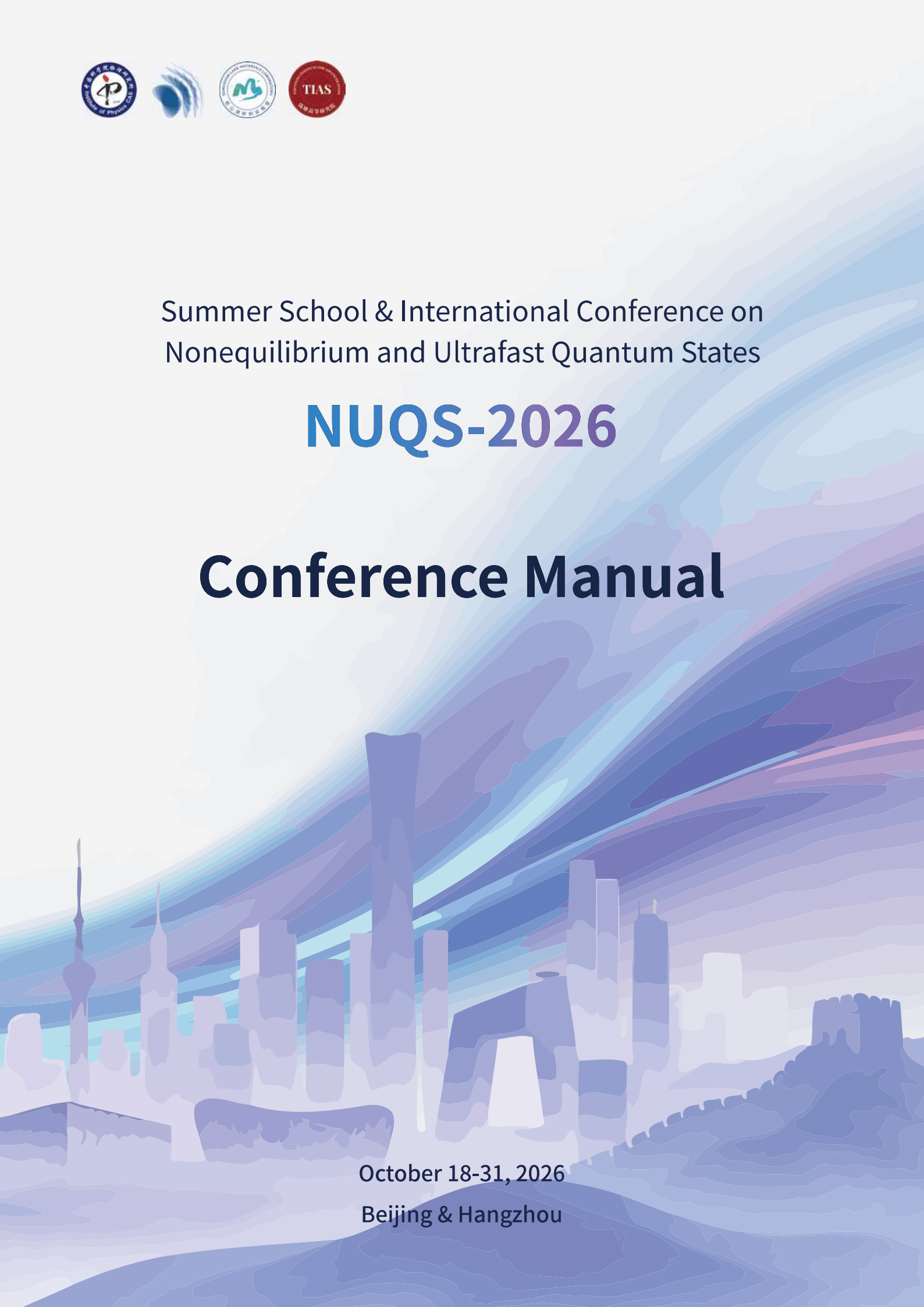
Summer School & International Conference on
Nonequilibrium and Ultrafast Quantum States

NUQS-2026

Conference Manual



October 18-31, 2026

Beijing & Hangzhou

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Conference Notification

Welcome to the Summer School & International Conference on Nonequilibrium and Ultrafast Quantum States (NUQS-2026). The conference is divided into two stages in Beijing and Hangzhou, and the arrangements during the Beijing session are as follows (the conference manual for the Hangzhou session will be provided separately).
If you have any questions, please contact the conference team for assistance. Thank you!

◆ Conference Date

Beijing: October 18-24, 2026 (registration on October 18)
Hangzhou: October 25-31, 2026 (registration on October 25)

◆ Conference Room

Oct. 19-22 Summer School: M234 Conference Hall, IOP Campus
Oct. 23-24 NUQS Conference: D210 Conference Hall, IOP Campus

◆ Registration

Oct. 18 8:00-11:00 Beijing Wuke Hotel
Oct. 18 14:00-17:00 M234 Conference Hall, IOP Campus

◆ Accommodation

Beijing Xiamen Mansion Yihao Hotel
(No. 46 Zhichun Road, Zhongguancun, Haidian District, Beijing)
Beijing Wuke Hotel
(No.8, 3rd South Street, Zhongguancun, Haidian District, Beijing)

◆ Dining

Lunch and dinner: Canteen on the third floor of Building H, IOP Campus

◆ Contact Us

Chunlu Tian (cltian@iphy.ac.cn, +86 18811599152)
Jiayi Yu (jiayi.yu@iphy.ac.cn +86 13391541966)
Yaxian Wang (yaxianw@iphy.ac.cn)
Sheng Meng (smeng@iphy.ac.cn)

Conference Kind Reminder

1. Please refer to the schedule in the conference manual and attend the meeting on time.

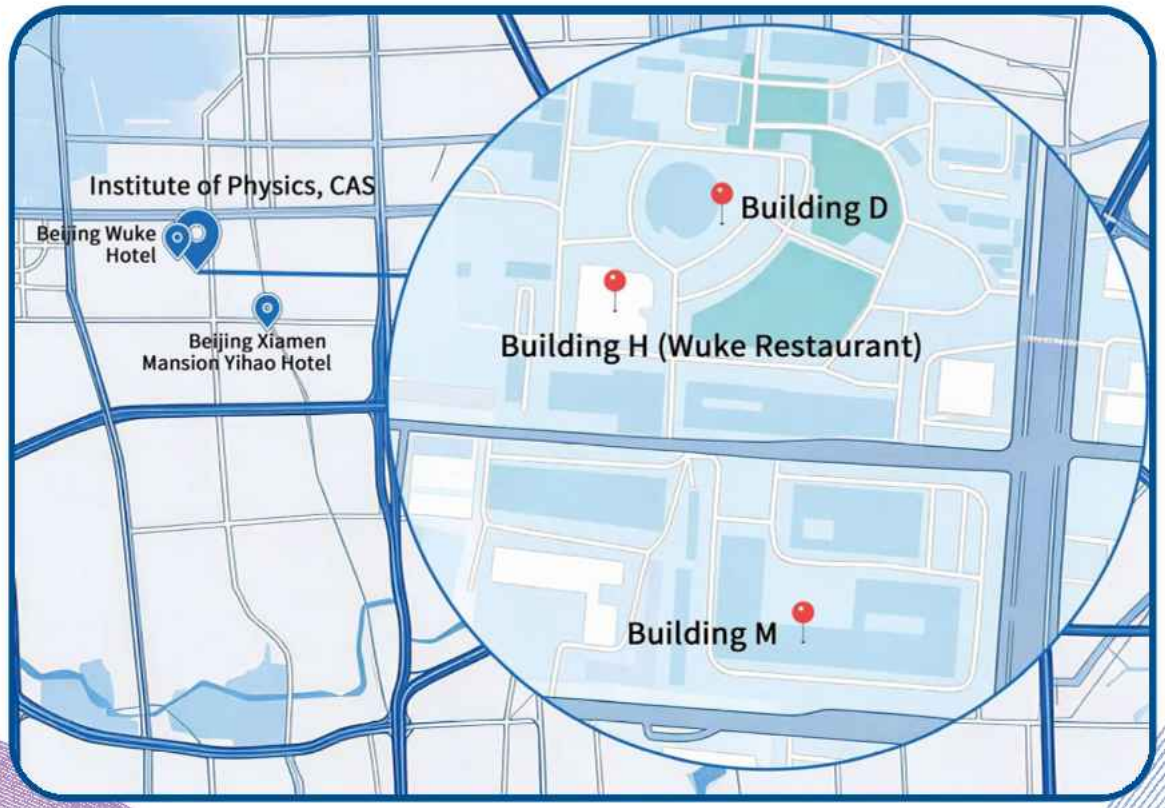
2. Please carry your conference manual and name badge with you. Meals will be redeemed using the voucher attached to your conference manual, so please keep it safe.

3. Presentation slides need to be submitted to the conference team for preparation.

4. For participants attending the Huairou Lab tour and discussion on October 22: please bring your personal identification document and pay attention to the notification and anoucement from our organization committee.

5. For participants joining phase 2 in Hangzhou: please retain your conference name badge which is valid for the Hangzhou session.

6. IOP Campus Map



Host Institutions and Conference Committee

Host Institutions

Institute of Physics, Chinese Academy of Sciences

Max Planck Institute for the Structure and Dynamics of Matter

Songshan Lake Materials Laboratory

TIAS Tsientang Institute for Advanced Study

Conference Advisors



Lu Yu

Institute of Physics CAS



Enge Wang

Institute of Physics CAS



Tao Xiang

Institute of Physics CAS



Zhong Fang

Institute of Physics CAS



Angel Rubio

Max Planck Institute for the Structure and Dynamics of Matter

Host Institutions and Conference Committee

Local Organizing Committee


Sheng Meng/ IOP


Yuan Wan/IOP


Jimin Zhao/IOP


Yuxiang Weng/IOP


Zhaohua Cheng/ IOP


Jiangi Li/ IOP


Peng Ye/ IOP/ SLAB


Pengju Zhang/ IOP/ SLAB


Feifan Wang IOP SLAB


Chao Lian/ IOP/ SLAB


Jiyu Xu/ IOP/ SLAB


Wei Lu/ SLAB


Faran Zhou/ IOP


Yaxian Wang/ IOP


Sijie Zhang/ IOP


Shuo Dong/ IOP


Cui Zhang/ IOP


Lede Xian/ TIAS

Summer School in Beijing

October 19, 2026 (Monday) M234 Conference Hall, IOP Campus

Time	Speaker	Talk
Chair: Enge Wang		
8:20-8:30	**Zhong Fang** Institute of Physics, CAS	Opening Ceremony
8:30-9:30	**Hardy Gross** The Hebrew University of Jerusalem & Tsientang Institute for Advanced Study	The exact factorization, a universal approach to non-adiabaticity
9:30-10:30	**Sheng Meng** Institute of Physics, CAS	Attosecond correlated electron-lattice-spin dynamics
10:30-11:00	**Break & Group Photo**	
Chair: Hardy Gross		
11:00-12:00	**Ying Jiang** Peking University	Ultrafast time-resolved scanning tunneling microscopy and spectroscopy
12:00-14:00	**Lunch**	
Chair: Sheng Meng		
14:00-15:00	**Nanlin Wang** Shanghai Jiao Tong University	Nonequilibrium & Nonlinear terahertz spectroscopy study on Higgs modes in NbN, YBCO, MgB2 superconductors
15:00-16:00	**Umberto De Giovannini** Università degli Studi di Palermo	Floquet engineering in quantum materials: real-time dynamics, spectroscopy and dissipation
16:00-16:30	**Break**	
Chair: Umberto De Giovannini		
16:30-17:30	**Jiangping Hu** Institute of Physics, CAS	Non-Hermitian Quantum Many Body Physics
17:30-17:45	**Alba de las Heras** Graz University of Technology (TU Graz)	High harmonic generation in a chiral topological Weyl semimetal: attosecond locally-chiral light and excited ladder electrons
17:45-18:00	**Chongxiao Fan** Max Planck Institute for the Structure and Dynamics of Matter	Cavity control of multiferroic order in single-layer NiI_2
18:00	**Dinner**	

Summer School in Beijing

October 20, 2026 (Tuesday) M234 Conference Hall, IOP Campus

Time	Speaker	Talk
Chair: Yuan Wan		
8:30-9:30	**Shuyun Zhou** Tsinghua University	Floquet Engineering of Quantum Materials: from black phosphorus to graphene
9:30-10:30	**Zhiyuan Sun** Tsinghua University	Predicting light induced nonequilibrium states by the ponderomotive force
10:30-11:00	**Break**	
Chair: Zhiyuan Sun		
11:00-12:00	**Yuan Wan** Institute of Physics, CAS	Multidimensional Coherent Spectroscopy and Time-Domain Quantum Interference in Quantum Matter
12:00-14:00	**Lunch**	
Chair: Simone Latini		
14:00-15:00	**Hanan Sheinfux** Bar-Ilan University	Extreme confinement with hyperbolic cavities – a new platform for quantum light-matter interactions
15:00-16:00	**Matthias Kick** Fritz Haber Institute	TDDFT at Large Scale: Challenges and Some Ways Around Them
16:00-16:30	**Break**	
Chair: Hanan Sheinfux		
16:30-17:30	**Simone Latini** Technical University of Denmark	Ab Initio Cavity Material Engineering: from Polaritons to Quantum Phases
17:30-17:45	**Jingkai Quan** Max Planck Institute for the Structure and Dynamics of Matter	Symmetry-Guided Cavity Materials Engineering: From Cavity-induced Symmetry Breaking to Macroscopic Responses
17:45-18:00	**Jie-Cheng Feng** Max Planck Institute for the Structure and Dynamics of Matter	Engineering Vacuum Fluctuations in Hyperbolic Heterostructures
18:00-19:00	**Dinner**	
19:00-20:30	**Poster**	

Summer School in Beijing

October 21, 2026 (Wednesday) M234 Conference Hall, IOP Campus

Time	Speaker	Talk
Chair: Emil Viñas Boström		
8:30-9:30	**Qihua Xiong** Tsinghua University	Manipulating Nonlinearity and Ultrafast Dynamics in 2D Microcavities and Heterostructures
9:30-10:30	**Kaihui Liu** Peking University	Optical Crystals of 2D Materials
10:30-11:00	**Break**	
Chair: Qihua Xiong		
11:00-12:00	**Angel Rubio** Max Planck Institute for the Structure and Dynamics of Matter	TDDFT: from non-equilibrium phenomena to quantum materials engineering
12:00-13:00	**Lunch**	
13:00-14:00	**Brief visit of IOP, CAS**	
Chair: Wentao Zhang		
14:00-15:00	**Xingjiang Zhou** Institute of Physics, CAS	Strong Electron Pairing along Fermi Pockets in High Temperature Cuprate Superconductors
15:00-16:00	**Emil Viñas Boström** Max Planck Institute for the Structure and Dynamics of Matter	Sub-diffraction Imaging of Collective Modes with Scanning Far-Field THz Spectroscopy
16:00-16:30	**Break**	
Chair: Matthias Kick		
16:30-17:30	**Cheng Cen** Institute of Physics, CAS	Uncovering Hidden Electronic Landscapes in Superconductors through Ultrafast Microscopy
17:30-18:30	**Wentao Zhang** Institute of Physics, CAS	Probing and Controlling Correlated Electron Materials with TRARPES
18:30	**Dinner**	

Summer School in Beijing

October 22, 2026 (Thursday) — Lab Tour & Discussion in Huairou

Time	Lab Tour & Discussion
9:30-11:00	**Visit Synergetic Extreme Condition User Facility (SECUF), IOP**
11:00-12:00	**Visit Interdisciplinary Institute of Light-Element Quantum Materials, Peking University**
12:00-13:00	**Lunch**
13:00-18:00	**Discussion with IOP and PKU faculties**
18:00	**Dinner**

