of ternary $Sb_2Se_yTe_{3-y}$ -based topological insulators	***Shailja Sharma*** IFW Dresden
10:30–11:15	**Coffee Break & Check-Out**	
11:15–12:00	**Closing Remarks & Award Ceremony**	***Prof. Matthias Bode***
12:00–13:30	**Lunch**	
13:30	**Departure/Start of third *ct.qmat* Spring School**	

Invited Speakers

Nonlinear THz field driven dynamics in conducting systems

Sergey Kovalev
Dortmund University, Germany

Non-linear processes in various systems play a very important role in our modern society. For example, the non-linear volt-ampere characteristics of electronic circuits lead to the possibility of active control of electrical signals, which in turn has led to the development of computers operating at GHz frequencies. The non-linear interaction of visible light with materials led to light frequency conversion/mixing, which is explicitly used for information transmission in fibre optic networks. Performing data processing and information transmission/storage at THz bandwidth is one of the current challenges in technology, leading to extensive research on ultrafast and nonlinear THz field-driven dynamics in various systems. Although the THz band lies between the well-developed microwave and visible frequency ranges, the nonlinear THz light-matter interactions are still under development. In this talk I will review the recent progress in nonlinear THz light-matter interactions based on several types of conducting systems, namely Dirac and Rashba type materials, magnetic heterostructures and heavy metal films with pronounced spin-Hall conductivity. In such systems the aspects of THz field driven charge carriers, spin and orbital polarisation dynamics will be considered.

Diagrammatic approach to frustrated quantum spin systems

Björn Sbierski
University of Tübingen, Germany

Frustrated quantum spin systems are often challenging to treat theoretically with state-of-the-art numerical methods. We review various diagrammatic approaches using both auxiliary particle representations of spins and an alternative technique working with spin operators directly. Many practical applications ranging from solid state quantum magnets to cold atom Rydberg quantum simulators are considered.

Workshops

Complex Content – Captivatingly Presented

Roland Wengenmayr

A glimpse into science journalism and what you can learn from it for your own presentations.

All scientists are constantly faced with a challenge: how to present their research in a captivating and understandable way so that even laypeople can remember the key messages. This is a challenge even for colleagues who do not conduct research in this specific field but who, for example, have a say in funding awards as reviewers. Science journalism, on the other hand, specializes in translating complex research topics into stories that are understandable and exciting to read. Roland Wengenmayr, a very experienced freelance science journalist and physicist, has been writing such stories for leading print media for decades. In his workshop, he teaches basic tools for presenting your own research work in such a way that the core message is successfully conveyed to the target audience. The workshop will start with a 30-minutes-talk with the option to ask questions afterwards, then followed by practical exercises with very short text formats.

About the trainer: Roland Wengenmayr studied physics, was in the 1990s a science book editor at Wiley-VCH and started a freelance science journalist's career in 2000. Since then, he wrote and writes frequently for leading German language media such as "Frankfurter Allgemeine", "Neue Zürcher Zeitung (NZZ)", specialized media such as "Max-Planck-Forschung". He is also editor of the German physics magazine "Physik in unserer Zeit" (published by Wiley-VCH). In 2013, he was awarded by the German Physical Society with the Medaille für naturwissenschaftliche Publizistik (Medal for Science Journalism) together with his collegue Thomas Bührke (https://www.dpg-physik.de/auszeichnungen/dpg-preise/medaille-fuer-naturwissenschaftliche-publizistik/preistraeger). He also works as a science cartoonist. More on his homepage: www.roland-wengenmayr.de

Publishing in Nature Portfolio journals

Silvia Conti

The talk "Publishing in Nature Portfolio journals" will be delivered by Dr. Silvia Conti, one of the editors of *Nature Reviews Electrical Engineering*, and is intended to cover the essential aspects of scientific writing and publishing with a strong emphasis on Nature journal standards and best practices. The presentation will provide the opportunity to learn about the Nature family of journals and its hierarchy. We will touch upon the editorial criteria, content types and peer-review process. Finally, the key strategies for writing a scientific publication will be presented with the emphasis on the differences between the publication process in Nature Reviews and Nature Research journals.

