ABOUT QPQIS-2024

Welcome to QPQIS-2024, the 6th International Symposium on Quantum Physics and Quantum Information Science, hosted by Beijing Academy of Quantum Information Sciences (BAQIS). QPQIS-2024 is held on October 22-24, 2024 (Beijing Time).

The theme of QPQIS-2024 is “Advances in Fundamental Research on Quantum States of Matter and Quantum Information”. The main topic of the symposium will be focused on quantum states of matter and quantum materials that could significantly promote the research on quantum information science and technology, including but not limited to superconductors, topological states of matter, quantum magnets, and novel semiconductors. The symposium will also discuss the applications of rapid-developing quantum information technologies such as quantum simulation and quantum sensing in the studies of novel quantum states of matter and quantum materials.

BEIJING ACADEMY OF QUANTUM INFORMATION SCIENCES

Beijing Academy of Quantum Information Sciences (BAQIS) was established on December 24, 2017. It is an innovative research institution initiated by Beijing Municipal Government and co-founded with China's top universities and research institutions such as Tsinghua University, Peking University, Chinese Academy of Sciences, etc.

BAQIS endeavors to address major fundamental issues of quantum physics and quantum information science to push forward next-generation quantum science and technology advancement. BAQIS encompasses five major research fields: quantum state of matter, quantum computation, quantum communication, quantum materials and devices and quantum precision measurement. In the meantime, it has developed two state-of-the-art experimental platforms to support the researches, i.e. the micro-nano processing platform and the synergetic testing platform.

To build a world-class research institution, BAQIS adopts an operating mechanism in line with international standards, coordinates all partners with their distinct and favorable resources, and vigorously introduces the world's top talent. BAQIS also strives to promote international academic exchanges and collaborations through various activities, such as QPQIS (International Symposium on Quantum Physics and Quantum Information Science) and the "Distinguished International Visiting Scholar Program".

QR Code of BAQIS Website

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PROGRAM

Day 1 / October 22

OPENING CEREMONY (Moderator: *Huaibin Zhuang* | BAQIS)

08:50-09:00 • **Opening Speech**
Tao Xiang | President of BAQIS

SESSION 1 (Session Chair: *Hongqi Xu* | Peking University / BAQIS)

09:00-09:35 • **Invited Talk I01: Graphene Quantum Devices**
Klaus Ensslin | ETH Zürich, Switzerland

09:35-10:10 • **Invited Talk I02: Semiconductor Quantum Dot Telecom Single-Photon Sources for Quantum Technologies**
Sven Höfling | University Würzburg, Germany

10:10-10:50 • **Group Photo & Tea Break**

SESSION 2 (Session Chair: *Qihua Xiong* | Tsinghua University / BAQIS)

10:50-11:25 • **Invited Talk I03: Search of Majorana Fermions in Superconductor/Magnet Heterostructures**
Tong Zhang | Fudan University, China

11:25-11:37 • **Oral Talk O01: Berezinskii-Kosterlitz-Thouless and Kugel-Khomskii Physics in Co-bilayers**
Gang Chen | Peking University, China

11:37-11:49 • **Oral Talk O02: Coexistence of High Temperature Superconductivity and Ferromagnetism in FeSe**
Ding Zhang | Tsinghua University / BAQIS, China

11:49-12:01 • **Oral Talk O03: Evidence of Finite-momentum Pairing in a Centrosymmetric Bilayer**
Dong Zhao | Institute of Physics, CAS, China

12:01-14:00 • **Lunch / Poster Session**

SESSION 3 (Session Chair: *Nanlin Wang* | Peking University / BAQIS)

14:00-14:35 • **Invited Talk I04: Higgs-Spectroscopy of Superconductors**
Stefan Kaiser | Technische Universität Dresden, Germany

14:35-15:10 • **Invited Talk I05: Understanding THz Optical Nonlinearity in Superconductors**
Lara Benfatto | Sapienza University of Rome, Italy

15:10-15:35 • **Tea Break**

SESSION 4 (Session Chair: *Ding Zhang* | Tsinghua University / BAQIS)

15:35-16:10 **Invited Talk I06: Atomic Physics Approaches to Quantum Critical States**
Hui Zhai | Tsinghua University, China

16:10-16:45 **Invited Talk I07: Recent Progress in Detecting Superconducting Collective Modes in NbN, MgB_2, and $YBa_2Cu_3O_{6+x}$ Using Nonequilibrium & Nonlinear Terahertz Spectroscopy**
Nanlin Wang | Peking University/BAQIS, China

16:45-16:57 **Oral Talk O04: Ultrafast Spin Dynamics in Few-layer $MnBi_2Te_4$**
Luyi Yang | Tsinghua University, China

16:57-17:09 **Oral Talk O05: Chemical Rules for Stacked Kagome and Honeycomb Topological Semimetals**
Tiantian Zhang | Institute of Theoretical Physics, CAS, China

17:09-17:21 **Oral Talk O06: Symmetry Breaking and Ascending in the Magnetic Kagome Metal FeGe**
Shangfei Wu | BAQIS, China

Day 2 / October 23

SESSION 5 (Session Chair: *Heng Fan* | IOPCAS / BAQIS)

09:00-09:35 **Invited Talk I08: Probing Topological Order on Quantum Computers**
Frank Pollmann | Technical University of Munich, Germany

09:35-10:10 **Invited Talk I09: Quantum Computation and Quantum Simulation With Strings of Trapped Ca^+ Ions**
Rainer Blatt | University of Innsbruck, Austria

10:10-10:35 **Tea Break**

SESSION 6 (Session Chair: *Jianhao Chen* | Peking University / BAQIS)

10:35-11:10 **Invited Talk I10: Topological Spin Dynamics in Quantum Matter**
Mathias Kläui | University of Mainz, Germany

11:10-11:22 **Oral Talk O07: Origin of Anti-bunching in Resonance Fluorescence**
Chengyong Hu | BAQIS, China

11:22-11:34 **Oral Talk O08: Coherent Quantum Transport of Microcavity Exciton Polaritons**
Sanjib Ghosh | BAQIS, China

11:34-11:46 **Oral Talk O09: Conditional Dynamics in Heterodyne-detected Superradiant Laser from Incoherently Pumped Atoms**
Yuan Zhang | Zhengzhou University, China

11:46-14:00 **Lunch / Poster Session**

SESSION 7 (Session Chair: *Dong Liu* | Tsinghua University / BAQIS)

14:00-14:35 **Invited Talk I11: Fragmented Superconductivity and Fluctuating Stripes in Strongly Correlated Electrons**
Alexander Wietek | Max Planck Institute for the Physics of Complex Systems, Germany

14:35-15:10 **Invited Talk I12: Universality of Time Crystalline Order in Magnets and Exciton-polaritons**
Sebastian Diehl | University of Cologne, Germany

15:10-15:22 **Oral Talk O10: Topological Surface States in γ-$PtBi_2$ Evidenced by Scanning Tunneling Microscopy**
Wei Li | Tsinghua University, China

15:22-15:34 **Oral Talk O11: High-precision Defect Control to Regulate Quantum States in Oxide Epitaxial Films**
Haoliang Huang | Quantum Science Center of Guangdong-Hong Kong-Macao Greater Bay Area, China

15:34-15:46 **Oral Talk O12: Giant G-factor Realization and Engineering with Metamorphic InAsSb/InSb Superlattices**
Yuxuan Jiang | Anhui University, China

15:46-16:00 **Tea Break**

16:00-17:30 **Poster Session**

Day 3 / October 24

SESSION 8 (Session Chair: *Jianhao Chen* | Peking University / BAQIS)

09:00-09:35 **Invited Talk I13: Quantized Topological States in Intrinsic Magnetic Topological Insulator $MnBi_2Te_4$**
Yuanbo Zhang | Fudan University, China

09:35-10:10 **Invited Talk I14: Nonlinear and Quantum Transport and Dynamics Spins in Magnets**
Eiji Saitoh | The University of Tokyo, Japan

10:10-10:35 **Tea Break**

SESSION 9 (Session Chair: *Katsumi Tanigaki* | BAQIS)

10:35-11:10 **Invited Talk I15: New Directions in Kagome Materials on the Mesoscale**
Philip Moll | Max Planck Institute for the Structure and Dynamics of Matter, Germany

11:10-11:22 **Oral Talk O13: Structural Phase Controlling Growth and Interfacial Engineering of 2D 1T'-MX_2**
Yi Zhang | Nanjing University, China

11:22-11:34	•	**Oral Talk O14: Quantum Phase Transitions in Quantum Anomalous Hall Insulators** *Peng Deng* | BAQIS, China
11:34-11:46	•	**Oral Talk O15: Unequivocal Determination of Spintriplet Superconductivity Using Composite Rings** *Xiaoying Xu* | Quantum Science Center of Guangdong Hong Kong-Macao Greater Bay Area, China
11:46-14:00	•	**Lunch / Poster Session**

SESSION 10 (Session Chair: *Ke He* | Tsinghua University / BAQIS)

14:00-14:35	•	**Invited Talk I16: Quantum Vacuum Dressed Materials** *Junichiro Kono* | Rice University, USA
14:35-14:47	•	**Oral Talk O16: Novel Detection of Light Dark Matter with Qubit Calorimeter** *Ningqiang Song* | Institute of Theoretical Physics, CAS, China
14:47-14:59	•	**Oral Talk O17: Designing Photosynthesis and Avian Compass by Quantum Computers** *Qing Ai* | Beijing Normal University, China
14:59-15:11	•	**Oral Talk O18: Molecule-based High-temperature Optically Driven Quantum Computing: First Principles, Open-quantum-system and Sensor-Network Calculations** *Wei Wu* | University College London, United Kingdom
15:11-15:35	•	**Tea Break**

SESSION 11 (Session Chair: *Kai Chang* | BAQIS)