NUQS-2026 Conference

Morning, October 23, 2026 (Friday) D210 Conference Hall, IOP Campus

Time	Speaker	Talk
Chair: Jimin Zhao		
8:30-9:00	**Angel Rubio** Max Planck Institute for the Structure and Dynamics of Matter	Cavity QED Materials Engineering: Photon-Mediated Interactions in van der Waals Heterostructures
9:00-9:30	**Heng Fan** Institute of Physics, CAS	Quantum computation and simulation on superconducting processors
9:30-10:00	**Zhaohua Cheng** Institute of Physics, CAS	Ultrafast Magneto-Optical Fingerprints of Altermagnetism in MnTe
10:00-10:30	**Break**	
Chair: Qi Zhang		
10:30-11:00	**Jimin Zhao** Institute of Physics, CAS	High Pressure Ultrafast Dynamics of $LaH_{10\pm\delta}$ and $La_3Ni_2O_7$ and Emergent Quantum State in 1*T*-TaS_2
11:00-11:15	**Sebastián de la Peña Ruiz** Max Planck Institute for the Structure and Dynamics of Matter	Quantum Driving and Entanglement in High Harmonic Generation
11:15-11:30	**Omid Nourmofidi** Max Planck Institute for the Structure and Dynamics of Matter	Linking critical temperature with electron localization for cavity-enhanced superconductivity
11:30-11:45	**Francesco Greco** Max Planck Institute for the Structure and Dynamics of Matter	Spin-glass mapping of electron correlations in optical cavities.
11:45-12:00	**Na Wu** Max Planck Institute for the Structure and Dynamics of Matter	Quantum squeezing of phonons through crystal symmetry
12:00-14:00	**Lunch**	

NUQS-2026 Conference

Afternoon, October 23, 2026 (Friday) D210 Conference Hall, IOP Campus

Time	Speaker	Talk
Chair: Mengxue Guan		
14:00-14:30	**Fabio Caruso** Rostock University	Electron-phonon interactions in the time domain: from quasiparticle dynamics to light-induced phase transitions.
14:30-15:00	**Qi Zhang** Nanjing University	Coherent three-wave mixing of collective excitations in 2D antiferromagnets
15:00-15:30	**Feifan Wang** Institute of Physics, CAS	Photo-induced ordering in metastable anharmonic solids
15:30-16:00	**Michael Sentef** Universität Bremen	Microscopic mechanism for resonant light-enhanced pair correlations in K3C60
16:00-16:30	**Break**	
Chair: Fabio Caruso		
16:30-17:00	**Mengxue Guan** Beijing Institute of Technology	Ultrafast Optical Control of Dynamic Symmetry and Non-Equilibrium Quantum States
17:00-17:15	**Peiwei You** The Hebrew University of Jerusalem	Correlated electron-nuclear dynamics with first-principles approaches
17:15-17:30	**Lukas Grunwald** Max Planck Institute for the Structure and Dynamics of Matter	Cavity Control of Strongly Correlated Electrons Beyond Resonant Coupling
17:30-17:45	**Simon Vendelbo Bylling Jensen** Max Planck Institute for the Structure and Dynamics of Matter	Ultrafast Multiband Electron Dynamics in Solids: Insights from Pulse-Duration-Controlled High-Harmonic Generation
17:45-18:00	**Huimin Wang** Universität Bremen	Fluence-Controlled Directional Sliding in a Polar Weyl Semimetal
18:00-18:15	**Benshu Fan** Max Planck Institute for the Structure and Dynamics of Matter	First-principles Floquet analysis from real-time propagation
18:15	**Dinner**	

NUQS-2026 Conference

Morning, October 24, 2026 (Saturday) D210 Conference Hall, IOP Campus

Time	Speaker	Talk
Chair: Hanan Sheinfux		
8:30-9:00	**Ji Feng** Peking University	Spin-Wave Dynamics: TDDFT Response and Adiabatic Theory
9:00-9:30	**Luyi Yang** Tsinghua University	Magneto-Optical Kerr Effect in Altermagnets
9:30-10:00	**Peizhe Tang** Beihang University	Light-induced Band Engineering in Layered Quantum Materials
10:00-10:30	**Break**	
Chair: Peizhe Tang		
10:30-10:45	**Matan Tsur** Max Planck Institute for the Structure and Dynamics of Matter	Measuring and controlling the birth of quantum attosecond pulses
10:45-11:00	**Roosmarijn de Wit** Max Planck Institute for the Structure and Dynamics of Matter	Coupling molecular vibrations to light: how cavity-induced electron correlations modify the nuclear ground state
11:00-11:15	**Xinle Cheng** Max Planck Institute for the Structure and Dynamics of Matter	Anyonic Chern Insulator in Graphene Induced by Surface Electromagnon Vacuum Fluctuations
11:15-11:30	**Jonas Reimann** Max Planck Institute for the Structure and Dynamics of Matter	Towards dynamic lattice-models using time-dependent Wannier functions
11:30-11:45	**Carlos Mauricio Bustamante** Max Planck Institute for the Structure and Dynamics of Matter	Tuning Optical Cavities to Enhance Molecular Raman Modes: Theoretical Approaches
11:45-12:00	**Emin Aliyev** Max Planck Institute for the Structure and Dynamics of Matter	Unraveling the Role of Lattice Dynamics in the Photoinduced Phase of Ta_2NiSe_5
12:00-14:00	**Lunch**	

NUQS-2026 Conference

Afternoon, October 24, 2026 (Saturday) D210 Conference Hall, IOP Campus

Time	Speaker	Talk
Chair: Michael Sentef		
14:00-14:30	**Pengju Zhang** Institute of Physics, CAS	Towards the control of electronic dynamics: from gas to solid
14:30-15:00	**Yingying Peng** Peking University	Time-Resolved X-ray Studies of Chiral Charge Order and Magnetic Order Dynamics
15:00-15:30	**Jin Zhang** National Center for Nanoscience and Technology, China	Artificial Intelligence Driven Nonequilibrium Materials Dynamics Simulations
15:30-15:40	**Closing Remarks**	
15:40-18:00	**Visit Peking University**	
18:00	**Dinner**	

Speakers and Abstract



Hardy Gross

Short Bio

Eberhard Gross received his PhD in Physics in 1980 at the Goethe University in Frankfurt, Germany. After a postdoctoral stay at the same university, he joined the group of Walter Kohn at the University of California, Santa Barbara, first as a postdoc, then as a Heisenberg fellow. In 1990, he became Professor of Physics at the University of Wuerzburg, Germany. From 2001 he had the Chair of Theoretical Physics at the Free University of Berlin, and from 2009 to 2019 he was Director of the Max Planck Institute of Microstructure Physics in Halle, Germany. Since 2017, he is Professor of Chemistry at the Hebrew University of Jerusalem, Israel. Together with Erich Runge, he laid the foundation of time-dependent density functional theory. He furthermore developed the Ensemble DFT of excited states, and an ab-initio theory of phonon-driven superconductivity. In recent years, he developed the exact factorization, a novel methodology describing all aspects of non-adiabatic chemical dynamics, in particular electronic decoherence and the molecular Berry phase. His work has been recognized with several prizes and awards, including the 2016 Bernie Alder CECAM prize, the 2016 Tsungming Tu prize in Taipei, the Schlumberger Award with medal, and the CMOA senior medal.
He is a member of the International Academy of Quantum Molecular Science, a Fellow of the American Physical Society and a Mercator Fellow of the German Science Foundation (DFG).

Talk Title

The exact factorization, a universal approach to non-adiabaticity



Sheng Meng

Short Bio

Dr. Sheng Meng is a professor and head of the Surface Quantum Dynamics group at Beijing National Laboratory for Condensed Matter Physics, and Institute of Physics, Chinese Academy of Sciences since 2009. He obtained his Bachelor degree in physics from University of Science and Technology of China (USTC) in 2000, and Ph.D. degree in applied physics from Chalmers University of Technology, Sweden in 2004. During 2005-2009, he worked at Harvard University's Department of Physics first as a post-doctoral researcher then a research associate.Dr. Meng's research interests focus on quantum interaction and dynamics at surfaces and in condensed matters. His previous work started with the simplest but most mysterious molecule in nature: water. Current interests include excited state dynamics, ambient quantum materials, and energy conversion mechanisms in artificial photosynthesis. He has published over 200 technical papers in peer-reviewed journals, and has received >14,000 citations.

Talk Title

Attosecond correlated electron-lattice-spin dynamics

Abstract

Photoexcitation and the resultant attosecond quasiparticle dynamics is a powerful means in distinguishing different interactions and manipulating the states of matter, especially in complex quantum materials, thus giving rise to a new focused area of 'attosecond condensed matter physics'. Here we give some examples of such afield by investigating photoexcitation-induced correlated electron-lattice dynamics at the attosecond timescale, with the recently developed new theoretical tools incorporating both nonadiabatic electron-nuclear couplings and nuclear quantum effects. In particular, we uncover the attosecond ultrafast processes of exciton formation, evolution and dissociation in monolayer hexagonal boron nitride, and the subsequent exciton-exciton interference phenomenon, where the resulting oscillatory signals of electron occupation allow us to extract phase information of exciton envelope function. Another example is the attosecond process of high harmonics generation (HHG) in solids, where by analyzing quasiparticle-coupled HHG the electronic structure and nonadiabatic quasiparticle (quantum) dynamics can be revealed. If time allowed we will also explore the potential of coherent control of quasiparticles (phonon, spin, etc.) and phase transitions with ultrafast lasers.



Ying Jiang

Short Bio

Ying Jiang is a Boya Distinguished Professor at the International Center for Quantum Materials (ICQM), School of Physics, Peking University, where he directs the Research Center for Light-Element Advanced Materials, and a Fellow of the American Physical Society. His research develops and applies advanced scanning probe microscopy, ultrafast lasers, and quantum sensing to resolve water and ice structures on surfaces, nuclear quantum effects of hydrogen bonds, nonequilibrium quantum matter, and nanoscale quantum sensing with atomic and submolecular resolution.

Talk Title

Ultrafast time-resolved scanning tunneling microscopy and spectroscopy

Abstract

In this lecture, I will focus on recent advances of ultrafast time-resolved scanning tunneling microscopy (tr-STM) by coupling the tunneling junctions with pulsed electric waves, THz, near-infrared and visible laser. The temporal resolution of STM can be improved from nanoseconds to femtoseconds, or even attoseconds. Their applications to probe the ultrafast dynamics of charge, spin, orbital, polaron and phonon will be highlighted. I will also introduce the very recent development of time-resolved scanning tunneling spectroscopy (tr-STS), which opens up new possibility to track the ultrafast temporal evolution of local density of states (LDOS) at atomic scale. The application of tr-STS in probing photoinduced phase transition of quantum materials will be demonstrated.



Nanlin Wang

Short Bio

Nanlin Wang is a T. D. Lee Chair Professor at the Tsung-Dao Lee Institute, Shanghai Jiao Tong University, in the Condensed Matter Division.His research focuses on high-temperature superconductivity, collective phenomena and competing orders in complex quantum materials, and nonequilibrium and nonlinear optical spectroscopy, including ultrafast manipulation and dynamics of quantum states.

Talk Title

Nonequilibrium & Nonlinear terahertz spectroscopy study on Higgs modes in NbN, YBCO, MgB2 superconductors

Abstract

Detection of the Higgs mode in superconductors using nonequilibrium and nonlinear terahertz spectroscopy is a key area of interest in condensed matter physics. Here, we present our recent progress in detecting the Higgs modes in conventional and unconventional superconductors, including NbN, YBCO and MgB2 using terahertz (THz) third harmonic generation (THG) spectroscopy and THz pump-probe techniques. We show that the disorders can induce nonlinear terahertz response. The THG spectrum of the strongly disordered NbN sample below Tc exhibits a broadened, multi-peak structure, which we attribute to quantum path interference between distinct channels involving unpaired electrons and Cooper pairs within emerging superconducting islands. In high-Tc YBCO superconductors, we observe the THG signal in the normal state, along with a beat feature near Tc. The study reveals the coupling of two modes with different origins. We also perform near-infrared pump THG probe measurement on YBCO, and find that superconductivity competes with the order developed in the normal state. The detection of the collective Higgs mode offers new insights into the interplay between the pseudogap and superconducting energy gap. For two-band superconductor MgB2, we show that, by adjusting the waveform shape and duration of the THz pump pulses, the Higgs and Leggett modes can be selectively excited and detected.



Umberto De Giovannini

Short Bio

Umberto De Giovannini is Associate Professor of Physics at the University of Palermo. His research focuses on the real-time dynamics of quantum materials, with particular emphasis on ultrafast phenomena, time-dependent density-functional theory, Floquet engineering, and time-resolved photoemission. He has worked extensively on the development and application of first-principles methods for light-driven solids, including the simulation of electronic dynamics, dissipation, and photoemission processes. Before joining the University of Palermo, he was Group Leader at the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg.

Talk Title

Floquet engineering in quantum materials: real-time dynamics, spectroscopy and dissipation

Abstract

Periodic driving provides a powerful route to transiently modify the electronic structure and properties of quantum materials. In this lecture I will introduce the basic concepts of Floquet engineering and discuss their connection to real-time simulations of laser-driven solids. Using graphene and related systems as representative examples, I will show how light-induced Floquet states emerge, how they can be described using real-time time-dependent density-functional theory, and how their signatures can be probed using time-resolved photoemission and optical observables. Particular attention will be given to the differences between the ideal Floquet picture and realistic ultrafast experiments, including finite-duration driving, electronic excitation, scattering and decoherence.



Jiangping Hu

Short Bio

Jiangping Hu is a Professor and Deputy Director of the Institute of Physics, Chinese Academy of Sciences (IOP CAS). His research focuses on strongly correlated electron systems, superconductivity, the topological properties and effects of condensed matter, and cold-atom systems.

Talk Title

Non-Hermitian Quantum Many Body Physics



Alba de las Heras

Short Bio

My research work focuses on theoretical and computational models of laser-matter interactions, attosecond science, and ultrafast nonlinear optics. My lines of expertise include multielectron correlated dynamics, structured-light high harmonic generation, chiral responses in quantum materials, and attosecond magnetic field generation.

Talk Title

High harmonic generation in a chiral topological Weyl semimetal: attosecond locally-chiral light and excited ladder electrons

Abstract

High harmonic generation in a chiral topological Weyl semimetal: attosecond locally-chiral light and excited ladder electrons
Alba de las Heras1,2*, Ofer Neufeld3 and Angel Rubio1,4
1Max Planck Institute for the Structure and Dynamics of Matter & Center for Free-Electron Laser Science,
Hamburg, 22761, Germany
2TU Graz, Graz, 8010, Austria
3Technion Israel Institute of Technology, Haifa, 3200003, Israel
4The Flatiron Institute, New York, 10010, USA
Corresponding author e-mail address: alba.de-las-heras@mpsd.mpg.de
We theoretically investigate high harmonic generation (HHG) in RhSi, a prototypical chiral Weyl semimetal. Our time-dependent density-functional theory (TDDFT) calculations in the chiral Weyl semimetal show two significant features. On the one hand, a pulse-duration-sensitive cutoff in HHG arises from a progressive promotion of electron population to high conduction bands. The intricate band crossing network of RhSi favors excited ladder electrons, a mechanism that can substantially extend HHG to higher photon energies. Unlike typical scenarios, the strong multi-band coupling establishes the driving pulse duration as a key parameter that has not been exploited in solid-state HHG.
On the other hand, the chiral crystal structure of RhSi enables the synthesis of locally chiral near fields exhibiting an asymmetric instantaneous torsion on attosecond timescales. The concept of locally chiral light constitutes a novel paradigm for efficient enantiomer detection, predicting higher chiral sensitivity than circularly polarized or orbital angular momentum beams. Our TDDFT results show that a 3D chiral polarization is naturally imprinted in the attosecond electric field emerging from the chiral Weyl semimetal in the interaction with a circularly polarized driving pulse.
These theoretical findings motivate future experiments to track high-energy band crossings and in-situ attosecond locally-chiral light, advancing prospects for compact extreme-ultraviolet sources, enantiomer detection, and ultrafast optoelectronics.
Keywords: Attosecond pulses, Chirality, Topological quantum materials, Extreme ultraviolet sources, Ultrafast electron dynamics



Chongxiao Fan

Short Bio

Chongxiao Fan is a PhD student at the Max Planck Institute for the Structure and Dynamics of Matter (MPSD). He earned his bachelor's degrees from Peking University and his master's degree from RWTH Aachen University. His research focuses on cavity quantum materials and excitonic insulators.