About the trainer: Dr. Silvia Conti is an Associate Editor at Nature Reviews Electrical Engineering at Springer Nature, where she oversees high-impact publications in the field of electrical and electronic engineering: https://www.nature.com/natrevelectreng/editors.
Before joining Springer Nature, Dr. Conti conducted research in printable and flexible electronics, organic and 2D materials, and advanced material characterization. Her expertise spans scientific writing, peer review, and the editorial workflow, positioning her to offer valuable insights into the academic publishing process.

Effective Presentation – Talks and Posters with Confidence

Alexander Schiller

Presenting your research effectively is a key skill for scientists, whether in conferences, group meetings, or poster sessions. This interactive training provides essential strategies for structuring engaging talks and designing impactful posters. Participants will learn how to captivate their audience, communicate complex ideas clearly, and handle Q&A sessions with confidence. Additionally, we will address common concerns about stage presence and provide practical techniques to enhance confidence and overcome stage fright. Through hands-on exercises and feedback, attendees will leave with concrete tools to improve their presentation skills and make a lasting impression.

About the trainer: Dr. Alexander Schiller is a habilitated chemist and experienced facilitator based in Jena, Germany. He has been enhancing academic teaching and coaching since 2000 at notable institutions such as LMU Munich, EPF Lausanne, UC Santa Cruz, and University Jena. He holds certifications as a facilitator and coach, specializing in interactive and simulation-based learning for professionals worldwide. Dr. Schiller has notably contributed to over 19,000 scientists' training through his company, Schiller & Mertens GbR(https://www.schillermertens.de/). His research in inorganic chemistry has led to numerous publications, fostering his ability to address scientists' real needs in professional development.

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Student Talks

#	Title	Presenter
1	Topological insulator surface states in a magnetic field	Shyam Sundar Yadav JMU Würzburg
2	Nuclear introduction, use of radioactive decay for insights in periodically polarized $LiNbO_3$	Hannes Gürlich TU Dresden
3	Klein tunneling Diode effect in Dirac p-n junction of zero-gap HgTe quantum wells	Shoubnik Mandal JMU Würzburg
4	Time-resolved Uni-directional Propagation Of Exciton-Polariton Condensates In a Kagome Edge Mode	Christian G. Mayer JMU Würzburg
5	PbCuTe2O6 is not just a quantum spin liquid candidate: structural insights	Alexander Mistonov TU Dresden
6	Fracton gauge theories from internal space MDMA	Alessio Cadeo JMU Würzburg
7	Phonon-mediated un3w2conventional superconductivity on the surface of Weyl semimetals	Kristian Mæland JMU Würzburg
8	Influence of effective mass on the Coherence properties of exciton-polariton condensates	Siddhartha Dam JMU Würzburg
9	Transport properties of ternary $Sb_2Se_yTe_{3-y}$ -based topological insulators	Shailja Sharma Leibniz Institute Dresden

Topological insulator surface states in a magnetic field

Shyam Sundar Yadav
JMU Würzburg

In a 3D TI the top and bottom topological surface states (TSS) are treated as two independent two dimensional Dirac systems and manifested by the observation of the odd filling factor emerges for the equal density at the top and bottom surface. In this talk I will be presenting the magneto transport study on a HgTe 3D TI with dual gated structure. Dual gated technique (V_{tg}, V_{bg}) allows to tune the density of the top and bottom layer individually. Under low magnetic field different transport phases in a Ïƒ (V_{tg} , V_{bg}) map are observed. For the equal density at the top and bottom surface we observe even number of filling factor together with weakly resolved odd filling factor along the equal density line. We explain our experimental observation by considering opposite chirality of the top and bottom surface that leads to the asymmetric Zeeman splitting of the top and bottom TSS. A model based on k.py calculations support the experimental observations. Electrostatic tunability of the individual surface sates can be a important ingredient that may lead to emergent of quantum electronic phases such as topological exciton condensation.