15:35-16:10	•	**Invited Talk I17: Recent Experiments on Quantum Computing and Fundamental Studies** *Chaoyang Lu* | University of Science and Technology of China, China
16:10-16:22	•	**Oral Talk O19: A New Framework for Quantum Phases in Open Systems: Steady State of Imaginary-Time Lindbladian Evolution** *Shuo Yang* | Tsinghua University, China
16:22-16:34	•	**Oral Talk O20: Novel Ground-state Phase Diagram and Emergent Quantum many-body Scars in a Two-species Rydberg Atom Array** *Jian Cui* | Beihang University, China
16:34-16:46	•	**Oral Talk O21: Variational Optimization for Quantum Problems Using Deep Generative Networks** *Zizhu Wang* | University of Electronic Science and Technology of China, China

CLOSING CEREMONY (Moderator: *Huaibin Zhuang* | BAQIS)

16:46-17:10	•	**Closing Remarks & Announcement of Best Poster Awards** *Qi-Kun Xue* | President of BAQIS

INVITED SPEAKERS

Lara Benfatto

Professor, Sapienza University of Rome, Italy

Lara Benfatto is a Full Professor at the Department of Physics of Sapienza University of Rome. She received her Diploma (1998) and her PhD (2002) from Sapienza University of Rome. She spent three years in Switzerland as post-doc, in the Universities of Firbourg and Geneva, working on charge-density-waves and Berezinskii-Kosterlitz-Thouless phsysics. She moved back to Rome in 2004 as post-doc at the INFM and she has been awarded in 2006 by a Grant of the Enrico Fermi Center. In 2009 she became staff researcher at the Institute of Complex Systems of the CNR. In 2018 she has been awarded by the Ludwig-Genzel Prize "for advancing the theoretical understanding of the dynamical response of interacting electronic systems, in particular superconductors". In 2019 she joined the faculty of Sapienza University as Associate Professor. Since 2022 she is Full Professor of Theoretical Condensed-Matter Physics and she leads a group working on theoretical aspects connected to the physics of correlated electron systems in low dimensions, including high-temperature cuprate and pnictide superconductors, graphene, disordered superconductors and superconducting heterostructures. In the last few years she has been focusing in particular on unconventional THz spectroscopies of collective superconducting modes.

Rainer Blatt

Professor, University of Innsbruck, Austria

Rainer Blatt studied physics and received his PhD at the University of Mainz. As postdoctoral fellow, he worked on laser cooling of atomic beams with John L. Hall (Nobelpreis 2005) in Boulder (USA) and as a research assistant at the University of Hamburg with P. Toschek he worked with single trapped ions. In 1994, he became professor of physics at the University of Göttingen and in 1995, he accepted a chair position at the Institut f. Experimentalphysik of the University of Innsbruck, where he works with trapped ions in Paul-traps for quantum computers, quantum simulations and quantum metrology. Since 2003 he is research director at the Institute for Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences (ÖAW) in Innsbruck. R. Blatt is co-founder of Alpine Quantum Technologies GmbH (AQT) in Innsbruck, a company developing commercial quantum computers. Since 2021, R. Blatt is the scientific manager and coordinator of the Munich Quantum Valley. For his quantum information research, he received the Schrödinger-Prize of the ÖAW in 2006, the Stern-Gerlach medal of the German Physical Society (DPG) in 2012, the John-Stewart-Bell prize of CQIQC (Toronto) in 2015 and the Micius Quantum Prize 2018. R. Blatt is a member of the Austrian Academy of Sciences, the Spanish Royal Academy of Sciences and the National Academy of Sciences of the USA.

Sebastian Diehl

Professor, University of Cologne, Germany

Sebastian Diehl is a professor at the Institute for Theoretical Physics at the University of Cologne, Germany. His research focuses on driven open quantum matter—systems at the interface of condensed matter, quantum optics, and quantum information, characterized by an interplay of coherent quantum dynamics with external driving, dissipation, and quantum measurement. He was a recipient of a START grant from the Austrian Science Fund in 2011 and a Consolidator Grant from the European Research Council in 2015.

Klaus Ensslin

Professor, ETH Zürich, Switzerland

Klaus Ensslin studied physics at the University of Munich and at ETH Zurich. After completing his doctoral dissertation at the Max Planck Institute in Stuttgart, he was a postdoc at the University of California in Santa Barbara, USA. From April 1991 until September 1995 he worked at the University of Munich. His habilitation thesis was awarded a prize from the University of Munich. In 1995 he received the Gerhard Hess prize of the German Science Foundation promoting outstanding young researchers. In 2020 her received the Edison Volta Prize of the European Physical Society.

The primary research interest of Klaus Ensslin lies in the physics of mesoscopic systems. The electronic properties of novel semiconductor nanostructures are investigated using material control down to the atomic scale. One important goal is the ever increasing control and improved understanding of the quantum properties of electrons in nanostructures.

Sven Höfling

Professor, University of Würzburg, Germany

Sven Höfling received his diploma degree in Applied Physics from the University of Applied Science in Coburg and his Ph.D. degree from Würzburg University. He was with the Fraunhofer Institute of Applied Solid-State Physics, Freiburg, Germany from 2001 to 2002 working on blue and white light emitting diodes. In 2003, he joint Würzburg University for his Ph.D. work on single mode emitting GaAs/AlGaAs quantum cascade lasers. From 2006 to 2013, he was head of the Optoelectronic Materials and Devices Group at Technische Physik, Würzburg University. Sven Höfling was a full professor at the University of St Andrews, Scotland from 2013 to 2021. In 2015 he rejoint the University of Würzburg, Germany as a professor of physics and as the Head of the Chair of Applied Physics and the Gottfried-Landwehr-Laboratory for Nanotechnologies. He is running a 550 sqm clean room with a full chain of semiconductor growth, processing and characterization tools. His research interests include the design, fabrication, and characterization of low-dimensional electronic and photonic nanostructures, including quantum wells and quantum dots, organic semiconductors, high-quality factor microcavities, photonic crystal devices, semiconductor lasers, organic optoelectronics and topological photonics.

Dr. Höfling is a member of German Physical Society (DPG), a Senior member of IEEE and SPIE, and a fellow of the Institute of Physics (IOP) and Optica.

Stefan Kaiser

Professor, Technische Universität Dresden, Germany

Stefan Kaiser is the professor at the Institute of Solid State and Materials Physics at the TU Dresden from March 2021. Within an ERC CoG "T-Higgs" starting 2023 Stefan and the group further develop Higgs Spectroscopy as novel tool for identifying and characterizing superconductords. The group also joins the local CRC on correlated magnetism applying advanced optical and THz techniques to quantum spin and topological systems.

He also became head of the independent Ultrafast Solid-State Spectroscopy group at the Max Planck Institute for Solid State Research in Stuttgart in December 2014 and was appointed Juniorprofessor at the University of Stuttgart. As a new concept the group works on the complex spectroscopy of driven collective modes and order parameters. That allowed eg. the direct experimental observation of a coherently driven order parameter in an excitonic insulator; a coherent state of excitons that otherwise can only be probed indirectly. Most exciting the group transfers this concept to Higgs modes, the amplitude oscillations in superconductors. This lays the foundation to a full Higgs Spectroscopy where the modes are used as amplitude- and phase-resolved spectroscopic tool to investigate ground state but also non-equilibrium properties of unconventional and light-driven superconducotrs.

Mathias Kläui

Professor, University of Mainz, Germany

Mathias Kläui is professor of physics at Johannes Gutenberg-University Mainz and adjunct professor at the Norwegian University of Science and Technology. He received his PhD at the University of Cambridge, after which he joined the IBM Research Labs in Zürich. He was a junior group leader at the University of Konstanz and then became associate professor in a joint appointment between the EPFL and the PSI in Switzerland before moving to Mainz. His research focuses on nanomagnetism and spin dynamics on the nanoscale in new materials. His research covers from blue sky fundamental science to applied projects with major industrial partners. He has published more than 300 articles and given more than 200 invited talks. He is a Fellow of the IEEE and has been elected to the technical and administrative committees of the magnetics society. He was an IEEE Magnetics Society Distinguished Lecturer and he is also a Fellow of the IOP and has been awarded a number of prizes and scholarships.

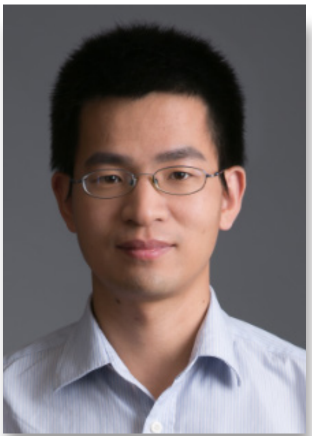
Junichiro Kono

Professor, Rice University, USA

Junichiro Kono received his B.S. and M.S. degrees in applied physics from the University of Tokyo in 1990 and 1992, respectively, and completed his Ph.D. in physics from the State University of New York at Buffalo in 1995. He was a postdoctoral research associate at the University of California Santa Barbara from 1995-1997, and the W. W. Hansen Experimental Physics Laboratory Fellow in the Department of Physics at Stanford University from 1997-2000. He joined the Department of Electrical and Computer Engineering of Rice University in 2000 as an Assistant Professor and was promoted to Associate Professor in 2005 and to Professor in 2009. He is currently Karl F. Hasselmann Chair in Engineering, serving as a Professor in the Departments of Electrical & Computer Engineering, Physics & Astronomy, and Materials Science & Nanoengineering as well as the Director of the Smalley-Curl Institute at Rice University.

Chaoyang Lu

Professor, University of Science and Technology of China, China



Chao-Yang Lu is a Chair Professor in Physics at the University of Science and Technology of China (USTC). He completed his BS and PhD degrees at the USTC and the University of Cambridge in 2011. He has been appointed as the Deputy Director of the Shanghai Center for Quantum Sciences and as the Executive Director of the Quantum Computing Division at the Hefei National Laboratory since 2022. His current research interest includes quantum computation, solid-state quantum photonics, quantum teleportation, superconducting circuits, and atomic arrays. His is the author of over 140 papers in major research journals which have attracted >30000 citations. His work have been selected as by Physics World as "Breakthrough of the Year" in 2015, by APS Physics as one of the top ten "Highlights of the Year" in 2021 and 2022, and by UNESCO as "World's top 10 digital innovation technologies" in 2021. He is an OSA/Optica Fellow, and a recipient of the EPS Fresnel Prize, AAAS Newcomb Cleveland Prize, Nishina Asian Award, IUPAP-ICO Young Scientist Prize in Optics, OSA Adolph Lomb Medal, APS Rolf Landauer and Charles H. Bennett Award in Quantum Computing, CLEO James P. Gordon Memorial Speakership, and OCPA Achievement in Asia Award. He serves as the Divisional Associate Editor.