Talk Title

Cavity control of multiferroic order in single-layer NiI2

Abstract

Cavity control of multiferroic order in single-layer NiI2
Chongxiao Fan1,2, Emil Viñas Boström1,3 , Xinle Cheng1, Lukas Grunwald1,2, Zhuquan Zhang4, Dante M. Kennes1,2, Dmitri N. Basov4, Angel Rubio1,3,5
1 Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany.
2 Institute for Theory of Statistical Physics, RWTH Aachen University, and JARA Fundamentals of Future Information Technology, Aachen, Germany.
3 Nano-Bio Spectroscopy Group and ETSF, Departamento de Polímeros y Materiales Avanzados, Fisica, Química y Tecnologia, Universidad del País Vasco UPV/EHU-, San Sebastián, Spain.
4 Department of Physics, Columbia University, New York, USA.
5 Initiative for Computational Catalysis, Flatiron Institute, Simons Foundation, New York City, NY, USA.
Corresponding author e-mail address: chongxiao.fan@mpsd.mpg.de
Abstract (About 500 words)
Controlling materials through their interactions with electromagnetic vacuum fluctuations is an emergent frontier in material engineering. Although recent experiments have demonstrated dark cavity effects for electronic material phases, like superconductivity, ferroelectricity and charge density waves, a smoking gun experiment for magnetic systems is lacking. Largely, this comes from the focus on phase transitions, where a large critical light-matter coupling is needed to observe cavity modifications. Here, we propose spiral magnets, where even a small cavity-mediated change in magnetic interactions is reflected in a change of the spiral wavelength, as a promising platform to observe cavity effects. We focus on the single-layer multiferroic NiI2, interacting with electric field fluctuations from surface phonon polaritons of the paraelectric substrate SrTiO3. With decreasing substrate-material distance, the ratio of nearest and third-nearest neighbor exchange interactions reduces, leading to an increase of the spiral wavelength and an eventual transition into a ferromagnetic state. Our work identifies a realistic platform to observe cavity vacuum renormalization effects in magnetic systems.
Objective + Methods + Results and Discussions + Conclusions
Objective: Investigate whether surface phonon polariton vacuum fluctuations from a SrTiO3 substrate can control the coupled magnetic and electric order of single-layer multiferroic NiI2.
Methods: A first-principles Hubbard-Kanamori model is downfolded into a cavity-dependent spin Hamiltonian using a Schrieffer-Wolff transformation, and the resulting magnetic states are obtained with classical Monte Carlo simulations.
Results and Discussions: Vacuum fluctuations modify J3 more strongly than J1, increasing |J1|/J3, reducing the spiral momentum, and elongating the spin spiral. Below dc ≈ 1.6 nm, NiI2 transitions from a helimagnetic multiferroic state to a ferromagnetic state with finite magnetization and vanishing polarization.
Conclusions: Single-layer NiI2 on SrTiO3 provides a realistic platform for cavity control of multiferroic order and a clear route to observing cavity-controlled magnetism without external driving.
Key words
cavity quantum materials; multiferroics.



Shuyun Zhou

Short Bio

Shuyun Zhou is a tenured Professor in the Department of Physics at Tsinghua University. Her research uses angle-resolved photoemission spectroscopy — including ultrafast time-resolved, nano-, micro- and spin-resolved variants — to study the electronic structures and quantum phenomena of low-dimensional materials such as graphene and transition-metal dichalcogenides and their heterostructures.

Talk Title

Floquet Engineering of Quantum Materials: from black phosphorus to graphene

Abstract

Floquet Engineering of Quantum Materials: from black phosphorus to graphene
Shuyun Zhou
Department of Physics, Tsinghua University, Beijing, P.R. China 100084
e-mail presenting author: syzhou@mail.tsinghua.edu.cn
Time-periodic light-field can dress the electronic states of quantum materials, providing a fascinating controlling knob for transient modifications of the electronic structure with versatile light-induced emergent phenomena [1]. In this talk, I will present our recent experimental progress on the Floquet engineering of quantum materials using time- and angle-resolved photoemission spectroscopy (TrARPES). In particular, experimental progress on the Floquet engineering of semiconducting black phosphorus [2], topological insulator [3], graphene [4] and graphite [5] will be presented. Experimental insights on Floquet engineering and light-matter interactions in quantum materials will also be discussed.

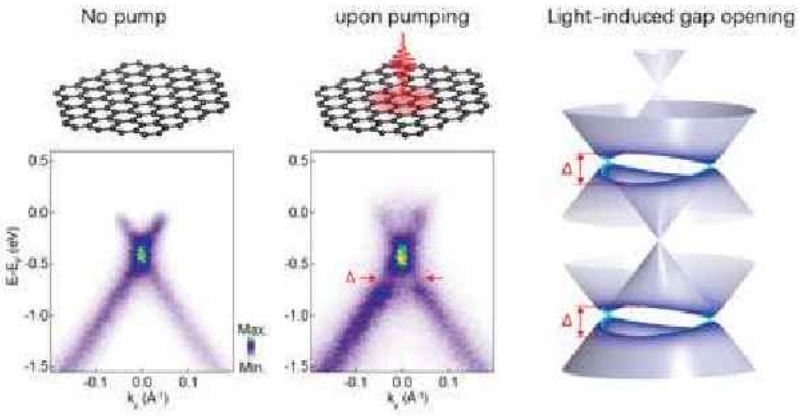


Figure 1: Schematic summary for light-induced gap opening in graphene

Reference:
1. Nat. Rev. Phys. 4, 33 (2022)
2. Nature 614, 75 (2023); PRL 131, 116401 (2023)
3. PRL 134, 146401 (2025); PRB 110, L201116 (2024)
4. Fei Wang et al., Nat. Mater. 25, 1140 (2026)
5. Fei Wang et al., Chin. Phys. Lett. 43, 050705 (2026)



Zhiyuan Sun

Short Bio

Zhiyuan Sun obtained his BS in 2012 from University of Science and Technology of China, and his PhD in 2018 from UC San Diego. He worked as a postdoctoral/associate research scientist at Columbia University during 2018~2021, and as an HQI postdoc Fellow at Harvard University during 2021~2022. Since 2022, he has been an assistant professor at the physics department of Tsinghua University. Zhiyuan works on condensed matter theory, specifically, nonequilibrium phenomena in many-body systems, light-matter interactions, and nano-optics.

Talk Title

Predicting light induced nonequilibrium states by the ponderomotive force



Yuan Wan

Short Bio

Yuan Wan (ORCID) is a theorist interested in a wide range of topics of condensed matter physics. His current research focus is the near and far from equilibrium dynamics of quantum materials.
Yuan Wan received both B.Sc. (2006) and M.Sc. (2009) from Nanjing University, and Ph.D. (2014) from the Johns Hopkins University. He joined the Institute of Physics in 2018 following a postdoctoral fellowship at the Perimeter Institute and a short stay at Oxford.

Talk Title

Multidimensional Coherent Spectroscopy and Time-Domain Quantum Interference in Quantum Matter

Abstract

Ultrafast optics provides a powerful framework for studying and controlling quantum states on picosecond and femtosecond time scales. This theory-focused lecture will introduce the principles of multidimensional coherent spectroscopy and its connection to nonlinear optical response and time-domain quantum interference. We will develop the underlying theoretical concepts and discuss how temporal interference encodes information about quantum dynamics, including electronic decoherence in metals and the mechanisms of electrical conduction in fluctuating superconductors. The lecture is intended for physics students and postdocs, and will emphasize the physical intuition needed to understand how ultrafast spectroscopies reveal the properties of quantum matter.



Hanan Sheinfux

Short Bio

Dr. Hanan Sheinfux is a Senior Lecturer in the Department of Physics, Faculty of Exact Sciences, at Bar-Ilan University. He earned his PhD in Physics at the Technion – Israel Institute of Technology under the supervision of Prof. M. Segev, and carried out his postdoctoral research with Prof. Frank Koppens at ICFO in Spain, following an earlier postdoctoral appointment at Bar-Ilan University. He holds an MSc in Physics, completed under Prof. A. Zigler at the Hebrew University of Jerusalem, and a BSc in Physics and Mathematics, also from the Hebrew University of Jerusalem. His research focuses on the manipulation of electrons and polaritons in two-dimensional materials by shaping the dielectric and electrostatic environment that surrounds them. For him, physics is above all a creative pursuit — finding the muse, coming up with good ideas, and bringing them to implementation.

Talk Title

Extreme confinement with hyperbolic cavities – a new platform for quantum light-matter interactions



Matthias Kick

Short Bio

Matthias Kick is a Group leader at the Fritz Haber Institute of the Max Planck Society. He received his PhD from the Technical University of Munich and conducted postdoctoral research at MIT. His work focuses on computational methods for excited-state dynamics, electronic-structure theory, and high-performance computing in complex materials. He is also a coordinator and core developer of FHI-aims.

Talk Title

TDDFT at Large Scale: Challenges and Some Ways Around Them

Abstract

TDDFT at Large Scale: Challenges and Some Ways Around Them
Matthias Kick
Theory Department, Fritz-Haber-Institut, Berlin, Germany
Understanding how the atomic structure of a nanomaterial controls absorption, emission, charge separation, and non-radiative loss requires identifying the excited states responsible and determining what they do after photoexcitation. In real nanostructures, increasing system size compresses the electronic level spacing while defects, surfaces, interfaces, and ligands introduce additional localized states. The resulting dense manifold can bury physically relevant excitations among many weak or dark transitions, and disorder can push states below the nominal band edge into a tail of localized trap states. The challenge is therefore not only to compute spectra, but to find and resolve the states that matter within a crowded spectral landscape, and then to follow their structural response to determine whether they localize, reorganize structurally, transfer charge, or enter trapping pathways. Throughout, we use nanocrystals as a showcase example, where these challenges appear in their most demanding form.
Meeting this challenge places severe demands on electronic-structure methods. Linear-response TDDFT approaches such as the Casida equation must converge excitations one root at a time, becoming prohibitively expensive as the manifold grows. I will present state-of-the-art examples of large-scale TDDFT calculations performed in FHI-aims on modern HPC hardware, illustrating both what is currently achievable and where the fundamental bottlenecks lie.
Even at this scale, the computational cost of resolving dense spectra remains a barrier. Real-time TDDFT offers a conceptually different route, propagating the electronic density directly in time and accessing the full spectrum in a single simulation. However, achieving the frequency resolution required to distinguish closely spaced features demands impractically long propagation times, making it impractical for large-scale applications. I will present new workflows and algorithms based on super-resolution approaches that overcome this limitation, combining exact short-time dynamics with approximate frequency-domain techniques. Unlike existing methods including compressed sensing, orthogonal matching pursuit, and MUSIC, which assume a sparse spectrum and fail in large systems with many overlapping excitations, the proposed approach makes no such assumption. It captures both sharp features and a broad quasi-continuum, significantly reducing the required simulation time and opening a practical route to accurate electronic spectra and excited-state forces in large molecules and materials.



Simone Latini

Short Bio

Simone Latini is an associate professor at the Technical university of Denmark. He is an expert of ab initio condensed matter physics and focuses on phenomena related to strong light-matter interaction in and out-of-equilibrium, spanning from polaritons to quantum phases.

Talk Title

Ab Initio Cavity Material Engineering: from Polaritons to Quantum Phases

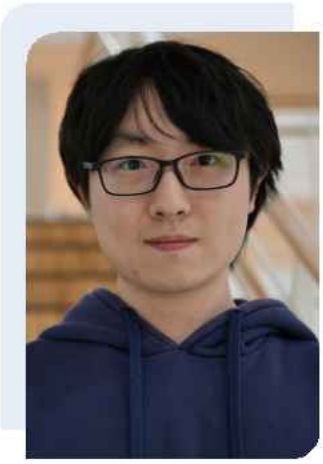
Abstract

Cavity material engineering is emerging as a promising route to manipulate the properties of quantum materials by exploiting their interaction with spatially confined electromagnetic fields. Beyond conventional optical driving, quantum cavities offer the possibility of modifying material properties without external illumination, leveraging both resonant light–matter hybridization and photon-mediated many-body interactions. Gaining insights and predicting these effects from first principles requires theoretical frameworks capable of treating light and matter on equal footing, beyond perturbative approximations.

In this talk, I will present the progressive development and application of ab initio quantum electrodynamical approaches to cavity material engineering, from the description of hybrid light–matter excitations to the emergence of cavity-modified electronic structures and collective phases.

Starting from the resonant regime, I will discuss how the combination of quantum electrodynamics and the Bethe–Salpeter equation enables a microscopic description of exciton-polaritons in two-dimensional materials. Moving beyond resonant hybridization, I will show how the coupling to quantized electromagnetic fields can be recast, under suitable approximations, into effective photon-mediated electron–electron interactions. This provides a complementary perspective on cavity material engineering, in which the cavity acts not only on optical excitations but also directly on the electronic ground state. Within QED Hartree–Fock and quantum-electrodynamical density functional theory (QEDFT), I will discuss how these interactions can lead to non-perturbative modifications of electronic properties, including the imprinting of photonic spatial and temporal symmetries onto electronic band structures, and open pathways toward cavity-controlled symmetry breaking and quantum phase transitions.

Together, these developments illustrate how ab initio QED is evolving as a predictive theory of polaritonic excitations into a broader framework for engineering electronic interactions, symmetries, and collective phenomena in quantum materials.



Jingkai Quan

Short Bio

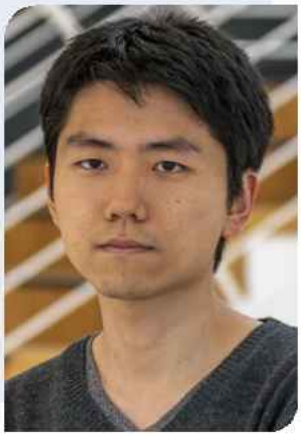
Jingkai Quan is currently a postdoctoral researcher at the Max Planck Institute for the Structure and Dynamics of Matter (MPSD). He earned his Ph.D. in 2025 from the Fritz Haber Institute of the Max Planck Society (FHI) and MPSD under the supervision of Prof. Matthias Scheffler and Prof. Angel Rubio. He received his B.Sc. in Materials Physics from Jilin University in 2020, where he worked under the supervision of Prof. Lijun Zhang. His research interests include light–matter interactions, cavity materials engineering, electronic-structure method development, and transport theory. He is also an active developer of FHI-aims, an all-electron ab initio electronic-structure and materials simulation package.