Nuclear introduction, use of radioactive decay for insights in periodically polarized LiNbO3

Hannes Gürlich
TU Dresden

To determine the crystal structure in periodically polarized $LiNbO_3$ (PPLN), the nuclear method Perturbed Angular Correlation (PAC) was used. For this hyperfine radioactive ^{111m}Cd was introduced at 30 keV into the z-cut crystal (~200 nm deep). During the decay process of ^{111m}Cd, two photons are emitted. The angle between these two photons depends on the electric field gradient (EFG) at the nucleus and, therefore, on the atomic environment of the in the crystal lattice integrated ^{111m}Cd. By measuring the angular correlation of several billion of these decays and comparing the EFG results to theoretical calculations, the positioning of the atoms in the crystal lattice can be deduced.

It was found that the EFG differs between the Z+ and Z− sides of the crystal. Furthermore, it is suggested that as ^{111m}Cd does not accumulate at the domain wall (in contrast to other ions), the domain wall influences ^{111m}Cd atoms up to 1 µm away from the domain wall.

Klein tunneling Diode effect in Dirac p-n junction of zero-gap HgTe quantum wells

Shoubhik Mandal
JMU Würzburg

HgTe quantum well (QW) with critical thickness is a single valley 2-D Dirac semimetal with a gapless linear energy band structure. We studied the gate voltage tunable p-n junction in this HgTe QW in the diffusive regime. The electrical transport of the Dirac carriers is supposed to be dominated by Klein-Tunneling effect at normal incidence through the barrier regardless of the potential height. In contrast, in the conventional semiconducting p-n junction, tunneling depends on the bias voltage polarity and the barrier height. We report that the bias voltage-dependent differential conductance measurement on a tri-gated microstructure device shows super-linear behavior (I â^□ V^Î±, Î±â‰^1.5) distinct from Ohmic linearity, as an indication of Zener-Klein current. In the case of a symmetric p-n junction, at high forward bias voltage close to built-in potential, we observed the sudden onset of current, denoted as the non-tunneling current in addition to Zener-Klein current. Reverse biased I-V curve is mostly dominated by Zener-Klein current, indicated as super-linear I-V curves (I â^□ VÎ±, Î±â‰^1.5). We elucidated the kâ^™p bandstructure calculation on the HgTe QW to show the consistency in the built-in potential value extracted experimentally. Further, we studied the application of magnetic field on I-V curves which show the significant shift in the built-in potential, probably due to the magnetic gap in Dirac cone. Our study will help to provide a clear view for the future development of n-p-n transistors that utilize highly mobile Dirac carriers.

Time-resolved Uni-directional Propagation Of Exciton-Polariton Condensates In a Kagome Edge Mode

Christian G. Mayer
JMU Würzburg

The strong coupling between photons and excitons in an optical microcavity gives rise to hybrid light-matter quasiparticles known as exciton-polaritons. Due to their bosonic nature, these quasiparticles undergo a phase transition at a critical density, forming a dynamic condensate through stimulated scattering. By confining exciton-polaritons, here within photonic potentials, it becomes possible to emulate two-dimensional lattice Hamiltonians. In this framework, the etch-and-overgrowth (EnO) technique provides new avenues for the realization and control of complex, densely packed polariton lattices in the III-V platform. Motivated by the intriguing properties of the Kagome lattice – such as flatband physics and intrinsic unit cell frustration – we observe an anomalous propagation behavior of the polariton condensate in this lattice. The edge mode appears spectrally below the S-flatband and exhibits unidirectional propagation. When a single site of the edge is excited, the locally generated polariton condensate propagates depending on the excitation position. We demonstrate the existence of this unidirectional propagating mode above threshold through energy-resolved imaging in both real and Fourier space. Furthermore, time-resolved measurements using a streak camera reveal that the condensate propagates in a single direction along the lattice edge, undergoing hopping transport across multiple sites in a two-dimensional lattice with a velocity of v_{prop}=(2.50±0.27) μm ps^{-1}. This study suggests that unidirectional edge-state transport can arise in a photonic platform without the requirement of engineered topology.