Philip Moll

Director, Max Planck Institute for the Structure and Dynamics of Matter , Germany

Philip Moll is a director at the Max-Planck Institute for the Structure and Dynamics of Solids in Hamburg, Germany. His "microstructured quantum matter" department investigates electronic transport on mesoscopically shaped 3D crystals of quantum materials.

Philip obtained his PhD in 2012 at ETH Zurich in the group of Bertram Batlogg, working on iron-based superconductors in high magnetic fields. He joined UC Berkeley to work with James Analytis on topological systems. In 2015, he was awarded an independent Max-Planck research group at the MPI for chemical Physics of Solids. Working with Andy Mackenzie and Claudia Felser, he focused on mesoscopic phenomena in ultra-clean layered metals and electron hydrodynamics. Moving to EPFL in 2018 as a tenure-track assistant professor, he established a group in the materials science department working towards shape/size control of topological systems. Since 2022, he is a director at MPI for the structure and dynamics of solids in Hamburg.

He was awarded the ETH Metal, the ABB award and the Swiss Microscopy Society award for his work in Switzerland. In 2018 he won the Nicholas Kurti Science prize and subsequently was awarded multiple prestigious junior grants, such as two ERC projects and a Swiss National Science Foundation Professorship.

Frank Pollmann

Professor, Technical University of Munich , Germany

Prof. Pollmann's research focuses on a variety of problems in the field of condensed matter theory. His main focus lies on the study of collective phenomena which arise due to quantum mechanical effects in systems of correlated particles. Areas of research include the study of topological phases of matter, frustrated spin systems, and the dynamics of disordered systems. To gain deeper insights into the physics of these systems, he employs concepts from quantum information theory. These concepts have proven to be very useful in acquiring a more fundamental understanding of the structure of quantum many-body states and in designing efficient computer algorithms for numerical simulations of correlated quantum systems.

Prof. Pollmann studied physics at TU Braunschweig and KTH Royal Institute of Technology in Stockholm. After completing his PhD at the Max Planck Institute for the Physics of Complex Systems (MPIPKS) in 2006, he worked as a postdoctoral researcher at the University of California, Berkeley. Starting from 2011 he headed a junior research group at MPIPKS. In 2016 he was appointed associate professor and in 2022 full professor at TUM.

Eiji Saitoh

Professor, The University of Tokyo , Japan

Eiji Saitoh is a Professor in the Department of Applied Physics at the University of Tokyo, and holding multiple prestigious positions within the University's research institutes.After earning his Ph.D. from the University of Tokyo in 1996, he assumed the role of an assistant professor in the Department of Physics at Keio University in 2001 and became a Senior Lecturer in 2003. In 2006, he took on the role of a Professor in the Institute for Materials Research at Tohoku University. In 2018, he was appointed as a professor in the Department of Applied Physics at the University of Tokyo. For his research, he has been awarded JSPS Prize(2011), Japan Academy Prize(2022), and the Nishina Memorial Prize(2022).

Eiji Saitoh's experiments unveiled the "inverse spin Hall effect," demonstrating the generation of strong electric fields by spin currents in films. This discovery paved the way for the detection and exploration of spin currents, sparking intense research interest worldwide. Throughout his career, Saitoh has continued to expand the boundaries of spin current science. He has observed and studied fundamental phenomena such as insulator spin currents, spin Seebeck effect, spin Hall magnetoresistance, and mechanical spin current generation.

Nanlin Wang

Professor, Peking University/BAQIS, China

Nan-Lin Wang is a chair professor and director of the international center for quantum materials (ICQM), School of Physics, Peking University. He also serves as a vice-president of Beijing Academy of Quantum Information Sciences. He obtained his PhD in condensed matter physics from the University of Science and Technology of China in 1992. His research focuses primarily on infrared and terahertz spectroscopy study of strongly correlated electronic systems, including high temperature superconductors, charge/spin density wave compounds, transition metal oxides/ chalcogenides, heavy fermions, quantum magnetic systems, 3D Dirac/Weyl semimetals in both equilibrium and nonequilibrium states. He is a fellow of the American Physical Society.

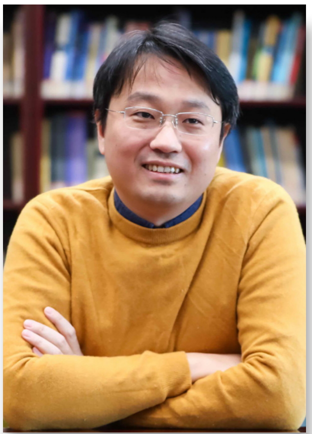
Alexander Wietek

Professor, Max Planck Institute for the Physics of Complex Systems, Garmany

Alexander Wietek is head of the research group “Superconductivity and Magnetic Correlations" at the Max Planck Institute for the Physics of Complex Systems in Dresden, Germany. Prior, he was a research fellow at the Flatiron Institute of the Simons Foundation in New York, USA, from 2018-2022. He holds Master’s degrees in mathematics and geophysics from the Technical University of Munich and Ludwig Maximilians University of Munich and pursued his PhD in Condensed Matter Physics at the University of Innsbruck with Prof. Andreas Läuchli. His research interests range from novel forms of superconductivity in strongly correlated electron systems, topological states of matter, and frustrated magnetism. A particular focus of his research is on advanced numerical algorithms for quantum many-body systems.

Hui Zhai

Professor, Tsinghua University, China



Hui Zhai is a Professor at the Institute for Advanced Study, Tsinghua University and his research is focused on ultracold atomic physics, condensed matter physics, and machine lea. rning. He was awarded a National Natural Science Foundation of China (NSFC) award for distinguished young scholars, and the RaoYutai Prize by the Chinese Physical Society.

Tong Zhang

Professor,Fudan University, China

Zhang Tong is a professor at the Department of Physics, Fudan University. He received his bachelor's degree from Shandong University in 2004 and his Ph.D. degree from the Institute of Physics, Chinese Academy of Sciences in 2010. He studies unconventional superconductors and topological quantum materials vis extremely low temperature scanning tunnelling microscopy, high-resolution tunnelling spectroscopy and MBE film growth. In recent years, his achievements include the understanding of pairing mechanism in single-layer FeSe/STO, the observation of nontrivial zero-energy mode in (LiFe)OHFeSe and FM/SC heterostructures, and high-energy resolved study of impurity and vortex bound states in various superconductors. He has published more than 60 articles on journals including Nat. Phys. PRL, PRX, Sci. Adv., Nat. Comm., which have been cited more than 5,500 times.

Yuanbo Zhang

Professor, Fudan University, China

Yuanbo Zhang received his Bachelor of Science degree from Peking University in 2000 and his PhD in Physics from Columbia University in 2006. He worked as a Miller Research Fellow at the University of California at Berkeley from September 2006 to June 2009 and as a postdoc research associate at IBM Almaden Research Center from March 2010 to September 2010. Since 2011, he has been a professor at Fudan University.

Yuanbo Zhang's research interests include electronic transport in low-dimensional systems such as graphene, as well as scanning probe techniques and their application in studying low-dimensional nanostructures. Yuanbo Zhang is a New Cornerstone Investigator. He has been recognized for his work with several honors, including the Yeh Chi-Sun Prize in 2021, Tencent Xplorer Prize in 2020, and IUPAP Young Scientist Prize in 2010.

Invited Talks

Day 1 Oct-22 2024
Session 1 Invited talk I01 09:00 - 09:35

Graphene Quantum Devices

Klaus Ensslin
ETH Zürich

Spin qubits are among the contenders for a future quantum information processor. So far pioneering work has been done mostly in GaAs-based devices. Present day best devices are realized in Si and lately also in Ge. In this talk I will discuss how quantum structure which are gate-defined in bilayer graphene offer a competitive platform for spin qubits and possible also for valley (and Kramers) qubits. We find lifetimes exceeding many 10s of seconds. Using twisted graphene layers also superconducting devices can be realized with unique tunability by gate voltages. It turns out that graphene is a unique platform for quantum devices and also complex quantum circuits.

Day 1 Oct-22 2024
Session 1 Invited talk I02 09:35 - 10:10

Semiconductor Quantum Dot Telecom Single-Photon Sources for Quantum Technologies

A. Pfenning, T. Huber-Loyola, and S. Höfling*
*lead presenter email: sven.hoefling@uni-wuerzburg.de
Julius-Maximilians-Universität Würzburg, Physikalisches Institut, Lehrstuhl für Technische Physik, Am Hubland, D-97074 Würzburg, Germany.

As high-performant sources of single photons, epitaxial quantum dots can be considered as a semiconductor launchpad for quantum photonic technologies.[1,2] There is still a variety of challenges to tackle on the road to an ideal source of single or entangled photons for quantum photonic applications. Here, we present an overview of recent developments in our group on the engineering of single-photon sources for quantum photonic applications made from III-V semiconductor quantum dots grown by molecular beam epitaxy.

Photonic wire-bonding of a quantum dot distributed Bragg grating waveguide was used to demonstrate a true plug-and-play fiber-coupled single-photon source, which allows for resonant-frequency pumping without the need of any additional cross-polarization filtering.[3]

By integrating InAs/InP quantum dots into circular Bragg grating resonators, Purcell-enhanced single-photon emission with $F_P \approx 7$ in the telecom C-band was achieved. [4] Low multi-photon emission probabilities are obtained, and Hong-Ou-Mandel two-photon interference is demonstrated.