Talk Title

Symmetry-Guided Cavity Materials Engineering: From Cavity-induced Symmetry Breaking to Macroscopic Responses

Abstract

Symmetry-Guided Cavity Materials Engineering: From Cavity-induced Symmetry Breaking to Macroscopic Responses
Jingkai Quan1,*, Chongxiao Fan1,2*, Benshu Fan1,*, I-Te Lu1, Dante M. Kennes2,1, and Angel Rubio1,3,*
1Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany
2Institute for Theory of Statistical Physics, RWTH Aachen University and JARA Fundamentals of Future Information Technology, 52062 Aachen, Germany
3Initiative for Computational Catalysis, The Flatiron Institute, Simons Foundation, New York City, NY 10010, United States of America
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Abstract
Cavity light–matter coupling offers a promising route to modify material properties through quantum vacuum fluctuations, without the need for external driving fields. In this talk, I will show how symmetry provides a general framework for understanding and designing such cavity-induced effects. Starting from an effective photon-free quantum-electrodynamics Hamiltonian, we analyze how linearly polarized cavity modes modify the symmetries of materials. This framework provides a systematic classification of cavity-induced symmetry breaking for crystallographic and magnetic point groups. Using quantum-electrodynamical density functional theory (QEDFT) calculations, we first illustrate these symmetry rules through cavity-induced lifting of band degeneracies and modifications of the vibrational spectra. We further demonstrate that cavity vacuum fluctuations can induce macroscopic polarization (magnetization), even in materials that lack spontaneous polarization (net magnetization) in free space. Based on symmetry analysis, we derive the form of the corresponding response tensors, whose elements can be obtained by QEDFT calculations. As examples, we demonstrate controllable cavity-induced polarization in α-quartz, as well as cavity-induced magnetization and anomalous Hall response in antiferromagnetic Mn_3Sn. Together, these results establish symmetry as a guiding principle for controlling material properties with quantum vacuum fields.
Key words
Cavity Quantum Electrodynamics, Cavity Materials Engineering, Group Theory, Magnetization, First Principles Calculations



Jie-Cheng Feng

Short Bio

2018-2022, Beijing Normal Univ, B.Sc. in Physics;
2022-2025, ETH Zurich, M.Sc. in Physics (Atac Imamoglu, Eugene Demler);
2025-now, MPSD, Ph.D. in Physics (Dante Kennes, Angel Rubio).

Talk Title

Engineering Vacuum Fluctuations in Hyperbolic Heterostructures

Abstract

Vacuum fluctuations can be engineered using optical cavities, resonators, and surface-polaritonic modes, but extending such control deep inside a material remains challenging. Here we show that the spatial and directional structure of the vacuum field within a hyperbolic material can be reshaped in a simple on-chip geometry by covering it with a second hyperbolic slab with differently oriented anisotropy. The mechanism is frequency selective, and occurs when the hyperbolic bands of the two media overlap. As an application, we use Eliashberg theory to study a two-dimensional superconducting layer inside the thicker hyperbolic material, showing that the overlayer can remotely change its critical temperature. Our results shed light on recent experiments reporting changes in superconductivity arising from a frequency-matched hyperbolic overlayer, and more broadly, establish hyperbolic heterostructures as a platform for long-range control of light--matter coupling.



Qihua Xiong

Short Bio

Qihua Xiong, Professor of Physics at Tsinghua University, APS/MRS/OSA Fellows and New Cornerstone Investigator. He obtained his Ph.D. degree from Penn State University in 2006, and then pursued three years postdoctoral training at Harvard University. He started his independent career as Nanyang Assistant Professor at Nanyang Technological University in 2009, then tenured in 2014 and promoted to full professor in 2016. He relocated to Tsinghua University in 2020. He was awarded Singapore National Foundation NRF Fellowship in 2009 and NRF Investigatorship in 2014, he received Nanyang Award for Research Excellence in 2014, IPS Nanotechnology Physics Award in 2015, IUMRS Mid-career Researcher Award (2024). He was recognized by Clarivate highly cited researchers worldwide (2019-2025).

Talk Title

Manipulating Nonlinearity and Ultrafast Dynamics in 2D Microcavities and Heterostructures

Abstract

Recently, group VI transition metal dichalcogenides (TMDs) have been emerging as promising two-dimensional (2D) semiconductors with a sizable direct bandgap and exceptional physical properties. The tightly bound excitons with giant oscillator strength render monolayer TMDs as an ideal platform to investigate the fundamental properties of excitons and their strong light-matter interactions when they are integrated with optical cavities. In addition, heterostructures provide a versatile tuning knob to manipulate the ultrafast charge and energy transfer pathways, as well as the interlayer excitons. In this talk, we will present our recent discovery of ultrafast charge transfer facilitated optical cooling in weakly bound 2D heterostructures, probed by transient optical spectroscopy. Secondly, we will discuss the strong nonlinearity interactions and ultrafast dynamics in 2D TMD microcavity devices, using WS2 as a model cavity system. Finally, we will conclude the talk by discussing the nonlinearity-driven ultrafast spin-dependent optical switching functionalities.



Kaihui Liu

Short Bio

Kaihui Liu is currently a Boya distinguished professor of Physics at Peking University. His current research interests are the designed growth of 2D single-crystals and the corresponding device applications. Professor Liu has published/accepted more than 100 correspondence-authored research articles, including Science (5), Nature (4) and other Nature series/PRL (30). He received the National Science Fund of China for Distinguished Young Scholars in 2020 and the Xplorer Prize in 2021. Currently, Prof. Liu serves as the dean of the Institute of Condensed Matter and Materials Physics at Peking University and the project leader of China's National Key R&D Program. His research works are selected for China's Major Technological Advances in 2020, the Top 10 Semiconductor Research Advances in China in 2020 and 2024, and recognized as a Major Achievement at the Zhongguancun Forum in 2024, 2025 and 2026.

Talk Title

Optical Crystals of 2D Materials

Abstract

Strong-field nonlinear physics serves as the cornerstone of extreme laser technologies, enabling the generation of extreme-ultraviolet wavelengths, attosecond pulses, and multiphoton entanglement sources. Traditional strong-field physics has predominantly focused on atomic and molecular systems, such as gases and liquids. Condensed-matter crystals, by virtue of their dense atomic packing, periodic symmetry point groups, and unique band structures, offer new opportunities for nonlinear optical research. In particular, two-dimensional (2D) crystals feature in-plane localized electronic wavefunctions, which are expected to give rise to exceptionally strong light–matter interactions. This could drive next-generation solid-state laser technologies toward ultimate performance limits, including shorter wavelengths, narrower pulse durations, and higher quantum coherence. In this presentation, I will report on our research progress in nonlinear optics of 2D crystals, including: (1) the discovery of a "lattice transport–interfacial growth" mechanism for materials preparation, enabling universal synthesis of meter-scale 2D crystals; and (2) the proposal of a "twist phase matching" optical theory, leading to the construction of novel high-efficiency optical crystals. Research on nonlinear optics of 2D crystals promises to unveil new physical effects and foster the development of novel extreme laser technologies.



Angel Rubio

Short Bio

Angel Rubio is the Director of the Theory Department of the Max Planck Institute for the Structure and Dynamics of Matter since 2014. He is also Distinguish Research Scientist at the Simons Foundation's Flatiron Institute (NY, USA) and Professor/Chair for condensed matter physics at the University of the Basque Country in Donostia-San Sebastián, Spain. He is also External Scientific Member of the Fritz Haber Institute of Max-Planck-Gesellschaft in Berlin as well as Full Professor at the University of Hamburg (since 2016). He is one of the founders of the European Theoretical Spectroscopy Facility (ETSF) (http://www.etsf.es) and the originator of the widely used ab initio open-source project Octopus. His work has been recognized by several awards, including the 2018 Max Born medal and prize, 2016 Medal of the Spanish Royal Physical Society, the 2014 Premio Rey Jaime I for basic research, the 2006 DuPont Prize in nanotechnology, the 2005 Friedrich Wilhelm Bessel Research Award of the Humboldt Foundation, 1st National Prize for Graduated in Physics and two European Research Council advanced grants (2011 and 2016). He is Fellow of the American Physical Society and the American Association for the Advancement of Science, member of the Academia Europaea and European Academy of Sciences, and a foreign associate member of the National Academy of Sciences and Chinese Academy of Sciences.

Talk Title

TDDFT: from non-equilibrium phenomena to quantum materials engineering

Abstract

One of the principal challenges in computational physics is to formulate an accurate yet computationally viable theory that can address non-equilibrium light-driven phenomena in molecules and quantum materials. Additionally, there is a need to simulate spatially and temporally resolved spectroscopies, ultrafast events, and newly emerging states of matter. In pursuit of this goal, TDDFT has emerged as the cutting-edge ab initio theoretical framework, enabling reliable and precise simulations of light-induced alterations in the physical and chemical characteristics of intricate systems. In this context, I will also introduce the recently developed framework of Quantum Electrodynamics Density-Functional Formalism (QEDFT). This framework offers a first-principles approach to predict, characterize, and manipulate the spontaneous emergence of ordered phases in strongly interacting light-matter hybrids, referred to as polaritons These phases manifest both as ground states, resulting in novel states of matter, as well as metastable states. Noteworthy examples include photon-mediated superconductivity, cavity fractional quantum Hall physics, and optically driven topological phenomena in low dimensions. This exploration brings to light a burgeoning field, which we term "Cavity Materials Engineering" or the science of strongly correlated electron-photon interactions. We will conclude with the great challenges ahead in this captivating field of research.

Talk Title

Cavity QED Materials Engineering: Photon-Mediated Interactions in van der Waals Heterostructures

Abstract

Structuring the photon density of states in an optical cavity offers a powerful route to tailoring material properties through strong light–matter coupling. Quantum electrodynamical density functional theory (QEDFT), grounded in non-relativistic quantum electrodynamics, extends time-dependent density functional theory by incorporating quantized electromagnetic fields directly into electronic structure theory, providing a first-principles framework for cavity-induced phenomena at equilibrium. Recent experiments — from photon-mediated superconductivity to optically engineered topological phases — show that vacuum fluctuations, rather than classical light, can reshape material ground states. In this talk I present an ab initio approach to cavity-induced phenomena in two-dimensional quantum materials. First, using QEDFT, we examine how vacuum field fluctuations reshape the electronic and structural properties of van der Waals layered systems. Cavity photons drive charge localization along the polarization axis and modify the electronic structure of every material we have studied: band gaps, valley shifts, and interlayer spacing become tunable, which in turn allows control of ferroelectric, nonlinear Hall, and optical responses. Second, a non-perturbative, photon-free self-consistent Hartree–Fock framework reveals cavity-mediated electron–electron interactions in graphene. Anisotropic photon modes produce wedge-shaped bands and open a Dirac gap, while isotropic modes preserve the gapless cone but strongly renormalize the Fermi velocity. Together, these results establish cavity photons as a quantum knob for engineering interactions and emergent phases in 2D materials.



Xingjiang Zhou

Short Bio

Xingjiang Zhou is currently a professor in the Institute of Physics, Chinese Academy of Sciences, Beijing. He received his B.S. and M.S. degrees from Tsinghua University and his Ph. D degree from the Institute of Physics, Chinese Academy of Sciences, Beijing. He developed a series of high-resolution vacuum ultra-violet laser-based angle-resolved photoemission systems. His research focuses on studying high temperature superconductors and other quantum materials. He got the Achievement in Asia Award in 2014 and the TWAS Prize in Physics in 2015. He is a Fellow of the American Physical Society and was elected as an academician of the Chinese Academy of Sciences in 2025.

Talk Title

Strong Electron Pairing along Fermi Pockets in High Temperature Cuprate Superconductors

Abstract

By using high-resolution spatially-resolved laser-based angle-resolved photoemission spectroscopy, we investigated the intrinsic electronic structures of the CuO2 planes in multilayer Bi-based cuprates Bi2Sr2Can−1CunO2n+4+d (n=5~8) [1,2]. The inner CuO2 planes are well shielded from the disorders in these multilayer cuprates, thus providing an ideal platform to probe the intrinsic electronic phase diagram. We observed Fermi pockets with a hole doping level as low as 0.007, demonstrating an abrupt transition from the parent Mott insulator to a metallic state upon the introduction of a tiny amount of doping. We identified a cuprate system that consists exclusively of hole Fermi pockets. It challenges the conventional understanding on the role of the nodal and antinodal electronic states in driving high temperature superconductivity. The observed Fermi pockets exhibit unusual layer-, momentum-, temperature- and Fermi surface-dependent energy gaps. Strong electron pairing is observed along a Fermi pocket with an energy gap up to ~42meV in lightly-doped CuO2 planes (p~0.05). These findings indicate that high temperature superconductivity can emerge in a system with only Fermi pockets and coexist with strong antiferromagnetic order, offering new insights into the pairing mechanism in high temperature cuprate superconductors.

[1] Hao Chen, Jumin Shi, Yinghao Li, Lin Zhao, X. J. Zhou et al., Nature Communications 17, 6195 (2026).
[2] Xiangyu Luo, Yinghao Li, Hao Chen, Lin Zhao, X. J. Zhou et al., arXiv: 2606.08643, Nature Communications 17, 8841 (2026).



Emil Viñas Boström

Short Bio

Emil Viñas Boström received his PhD from Lund University, Sweden, in 2018. He subsequently joined the Max Planck Institute for the Structure and Dynamics of Matter (MPSD) in Hamburg as a postdoctoral researcher in the group of Prof. Angel Rubio, developing theoretical methods for light-induced dynamics in low-dimensional materials and their coupling to quantized electromagnetic fields. In 2023, he was awarded a Marie Skłodowska-Curie fellowship at the University of the Basque Country in San Sebastián, Spain, where he investigated cavity control of correlated and topological phases and optical readout of cavity–matter systems. Since 2025, he has been a group leader at MPSD. His research focuses on the dynamics of correlated quantum materials and on using light–matter interactions to control and probe their properties.

Talk Title

Sub-diffraction Imaging of Collective Modes with Scanning Far-Field THz Spectroscopy

Abstract

The spatial resolution of conventional far-field spectroscopy is limited by the wavelength of light. For the many collective excitations that lie in the terahertz (THz) range, this corresponds to length scales of order 100 micrometres, far larger than the structures in which plasmons and polaritons can be confined. Resolving these excitations is important both for understanding collective phenomena and for developing electromagnetic environments that control material properties. In a recent experiment published in Nature [1], we demonstrated how to achieve sub-diffraction THz imaging of collective excitations by combining localized excitation of a spintronic emitter with far-field electro-optic detection. How can spatial information carried by strongly confined, finite-momentum modes survive in the detected far field?

In this talk, I will introduce the electrodynamics underlying this technique. A localized THz source supplies a broad distribution of in-plane momenta and can therefore excite confined plasmons that are inaccessible to conventional plane-wave illumination. The boundaries of a finite sample allow these excitations to couple to propagating radiation, making their response observable in the far field. I will show how this process can be described through the nonlocal current response of the coupled emitter–sample system and how its resonances correspond to plasmon-polariton modes. Near an isolated resonance, scanning the excitation position probes the spatial mode profile through its overlap with the localized source, with a resolution set by the source profile and a signal strength determined by coupling to the detected radiation.

Finally, I will discuss what information these measurements reveal, when they can be interpreted as images of collective modes, and how this differs from measuring a local optical conductivity. The aim is to provide an intuitive framework for understanding how local excitation and nonlocal far-field detection together enable sub-diffraction spectroscopy of collective excitations.

[1] Imaging a terahertz superfluid plasmon in a two-dimensional superconductor, A. von Hoegen et al., Nature 650, pages 869–874 (2026).



Cheng Cen

Short Bio

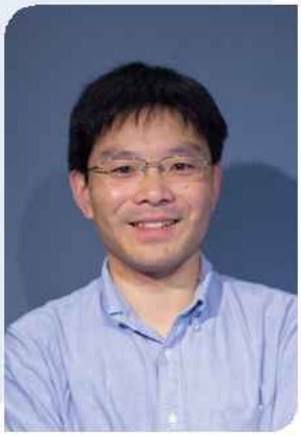
Cheng Cen is a Distinguished Research Fellow and doctoral supervisor in the Huairou Research Division of the Institute of Physics, Chinese Academy of Sciences (IOP CAS). Her research uses scanning probes and light fields to excite and characterize novel phases in quantum materials at the micro- and nanoscale, and to achieve active, spatially programmable control of quantum phase transitions.