$PbCuTe_2O_6$ is not just a quantum spin liquid candidate: structural insights

Alexander Mistonov
TU Dresden

$PbCuTe_2O_6$ (PCTO) is well known as a promising candidate for quantum spin liquid compounds. Magnetic ordering does not occur down to 0.02 K [1]. Additionally, diffuse continua are observed in magnetic spectra [2]. At the same time, heat capacity and dielectric response demonstrate signatures of an order-disorder ferroelectric (FE) transition at ~ 1 K [3]. According to thermal expansion measurements, this transition is believed to be accompanied by structural changes. We have performed a high-energy single-crystal X-ray diffraction experiment using a dilution refrigerator to investigate it for the first time. We have observed Bragg peaks that are forbidden for the reported high-temperature crystal structure (space group $P4_132$ [4]) and studied their evolution. In the current work, we share our findings from below and above the FE transition.

References:

1. P. Khuntia et al., Phys. Rev. Lett. 116, 107203 (2016).

2. S. Chillal et al., Nat. Commun. 11, 2348 (2020).

3. C. Thurn et. al., npj Quantum Mater. 6, 95 (2021).

[4] A. R. N. Hanna et al., Phys. Rev. Mat. 5, 113401 (2021).

Fracton gauge theories from internal space MDMA

Alessio Caddeo

JMU Würzburg

Fractons are quasiparticles characterised by restricted mobility. Fracton gauge theories feature exotic conservation laws, such as multipole or subsystem symmetries. I will discuss how fracton theories can be derived by realising the monopole-dipole-momentum algebra (MDMA) in an internal space, and how this realisation enables coupling to curved spacetimes.

Phonon-mediated un3w2conventional superconductivity on the surface of Weyl semimetals

Kristian Mæland

JMU Würzburg

Recent experiments on $PtBi_2$ show that Weyl semimetals can host surface superconductivity in the Fermi arcs, while remaining metallic in the bulk. We study an effective lattice model of a Weyl semimetal to see if phonons are a candidate pairing mechanism to explain this phenomenon. Specifically, we make predictions about the momentum dependence of the gap function by solving gap equations within a weak-coupling approach to superconductivity. We connect the momentum dependence of the gap function to properties of the phonon-mediated pairing mechanism.

Influence of effective mass on the Coherence properties of exciton-polariton condensates

Siddhartha Dam

JMU Würzburg

The coherence properties of exciton-polariton condensates reveal important aspects of their macroscopic nature. These macroscopic condensates are intricately dependent on the microscopic properties of the system, such as excitons. However, tuning the effective mass of these condensates also plays a vital role in the buildup of the spontaneous coherence in these systems, which can be achieved using photonic lattices. The condensate's effective mass integrates the lattice geometries into its microscopic properties, thereby affecting the coherence of the emitted light. Here, we show how the different effective masses at the high-symmetry points of a simple square lattice and a trigonal lattice give rise to strikingly different coherence properties. We also demonstrate how this understanding can be exploited to observe interesting physical effects in these systems.

Transport properties of ternary $Sb_2Se_yTe_{3-y}$ -based topological insulators

Shailja Sharma
Leibniz Institute for Solid State and Materials Research Dresden

Electrical and thermoelectric transport properties of $Sb_2Se_yTe_{3-y}$ (y = 0.3… 2) were determined on single crystals in the temperature range 1.8 - 380 K. The measured structural and transport parameters follow systematically the Sb2Se3-Sb2Te3 alloy system across the miscibility range and structural change. The crystals showed dominance of p-type charge carriers with very low thermal conductivity in the order of 1 W/m-K at 300 K. Clear indications of multi-band transport were seen in Hall resistivity and in Seebeck coefficients, the most pronounced at nominal y=1, where a sign change to negative values was observed. Crystals with nominal y = 1.2 and 1.5 showed very low Seebeck coefficient values from about 30 K downwards and large magnetoresistance values. This study suggests a substantial modification to the electronic band structure and Fermi surface as a result of the variation in Se/Te content in the $Sb_2Te_{3-y}Se_y$ - based systems