The displacement with regard to the cavity center strongly determines the polarization characteristics from quantum dots in circular Bragg grating resonators, as the symmetry of the coupled QD-cavity device is broken, and the quantum dot will couple differently strong to the degenerate fundamental resonator modes. [5]

We demonstrated that GaSb quantum dots are a scientifically rich alternative material system for the generation of single-photons in the telecom S-band promising strain-free spin physics. [6]

References:
[1] C.-Y. Lu and J.-W. Pan, Nature Nanotechnology 16, 1294 (2021).
[2] Zhou, Xiaoyan, Liang Zhai, and Jin Liu. Photonics Insights 1 (2023): R07-R07.
[3] De Gregorio, et al. Adv. Quantum Technol. 7, 2300227 (2023).
[4] Kaupp, et al., Adv. Quantum Technol. 6, 2300242 (2023).
[5] Peniakov, et al., Laser Photonics Rev, 2300835 (2024).
[6] Michl, et al. Adv. Quantum Technol. 6, 2300180 (2023).

Day 1 Oct-22 2024
Session 2 Invited talk I03 10:50 - 11:25

Search of Majorana fermions in Superconductor/Magnet Heterostructures heterostructures

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[1]Hefei National Laboratory for Physical Sciences at the Microscale, and Department of Physics, Univ. of Sci. & Tech. of China, China
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Majorana zero modes (MZM) are the building blocks for topological quantum qubits, and they could live in the vortices and edges of topological superconductors (TSC). After finding them in the vortices of several FeSe-based superconductors by scanning tunneling microscopy (STM) [1,2], we were searching Majorana fermions in low dimensional systems, which are likely more feasible for further braiding operations. In this talk, I discuss our recent findings in this direction.

1. We synthesized a trilayer heterostructure of MnTe/Bi_2Te_3/Fe(Te,Se) which integrates superconductivity, layer-dependent magnetism and strong spin-orbit coupling. We observed robust zero-bias conductance peaks (ZBCP) with nontrivial properties and an enhanced SC gap on single unit cell (1-UC) thick MnTe. In contrast, no ZBCP was observed on 2-UC MnTe. Our first principle calculations suggest the 1-UC MnTe case has enhanced interfacial DMI and frustrated AFM which could promote noncolinear spin textures. Consequently, this trilayer heterostructure represents a promising platform for exploring TSC. [3]

2. We studied the candidate of higher-order topological insulator (HOTI), bismuth (Bi), in the form of mesoscopic crystals grown on V3Si. Using LT-STM, we observed dispersive 1D states on various crystal hinges, and confirmed their spin-helical structure via magnetic scatterer. Combining with first-principle calculation and symmetry analysis, we show the spin-helical hinge states formed a closed loop encircling the crystal, providing the first evidence of higher-order topological bulk-boundary correspondence.

Furthermore, proximity SC is induced in the hinge states, enabling HOTI as a promising platform for realizing Majorana quasiparticles. [4]

3. We fabricated a FM/SC heterostructure of single-layer $CrBr_3/NbSe_2$. The CrBr3 layer is insulating and acts like a vacuum barrier. In-gap features appear at the edges of $CrBr_3$ island, manifesting as either a ZBCP or a pair of bound states. Their emergence closely correlates with lattice reconstruction at edges and displays a discrete distribution. At increased tunneling transmissivity, the ZBCP splits and the bound state pair shifts. These behaviors are unexpected for Majorana modes, but is consistent with conventional Yu-Shiba-Rusinov states. Our results provide critical information for further understanding the interfacial coupling in FM/SC heterostructures. [5].

4. We have fabricated other FM(AFM)/SC heterostructures such as $CrTe_2/NbSe_2$, $MnSi/V_3Si$, $MnTe_2/NbSe_2$, FeTe/Fe(Te,Se). None of them show proximity SC in the magnetic side.

Our findings suggest that proximity effect induced nontrivial pairing is rare in superconductor/magnet heterostructure. To achieve it, one needs to fine tune the form and strength of magnetism and its coupling to superconductor. Conduction electrons with noncollinear magnetic interaction and strong pairing potential are probably favored.

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Day 1 Oct-22 2024
Session 3 Invited talk I04 14:00 - 14:35

Higgs-Spectroscopy of Superconductors

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High field THz-pulses allow accessing the Higgs mode, the amplitude mode of the order parameter, in superconductors. Using a phase-resolved THz-high-harmonics-spectroscopy we perform a complex Higgs-spectroscopy of the order parameter dynamics, symmetry and interaction with other collective modes [1,2]. In high-Tc cuprates and $NbSe_2$ this allows investigating the interplay of charge density waves (fluctuations) and superconductivity based on a generalised Fano-interference of the driven order parameters [1,3,4]. As time-resolved technique THz-Higgs spectroscopy also allows probing transient superconducting states driven by ultrashort light pulses [5] and applying a 2D THz-third harmonics spectroscopy disentangles different sources of third harmonics generation. A novel and direct view on Higgs can be opened by non-equilibrium Raman spectroscopy in the anti-Stokes channel [6].

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Day 1 Oct-22 2024
Session 3 Invited talk I05 14:35 - 15:10

Understanding THz Optical nonlinearity in Superconductors

Lara Benfatto
Department of Physics, Sapienza University of Rome

The recent experimental advances in generating intense and short-lived THz light pulses opened the way for a plethora of potential ground-breaking applications. Indeed, the THz spectral window corresponds to the timescale of several collective excitations in solids, ranging from lattice vibrations to collective modes of the electron system across a phase transitions, like e.g the superconducting one. In the case of superconductors different source of optical non-linearity have been discussed in the past, ranging from BCS quasiparticle excitations, whose spectrum is modified by the gap opening as compared to the metallic state, to amplitude (Higgs) and phase fluctuations of the superconducting order parameter, that only emerge below Tc. In this talk I will review our theoretical contribution to the understanding of the origin of optical non-linearity in superconductors, which represent the perfect benchmark to highlight difficulties and advantages in the interpretation of existing experimental data. In particular, I will focus on the role of disorder to trigger a strong non-linear response in superconductors[1,2,3], and on the specific pathways we recently identified for the excitation of the amplitude Higgs mode in conventional NbN superconductor [4]. For what concerns the phase mode I will discuss the intrinsic difference between metallic and Josephson plasmons[5,6], and their implication for experimental data in layered cuprates.

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[3] L. Benfatto, C. Castellani and G. Seibold, Phys. Rev. B 108, 134508 (2023)
[4] Kota Katsumi, Jacopo Fiore, Mattia Udina, Ralph Romero III, David Darbalas, John Jesudasa, Pratap Raychaudhuri, Goetz Seibold, Lara Benfatto, N.P. Armitage, Phys. Rev. Lett. 132, 256903 (2024)
[5] Francesco Gabriele, Mattia Udina and Lara Benfatto, Nat. Comm. 12, 752 (2021)
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Day 1 Oct-22 2024
Session 4 Invited talk I06 15:35 - 16:10

Atomic Physics Approaches to Quantum Critical States

Hui Zhai
Tsinghua University

Quantum critical states exhibit unconventional spectral function, algebraically decayed spatial correlation, and log-volume law entanglement. They broadly exist in quantum critical regimes and low-dimensional systems in condensed matter and cold atom physics. This talk will highlight several cold atom physics approaches to study quantum critical states. These approaches bring out the connection between quantum thermalization and criticality, utilize dissipation to measure anomalous dimensions, and uncover unconventional spatial correlation functions that emerge at critical regimes by quantum computers.

Day 1 Oct-22 2024
Session 4 Invited talk I07 16:10 - 16:45

Recent progress in detecting superconducting collective modes in NbN, MgB_2, and $YBa_2Cu_3O_{6+x}$ using nonequilibrium & nonlinear terahertz spectroscopy

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We present recent progress in detecting superconducting collective modes in NbN, MgB_2, and $YBa_2Cu_3O_{6+x}$ utilizing nonequilibrium and nonlinear terahertz (THz) spectroscopy methods. These techniques comprise broadband (single-cycle) THz pump-THz probe, narrowband (multiple cycles) THz pump-THz probe, and third harmonic generation (THG) spectroscopy upon intense multiple THz driving.
In the case of NbN, we observed transient Higgs oscillations in THz driving experiments and identified a higher-order nonlinear light-Higgs mode coupling effect. In MgB2, we confirmed the detection of Leggett mode in the broad band THz pump-THz probe experiment. Additionally, when driving at fundamental frequencies of 0.35 or 0.42 THz, we observed the Higgs mode response corresponding to the dirty π band. We demonstrated the gradual transition from the Higgs mode to a region where both the Higgs and the Legget modes contribute with increasing driving frequency.
In the driving experiments on high-Tc YBCO samples, the THG signal emerged in the normal state, which is consistent with the crossover temperature T* of pseudogap over broad doping levels. Upon lowering temperature, the THG signal shows anomaly just below Tc. Strikingly, we observe a beat pattern directly in the measured real time waveform of THG signal. We elaborate that the Higgs mode, which develops below Tc, couples to the mode already developed below T*, resulting in an energy level splitting. The strong coupling effect offers new insight into the interplay between superconductivity and pseudogap. The result suggests that the pseudogap phase is not likely a precursor of superconductivity but represents a distinct order.

Work done with T. Dong, J. Y. Yuan, Z. X. Wang, H. Wang, S. J. Zhang, X. Y. Zhou, L. Y. Shi, X. Q. Jia, Y. Wang, K. Jin, B. H. Li, L. Yue

Day 2 Oct-23 2024
Session 5 Invited talk I08 09:00 - 09:35

Probing Topological Order on Quantum Computers

Frank Pollmann
Technical University of Munich, Germany

The interplay of quantum fluctuations and interactions can yield novel quantum phases of matter with fascinating phenomena such as topological order and fractionalization Understanding the physics of such systems is a very challenging problem as it requires to solve quantum many body problems—which are generically exponentially hard to solve on classical computers. In this context, universal quantum computers are potentially an ideal setting for simulating the emergent quantum many-body physics. In this talk, we will first focus on the realization of topological ordered phases and simulate the braiding as well as the dynamics of anyonic excitations. We then investigate phase transitions between different symmetry enriched topological phases.