Talk Title

Uncovering Hidden Electronic Landscapes in Superconductors through Ultrafast Microscopy

Abstract

Linking superconducting behavior to specific structural or electronic characteristics of a material often requires information beyond the reach of conventional transport measurements. Ultrafast microscopy addresses this challenge by combining optical sensitivity to transient dynamics with contact-free spatial mapping. In superconducting systems, time resolution offers two complementary opportunities: it enables characterization of the superconducting state, from determining its critical temperature to gaining insights into gap structure and quasiparticle coupling to collective excitations; it also reveals distinctive normal-state relaxation signatures correlated with superconducting behavior that may remain unresolved in equilibrium measurements. Spatial resolution further connects these dynamical signatures to naturally occurring or deliberately introduced variations in local parameters, enabling controlled comparisons within a single specimen that are difficult to achieve across separately prepared samples. Drawing on studies of nickelate films, $KTaO_3$-based two-dimensional electron gases, and hydride superconductors under high pressure, this talk will discuss how complementary spatial and temporal information can help distinguish subtle variations in superconducting states, identify normal-state dynamical signatures relevant to the emergence of superconductivity, and clarify the influence of structural and interfacial environments. By resolving where electronic responses differ and how they evolve in time, ultrafast microscopy provides a route to uncovering hidden electronic landscapes central to understanding emerging superconducting materials.



Wentao Zhang

Short Bio

Dr. Wentao Zhang leads a TRARPES research group at the Institute of Physics, Chinese Academy of Sciences. He received his Ph.D. in condensed matter physics from the Institute of Physics, CAS in 2010. His research focuses on ultrafast electronic dynamics and light-induced phenomena in correlated quantum materials, including charge-density-wave systems and superconductors. His group develops advanced instrumentation for time- and angle-resolved photoemission spectroscopy and time-resolved transport measurements to investigate these phenomena.

Talk Title

Probing and Controlling Correlated Electron Materials with TRARPES

Abstract

Ultrafast spectroscopy provides a powerful approach to probing and controlling correlated electron materials beyond equilibrium. In this talk, I will present our development of high-resolution time- and angle-resolved photoemission spectroscopy (TRARPES) instruments with IR and MIR pumping, alongside a time-resolved transport apparatus for investigating transient electrical responses. I will then discuss our studies of TiSe2, TaS2, and the kagome metal KV3Sb5, focusing on charge-density-wave dynamics, electronic band reconstruction, and light-induced metastable states. These investigations reveal the interplay between electronic correlations and lattice degrees of freedom, illustrating how complementary measurements of electronic structure and transport can advance our understanding of collective phenomena and guide the optical control of quantum materials.



Heng Fan

Short Bio

Heng Fan is a Professor at the Institute of Physics, Chinese Academy of Sciences (IOP CAS). His research spans quantum computation and quantum information, quantum theory, and condensed matter physics, with recent focus on superconducting quantum computation.

Talk Title

Quantum computation and simulation on superconducting processors.



Zhaohua Cheng

Short Bio

Dr. Zhao-Hua Cheng, Professor at Institute of Physics, Chinese Academy of Sciences. He earned his Bachelor's and Master's degrees from Lanzhou University in 1990 and 1993, respectively, and obtained his Ph.D. in Condensed Matter Physics from Institute of Physics, CAS, in 1996. From 1996 to 2000, he conducted postdoctoral research at the Max Planck Institute for Metals Research in Germany and the Department of Physics at Dalhousie University in Canada. His primary research focuses on magnetic nanostructures and femtomagnetism. He has published over 300 papers in major international academic journals such as Adv. Mater., Phys. Rev. Lett., Nature Comm., Nano. Lett., PNAS, and Phys. Rev. B. His publications have been cited more than 5,000 times by others. He has delivered over 30 invited talks at international academic conferences. He has received numerous awards, including the Ninth China Youth Science and Technology Award, the First Prize of Beijing Science and Technology Award, the 1997 Ye Qisun Physics Prize of the Chinese Physical Society, and the Second Prize of the National Education Commission's Science and Technology Progress Award.

Talk Title

Ultrafast Magneto-Optical Fingerprints of Altermagnetism in MnTe

Abstract

Recently identified altermagnets exhibit a distinctive dual-space nature: they possess spin-split electronic bands akin to ferromagnets in momentum space while maintaining the fully compensated magnetization of antiferromagnets in real space. This inherent duality, originating from the same crystal symmetry, gives rise to various intriguing physical phenomena unique to altermagnets. Consequently, a robust and efficient experimental signature capable of revealing this dual character is critically needed. The magneto-optical Kerr and Voigt effects, given their high sensitivity to ferromagnetism and antiferromagnetism, respectively, are ideally suited to probe this duality. Here, using time-resolved pump-probe magneto-optical measurements, we report the coexistence of pronounced Kerr and Voigt effects in the altermagnet MnTe. Combining the magnetization measurement and first-principles calculations, we demonstrate that the Kerr effect originates from the intrinsic Berry curvature of altermagnetism distribution in momentum space, while the Voigt effect arises from an anisotropic permittivity induced by the in-plane Néel order in real space, directly revealing the dual-space nature of altermagnets. Furthermore, the transient Kerr signal exhibits faster relaxation dynamics than the transient Voigt signal, underscoring their distinct origins in Berry curvature and Néel order, respectively. These findings establish transient magneto-optical responses as distinctive fingerprints of altermagnetism and position altermagnets as promising platforms for manipulating magneto-optical phenomena in ultrafast spin-optoelectronics.



Jimin Zhao

Short Bio

Professor Jimin Zhao, OPTICA Fellow, serves as full professor and group leader at the Institute of Physics, CAS. He earned his B.S. and M.S. from Tsinghua University and Ph.D. from the University of Michigan (Ann Arbor). His research interest focuses on ultrafast spectroscopy and dynamics of correlated quantum materials. He has innovated on-site in situ high-pressure ultrafast spectroscopy, investigated ultrafast dynamics of superconductors, charge density waves, topological quantum states, etc. He serves on the Academic Committee of Light Scattering, CPS, and as Vice Chair of Optica's Ultrafast Phenomena Technical Group. He leads major national research programs, including the National Key R&D Program, NSFC Key Project and CAS Interdisciplinary Innovation Team.

Talk Title

High Pressure Ultrafast Dynamics of LaH10±δ and La3Ni2O7 and Emergent Quantum State in 1T-TaS2

Abstract

I will present our recent works on high-pressure ultrafast spectroscopy. We have innovated an on-site in situ high pressure pump-probe ultrafast spectroscopy instrument [1,2], which enables precise measurements of both the amplitudes and lifetimes, featuring independent tuning and precise control of pressure and temperature at low and varying temperatures. Using this instrument, we found pressure-induced phonon-bottleneck effect [3]. Further, we have achieved time-resolved low temperature ultrafast spectroscopy of LaH10±δ under an ultrahigh pressure [4]. This first ultrafast dynamics investigation of superhydrides provides direct experimental evidence that strong EPC is responsible for the near-room-temperature superconductivity in clathrate superhydrides. Significantly, we have experimental detected the ultrafast dynamics of pressurized nickelate superconductor La3Ni2O7, revealing relatively strong EPC and precisely measuring its superconducting gap [5]. Finally, our high-precision ultrafast collective dynamic measurements uncover an emergent quantum state in the CDW material 1T-TaS2 below 65 K [6].

[1] Y. L. Wu, Jimin Zhao, et al., Rev. Sci. Instrum. 92, 113002 (2021). [2] Jiazila Hasaien, Jimin Zhao, et al., Rev. Sci. Instrum. 96, 013004 (2025). [3] Y. L. Wu, Jimin Zhao, et al., Chin. Phys. Lett. (Express Letter) 37, 047801 (2020). [4] Y. L. Wu, Jimin Zhao, et al., Nat. Commun. 15, 9683 (2024). [5] Y. N. Zhai, Jimin Zhao, et al., Phys. Rev. Lett., under review (2026). [6] Jiazila Hasaien, Jimin Zhao, et al., PNAS 122, e2406464122 (2025).



Sebastián de la Peña Ruiz

Short Bio

Sebastián is a Ph.D. student working in the field of quantum high harmonic generation under the supervision of Prof. Angel Rubio. His research focuses on exploring the limitations of semiclassical methods for simulating the interaction between light and matter under strong-field driving conditions. He received his B.Sc. in Physics and M.Sc. in Nanophysics from the Universidad Autónoma de Madrid, Spain. He subsequently pursued his doctoral research at the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg, Germany, where he investigates the quantum aspects of light–matter interactions in strong fields.

Talk Title

Quantum Driving and Entanglement in High Harmonic Generation

Abstract

High harmonic generation (HHG) is traditionally described using semiclassical theories in which the electromagnetic field is treated classically. However, recent developments suggest that quantum-optical phenomena such as squeezing and entanglement are either intrinsically present in HHG or can be artificially generated during the process. This has opened a debate about the appropriate theoretical framework for capturing the quantum nature of HHG processes. In this work, we investigate the limits of semiclassical methods for quantum HHG and compare them with exact quantum calculations, highlighting situations in which a fully second-quantized treatment becomes relevant.



Omid Nourmofidi

Short Bio

2021-2025: Bachelor and Master of Science in Physics, University of Hamburg, Germany
2025-: PhD Student at Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany at the Theory group lead by Angel Rubio

Talk Title

Linking critical temperature with electron localization for cavity-enhanced superconductivity

Abstract

Predicting superconducting properties from first principles—especially in non-equilibrium conditions—is computationally intensive. Here, we propose a more efficient approach by using the electron localization function (ELF) as a proxy for estimating the superconducting critical temperature T_C . Through first-principles calculations, we investigate how coupling conventional superconductors to an optical cavity—without external driving—modifies their phonon properties and electron–phonon interactions via vacuum fluctuations alone. We focus on three representative materials: lead (Pb), niobium (Nb), and magnesium diboride (MgB_2). Our methodology combines Density Functional Theory (DFT), Density Functional Perturbation Theory (DFPT), Quantum Electrodynamical Density Functional Theory (QEDFT), and Wannier-based electron–phonon coupling to solve the Eliashberg equations for T_C. For the materials studied here, our results indicate that the ELF captures some trends in the superconducting behavior under light–matter coupling, suggesting it may serve as a low-cost descriptor to guide the screening or design of superconductors in equilibrium and cavity-modified regimes.



Francesco Greco

Short Bio

Francesco is a PhD student in the Theory Department of the Max Planck Institute for the Structure and Dynamics of Matter (MPSD) in Hamburg, Germany, under the supervision of Prof. Angel Rubio. His research investigates the effects of strong light-matter coupling on molecules in optical cavities, using ab initio theoretical and computational methods. His work is part of the ERC Synergy project UnMySt. Before joining MPSD, he received his Bachelor's and Master's degrees in Physics from the University of Calabria, Italy, specializing in condensed matter physics.

Talk Title

Spin-glass mapping of electron correlations in optical cavities.

Abstract

Spin-glass mapping of electron correlations in optical cavities.
Francesco Greco and Michael Ruggenthaler
Max Planck Institute for the Structure and Dynamics of Matter and Center for Free-Electron Laser Science, Luruper Chaussee 149, Hamburg 22761, Germany and
The Hamburg Center for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany
Dominik Sidler
Zurich University of Applied Sciences, School of Engineering, Technikumstrasse 71, Winterthur 8400, Switzerland and
Max Planck Institute for the Structure and Dynamics of Matter and Center for Free-Electron Laser Science, Luruper Chaussee 149, Hamburg 22761, Germany
Angel Rubio
Max Planck Institute for the Structure and Dynamics of Matter and Center for Free-Electron Laser Science, Luruper Chaussee 149, Hamburg 22761, Germany
The Hamburg Center for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany
Center for Computational Quantum Physics (CCQ), Initiative for Computational Catalysis (ICC), The Flatiron Institute, 162 Fifth avenue, New York, NewYork 10010, United States of America

Collective strong coupling of molecular ensembles to optical cavities can modify matter through collective electronic correlations, yet the underlying microscopic mechanism remains unclear [1]. Building on a recently established mapping of cavity-mediated transverse electron correlations onto the analytically solvable spherical Sherrington-Kirkpatrick (SSK) spin-glass model[2], we consider a manifold of collectively degenerate cavity-dressed states. We identify two distinct routes to an extensive correlation energy: an insulating one, with an almost empty or almost filled degenerate manifold, and a metallic one with a fractionally filled manifold. Focusing on the latter, we integrate the free energy under our scaling constraints[3] and obtain a phase diagram featuring two phases beyond the usual uncorrelated one: a "paracorrelated" and a "spin-glass" phase[4]. Entropy maximization can drive the system into either phase, outweighing the Coulomb energy barrier. Since the model does not rely on macroscopic quantum coherence, it remains plausible at room temperature and for the modified electric susceptibility and other properties observed in cavity experiments. Combined with numerical simulations of Rayleigh scattering processes from molecules in a cavity, this work bridges theory and experiment[5] towards a global framework for these phenomena. Future work will extend the treatment to higher electronic excitations (ideally a full-CI picture), address non-Gaussian distributions of the intermolecular couplings, and analyze the effects of aging dynamics and the breakdown of fluctuation-dissipation relations on the molecular physics.

[1] M. Ruggenthaler, D. Sidler, and A. Rubio, "Understanding Polaritonic Chemistry from Ab Initio Quantum Electrodynamics," Chem. Rev., vol. 123, no. 19, pp. 11191–11229, Oct. 2023, doi: 10.1021/acs.chemrev.2c00788.

[2] D. Sidler, M. Ruggenthaler, and A. Rubio, "Collectively-Modified Intermolecular Electron Correlations: The Connection of Polaritonic Chemistry and Spin Glass Physics: Focus Review," Chem. Rev., vol. 126, no. 1, pp. 4–27, Jan. 2026, doi: 10.1021/acs.chemrev.4c00711.

[3] F. Greco, M. Ruggenthaler, D. Sidler, and A. Rubio, in preparation

[4] D. Sidler, F. Greco, M. Ruggenthaler, and A. Rubio, "Cavity-mediated localization and collective electron correlation phases," Aug. 04, 2026, arXiv. doi: 10.48550/ARXIV.2605.01551.

[5] K. Sandeep et al., "Cluster Formation and Phase Transitions Induced by Vibrational Strong Coupling," Angew. Chem. Int. Ed., vol. 65, no. 1, p. e16917, Jan. 2026, doi: 10.1002/anie.202516917.



Na Wu

Short Bio

Na Wu is a Marie Skłodowska-Curie Postdoctoral Fellow in the Theory Department at the Max Planck Institute for the Structure and Dynamics of Matter (MPSD) in Hamburg, Germany, working with Prof. Ángel Rubio. She received her PhD from the Institute of Physics, Chinese Academy of Sciences in 2024. Her research focuses on nonequilibrium dynamics and light–matter interactions in quantum materials, particularly (driven-) cavity-controlled phonon dynamics. She combines first-principles calculations with effective theoretical models and quantum dynamical simulations to investigate how light and optical cavities can manipulate the magnetic, vibrational, and electronic properties of materials.