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Student Poster Contributions

#	Title	Presenter
1	A Single Crystal Study of the Kagome Magnets RMn6Sn6 (R = Er and Tm)	Ana Kurtanidze HZDR
2	Non-Hermitian Skin Effect in Quantum Emitter Chains	Pia Kress JMU Würzburg
3	Growth of altermagnetic MnTe thin films	Lena Hirnet JMU Würzburg
4	Moire Phases of an Epitaxial Honeycomb Monolayer AgTe/Ag(111)	Romana Ganser JMU Würzburg
5	From Condensed Matter to Holography: Complexity Dynamics of Rotating Strings via the XXX Spin Chain	Rathindra Nath Das JMU Würzburg
6	Encapsulated Macroscopic WS2 in open-cavity photonic lattices	Sander Scheel JMU Würzburg
7	Spectroscopic Study of the Interface between Organic Molecules and Platinum Tellurides	Lorenz Klein JMU Würzburg
8	Phase diagram of the J–Jd Heisenberg model on the maple leaf lattice: Neural networks and density matrix renormalization group	Jonas Beck JMU Würzburg
9	Meissner-Effect in Non-Hermitian Superconductors	Linus Aliani JMU Würzburg
10	Proposed STM Study on FeSe: Investigating the Superconducting Nature and Surface Properties	Soumya Datta JMU Würzburg
11	CDW transition in AV_3Sb_5 kagome metals	Stefan Enzner JMU Würzburg
12	Engineering Topological Laser in Organic Microcavities	Harman Jot Singh JMU Würzburg
13	Chiral spin liquid in external magnetic field: Phase diagram of the decorated-honeycomb Kitaev model	Sabastian Granberg Cauchi TU Dresden
14	Accessing Anti-de-Sitter spacetime using optical lattices	Coraline Bacq JMU Würzburg

A Single Crystal Study of the Kagome Magnets RMn_6Sn_6 (R = Er and Tm)

Ana Kurtanidze
HZDR

The kagome magnets RMn_6Sn_6 (R = Sc, Y, Gd-Lu) with a hexagonal structure (P6/mmm) attract attention due to a possible correlation between the observed topological electronic properties and various magnetic phases. We synthesized high-quality single crystals of RMn_6Sn_6 (R = Er and Tm) by a tin-flux method. We performed scanning electron microscopy, energy-dispersive x-ray spectroscopy, and wavelength-dispersive x-ray fluorescence measurements to characterize the phase purity of the samples, which showed a composition close to the nominal stoichiometric ratio. We observed approximately 0.25 at.% aluminum impurity, which originated from the alumina crucibles used. In addition to the chemical characterization, we will discuss the magnetic properties from our preliminary magnetization and ultrasound results under magnetic fields applied along the principal crystallographic axes.

Non-Hermitian Skin Effect in Quantum Emitter Chains

Pia Kress
JMU Würzburg

We theoretically investigate the emergence of the non-Hermitian skin effect (NHSE) in a one-dimensional chain of quantum emitters coupled to a waveguide. Mediated by the waveguide, the emitters interact via non-reciprocal long-range couplings, rendering the system a generalized Hatano-Nelson model. We explore the topology of this non-Hermitian system by analyzing the winding number as a topological invariant in the complex energy spectrum. Beyond a critical asymmetry, multiple spectral loops are formed, yielding a nonzero winding number. Furthermore, we study the relation of the spectral winding number to the emergence of the NHSE in presence of long-range couplings.