Day 2 Oct-23 2024
Session 5 Invited talk I09 09:35 - 10:10

Quantum Computation and Quantum Simulation With Strings of Trapped Ca^+ Ions

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This talk reviews the advanced capabilities of the trapped-ion quantum computer at Innsbruck [1]. We provide an overview of the quantum toolbox available and discuss the scalability of our approach. With control over up to 50 ion qubits, we perform quantum simulations to explore quantum transport [2] and hydrodynamic properties [3]. Additionally, we utilize the quantum toolbox to optimize parameters for quantum metrology [4] and showcase quantum-enhanced sensing of an optical transition through collective quantum correlations [5]. We also investigate large-scale entanglement through quantum simulations [6]. To shield quantum computers from noise, we redundantly encode logical quantum information across multiple qubits using errorcorrecting codes. Following a fault-tolerant circuit design, we mitigate the spread of uncontrolled errors when manipulating logical quantum states with imperfect operations [7] and demonstrate a fault-tolerant universal set of gates on two logical qubits in the trapped-ion quantum computer [8].

[1] I. Pogorelov et al., PRX Quantum 2, 020343 (2021)
[2] C. Maier et al., Phys. Rev. Lett. 122, 050501 (2019)
[3] M. K. Joshi et al., Science 376, 720 (2022)
[4] C. D. Marciniak et al., Nature 603, 604 (2022)
[5] J. Franke et al., Nature 621, 740 (2023)
[6] M. K. Joshi et al., Nature 624, 539 (2023)
[7] L. Postler et al., PRX Quantum 5, 030326 (2024)
[8] L. Postler et al., Nature 605, 675 (2022)

Day 2 Oct-23 2024
Session 6 Invited talk I10 10:35 - 11:10

Topological Spin Dynamics in Quantum Matter

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Novel spintronic devices can play a role in the quest for GreenIT. Devices have been proposed, where switching by energy-efficient approaches is used [1,2]. Materials that exhibit quantum correlations are of particular interest as they can exhibit certain topological phases and host topological spin structures.
We combine ultimate stability of topological states due to chiral interactions [3,4] with ultra-efficient manipulation using novel spin torques [3-5] and orbital torques [6]. We demonstrate that these spin structures can be potentially used for different types of computing beyond conventional Boolean logic.
In particular, we use skyrmion dynamics for non-conventional stochastic computing [7,8] and synthetic antiferromagnets are promising for high performance [9,10].

References:
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2.K. Everschor-Sitte et al., J. Appl. Phys., vol. 124, no. 24, 240901, 2018.
3.S. Woo et al., Nature Mater., vol. 15, no. 5, pp. 501–506, 2016.
4.K. Litzius et al., Nature Phys., vol. 13, no. 2, pp. 170–175, 2017.
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6.S. Ding et al. PRL 125, 177201, 2020; PRL 128, 067201, 2022.
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8.K. Raab et al., Nature Commun. vol. 13, pp. 6982, 2022;
9.T. Dohi et al., Nature Commun. vol. 14, pp. 5424, 2023.
10.M. Bhukta et al., Nature Commun. vol. 15, pp. 1641, 2024

Day 2 Oct-23 2024
Session 7 Invited talk I11 14:00 - 14:35

Fragmented Superconductivity and Fluctuating Stripes in Strongly Correlated Electrons

Alexander Wietek
Max Planck Institute for the Physics of Complex Systems , Germany

Many of the most enigmatic states of matter emerge whenever interactions between particles are strong, especially in quantum mechanics. The physics when tuning the ratio between kinetic and interaction energy of electrons in a solid is described by the so-called Hubbard model. Despite its minimalistic formulation, it captures key aspects of unconventional superconductors, recent moiré materials, and many quantum spin liquid candidates. Recent years have seen exciting progress in our understanding of this paradigmatic model due to modern numerical and analytical approaches. In this talk, I will focus on two of our recent findings achieved using tensor network methods. I demonstrate how stripe order observed in cuprate superconductors melts and forms extended charge clusters at intermediate temperatures. Thereafter, we discuss a state where a charge density wave and superconductivity coexist. Remarkably, this then leads to a "fragmentation" of the superconducting condensate.

[1] Alexander Wietek, Yuan-Yao He, Steven R. White, Antoine Georges, and E. Miles Stoudenmire, Phys. Rev. X 11, 031007 (2021)
[2] Alexander Wietek, Phys. Rev. Lett. 129, 177001 (2021)
[3] Niccolò Baldelli, Benedikt Kloss, Matthew Fishman, Alexander Wietek, arXiv:2307.11820

Day 2 Oct-23 2024
Session 7 Invited talk I12 14:35 - 15:10

Universality of Time Crystalline Order in Magnets and Exciton-Polaritons

Sebastian Diehl
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According to Landau's effective theory, the macroscopic properties of magnetic materials can be described by paradigmatic O(N) models. We study this class of models when pushed out of equilibrium, for example by simple parametric driving protocols applied to the underlying quantum material. Their dynamical phase diagram hosts an extended parameter region exhibiting time crystalline order, and we examine the phase transitions leading to its emergence. The spontaneous breaking of time translation symmetry, along with its Goldstone mode, is captured by an effective description with O(N)×SO(2) symmetry. Through a renormalization group analysis, we identify a new non-equilibrium universality class. Remarkably, this universality class governs the long-distance physics even with infinitesimal microscopic breaking of equilibrium conditions. A hallmark of this transition is a universally divergent effective temperature. The relevant symmetry group is realized for magnon condensation in pumped yttrium iron garnet (YIG) films and in exciton-polariton systems with a polarization degree of freedom. Additionally, we discuss the potential for realizing Kardar-Parisi-Zhang physics through spontaneous time translation symmetry breaking.

Day 3 Oct-24 2024
Session 8 Invited talk I13 09:00 - 09:35

Quantized Topological States in Intrinsic Magnetic Topological Insulator $MnBi_2Te_4$

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In magnetic topological insulators, the interplay between nontrivial band topology and magnetic order leads to exotic states of matter like quantum anomalous Hall (QAH) and axion insulators. Traditional approaches using doped topological insulators introduce disorder, limiting further exploration of topological quantum effects. We address this by studying $MnBi_2Te_4$, an intrinsic magnetic topological insulator. We observe a robust zero-field QAH effect in five-layer $MnBi_2Te_4$ specimens at temperatures up to 4 K. The high material quality allows us to explore a variety of topological states under magnetic fields up to 45 Tesla, revealing a hierarchy of quantized states. These findings indicate spectral asymmetry and the formation of helical edge states. I will also discuss the potential for developing novel topological devices based on $MnBi_2Te_4$.

Day 3 Oct-24 2024
Session 8 Invited talk I14 09:35 - 10:10

Nonlinear and Quantum Transport and Dynamics Spins in Magnets

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The University of Tokyo, Tokyo 113-8656, Japan

Spin dynamics and transport in condensed matter are key elements that give rise to various functions of spintronics. Recent development of spintronics measurement technique and spectroscopy has allowed us to approach quantum spin dynamics and transport. Here we report nonlinear magnetization dynamics in ferrimagnets measured in terms of Wigner functions, nuclear spin transport in antiferromagnets, and electron spin transport in spin liquids in oxides.

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[2] Y. Shiomi, J. Lustikova, S. Watanabe, D. Hirobe, S. Takahash, E. Saitoh, Nature Physics 15 22–26 (2019).
[3] T. Kikkawa, D. Reitz, H. Ito, T. Makiuch, T. Sugimoto, K. Tsunekaw, S. Daimon, K. Oyanagi, R. Ramos, S. Takahashi, Y. Shiomi, Y. Tserkovnyak, E. Saitoh, Nature Communications 12 4356 (2021).
[4] D. Hirobe, M. Sato, T. Kawamata, Y. Shiomi, K. Uchida, R. Iguchi, Y. Koike, S. Maekawa, E. Saitoh, Nature Physics 13 30–34 (2017).
[5] Y. Chen, M. Sato, Y. Tang, Y. Shiomi, K. Oyanagi, T. Masuda, Y. Nambu, M. Fujita, E. Saitoh, Nature Communications 12 5199 (2021).

Day 3 Oct-24 2024
Session 9 Invited talk I15 10:35 - 11:10

New Directions in Kagome Materials on the Mesoscale

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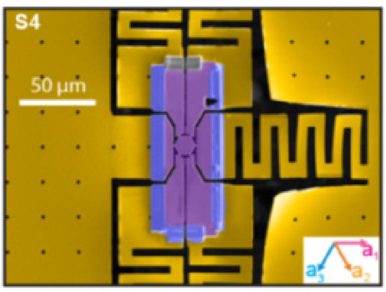
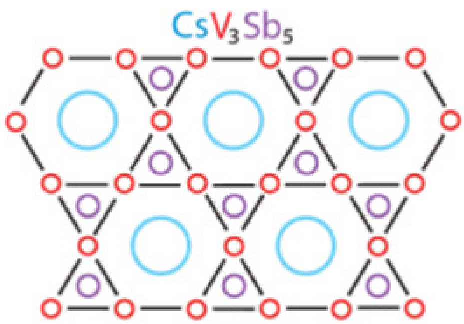
Materials that can host different states of electronic order form a recurring theme in physics and materials science, and they are of particular interest if the ordered states are coupled strongly. Recently, materials based on the structural motif of the Kagome web have attracted significant attention for their tendency to host such strongly coupled phases. In particular, the centro-symmetric layered Kagome metal (K,Rb,Cs)V3Sb5 have entered the focus of experimental and theoretical research. They host a charge-density-wave type transition at elevated temperatures ~100K, followed by a superconducting transition at 3K. Yet there is another type of electronic order which thus far eludes exact microscopic identification. A series of experimental probes detects the onset of anomalous behavior around T'~30-40K, including thermal Hall, μSR, NMR, magnetic torque, Kerr rotation. The anomalous low-temperature state carries the characteristics of a chiral, nematic and time-reversal-symmetry breaking fluid (all of which are under most active debate currently). I will review new insights into this materials class from the viewpoint of mesoscopic 3D devices machined by Focused Ion Beam milling. Integrating novel quantum materials onto chips, and probing their responses on the relevant length scales will be a first step to assess their function and their application potential. We demonstrate how strain management is crucial to access the pristine ground state, and how it can be utilized to manipulate the correlated order.