Talk Title

Quantum squeezing of phonons through crystal symmetry

Abstract

Crystal symmetry offers a route to controlling phonon quantum fluctuations without inducing a mean displacement. We identify a point-group criterion that allows a driven phonon to modulate the restoring stiffness of a target mode while forbidding a pump-induced rectifying force. For a totally symmetric pump, the target mean remains zero when the state and environment preserve the crystal symmetry. Applying this criterion to the A1–E channel in lithium niobate, we combine first-principles anharmonic couplings with explicit quantum reservoirs. A self-consistent Gaussian reference calculation for the pump and one target component predicts 3.63 dB of sub-vacuum squeezing at 5 K. Gaussian and truncated-Wigner calculations retaining both target components support the persistence of squeezing. These results link a general symmetry criterion to a material-specific prediction of quantum-noise control in an open solid.



Fabio Caruso

Short Bio

Fabio Caruso earned a PhD in Theoretical Physics at the Fritz Haber Institute of the Max-Planck Society in Berlin in 2013. He then held postdoctoral positions at the University of Oxford (2013–2016) and Humboldt University of Berlin (2017–2020). He has been appointed Junior Professor (2020–2025) and Associate Professor (2025–2026) at the University of Kiel. Since 2026, he has been Full Professor of Theoretical Physics at the University of Rostock, Germany. His research interests span computational materials science, the development of ab-initio methods, many-body theory, and non-equilibrium phenomena.

Talk Title

Electron-phonon interactions in the time domain: from quasiparticle dynamics to light-induced phase transitions.

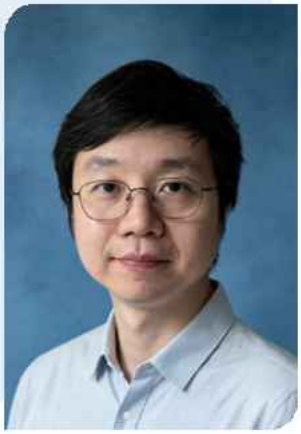
Abstract

Electron-phonon interactions in the time domain:
from quasiparticle dynamics to light-induced phase transitions.

Fabio Caruso, Rostock University, Germany

Electron-phonon coupling largely governs the non-equilibrium dynamics of solids on timescales ranging from hundreds of femtoseconds to a few picoseconds. Prominent examples include the emergence of hot and coherent phonons, polarons, exciton self-trapping, and light-induced phase transitions. By combining density functional theory with a many-body formulation of structural motion and electron-phonon interactions (EPI), we establish a general framework to model light-induced structural dynamics and EPI fully from first principles in reciprocal space. I will illustrate this framework through several applications: coherent phonon dynamics in WTe_2 [1], the real-time formation of polaronic quasiparticles in MgO [2], and the light-induced melting of charge-density-wave order in monolayer $TiSe_2$ [3]. A key advantage of our approach consists in recasting the lattice dynamics in reciprocal space, which naturally captures long-range order and symmetry switching without resorting to large supercell simulations.

[1] C. Emeis, F. Caruso, Phys. Rev. X 15, 021039 (2025)
[2] V. Garcia-Herrero et al, arXiv:2601.21810 (2025)
[3] C. Emeis, F. Caruso, arXiv:2604.09242 (2026)practical route to accurate electronic spectra and excited-state forces in large molecules and materials.



Qi Zhang

Short Bio

Qi Zhang is a Professor at Nanjing University, where he has been a faculty member since 2019. His research focuses on light–matter interactions, low-energy excitations, and ultrafast phenomena in low-dimensional quantum materials, using terahertz and Raman spectroscopy and magneto-optical techniques. He received his Ph.D. from Rice University in 2015 and previously held research positions at Argonne National Laboratory and the University of Washington.

Talk Title

Coherent three-wave mixing of collective excitations in 2D antiferromagnets

Abstract

Collective excitations in quantum materials encode many-body interactions that are often hidden from linear spectroscopy. Coherent three-wave mixing, in which two excitations combine to generate a third at a sum or difference frequency, provides a powerful route to revealing and controlling these nonlinear couplings. Layered van der Waals antiferromagnets are particularly promising because of their reduced dimensionality, strong correlations, and tunable magnetic anisotropy. In this talk, I will discuss coherent magnon–phonon and magnon–magnon three-wave mixing in FePS3 and NiPS3 using multidimensional terahertz spectroscopy. The observed frequency conversion and activation of dark magnons demonstrate nonlinear control of coupled spin and lattice excitations in 2D antiferromagnets.



Feifan Wang

Short Bio

Feifan Wang engaged in solid-state spectroscopy and is currently an associate professor in Institute of Physics, Chinese Academy of Sciences. He received a BS degree from Shandong University in 2012 and a PhD degree from Peking University in 2017. After postdoctoral researches with Xiaoyang Zhu at Columbia University (2017-2021) and with Manfred Fiebig at ETH Zurich (2021-2023), he obtained a joint professorship by Institute of Physics and Songshan Lake Materials Laboratory. His honors include ETH career seed award, HORIBA Scientific outstanding graduate scholarship, etc. He served as the session chair on the DPG conference and the independent reviewer of Science Advances, Journal of Chemical Physics, etc.

Talk Title

Photo-induced ordering in metastable anharmonic solids

Abstract

The identification and manipulation of metastable states are crucial for understanding and eventually utilizing the nonequilibrium dynamics of phase transitions. These transient states can host exotic properties, offering a pathway to innovative functional devices whose response times are governed by ultrafast processes. However, such states are often thermodynamically inaccessible, making their discovery rare. Here, we use ultrafast laser excitation to steer a quasi-two-dimensional solid material into a metastable state. In this state, we observe in-plane and out-of-plane symmetry reduction with respect to the ground state, evidenced by the emergence and frequency shift of nonequilibrium phonon modes via coherent phonon spectroscopy and time-resolved terahertz spectroscopy. Accompanying this transition, we detect a transient anisotropy in the optical conductivity. We further rationalize our observations by recalling the material characteristics of lattice anharmonicity and electron–phonon coupling. Our findings might open avenues for developing novel, ultrafast switchable optoelectronic devices.

Key words: coherent phonon, electron–phonon coupling, excited-state, quantum materials, terahertz spectroscopy.



Michael Sentef

Short Bio

Prof. Michael A. Sentef is a Professor of Theoretical Solid State Physics at the University of Bremen, Germany, and a Visiting Scientist at the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg. He received his PhD in Physics from the University of Augsburg in 2010 for work on electronic correlations in metals, insulators, and superconductors. After postdoctoral research at Stanford University and SLAC National Accelerator Laboratory (2011-2014), and at the University of Bonn (2014-2015), he joined the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg, first as a Group Leader in the Theory Department and subsequently as an Emmy Noether Group Leader funded by the Deutsche Forschungsgemeinschaft. Following a period as Associate Professor of Physics at the University of Bristol, UK, he moved to the University of Bremen in 2023, where he leads the Light-Matter Control of Quantum Materials group within the Bremen Center for Computational Materials Science. His research focuses on the theoretical modeling and computational physics of light-driven quantum materials, with particular emphasis on light-induced phase transitions, dynamical control of emergent phenomena, Floquet states of matter, and cavity quantum materials, a field he helped pioneer. More broadly, his work explores new directions at the interfaces of condensed matter physics, quantum optics, ultrafast science, and polariton physics. He is the recipient of the ERC Consolidator Grant CAVMAT - Cavity Quantum Materials (2024-2029). Since 2025, he has served as Director of the CECAM-DE-QMDYN node (Quantum Materials Dynamics), a joint initiative of Bremen, Oldenburg, Hamburg, and Aachen supporting the community, in particular early-career researchers, in theoretical and computational materials science. He also serves on the FIS-PRIO Committee for Large Research Infrastructures of the German Science and Humanities Council (Wissenschaftsrat), advising the German Government on strategic questions of research infrastructure.

Talk Title

Microscopic mechanism for resonant light-enhanced pair correlations in K3C60

Abstract

Microscopic mechanism for resonant light-enhanced pair correlations in K3C60
Juan I. Aranzadi, Joseph Tindall, Paul Fadler, Michael A. Sentef
Recent experiments on K3C60 revealed a giant enhancement of the light-induced superconducting-like optical response for pump frequencies near 10 THz, with an efficiency roughly two orders of magnitude larger than for off resonant excitation. Here we show that a resonant enhancement of pair correlations arises naturally in a driven purely electronic model of K3C60 with ab initio parameters. The underlying mechanism is a symmetry constrained two-photon pathway: the first photon drives the system from the even-parity ground state to an intermediate odd-parity manifold, while the second photon induces a transition to an even-parity excited state with enhanced pair correlations. Larger-cluster calculations show that the corresponding resonance energy is strongly renormalized downward with system size and connectivity, reflecting the kinetic-energy gain of delocalized photo-excited doublon-holon configurations. A simplified single-orbital model reproduces this scaling trend and reaches a 14-site fcc cluster, where the resonant peak is pushed to 30 THz, with a trend compatible with a further reduction toward the experimental 10 THz scale in larger systems. Varying the Hubbard coupling strength, we find that the resonance is lowest and the pairing enhancement strongest near intermediate couplings, where doublon-holon excitations are both well defined and mobile. Our results establish a purely electronic mechanism for resonant light-enhanced pair correlations in K3C60 and support the interpretation of the experimental 10 THz resonance as optical access to a paired many-body excited state rather than improved metallicity. More broadly, they suggest that related resonant pathways may arise in other intermediate-coupling Hubbard materials.



Mengxue Guan

Short Bio

Dr. Mengxue Guan is an Associate Professor at Beijing Institute of Technology, China. Holding a Ph.D. from the Institute of Physics, Chinese Academy of Sciences, she centers her theoretical research on excited-state quantum dynamics and ultrafast processes. She is particularly interested in light-driven non-equilibrium phase transitions, dynamic symmetry control, and novel optoelectronic responses in topological and correlated quantum materials. To date, Dr. Guan has published more than 30 academic papers, with 18 high-impact publications as the first or corresponding author in top-tier journals including PRL, Sci. Adv. and Nat. Commun..

Talk Title

Ultrafast Optical Control of Dynamic Symmetry and Non-Equilibrium Quantum States

Abstract

Ultrafast Optical Control of Dynamic Symmetry and Non-Equilibrium Quantum States
Mengxue Guan* and Yamei Zhou
Centre for Quantum Physics, Key Laboratory of Advanced Optoelectronic Quantum Architecture and Measurement (Ministry of Education), School of Physics, Beijing Institute of Technology, Beijing 100081, China
Contact: mxguan@bit.edu.cn

This report focuses on dynamic symmetry control driven by ultrafast optical fields, highlighting our recent theoretical studies in topological and correlated quantum systems. We explore how polarization and timescale selectivity of optical fields couple electronic, orbital, lattice, and magnetic degrees of freedom, controlling non-equilibrium states through symmetry preservation, breaking, and competition. Our work demonstrates that symmetry selection rules generate non-equilibrium carrier excitations that drive ultrafast reconstruction via electron-lattice coupling. Furthermore, coherent lattice modes with distinct symmetries open alternative topological channels, showing how symmetry competition dictates the pathways of light-induced topological phase transitions [1]. By reshaping non-equilibrium potential surfaces, relieving geometric frustration, or breaking spatial and time-reversal symmetries, optical fields can also induce hidden electronic states and transient magnetic orders that are inaccessible in equilibrium [2,3].

[1] Y. M. Zhou et al., Nano Lett. 26, 5019 (2026).
[2] M. X. Guan et al., Phys. Rev. Lett. 131, 256503 (2023).
[3] M. X. Guan et al., ACS Nano 20, 15963 (2026).



Peiwei You

Short Bio

Peiwei You is affiliated with the Hebrew University of Jerusalem and Zhejiang University. My research focuses on developing first-principles methods to study coupled electron–nuclear dynamics and electronic correlations in materials. I combine time-dependent density functional theory, molecular dynamics, and exact factorization to investigate nonadiabatic processes and nuclear quantum effects, with applications to photoinduced phenomena and photocatalysis. I also develop conditional probability density functional theory for periodic solids to explore electronic pair densities, exchange-correlation holes, and correlation effects in low-dimensional systems and kagome materials.

Talk Title

Correlated electron-nuclear dynamics with first-principles approaches

Abstract

Correlated electron-nuclear dynamics with first-principles approaches
Peiwei You1, 2, Sheng Meng3, Kieron Burke4, and E. K. U. Gross5, 1
1Fritz Haber Center for Molecular Dynamics, Institute of Chemistry, The Hebrew University of Jerusalem, Jerusalem 91904, Israel
2Center for Quantum Matter, School of Physics, Zhejiang University, Hangzhou 310058, China
3 Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China
4Departments of Physics and Astronomy and of Chemistry, University of California, Irvine, California 92697, USA
5Quantum Dynamics Laboratory, Tsientang Institute of Advanced Study, Hangzhou, Zhejiang, 310024, China
Corresponding author e-mail address: peiwei.you@mail.huji.ac.il
Abstract:
Within the Born–Oppenheimer adiabatic approximation, ground-state density functional theory molecular dynamics has revealed fundamental physical mechanisms in materials and found broad applications in physics and chemistry. However, time-dependent nonadiabatic phenomena, including photoinduced phase transitions, high-harmonic generation, and photocatalytic water splitting, require an explicit treatment of electronic excitations and coupled electron–nuclear motion. We develop first-principles approaches based on time-dependent density functional theory (TDDFT) and molecular dynamics, using numerical atomic-orbital basis sets to investigate these processes beyond the adiabatic picture.

At the water–rutile TiO2(110) interface, our simulations identify both field-induced and photogenerated-hole-driven water dissociation. In the former, the optical field redistributes interfacial charge and weakens the oxygen–hydrogen bond. In the latter, hole transfer to water is assisted by a photoexcited polaron through coupled electronic and nuclear dynamics. Photoexcitation changes the distribution of localized titanium 3d electrons, driving polaron expansion through Jahn–Teller distortion. Subsequent contraction and electronic relaxation reshape the local potential and promote hole transfer to adsorbed water, triggering dissociation. Phonon analysis identifies the principal contributions of Eu and A1g modes to this response. This dynamical mechanism, inaccessible to conventional Born–Oppenheimer molecular dynamics, establishes how localized electrons and lattice motion cooperate to drive interfacial chemistry and suggests new strategies for photocatalyst design.

A further description of such coupled dynamics calls for treating both nuclear quantum effects and electronic correlations. We combine TDDFT with path-integral nuclear quantization and pursue quantum electron–nuclear dynamics through exact factorization of the total wavefunction. Extending the conditional-wavefunction perspective to interacting electrons also motivates our development of conditional probability (CP) density functional theory (DFT) for solids. By solving CP Kohn–Sham equations, we obtain pointwise pair densities and exchange-correlation holes. For stretched hydrogen chains, the exchange-correlation holes exhibit long-range, approximately power-law decay. In the Kagome metal CsV3Sb5, CP-DFT reveals structured 3d orbital correlations, an enhanced probability of finding electrons at finite separation, and local charge-density-wave-related modulations. It also predicts a 20–40 meV downward shift of a van Hove band near the Fermi level, linking real-space correlations to low-energy electronic structure. These developments connect nonadiabatic reaction dynamics with the quantum correlations underlying electronic structure, advancing a microscopic understanding of photoinduced processes and correlated materials.

Key words: TiO2 photocatalysis; nonadiabatic dynamics; polarons; conditional probability density functional theory; electronic pair density



Lukas Grunwald

Short Bio

Lukas Grunwald studied physics at RWTH Aachen University, where he completed his master's thesis at the Institute for Theory of Statistical Physics and was awarded the Friedrich-Wilhelm-Preis. He is now a final-year doctoral student in the Theory Department of the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg, a position held jointly with RWTH Aachen and supported by an IMPRS Fellowship. His research concerns cavity material engineering in strongly correlated systems in and out of equilibrium, with the aim of bringing cavity modeling closer to an ab-initio description. Recent work establishes the off-resonant nature of cavity-induced ground-state modifications and proposes schemes for probing cavity-embedded matter through the cavity photons.