Growth of altermagnetic MnTe thin films

Lena Hirnet
JMU Würzburg

Recently, altermagnets have attracted great attention combining antiferromagnetic spin alignment in real space with a momentum-dependent spin polarization of the electronic states in the band structure. One of the proposed altermagnet workhorse materials is MnTe [1,2]. Here, we investigate the epitaxial growth of MnTe on different substrates ranging from trivial band insulators to topological van der Waals metals with spin-momentum-locked surface states. The atomic and electronic structure of these films is studied employing low-energy electron and x-ray diffraction as well as soft x-ray angle-resolved photoemission spectroscopy, respectively.

References:

1. L. Šmejkal et al., Phys. Rev. X 12, 031042 (2022)

2. J. Krempaský et al., Nature 626, 517-522 (2024)

Moire Phases of an Epitaxial Honeycomb Monolayer AgTe/Ag(111)

Romana Ganser
JMU Würzburg

We present angle-resolved photoemission spectroscopy (ARPES) measurements on tunable one-dimensional moiré phases of an epitaxial honeycomb monolayer AgTe/Ag(111) [1]. In this model system, the moiré structure can be tuned almost continuously, in contrast to the hardly controllable twist angles in bilayer van-der-Waals heterostructures [2]. We experimentally observe moiré minibands and band gaps of up to 170 meV, suggesting sizable superlattice potentials. By comparing the experimental data to simple model calculations, we analyze the local character of the potential. This provides important information on interface hybridization effects on the band structure, which may not be limited to the system at hand but rather a broad range of moiré interfaces.

References:

1. Ünzelmann, M. et al. PRL, 124, 176401 (2020).
2. Lisi, S. et al. Nat. Phys, 17, 189-193 (2021).

From Condensed Matter to Holography: Complexity Dynamics of Rotating Strings via the XXX Spin Chain

Rathindra Nath Das
JMU Würzburg

State complexity in the Krylov subspace, known as the spread complexity, is a quantum information-theoretic measure of operator and state growth that has emerged as a powerful tool for analyzing quantum many-body dynamics. In this work, we extend the spread complexity beyond bosonic systems to fermionic and supersymmetric settings, enabling its application in holography and the AdS/CFT correspondence. We compute the spread complexity of large-charge semiclassical string states propagating in $AdS_5 \times S^5$, utilizing the integrable XXX spin chain—a fundamental model in condensed matter physics—to construct the Krylov basis. By employing coherent states and spin chain techniques, we describe the evolution of complexity as a Krylov path in a higher-dimensional lattice, effectively capturing the geometry governing the string's propagation. This work establishes a direct connection between quantum information, condensed matter physics, and holography, demonstrating how spread complexity, applied to the XXX spin chain and coherent states, reveals new insights into semiclassical string dynamics and emergent dynamical symmetries in Krylov space.

Encapsulated Macroscopic WS_2 in open-cavity photonic lattices

Sander Scheel
JMU Würzburg

Transition metal dichalcogenide (TMDC) monolayers are promising candidates for optoelectronic applications, but so far, their high optical quality is typically limited to micrometer-sized flakes, requiring labor-intensive production methods. Large-area TMDC films, however, are often affected by surface defects and optical inhomogeneities due to the lack of effective passivation.

In this work, an alternative encapsulation technique using 1-dodecanol is investigated to passivate gold tape-aided exfoliated WS_2 monolayers, ensuring uniform high optical quality over lateral scales exceeding 0.5 x 0.5 mm^2. These samples are compared in an open optical microcavity system to the well-known hBN-encapsulated WS_2 monolayers obtained by scotch-tape exfoliation. After establishing the high optical quality of the 1-dodecanol encapsulated monolayer, we were able to conduct investigations involving extended photonic lattices that were previously restricted by the limited material size. The results indicate that 1-dodecanol encapsulation preserves excitonic properties and enables scalable integration with photonic architectures, representing an important step towards large-area experiments on (strong) light-matter coupling and next-generation optoelectronic devices.