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INVITED TALKS

Day 3 Oct-24 2024
Session 10 Invited talk I16 14:00 - 14:35

Quantum Vacuum Dressed Materials

A. Baydin[1,2] , F. Tay[1,3] , D. Kim[1,3] , H. Xu[4] , T. E. Kritzell[1,3] and J. Kono[1,2,4,5]
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There has been a growing realization that the properties of a material can be modified just by placing it in an optical cavity. The quantum vacuum fields surrounding the material inside the cavity can cause nonintuitive modifications of electronic states through ultrastrong vacuum–matter coupling, producing a vacuum-dressed material with novel properties. Existing theoretical predictions include cavity-enhanced, cavity-induced, and cavity-mediated enhancement of electron–phonon coupling and superconductivity, electron pairing, anomalous Hall effect, ferroelectric phase transitions, quantum spin liquids, and photon condensation.

The so-called ultrastrong coupling (USC) regime is a prerequisite for observing these effects, which arises when the interaction energy becomes a significant fraction of the bare photonic mode and matter excitation frequencies. Most intriguingly, when a material is ultrastrongly coupled with cavity-enhanced vacuum electromagnetic fields, its ground state will contain virtual photons. This nonperturbative virtual driving without external fields can lead to phase transitions in thermal equilibrium.

This talk will describe our recent studies of USC phenomena in various solid-state cavity quantum electrodynamics systems in search of such vacuum-induced phases of matter. We utilize the phenomenon of Dicke cooperativity, i.e., many-body enhancement of light–matter interaction, to explore quantum-optical strategies for creating, controlling, and utilizing novel phases in condensed matter enabled by the quantum vacuum.

Day 3 Oct-24 2024
Session 11 Invited talk I17 15:35 - 16:10

Recent Experiments on Quantum Computing and Fundamental Studies

Chao-Yang Lu
Chair Professor in Physics at the University of Science and Technology of China (USTC)

I will go through our recent efforts in my group using photons and atoms for fundamental studies of quantum physics and quantum information technologies. We use the protocol of Gaussian boson sampling to demonstrate quantum computational advantage, with up to 255 detected photons [Zhong et al. Science 2020, PRL 2021, Deng et al. PRL 2023]. We develop an AI-enabled constant-time-overhead rearrangement protocol to prepare a 2024 defect-free atomic array [Lin et al. 2024]. Using a single atom trapped in an optical tweezer and cooled to the motional ground state in three dimensions, we faithfully realize the Einstein-Bohr recoiling-slit gedankenexperiment tunable at the quantum limit [Zhang et al. 2024]. Based on a bottom-up quantum engineering approach, we experimentally created the fractional quantum Hall state using strongly interacting photons [Wang et al. Science 2024]. We further use the quantum computing platform to rule out a real-value description of standard formalism of quantum theory [Chen et al. PRL 2022].

Oral Talks

Day 1 Oct-22 2024
Session 2 Oral Talk O01 11:25-11:37

Berezinskii-Kosterlitz-Thouless and Kugel-Khomskii physics in Co-bilayers

Gang Chen[1],
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We consider an extended XXZ model for the triangular lattice bilayer colbaltate $K_2Co_2(SeO_3)_3$. The model is composed of interacting Co^{2+} dimers on the triangular lattice, where the Co^{2+} ion provides an effective spin-1/2 local moment via the spin-orbit coupling and the crystal field effect. The intra-dimer interaction is dominant and would simply favor the local spin singlet, and the inter-dimer interactions compete with the inter-dimer interaction, leading to rich behaviors. With the easy-axis anisotropy, it is shown that, in the ground state manifold of the intra-dimer Ising interaction, the system realizes an effective quantum Ising model, where the ground state is either a 3-sublattice order with a mixture of antiferromagnetic Ising order and a valence-bond spin singlet or Ising disordered. The finite temperature regime realizes the Berezinskii-Kosterlitz-Thouless physics. To explore the full excitations, we incorporate the excited state manifold of the intra-dimer Ising interaction and establish the emergent Kugel-Khomskii physics.

[1] G. Chen, arXiv:2402.04745 (2024)

Day 1 Oct-22 2024
Session 2 Oral Talk O02 11:37-11:49

Coexistence of High Temperature Superconductivity and Ferromagnetism in FeSe

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Superconductivity and ferromagnetism are two usually incompatible macroscopic quantum phenomena that are of both fundamental interest and practical importance. Merging these two together in a single material promises transformative technology. Recently, we found that lithium intercalated FeSe superconductor, with a superconducting transition temperature exceeding 40 K, shows coexisting ferromagnetism with a Curie temperature higher than 200 K. This coexistence manifests itself as profound evolution of the anomalous Hall loop and butterfly pattern of magnetoresistance, both persisting deep into the superconducting state. Furthermore, we find evidence for enhanced superconductivity when the magnetic field mainly acts as a paramagnetic source that polarizes the electronic spins. It suggests that spin polarized Cooper pairing is favorable in the system. Our work therefore provides new insight into the pairing symmetry of iron-based superconductors.

[1] Y. Hu, *et al.*, Possible spin-polarized Cooper pairing in high temperature FeSe Superconductor, *arXiv*: 2405.10482

Day 1 Oct-22 2024
Session 2 Oral Talk O03 11:49-12:01

Evidence of Finite-momentum Pairing in a Centrosymmetric Bilayer

Dong Zhao[1], Lukas Debbeler[1], Matthias Kühne[1], Sven Fecher[1], Nils Gross[1], and Jurgen Smet[1],
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A phase characterized by a spatially-modulated order parameter is counter-intuitive because of the entropy penalty that the modulations incur. Its possible existence in superconductors was first proposed under conditions that the formation of Cooper pair is limited to some segments of the Fermi surface and that the Cooper pairs carry momentum above the Pauli limit. This prediction motivated experimental efforts to identify such non-uniform superconducting states in organic superconductors, heavy fermion compounds and cuprates. In the talk, I will present experimental evidences [1] for a new type of finite-momentum pairing, concomitantly possessing a non-uniform order parameter, that manifests below the Pauli limit. It is driven by the orbital effect and does not rely on Fermi surface segmentation. We have evidences for this spatially modulated superconducting state in a hexagonal MoS2 bilayer through remote intercalation that offers both balanced doping and firm out-of-plane coherence between both layers.

[1] D. Zhao et al., Nat. Phys. 19, 1599–1604 (2023).

ORAL TALKS

Day 1 Oct-22 2024
Session 4 Oral Talk O04 16:45-16:57

Ultrafast spin dynamics in few-layer $MnBi_2Te_4$

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Magnetic topological materials not only exhibit novel exotic quantum phenomena like the quantum anomalous Hall effect but also hold promise for various applications, including information storage and dissipationless transport. In this talk, I will discuss our recent ultrafast studies in few-layer $MnBi_2Te_4$, a novel magnetic topological insulator, using time-resolved optical techniques.

Below the Neel temperature, we observe laser-induced magnetization processes that can be used to accurately track the distinct magnetic states in different magnetic field regimes, including showing clear odd-even layer number effects. In addition, strongly field-dependent antiferromagnetic magnon modes with tens of gigahertz frequencies are optically generated and directly observed in the time domain [1]. More recently, we studied few-layer MnBi2Te4 on a transparent substrate, enabling us to investigate optical response in both reflection and transmission geometries simultaneously. We observe pump-induced PT-symmetry breaking in even-layered samples and possibly chiral phonon generation [2].

These measurements pave the way for potential applications in 2D antiferromagnetic spintronics and magnonics as well as further studies of ultrafast control of both magnetization and topological quantum states.

[1] Bartram et al., Science Bulletin 68, 2734-2742 (2023).
[2] Liu *et al.*, in preparation (2024).

ORAL TALKS

Day 1 Oct-22 2024
Session 4 Oral Talk O05 16:57-17:09

Chemical Rules for Stacked Kagome and Honeycomb Topological Semimetals

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The chemical rules for predicting and understanding topological states in stacked kagome and honeycomb lattices are studied in both analytical and numerical ways. Starting with a minimal five-band tight-binding model, all the topological states are sorted into five groups, which are determined by the interlayer and intralayer hopping parameters. Combined with the model, an algorithm is designed to obtain a series of experimentally synthesized topological semimetals with kagome and honeycomb layers, i.e., IAMX family (IA = Alkali metal element, M = Rare earth metal element, X = Carbon group element), in the inorganic crystal structure database. A follow-up high-throughput calculation shows that IAMX family materials are all nodal-line semimetals and they will be Weyl semimetals after taking spin-orbit coupling into consideration. To have further insights into the topology of the IAMX family, a detailed chemical rule analysis is carried out on the high-throughput calculations, including the lattice constants of the structure, intralayer and interlayer couplings, bond strengths, electronegativity, and so on, which are consistent with the tight-binding model. This study provides a way to discover and modulate topological properties in stacked kagome and honeycomb crystals and offers candidates for studying topology-related properties like topological superconductors and axion insulators.

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Day 1 Oct-22 2024
Session 4 Oral Talk O06 17:09-17:21

Symmetry Breaking and Ascending in the Magnetic Kagome Metal FeGe

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Spontaneous symmetry breaking - the phenomenon in which an infinitesimal perturbation can cause the system to break the underlying symmetry - is a cornerstone concept in the understanding of interacting solid-state systems. In a typical series of temperature-driven phase transitions, higher-temperature phases are more symmetric due to the stabilizing effect of entropy that becomes dominant as the temperature is increased. However, the opposite is rare but possible when there are multiple degrees of freedom in the system.