Talk Title

Cavity Control of Strongly Correlated Electrons Beyond Resonant Coupling

Abstract

Interfacing materials with electromagnetic cavities offers a route to modify equilibrium properties through structured vacuum fluctuations. The coupling between light and correlated electrons lacks a characteristic energy scale, making vacuum induced ground state modifications of such systems inherently off-resonant and sensitive to the full photon mode structure.

We develop a consistent cavity-QED formalism for dispersive electromagnetic environments in the Coulomb gauge, capturing both dynamical dressing via the vector potential and static screening by the dielectric. With this formalism, we perform a non-perturbative study of the cavity-induced modification of magnetism in the Hubbard model close to half-filling, including all cavity modes and with parameters determined from first principles.

At half-filling, we show that the modification of the magnetic exchange interaction ξJξ is controlled by a generalized Purcell factor, proportional to the frequency integrated photonic density of states relative to free space. This result identifies polaritonic surface cavities as promising platforms to modify correlated systems.

For the surface cavity a competition between static screening and dynamical dressing via the vector potential leads to a net enhancement of ξJξ, directly observable in two-magnon Raman spectroscopy. The inclusion of screening is essential to obtain even qualitatively correct results.

At weak doping, a variational exact diagonalization of the cavity-coupled ξtξ-ξJξ polaron reveals that a low-frequency surface cavity can reverse the nodal-antinodal dichotomy of the bare polaron dispersion. This effect lies beyond mean field theory and is observable via ARPES measurements.

Our framework establishes a concrete design principle linking cavity geometry to material response in the off-resonant regime, which will guide future experimental and theoretical explorations.

Author List: Lukas Grunwald*, Xinle Cheng*, Emil Viñas Boström, Michael Ruggenthaler, Marios H. Michael, Dante M. Kennes, Angel Rubio (* denotes shared-first authorship)

Arxiv-Link: https://arxiv.org/abs/2603.18933



Simon Vendelbo Bylling Jensen

Short Bio

Simon Vendelbo Bylling Jensen is an Alexander von Humboldt Postdoctoral Fellow at the Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, developing first-principles theories of ultrafast, light-driven quantum phenomena in materials. He holds a Ph.D. in Physics from Aarhus University, where he will soon return as a Carlsberg Reintegration Fellow to establish an independent research program on light-engineered quantum materials.

Talk Title

Ultrafast Multiband Electron Dynamics in Solids: Insights from Pulse-Duration-Controlled High-Harmonic Generation

Abstract

A central goal in strong-field solid-state science is to gain active control over ultrafast electron processes within a material's band structure. High-harmonic generation (HHG) provides a sensitive probe of such dynamics, as the emitted spectrum encodes intraband acceleration, interband coherence, and band-specific transition pathways. While driving-field intensity, wavelength, and crystal orientation are known to shape this response, pulse duration, which sets the temporal window for coherent electron motion before decoherence intervenes, has remained a comparatively unexplored control parameter.

I will present experimental and ab initio time-dependent density-functional theory results demonstrating pulse-duration control over multiband electron dynamics in the dielectric MgO. By jointly tuning pulse duration (5–29 fs) and intensity (0.8–74 TW/cm^2), we identify two distinct regimes of interband electron transfer: a multicycle, accumulative pathway promoting carriers into higher conduction bands, and a subcycle pathway transferring carriers across multiple bands within a single half-cycle. Both extend the harmonic cutoff to 25–50 eV via markedly different electron trajectories, which we connect to threshold field strengths for accessing specific high-symmetry points using a semiclassical trajectory analysis.

These results establish pulse duration as a powerful handle for controlling which electronic bands are accessed and on what timescale, opening a route toward band-structure-guided design of coherent extreme-ultraviolet sources. In the end, I will also address further work extending such processes to magnetic and correlated-electron materials.

Reference: Pulse-Duration Control of Subcycle Multiband Electron Dynamics Extends the High-Harmonic Cutoff in a Light-Driven Insulator, Hortense Allegre, Simon V. B. Jensen, Joseph J. Broughton, Tim Klee, Yan Li, Jon P. Marangos, Nicolas Tancogne-Dejean, Angel Rubio, John W. G. Tisch, and Mary R. Matthews, arXiv:2608.06129



Huimin Wang

Short Bio

Huimin Wang is a postdoctoral researcher at the Institute for Theoretical Physics, University of Bremen, Germany. She received her Ph.D. in condensed matter physics from the Institute of Physics, Chinese Academy of Sciences. Her research focuses on first-principles simulations of nonequilibrium quantum materials and ultrafast light–matter interactions, with particular interests in electron–phonon coupling and its role in polarons, ferroelectricity, and topological phenomena.

Talk Title

Fluence-Controlled Directional Sliding in a Polar Weyl Semimetal

Abstract

Fluence-Controlled Directional Sliding in a Polar Weyl Semimetal
Huimin Wang1*, Matthew W. Day2,3, Dante M. Kennes4,5, Michael A. Sentef1,5
1Institute for Theoretical Physics and Bremen Center for Computational Materials Science, University of Bremen, 28359 Bremen, Germany
2Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee 37235, USA; 3Department of Electrical and Computer Engineering, Vanderbilt University, Nashville, Tennessee 37235, USA
4Lehrstuhl für Theoretische Physik der kondensierten Materie, RWTH Aachen University, 52074 Aachen, Germany; 5Max Planck Institute for the Structure and Dynamics of Matter, Center for Free-Electron Laser Science (CFEL), 22761 Hamburg, Germany
Corresponding author e-mail address: huimin@uni-bremen.de
Abstract
Light-driven interlayer sliding in van der Waals materials offers a route to ultrafast control of coupled ferroelectricity and topology, yet its microscopic mechanism and directional control remain elusive. Using real-time time-dependent density-functional theory combined with molecular dynamics, we show that photoinduced sliding in Td-MoTe2 can be tuned in magnitude and reversed in direction by pump fluence alone. This fluence selectivity originates from a nonlinear redistribution of photocarriers among electronic states that generate oppositely directed sliding forces. Along the selected pathway, nonlinear electron-phonon coupling reshapes the nonequilibrium potential-energy surface, enabling ferroelectric suppression, reversible switching, melting, and enhancement, accompanied by Weyl-node evolution. Our results resolve the microscopic origin of the nonequilibrium phase diagram and establish laser fluence as a simple pathway-selection knob, without requiring momentum- or valley-selective excitation. More broadly, they reveal a general mechanism whereby photocarrier redistribution selects the direction of structural motion, while electron-phonon coupling determines the accessible states.

Key words: Coherent Phonon; Sliding Ferroelectricity; Weyl Semimetal; Ultrafast phase transition; Real-Time TDDFT Molecular Dynamics (rt-TDDFT-MD)



Benshu Fan

Short Bio

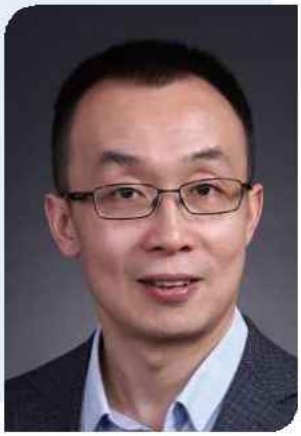
Benshu Fan is a postdoctoral researcher at the Max Planck Institute for the Structure and Dynamics of Matter (MPSD) in Hamburg. He received his B.S. in Applied Physics (Wang Daheng Talents Program of Physics) from Dalian University of Technology in 2019 and his Ph.D. from Tsinghua University in 2024. His research focuses on first-principles studies of nonequilibrium quantum materials, including Floquet engineering, real-time TDDFT, time-resolved photoemission, and cavity-modified quantum materials.

Talk Title

First-principles Floquet analysis from real-time propagation

Abstract

First-principles Floquet analysis from real-time propagation
Ruipeng Li1,*, Benshu Fan1,*, Umberto De Giovannini1,2, Hannes Hübener1,†, Angel Rubio1,3,‡
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2Dipartimento di Fisica e Chimica - Emilio Segrè, Università degli Studi di Palermo, Via Archirafi 36, 90123 Palermo, Italy
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* These authors contributed equally.
Corresponding author e-mail addresses: † hannes.huebener@mpsd.mpg.de; ‡ angel.rubio@mpsd.mpg.de
Abstract
We present a real-time Floquet analysis method for extracting quasi-energies and Floquet states directly from propagated wavefunctions. By reconstructing the one-period evolution operator from overlaps between time-evolved states, the method avoids the explicit construction of the enlarged Floquet Hamiltonian and adds negligible computational overhead to time-dependent simulations. To resolve the ambiguity inherent in the reduced-zone representation, we introduce an unfolding procedure based on the harmonic decomposition of Floquet states, which recovers their underlying equilibrium band character beyond the reduced Floquet Brillouin zone. The reconstructed wavefunctions further provide access to the symmetry properties of individual light-induced sidebands. We demonstrate the applicability and generality of the method in first-principles time-dependent simulations of real materials, ranging from two-dimensional monolayers to a three-dimensional bulk semiconductor, and including finite pulses without strict time periodicity. This framework directly connects real-time simulations with Floquet observables, enabling practical analysis of light-driven electronic structure in materials.
Key words: Floquet analysis; real-time propagation; first-principles simulations; light-driven electronic structure



Ji Feng

Short Bio

Ji Feng is a Boya Distinguished Professor at the International Center for Quantum Materials, School of Physics, Peking University. His research spans condensed matter theory and computational materials modeling, including density-functional theory, Berry-phase physics of Bloch bands (topological states and valleytronics), correlation effects such as magnetism, electron-phonon coupling and charge-density waves, and strain engineering in low-dimensional materials.

Talk Title

Spin-Wave Dynamics: TDDFT Response and Adiabatic Theory

Abstract

Time-dependent density functional theory (TDDFT) provides a rigorous theoretical and computational framework for studying the response properties of many-electron systems in real materials. We have developed a linear-response implementation within the projector augmented-wave (PAW) formalism, enabling self-consistent calculations of coupled charge–spin density response functions and the full four-component polarizability under electromagnetic perturbations. This computational framework enables first-principles calculations of spin-wave excitation spectra without relying on empirical models or adjustable parameters. Direct linear-response TDDFT calculations of spin-wave dynamics, however, can be computationally prohibitive. To address this challenge, we use first-order wavefunctions and density responses obtained from density functional perturbation theory (DFPT) to construct and solve the Niu–Kleinman equation for adiabatic spin dynamics. This provides an efficient and general approach for determining spin-wave dispersion relations and their associated collective eigenmodes. I will also discuss theoretical approaches for investigating the geometric phases and topological properties of spin-wave excitations within this first-principles framework. Time permitting, I will discuss extensions beyond the adiabatic approximation.



Luyi Yang

Short Bio

Prof. Luyi Yang received her B.S. in physics and mathematics from Tsinghua University (2007). She earned her Ph.D. in physics from the University of California at Berkeley (2013). Then she worked as a Los Alamos Director's Postdoctoral Fellow at the National High Magnetic Field Laboratory at Los Alamos. She became an Assistant Professor at the University of Toronto in 2016. She joined the Department of Physics, Tsinghua University as an Associate Professor in September 2019. She was awarded Canada Research Chair, CIFAR Global Scholar and Young Thousand Talents. Her research interests focus on the development of novel optical spectroscopies and their application to problems at the forefront of condensed matter and materials physics.

Talk Title

Magneto-Optical Kerr Effect in Altermagnets

Abstract

Altermagnets have garnered substantial interest due to their fascinating physics and potential applications in spintronics. Unlike conventional antiferromagnets, altermagnets feature spin-split band structures while maintaining a net magnetization of zero. In this presentation, I will discuss our recent findings on the magneto-optical properties of hematite (α-Fe2O3), a candidate for altermagnetism. We have observed significant magneto-optical Kerr effect (MOKE) signals at room temperature, which are associated with the Neel vector. Furthermore, our research demonstrates that these pronounced MOKE effects facilitate optical imaging of altermagnetic domains and enable the study of their reversible domain wall motion. These findings suggest that MOKE can serve as a tool for identifying potential altermagnetic materials, potentially broadening the existing research landscape in the field of altermagnetism.



Peizhe Tang

Short Bio

Tang Peizhe graduated with a bachelor's degree from Lanzhou University and then pursued a doctoral degree at Tsinghua University. He obtained his Ph.D. from the Department of Physics at Tsinghua University in January 2015, under the supervision of Academician Duan Wenhui. From March 2015 to October 2017, he conducted postdoctoral research in Professor Zhang Shoucheng's research group at Stanford University in the United States. From November 2017 to April 2018, he conducted postdoctoral research in the research group of Academician Angel Rubio at the Max Planck Institute for Structure and Dynamics of Matter (MPSD) in Germany; in April 2018, he was awarded the Marie-Curie Fellowship and continued to work in Academician Angel Rubio's research group. In 2019, he was selected for the National "Youth Overseas High-Level Talent Program" and is currently an associate professor and Ph.D. supervisor at the School of Materials Science and Engineering, Beihang University.

As of April 2020, he has published more than 30 papers in high-impact journals, including 4 in Science and Nature sub-journals (1 in Science, 1 in Nature Nanotechnology, 1 in Nature Physics, 1 in Nature Communications), and 6 in Physical Review Letters (PRL), with a total of over 2,000 citations. He is currently a guest reviewer for journals including Nature, Nature Physics, Science Advances, Nature Communications, PNAS, PRL, PRX, and Nano Letters.

Talk Title

Light-induced Band Engineering in Layered Quantum Materials

Abstract

Light–matter interactions provide a route to out-of-equilibrium states in quantum solids and to the new correlated phases that can emerge from them. Periodic light driving has become an efficient means of engineering such states, and the resulting Floquet bands and light-induced band renormalization are now widely sought. Here we demonstrate Floquet engineering and light-induced band renormalization in monolayer black phosphorus. Using time-dependent density functional theory (TDDFT), we track the dynamical evolution of the Floquet states as they manifest in the photoemission spectra, and show that each sideband acquires spectral weight only at specific crystal momenta. Furthermore, we will introduce the light-induced magnetism in twisted BN bilayer, in which the circular THz laser excited the chiral phonon and resulted in the spatially varied antiferromagnetic patterns.



Matan Tsur

Short Bio

Matan Even Tzur is a postdoctoral researcher at the Max Planck Institute for the Structure and Dynamics of Matter (MPSD) in Hamburg, working in the group of Andrea Cavalleri. He received his PhD in Physics from the Technion - Israel Institute of Technology, where he worked with Oren Cohen on the intersection between attosecond physics and quantum optics.

Talk Title

Measuring and controlling the birth of quantum attosecond pulses

Abstract

Until recently, attosecond optical spectroscopy and quantum optics evolved along non-overlapping directions. In attosecond science, attosecond pulses have been regarded as classical waves, applied to probe electron dynamics on their natural time scale. Here, we transfer fundamental concepts of quantum optics into attosecond physics, enabling control of both the properties of the XUV attosecond pulses and the quantum fluctuations of matter on attosecond time scales. By combining bright squeezed vacuum (BSV) with a strong laser field to drive high-harmonic generation, we transfer the quantum properties of the BSV onto the resulting XUV attosecond pulses. Applying advanced attosecond interferometry, we reconstruct the quantum state of the XUV high harmonics and their associated attosecond pulses with attosecond precision. Finally, we resolve the squeezing of the electron's wavepacket during one of the most fundamental strong-field phenomena - field induced tunneling. The ability to measure and control quantum correlations in both electrons and XUV attosecond pulses establishes a foundation for attosecond quantum electrodynamics, manipulating the quantum state of electrons and photons with sub-cycle precision.