Spectroscopic Study of the Interface between Organic Molecules and Platinum Tellurides

Lorenz Klein
JMU Würzburg

Van der Waals heterostructures of organic molecules and transitionmetal chalcogenides (TMCs) represent excellent model systems for thestudy of weak molecule-substrate interactions.Here, we use two phases of metallic platinum telluride, which bothhost spin-polarized surface states in their electronic surface band structures.Using those as substrates, we deposit copper phthalocyanine(CuPc) and study the resulting atomic and electronic interface structureby means of x-ray (XPS) and angle-resolved photoemission spectroscopy(ARPES) as well as low-energy electron diffraction (LEED).On that basis, we discuss the differences in surface ordering, workfunction, and the binding energies of the observed molecular features.

Phase diagram of the J–Jd Heisenberg model on the maple leaf lattice: Neural networks and density matrix renormalization group

Jonas Beck
JMU Würzburg

We microscopically analyze the nearest-neighbor Heisenberg model on the maple leaf lattice through neural quantum state (NQS) and infinite density matrix renormalization group (iDMRG) methods. Embarking to parameter regimes beyond the exact dimer singlet ground state with a dimer bond spin exchange coupling Jd varied against the exchange strength J of all other bonds, the iDMRG (NQS) method finds a dimer state paramagnetic phase for Jd/J>1.464 (Jd/J>1.39) and a canted 120∘ magnetic order for Jd/J<1.419 (Jd/J<1.23). Assessing training convergence inaccuracies of the NQS method and the influence of finite cylindric circumference in the iDMRG method, we discuss the possible existence of an intermediate phase between the magnet and the dimer paramagnet.

Meissner-Effect in Non-Hermitian Superconductors

Linus Aliani
JMU Würzburg

The Meissner effect in non-hermitian BCS superconductors is theoretically studied. It is shown how the variation of the parameters (temperature and chemical potential and the value of the mean-field) leads to a paramagnetic or diamagnetic Meissner effect.

Proposed STM Study on FeSe: Investigating the Superconducting Nature and Surface Properties

Soumya Datta
JMU Würzburg

The study of iron selenide (FeSe), an unconventional superconductor, offers exciting opportunities to probe novel electronic states and investigate the interplay between superconductivity and topological surface phenomena. This research aims to utilize a state-of-the-art Low-Temperature Scanning Tunneling Microscope (LT-STM), which is currently being set up at the Surface Characterization Station at the Institute for Topological Insulators (ITI). FeSeâ€™s intriguing superconducting properties, including the possible presence of nematic order and the potential for topological superconductivity, provide an excellent platform for atomic-scale investigations. The primary goal of this work is to characterize the superconducting gap structure, quasiparticle interference (QPI), and any signatures of Majorana bound states at the surfaces and interfaces of FeSe. The investigation will be conducted on thin layers of FeSe on $SrTiO_3$, a system known for its enhanced superconductivity and potential for Majorana fermions. Using LT-STM, atomic-resolution imaging will allow for the direct observation of the gap anisotropy and topological surface states that may emerge in this material. This study will contribute to a deeper understanding of the electronic and topological properties of FeSe, with the ultimate aim of linking these findings to potential applications in quantum computing and topological quantum materials. Initial progress will focus on sample preparation and system installation, followed by data collection once the STM system is operational.

CDW transition in AV_3Sb_5 kagome metals

Stefan Enzner
JMU Würzburg

The origin of charge density wave (CDW) formation and the nature of structural transitions in **AV_3Sb_5** kagome metals remain highly debated. While van Hove singularity (VHS) nesting scenarios have been widely proposed as key drivers, our **ab-initio** calculations challenge this conventional view. We find that the electronic instabilities leading to the CDW originate deep within the Brillouin zone, away from high-symmetry points, suggesting a more intricate electron-phonon-driven mechanism. Furthermore, our Raman spectroscopy data, supported by density functional perturbation theory (DFPT) calculations, reveal a splitting of the **E_2g** phonon mode. This indicates a rotational symmetry breaking (**D_6h → D_2h**) accompanying the CDW transition, providing new insight into the structural evolution of these systems.