Here, we present such an example of a symmetry-ascending phenomenon upon cooling in a magnetic kagome metal FeGe by utilizing neutron Larmor diffraction and Raman spectroscopy. FeGe has a kagome lattice structure with simple A-type antiferromagnetic order below Neel temperature TN=400 K and a charge density wave (CDW) transition at TCDW=110 K, followed by a spin-canting transition at around 60 K. In the paramagnetic state at 460 K, we confirm that the crystal structure is indeed a hexagonal kagome lattice. On cooling to around TN, the crystal structure changes from hexagonal to monoclinic with in-plane lattice distortions on the order of 10-4 and the associated splitting of the double-degenerate phonon mode of the pristine kagome lattice. Upon further cooling to TCDW, the kagome lattice shows a small negative thermal expansion, and the crystal structure gradually becomes more symmetric upon further cooling. A tendency of increasing the crystalline symmetry upon cooling is unusual; it originates from an extremely weak structural instability that coexists and competes with the CDW and magnetic orders. Thus, the determination of the crystalline lattice symmetry as well as the unusual spin-lattice coupling is a first step towards understanding the rich electronic and magnetic properties of the system, and it sheds new light on intertwined orders where the lattice degree of freedom is no longer dominant [1].

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ORAL TALKS

Day 2 Oct-23 2024
Session 6 Oral Talk O07 11:10-11:22

Origin of Anti-bunching in Resonance Fluorescence

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The phenomenon of resonance fluorescence from a single two-level emitter (TLE) is fundamental in quantum optics and crucial in optical quantum technologies for generating high-quality single photons. The observed anti-bunching in resonance fluorescence is commonly explained by the concept that a TLE can only scatter (or absorb and emit) single photons. In this talk, we challenge this notion and demonstrate that the anti-bunching in the Heitler regime results from quantum interference between the reflected driving field and the super-bunched cavity output field, using a single quantum dot in an optical microcavity in the Purcell regime. Fully destructive interference erases the two-photon probability amplitude in the reflected driving field and results in anti-bunching, confirming the interference picture of resonance fluorescence proposed by Dalibard and Reynaud in 1983 [1]. The super-bunching of the QD-cavity output field (or the transmitted light field) indicates that a single QD can scatter two or multiple photons simultaneously at low driving fields, resembling the degenerate four-wave mixing (FWM). This work paves the way for tailoring the photon statistics of laser light through cavity or waveguide quantum electrodynamics and interference. Inheriting the laser's ultra-long coherence time and robust photon indistinguishability, coherent single photons generated by this interference-based approach [2] could be a key resource for interference-based quantum information technologies [3-4].

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Day 2 Oct-23 2024
Session 6 Oral Talk O08 11:22-11:34

Coherent Quantum Transport of Microcavity Exciton Polaritons

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Microcavity exciton polaritons are versatile hybrid quasi-particles that combine exceptional optical properties (e.g., strong nonlinearity and ultralow-threshold lasing) with electronic characteristics (e.g., coupling with electromagnetic fields and spin-dependent responses). Here, we present that the hybrid nature of exciton polaritons induces a richer form of quantum transport than their traditional counterparts [1]. We emphasize the roles of nonlinear interactions, quantum coherence, finite lifetimes, and spin-dependent responses in quantum transport, showing how these factors interplay to induce a range of phenomena within semiconductor microcavities. Notably, we reveal that scattering of exciton polaritons due to natural disorder introduces anomalous quantum propagation, markedly different from that of particles governed by the Schrödinger or Gross-Pitaevskii equations [1]. Additionally, when spin-dependent properties are incorporated, they give rise to critical phenomena such as the non-Hermitian skin effect [2] and the optical spin-Hall effect [3]. We report our latest experimental efforts in this direction, presenting the direct observation of coherent exciton polariton transport [4], including their spin responses, and the realization of practical devices like spin-polarizing beam splitters and spin-based NOT gates [3].

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Day 2 Oct-23 2024
Session 6 Oral Talk O09 11:34-11:46

Conditional Dynamics in Heterodyne-detected Superradiant Laser from Incoherently Pumped Atoms

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In 2009, D. Meiser et. al. proposed that optical lattice clocks can be explored to realize a superradiant laser with an ultra-narrow spectrum [1], which has a high application potential in quantum metrology [2]. Although the narrower spectrum has been demonstrated experimentally by measuring the quasi-steady state superradiance with heterodyne detection [3,4], there still lacks a unified theory to explore the intriguing physics involved and predict the frequency precision. In this talk, we present such a theory based on stochastic mean-field approach, and discuss the results for the atoms coherently [5] and incoherently pumped [6]. In the former case, the coherence due to the driven laser determines the collective atomic dynamics, and the measurement adds merely noise to the detected signal. In the latter case, the measurement backaction introduces a random initial phase of the optical coherence, and the frequency precision can be improved with the persistent superradiance. In addition, we predict an Allan deviation 10-15/(τ/s)-1/2 for the 43P1->41S0 transition of calcium atoms, but 2x10-17(τ/s)-3/2 for the (5s5p)3P1->(5s2)1S0 transition of strontium-87 atoms. Here, the fast scaling might be attributed to the white-noise phase modulation [7], and will be investigated systematically in the future.

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Day 2 Oct-23 2024
Session 7 Oral Talk O10 15:10-15:22

Topological Surface States in γ-PtBi2 Evidenced by Scanning Tunneling Microscopy

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γ-PtBi2 has been demonstrated to be a Weyl semimetal possessing superconducting Fermi arcs by photoemission spectroscopy. However, the evidence of its topological surface states is lacking by scanning tunneling microscopy (STM). Here, we show multiple STM evidences for the existence of topological surface states in γ-PtBi2. We observe not only the step-edge and point-defect induced quasiparticle interference fringes, originating from the electron scatterings between the Fermi arcs of γ-PtBi2, but also the back-scattering prohibition related to the spin-flip process, which is the direct evidence for the topological nature of the surface states. Moreover, we demonstrate that the topological surface states are precisely located over a narrow energy range near the Fermi level, within which sharply enhanced intensity and slow spatial decay of quasiparticle interference are observed.

Day 2 Oct-23 2024
Session 7 Oral Talk O11 15:22-15:34

High-precision defect control to regulate quantum states in oxide epitaxial films

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Atomic-scale film growth techniques enable the precise manipulation of emergent macroscopic quantum phenomena, including the topological Hall effect and superconductivity in transition metal oxides, through the application of strain, dimensionality, interfacial engineering, doping, and defect introduction. Nonetheless, achieving precise defect control is challenging due to the delicate balance required between thermodynamic stability, kinetic mobility, and synthetic precision, often resulting in stochastic distribution of defect concentration and type within the samples. Consequently, it is imperative to strive for samples with minimal defects or to impose an orderly modulation of defect states in the study of quantum states at the atomic level. Here, we will delineate our advancements in two key areas: Initially, we will discuss the preparation of defect-minimized cuprate and nickelate superconducting oxide epitaxial films through the application of the gigantic-oxidative atomically layered epitaxy technique, which significantly amplifies the oxidative capacity of oxide molecular beam epitaxy and pulsed laser deposition by 3-4 orders of magnitude, while maintaining the atomic layer-by-layer growth of the intended complex structure.[1] Subsequently, we will present our methodology for high-precision defect concentration control, which allows for the systematic regulation of defect concentration and distribution, enabling the induced structural transition from an orthogonal to a tetragonal phase in SrRuO3 thin films, thereby facilitating the modulation of the topological Hall effect.[2,3]

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Day 2 Oct-23 2024
Session 7 Oral Talk O12 15:34-15:46

Giant g-factor realization and engineering with metamorphic InAsSb/InSb superlattices

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Realizing a large Land´e g-factor of electrons in solid-state materials has long been thought of as a rewarding task as it can trigger abundant immediate applications in spintronics and quantum computing. Here, we demonstrate an unprecedented high value of $g \approx 104$, twice larger than that in bulk InSb, in metamorphic InAsSb/InSb superlattices (SLs) where the effective lattice constant can be controlled and ultra-narrow bandgaps can be realized. In addition, we show that the g-factor can be widely tuned on demand from 20 to 110 via varying the SL period [1].

The key ingredients for such a large g-factor and wide tunability requires a small band gap in multiple band system and the wavefunction mixing between different electron and hole states. Further calculation reveals an even larger g factor of $g \approx -200$ with a peculiar relativistic Zeeman effect that disperses as the square root of magnetic field toward a zero-gap limit [2]. Moreover, we also find that the wavefunction overlap between the spatially separated electron and hole states in SLs has a strong effect on its g-factor, which is less highlighted in prior studies.

Our work not only establishes metamorphic InAsSb/InSb superlattice as a promising and competitive material platform for future quantum devices but also provides new insights into g-factor engineering in semiconductor materials.

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Day 3 Oct-24 2024
Session 9 Oral Talk O13 11:10-11:22

Structural Phase Controlling Growth and Interfacial Engineering of 2D 1T'-MX_2

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Transition metal dichalcogenides MX2 (M = W, Mo; X = S, Se, Te) monolayer with 1T’ structural phase is an ideal two-dimensional (2D) topological insulator. However, the 1T’-MX2 with a large topological band gap (MoS2, MoSe2, WS2, WSe2) are always in metastable phase. Therefore, controllable synthesis of a stable MX2 monolayer in 1T’ phase is very challenging. In this talk, I will introduce our recent serial progresses on the phase-selectable growth of WSe2 and WS2 monolayers with 1T’ and 2H phases, and the interfacial effects on their phase stability and electronic structures.

We first realized the growth of 1T’-WSe2 on bilayer graphene (BLG) substrate and found that the stability of 1T’ structural phase depends highly on the interfacial interaction [1]. Inspired by this research, The stable single-phase 1T’-WSe2 monolayer was synthesized for the first time on the SrTiO3 substrate with the assistance of enhanced interfacial interaction. Meanwhile, we can realize the selectable growth of 1T’ and 2H phases by controlling the interfacial interaction. Besides, we found that the interfacial strain will profoundly affect the topological band structure of the grown 1T’-WSe2, leading a heavily doped negative gap [2]. Nevertheless, a robust coulomb gap can open at Fermi level and was experimentally observed due to the suppression of screening effect in monolayer limit [3]. We have also realized the growth of single-phase 1T’-WS2 monolayer on SrTiO3. This grown 1T’-WS2 presents a much stronger interfacial interaction, inducing a flat-band feature and an abnormally large band gap (0.65 eV) than the theoretical expectance [4]. Very recently, we found that the monolayer FeSe/SrTiO3 subtract can also stabilized the 1T’ phase of the grown WSe2. More advantageously, this substrate shows less interfacial strain and no electronic doping to the grown 1T’-WSe2. Therefore, the Fermi level is located within the large topological band gap, and a characterized topological edge state can be clearly observed [5].