Roosmarijn de Wit

Short Bio

I am a Postdoc at the Max Planck Institute for the Structure and Dynamics of Matter in Germany. My work primarily revolves around strong light-matter coupling effects in molecules inside a cavity, and how we can use spin glass theory to better understand such effects. Previously, my PhD focused on time correlations in open quantum systems, particularly to model electron-vibrational interactions in ultrafast optical spectroscopy experiments.

Talk Title

Coupling molecular vibrations to light: how cavity-induced electron correlations modify the nuclear ground state

Abstract

In recent years, experiments have demonstrated that placing a molecular ensemble inside an optical cavity may modify its physical and chemical properties. Remarkably, such effects may even take place 'in the dark', without external pumping of the cavity. This could suggest that these observations result from interactions between infrared-active molecular and the vacuum electromagnetic field inside the cavity. Theoretical work has moreover shown that under strong light-matter coupling, the resulting correlations between intermolecular electron can behave like a spin glass, described by the spherical Sherrington-Kirkpatrick model. Here we investigate how entering such a spin glass phase influences the nuclear degrees of freedom, when the cavity couples to collective vibrational modes of the ensemble. In particular, we find that the spin glass phase significantly alters the potential energy surface felt by the nuclei, resulting in a collective displacement of the vibrational ground state. Additionally, we discuss how such a change in the nuclear behaviour could be observed experimentally.



Xinle Cheng

Short Bio

Xinle Cheng, graduate student,
Max Planck Institute for the structure and dynamics of matter

Talk Title

Anyonic Chern Insulator in Graphene Induced by Surface Electromagnon Vacuum Fluctuations

Abstract

文题: Anyonic Chern Insulator in Graphene Induced by Surface Electromagnon Vacuum Fluctuations
作者: Xinle Cheng, Emil V. Bostrom, Frank Y. Gao, Edoardo Baldini, Dante M. Kennes, Angel Rubio
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关键词: magnetoelectric material, axion electrodynamics, Chern insulator, anyon, cavity engineering
摘要内容:
Sub-wavelength cavities have emerged as a promising platform to realize strong light-matter coupling in condensed matter systems. Previous studies are limited to dielectric sub-wavelength cavities, which preserve time-reversal symmetry. Here, we lift this constraint by proposing a cavity system based on magneto-electric materials, which host surface electromagnons with non-orthogonal electric field and magnetic field components. The quantum fluctuations of the surface electromagnons drive a nearby graphene monolayer into an anyonic Chern insulator, characterized by anyonic quasi-particles and a topological gap that decays polynomially with the graphene-substrate distance. Our work opens a path to controllably break time-reversal symmetry and induce exotic quantum states through cavity vacuum fluctuations.



Jonas Reimann

Short Bio

From October 2017 to November 2023, I did my Bachelor and Master degree in Physics at RWTH Aachen University. My master thesis with Dante M. Kennes had the topic "Dynamics of Moiré excitons". In 2024, I started my PhD as an IMPRS UFAST fellow at the MPSD in Hamburg with Dante M. Kennes, Michael Ruggenthaler and Angel Rubio. My research interests include ab-initio modeling and cavity material engineering.

Talk Title

Towards dynamic lattice-models using time-dependent Wannier functions

Abstract

Static lattice models derived from maximally localized Wannier Hamiltonians provide a compact real-space representation of the electronic structure with hopping matrix elements and onsite energies, in which a relevant subset of bands is mapped onto localized orbitals. In equilibrium, such models are widely used to analyze band topology, transport, magnetism, optical response and correlated-electron physics, either directly or as input to many-body solvers. Wannier Hamiltonians are also commonly used as the starting point for non-equilibrium simulations, for example by coupling the hopping amplitudes to an external vector potential through a Peierls substitution. This assumes that the underlying lattice basis remains static, and that the non-equilibrium response istime-dependent adequately captured through occupations, phases, or external-field dressing of fixed matrix elements. Accessing time-dependent (TD) Wannier functions opens a route to studying how non-equilibrium dynamics affect Wannier Hamiltonians and the lattice models derived from them. In particular, it allows changes in onsite energies, hopping amplitudes, and orbital character to be extracted directly from the evolving ab initio electronic state, rather than through field-dressing of a fixed basis or the addition of phenomenological couplings. Wannierization along a TD trajectory therefore provides a means of investigating time-resolved lattice Hamiltonians for driven materials, and of quantifying when conventional static-model approximations remain valid. Here we dissect the different contributions included from ab-initio TDDFT and analyze the resulting TD lattice models with respect to those contributions. In particular, this allows us to quantify the effect of approximations at various levels. We also compare the obtained TD lattice models against the Peierls substitution. Our findings provide a better understanding for the construction of TD lattice models and its connection to ab-initio formulations. Additionally, this approach opens a potential pathway to include additional ingredients, such as interactions, in a well-defined fashion in the future.



Carlos Mauricio Bustamante

Short Bio

I am a postdoctoral researcher in the field of polaritonic chemistry, focusing on numerical implementation of semiclassical methods based on Maxwell's equations, quantum dynamics, and molecular dynamics. I received my M.Sc. in Chemistry from the Universidad Nacional de Tucumán and later earned my Ph.D. in Theoretical Chemistry from the Universidad de Buenos Aires. Subsequently, I was awarded an Alexander von Humboldt Research Fellowship, which enabled me to continue my career as a postdoctoral researcher at the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg, Germany. There, I investigate the effects of optical cavities on molecular systems.

Talk Title

Tuning Optical Cavities to Enhance Molecular Raman Modes: Theoretical Approaches

Abstract

Strong coupling between molecular ensembles and confined optical modes creates molecular polaritons that can alter molecular dynamics. However, coupled electron-nuclear dynamics in driven cavities remain largely unexplored. Building on our previous work showing their importance for Raman activation under electronic strong coupling [1], we use topology optimisation to design cavities that enhance selected molecular Raman modes. The designs are evaluated by coupling Maxwell-equation propagation with time-dependent density functional tight-binding simulations. Enhancement is achieved by increasing the collective coupling to tune the Rabi splitting or by using multimode cavities. This workflow offers a promising route toward experimentally realizable cavity designs.

Bustamante, C. M.,et al. (2026). Collective rabi-driven vibrational activation in molecular polaritons.Nano Letters,26(15), 5298-5306.



Emin Aliyev

Short Bio

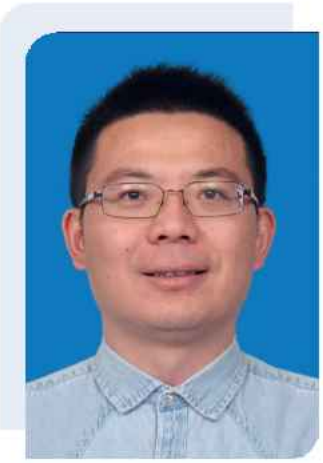
Emin Aliyev is a Ph.D. student working in the field of condensed matter physics under the supervision of Prof. Angel Rubio. He received his B.Sc. in Mechanical Engineering from the Abdullah Gül University, Turkey and M.Sc. in Material Science and Nanotechnology from the Bilkent University, Turkey. He then continued his research as a doctoral candidate at the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg, Germany, where he employs first-principles methods to investigate phase transitions, excitonic phenomena, and light–matter interactions in nonequilibrium systems.

Talk Title

Unraveling the Role of Lattice Dynamics in the Photoinduced Phase of Ta2NiSe5

Abstract

Ta_2NiSe_5 is a promising excitonic-insulator candidate exhibiting strongly coupled structural and electronic phase transitions. Near 328 K, it undergoes an orthorhombic-to-monoclinic structural transition accompanied by substantial changes in its electronic band structure. The coexistence of excitonic correlations, lattice distortion, and strong electron–phonon coupling has led to continuing debate over the microscopic mechanism of the phase transition. Photoexcitation provides an additional route for driving Ta_2NiSe_5 into distinct structural and electronic states, as observed using ultrafast electron diffraction (UED) and time-resolved angle-resolved photoemission spectroscopy (ARPES). In this work, we use density functional theory to investigate the structural and electronic phases of Ta_2NiSe_5 under photoexcited conditions. We examine the evolution of phonon modes, structural instabilities, electronic band dispersions, and the band gap for photodoped crystal structures. Particular emphasis is placed on identifying the phonon modes most strongly coupled to the electronic structure and associated with the photoinduced transition. We compare the calculated frequencies and atomic displacement patterns with frequency spectra obtained from UED and ARPES measurements to clarify how photoexcitation alters the lattice and electronic states and how these changes are coupled in Ta_2NiSe_5.



Pengju Zhang

Short Bio

Applications are invited for two-years postdoctoral positions (three) in experimental (two) and theoretical (one) physics in the center of ultrafast science, Institute of Physics, Chinese Academy of Sciences, Beijing, China. The initial appointment is for two years, with the possibility to renew for a third year. The positions are available from 1 September, 2025 (earlier or later start may be possible).

Candidates should have a Ph.D. in Physics, Chemistry, Material Science. A strong background in atomic, molecular, optical (AMO) physics and ultrafast optics skills (e.g., High harmonic generation, OPCPA, NOPA, hollow fiber compression) are essential. The main theme of our research is to develop and apply state-of-the-art attosecond transient absorption spectroscopy (ATAS) for characterizing and understanding electronic-dominated dynamics in molecules, liquids, and strong-correlated solid samples.

Talk Title

Towards the control of electronic dynamics: from gas to solid

Abstract

Electron motion drives chemical bonding, energy transfer, and the optical response of matter, yet controlling it on its natural timescale remains difficult when electron correlation and coupling to nuclear or lattice motion are included. In this work, we show that ultrafast electronic dynamics in the gas and solid phases can be measured and controlled by table-top ultrafast light sources. Our experiments combine monochromatized table-top high-harmonic generation (HHG) sources with time-resolved photoelectron spectroscopy and nonlinear wave mixing. In gas-phase helium, we introduce photoelectron frequency-resolved optical gating (photoelectron FROG) to first launch a structured electronic wave packet inside a prototypical Fano resonance; a weak near-infrared (NIR) probe samples its evolution in time and frequency. In gas-phase nitrogen molecule, tunable XUV pulses prepare vibronic wave packets in two manifolds (A and B) of autoionizing states. A time-delayed NIR probe records their evolution, while ab-initio calculations treat the electronic and nuclear degrees of freedom on the same quantum-mechanical level. In ZnO, two-color high-harmonic wave mixing follows phase-sensitive emission against pump-probe delay, supported by time-dependent density-functional and electron-phonon coupling simulations. In helium, photoelectron FROG reconstructs the full amplitude and phase of the wave packet created in the Fano resonance and follows its build-up and decay in real time. In N_2, the composition of the vibronic wave packet controls electron correlation, which drives both autoionization into the ionic ground state and the coupling between resonances. The slower-decaying A resonances and the faster-decaying B resonance exchange population, giving a cyclic sequence of decay, transient stabilization, and revival. In ZnO, phase information created by the pump survives electronic dephasing by transferring into correlated electron–lattice motion. A normally optically silent phonon mode encodes this memory, and the delayed mixed-frequency emission persists for about one picosecond, more than two orders of magnitude beyond the initial electronic coherence. Removing electron–phonon correlations suppresses the delayed response, which separates this memory from an ordinary long-lived lattice oscillation. Electronic dynamics can be measured and controlled in both phases. Phase retrieval unfolds the full quantum state of a structured electronic wave packet, vibronic superpositions steer correlation-driven decay, and lattice motion stores and returns electronic phase. These results provide control knobs that could extend to molecular, excitonic, magnetic, and correlated systems, connecting fast electronic coherence to the subsequent non-adiabatic chemical and energy-transfer processes.



Yingying Peng

Short Bio

Dr. Yingying Peng is an Associate Professor at the International Center for Quantum Materials, Peking University. Her research uses advanced X-ray techniques, particularly resonant elastic and inelastic X-ray scattering, to investigate high-temperature superconductivity and emergent phenomena in strongly correlated quantum materials. Her work focuses on charge, spin, orbital, and lattice excitations and their interplay in unconventional superconductors. She has also contributed to developing advanced instrumentation, including the high-resolution RIXS spectrometer at the European XFEL. Dr. Peng has authored more than 80 peer-reviewed publications, including papers in Science, Nature Portfolio journals, and Physical Review Letters, with over 7,000 citations.

Talk Title

Time-Resolved X-ray Studies of Chiral Charge Order and Magnetic Order Dynamics

Abstract

Ultrafast optical excitation can reshape the free-energy landscape of quantum materials, but the pathways by which a system moves between competing ordered states remain less understood. Here, I will present time-resolved X-ray studies of two distinct nonequilibrium pathways involving chiral charge order and spiral magnetism.

In Ti-substituted 1T-TaS2, two mirror-related chiral charge-density-wave domains coexist in equilibrium. Femtosecond X-ray diffraction reveals that optical excitation redistributes these domains within 500 fs while strongly reducing their interlayer coherence. Above a threshold fluence of approximately 0.85 mJ cm^{-2}, the redistributed state persists beyond 10 ns. Time-dependent density-functional-theory molecular dynamics identifies a coherent lattice mode near 2 THz, suggesting a collective-mode pathway connecting the two chiral configurations. A contrasting response occurs in the kagome magnet YMn6Sn6-xGax, where competing interlayer exchange interactions stabilize nearby spiral magnetic states. Time-resolved resonant X-ray scattering at the Mn L3 edge reveals distinct dynamics of the coexisting magnetic components. For x=0.26, optical excitation induces a magnetic peak at a nearby wave vector only after approximately 100 ps, consistent with the nucleation and growth of metastable magnetic domains.

Together, these results show how chemical tuning places quantum materials near competing states, while ultrafast excitation selects different transformation pathways, ranging from coherent collective motion to slow domain formation.



Jin Zhang

Short Bio

Dr. Jin Zhang is a professor and PhD Supervisor at the National Center for Nanoscience and Technology (NCNST), Chinese Academy of Sciences. He received his PhD in Physics from the Institute of Physics, Chinese Academy of Sciences, in 2019 (advisor: Jin Zhang), and conducted postdoctoral research at the Max Planck Institute for the Structure and Dynamics of Matter (MPSD), where he was a Marie Skłodowska-Curie Individual Fellow (advisor: Angel Rubio).

His research combines artificial intelligence, machine learning, and first-principles simulations to investigate complex dynamical processes in quantum and nanoscale materials. His main research directions include:

1. Development of artificial intelligence methods and machine learning models for materials simulations;
2. AI assisted studies of nonequilibrium dynamics, including field- and photoinduced electronic, structural, and ionic dynamics;
3. Theoretical investigation of excited-state dynamics, with a focus on ultrafast charge, lattice, and coupled processes.

Talk Title

Artificial Intelligence Driven Nonequilibrium Materials Dynamics Simulations

Abstract

Artificial Intelligence Driven Nonequilibrium Materials Dynamics Simulations

Prof. Jin Zhang
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Abstract

We develop a machine learning framework for nonequilibrium materials dynamics simulations based on equivariant graph neural networks. The ElectronicE3NN architecture explicitly incorporates electronic charge and external electric fields, enabling accurate modeling of charge-lattice coupled dynamics under external stimuli. Using moire ferroelectric 3R MoS2 as a model system, machine-learning molecular dynamics simulations reveal thermally driven interlayer superlubric sliding and demonstrate that domain wall relaxation significantly lowers the sliding barrier. Furthermore, even ultralow concentrations of sulfur vacancies can effectively pin the interlayer motion, providing a microscopic mechanism that reconciles theoretical predictions with experimental observations. This work establishes a general machine learning framework for studying nonequilibrium materials dynamics and field-driven phenomena in complex quantum materials.

HOST INSTITUTIONS

Institute of Physics, Chinese Academy of Sciences
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