Engineering Topological Laser in Organic Microcavities

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In this work, we study the physics of exciton-polaritons in highly controllable and versa- tile potential landscapes. Exciton-polaritons are quasi-particles that emerge from the strong coupling of bound electron-hole pairs to light. This is achieved by modifying the electric field distribution in z-direction via distributed bragg reflectors (DBRs). Additional confinement in the x-y plane can be achieved by milling hemielliptical shaped potentials in the glass substrate of the upper DBR, this results in Laguerre-Gaussian eigenmodes. When potentials are arranged in a lattice structure analogous to atomic lattices, the resulting modes can overlap, forming polaritonic band structures. This phenomenon is similar to how bound, quantized electronic states in atoms overlap in solids to create electronic band structures, which are often described using the tight binding model.

A deformed honeycomb lattice, with stretched and compressed hexagonal unit cells is a realization of the topological crystalline insulator model and shows topologically protected edge states at their boundary [1]. These edge states have nonzero group velocity and are robust against small differences between resonators [2]. Topological insulator lasers are arrays of semi- conductor lasers that exploit fundamental features of topology to force all emitters to act as a single coherent laser [2]. The use of topological platforms enables mode locking of several emitters and lase as a single coherent laser due to the topological properties of the device [3], in the topological protected state. These protected states increases the output efficiency as well as provides platform for other applications requiring coherence,interference, imaging with coupled laser array systems. In this project we aim to show this topological laser array in organic (m- Cherry) based microcavities in topologically crystalline structure of honeycomb lattice. The technological control over the hoppings and eigenmode energies is important with respect to topological gap, which is governed by hemielliptical shape and overlap distance of confinement. In this project, we systematically study the variation of shape, size and depth of potentials in regard to the parameters of milling device (Focused ion beam parameters such as dwell time, passes) which affects the quantised energy levels of polaritonic states. The impact of over- lapping of potentials on the energy splitting of the fundamental mode and therefore coupling of adjacent lattice sites, is studied through series photoluminescence measurements. These measurements allow for precise tuning of the potential landscape, facilitating the formation of topological crystalline structures in organic materials.

References

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Chiral spin liquid in external magnetic field: Phase diagram of the decorated-honeycomb Kitaev model

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Studies of Kitaev models on different lattices have shown signatures of topological phase transitions as a function of external magnetic field direction and magnitude. These transitions are often accompanied by a change in the statistics of the low-energy anyonic excitations. In particular, the antiferromagnetic Kitaev system yields a field-induced spin liquid, of arguably gapless U(1) or Abelian character. The existence of field-induced spin liquids on different lattices has consequently been intensely investigated. Here, we determine the phase diagram of the decorated-honeycomb Kitaev model for different inter- and intra-triangle coupling ratios and magnetic fields using a mean-field theory derived from Kitaev's Majorana parton decomposition.

Accessing Anti-de-Sitter spacetime using optical lattices

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Reconciling quantum mechanics with gravity remains a fundamental challenge in high-energy physics. The AdS/CFT correspondence provides a promising framework by relating a quantum theory in an asymptotically d+1-dimensional Anti-de Sitter (AdS) spacetime to a conformal field theory (CFT) on its d-dimensional boundary. Directly probing quantum gravity in experiments is infeasible due to the small length scales involved, but analog quantum simulations offer alternative approaches. Here, we investigate the propagation of light in one-dimensional coupled waveguide arrays and demonstrate that, when appropriately engineered, these systems can emulate the evolution of Dirac fermions in a two-dimensional AdS spacetime. Specifically, we show that the center-of-mass motion of a light beam follows the expected geodesic trajectory of a Dirac fermion in AdS. Additionally, in flat spacetime, a Dirac fermion exhibits Zitterbewegung, an oscillatory motion around its mean trajectory. We explore how this effect is modified in the presence of spacetime curvature. Our results suggest that optical platforms provide a viable route for simulating quantum dynamics in curved backgrounds, with potential implications for both condensed matter and high-energy physics.