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Day 3 Oct-24 2024
Session 9 Oral Talk O14 11:22-11:34

Quantum Phase Transitions in Quantum Anomalous Hall Insulators

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In multilayered magnetic topological insulators, the magnetization reversal process can drive topological phase transitions between quantum anomalous Hall (QAH), axion insulator (AXI), and normal insulator (NI) states. As the system approaches the critical point of a quantum phase transition, it exhibits critical behaviors that deviate from those observed in the ordered phases. These critical behaviors are generally universal and independent of sample specifics.

In this talk, we will discuss the critical behaviors observed during the quantum phase transitions of QAH insulators. We used molecular beam epitaxy to grow QAH films and conducted electrical transport measurements. By performing scaling analysis with a new protocol, we observed quantized longitudinal resistance at the critical points of both the QAH-AXI and QAH-NI transitions, despite the significant differences between these transitions. Our results demonstrate that the critical behaviors in QAH transitions are of electronic, rather than magnetic, origin. These findings offer a new platform for studying phase transitions and criticality in QAH insulators.

Day 3 Oct-24 2024
Session 9 Oral Talk O15 11:34-11:46

Unequivocal Determination of Spin-Triplet Superconductivity Using Composite Rings

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Spin-triplet pairing is key for realizing topological superconductivity and Majorana fermions. Yet identifying any spin-triplet superconductors remains an experimental challenge. Fermi statistics dictates odd-parity symmetry for the triplet pairing states, under which the sign of the gap function reverses upon the inversion of the momentum, i.e., $\Delta_k=-\Delta_{-k}$. We have carried out a set of phase-sensitive experiments to unambiguously determine this key signature. In polycrystalline superconducting rings, the triplet pairing gives rise to half-integer flux quantization $\Phi' = (n+½)\ \Phi_0$, in stark contrast to the conventional integer flux quantization $\Phi' = n\Phi_0$ established in spin-singlet superconductors. We have identified triplet pairing states in β-Bi_2Pd [1] and α-BiPd [2]. Both are candidates for topological superconductors. Moreover, the odd-parity symmetry can be directly observed as the half-integer flux quantization in composite ring devices, where the triplet SC is connected by a conventional s-wave SC on the two opposite crystalline ends [3]. Modern nanofabrication technology breathes new life into phase-sensitive studies, which may constitute a new paradigm for studying unconventional superconductivity.

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Day 3 Oct-24 2024
Session 10 Oral Talk O16 14:35-14:47

Novel Detection of Light Dark Matter with Qubit Calorimeter

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Dark matter is the most elusive particle in the Universe, and uncovering the nature of dark matter is one of the most important topics in particle physics and cosmology. As the traditional WIMP dark matter is tightly constrained in direct detection experiments, the light dark matter frontier is less explored. We propose to search for light dark matter with qubit array as calorimeter. The scattering of light dark matter may trigger the production of quasi-particles, which translate to detectable signals in the qubit array. The new approach may dramatically lower the experimental threshold, and allow to study the sub-GeV dark matter parameter space that was not kinematically accessible before.

Day 3 Oct-24 2024
Session 10 Oral Talk O17 14:47-14:59

Designing Photosynthesis and Avian Compass by Quantum Computers

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To examine the efficiency of light-harvesting in photosynthesis and sensitivity of avian navigation, the exact quantum dynamics therein should be provided. However, the widely-used hierarchical equation of motion is time-consuming which scales exponentially with the dimension of the system and complexity of the bath. In this talk, we propose an efficient quantum algorithm to faithfully reproduce the open quantum dynamics of photosynthetic energy transfer and charge separation. By this algorithm, we experimentally demonstrate that we can use quantum computers to design light-harvesting complexes with high efficiency, which manifest clustered geometries and a resonant bath. On the other hand, we show that in a multi-radical model, the sensitivity of avian navigation can be enhanced by quantum criticality. We also generalize the cluster-correlation expansion method to exactly reproduce the full open quantum dynamics of radical pair in a spin bath. Our approach may benefit the design of sensitive quantum navigation based on radical-pair mechanism.

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Day 3 Oct-24 2024
Session 10 Oral Talk O18 14:59-15:11

Molecule-Based High-Temperature Optically Driven Quantum Computing: First Principles, Open-Quantum-System and Tensor-Network Calculations

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Spin-bearing molecules have been demonstrated to have great potentials for quantum technology due to their tunability, portability, scalability [1-3]. In the meantime, nanophotonic devices, which have been well developed recently, can be integrated with appropriate materials platform to provide programmable and controlling functionalities for important applications such as quantum computing (QC) [4,5]. Here we propose a spin-based molecular QC architecture, by integrating two-dimensional molecular networks with nanophotonic devices for the realization of programmable quantum gate operations [2,3]. Our proposal is based on (1) the rigorous hybrid-exchange density-functional-theory (DFT) calculations validated by relevant experimental observations [6] and (2) an open-quantum-system simulation of the time-resolved electron paramagnetic resonance (TREPR) with realistic experimental parameters [2,3]. Our DFT calculations also suggest the exchange interaction can be optically enhanced significantly [6]. Moreover, we have found the spin entanglement between radicals can be generated by using the excited triplet state. And the computed quantum gate fidelity of the two-qubit quantum gate turns out to be very high. We have also used tensor network techniques to compute the optically driven entanglements in our designed two-dimensional network formed by spin-1/2 and spin-1 and found the edge enhancement of the entanglement [7]. Our work [2,3] would therefore lay a solid theoretical cornerstone for high-temperature spin-bearing-molecule-based QC. Moreover, our design strategy for connecting the molecular spin qubit and the spin coupler at the nanoscale has a great potential to scale up the quantum circuits tremendously in a systematic way through "Click Chemistry" [8].

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Day 3 Oct-24 2024
Session 11 Oral Talk O19 16:10-16:22

A New Framework for Quantum Phases in Open Systems: Steady State of Imaginary-Time Lindbladian Evolution

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This study delves into the concept of quantum phases in open quantum systems, examining the shortcomings of existing approaches that focus on steady states of Lindbladians and highlighting their limitations in capturing key phase transitions. In contrast to these methods, we introduce the concept of imaginary-time Lindbladian evolution as an alternative framework. This new approach defines gapped quantum phases in open systems through the spectrum properties of the imaginary-Liouville superoperator. We find that, in addition to all pure gapped ground states, the Gibbs state of a stabilizer Hamiltonian at any finite temperature can also be characterized by our scheme, demonstrated through explicit construction. To illustrate the effectiveness of this framework, we apply it to investigate the phase diagram for open systems with $\mathbb{Z}_2^\sigma \times \mathbb{Z}_2^\tau$ symmetry, including cases with nontrivial average symmetry protected topological order or spontaneous symmetry breaking order. Our findings demonstrate universal properties at quantum criticality, such as nonanalytic behaviors of steady-state observables, divergence of correlation lengths, and closing of the imaginary-Liouville gap. These results advance our understanding of quantum phase transitions in open quantum systems.

Ref: arXiv:2408.03239.

Day 3 Oct-24 2024
Session 11 Oral Talk O20 16:22-16:34

Novel ground-state phase diagram and emergent quantum many-body scars in a two-species Rydberg atom array

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Rydberg atom array has been established as one appealing platform for quantum simulation and quantum computation [1]. Recent experimental development of trapping and controlling two-species atoms using optical tweezer arrays has brought more complex interactions in this game, enabling much versatile novel quantum states of matter to emerge. In this paper we systematically calculate the ground state phase diagram of alternating two-species atom array and find some novel quantum states that cannot exist in traditional cold-atom platforms, for instance the period 4 $\ket{1100}$, the period 6 $\ket{111000}$ product states and order-disorder separation phase. We also find the floating phase in this two-species atoms' phase diagram, however, in this system it has to be described by two interacting bosonic fields whereas that in the single species Rydberg atom array can be understood as free bosons. More interestingly, we discover a type of new quantum many-body scar distinct from that previous found in single species atoms which is explained by low-energy effective theory of the PXP model. Instead, the underlying physics of the newly found quantum many-body scar can be described by a perturbation theory spanning the whole energy spectrum. Detailed analysis on how to experimentally prepare the states and observe these phenomena is provided. Numerical evidence shows that the proposed scheme is robust against major experimental imperfections and thus it is implementable. Our work opens new avenue for quantum simulating novel quantum many-body states both in and out of equilibrium arising from the interplay of competing interactions of different atom species and quantum fluctuations.

Day 3 Oct-24 2024
Session 11 Oral Talk O21 16:34-16:46

Variational Optimization for Quantum Problems Using Deep Generative Networks

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Optimization is one of the keystones of modern science and engineering. Its applications in quantum technology and machine learning helped nurture variational quantum algorithms and generative AI respectively. We propose a method to perform variational optimization based on classical generative models: the Variational Generative Optimization Network (VGON). We use three quantum tasks to show its quick convergence in the training phase and its ability to generate accurate and diverse nearly optimal solutions. For the first task of finding the best state in an entanglement-detection protocol, VGON greatly reduces the optimization time compared to stochastic gradient descent while generating nearly optimal quantum states. For the second task of finding the ground state of a 1D quantum spin model with variational quantum circuits, VGON alleviates the barren plateau problem in variational quantum circuits. For the final task of generating degenerate ground states of many-body quantum Hamiltonians, VGON can identify the degenerate ground state spaces after a single stage of training and generate a variety of states therein.

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20. Magnetic-electrical synergetic control of non-volatile states in bilayer graphene-CrOCl heterostructures
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22. Experimental Study of Universal Scaling in Super-radiant Quantum Phase Transitions with Single Trapped Ion
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23. Atomic flow driven by superradiance and particle pumping in an incommensurate optical lattice
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30. Multi-Ion Quantum Memory: Precision Control of Individual Bases
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37. Novel ground states and emergent quantum many-body scars in a two-species Rydberg atom array
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  16:00 - 17:30 October 23 (Poster Session)
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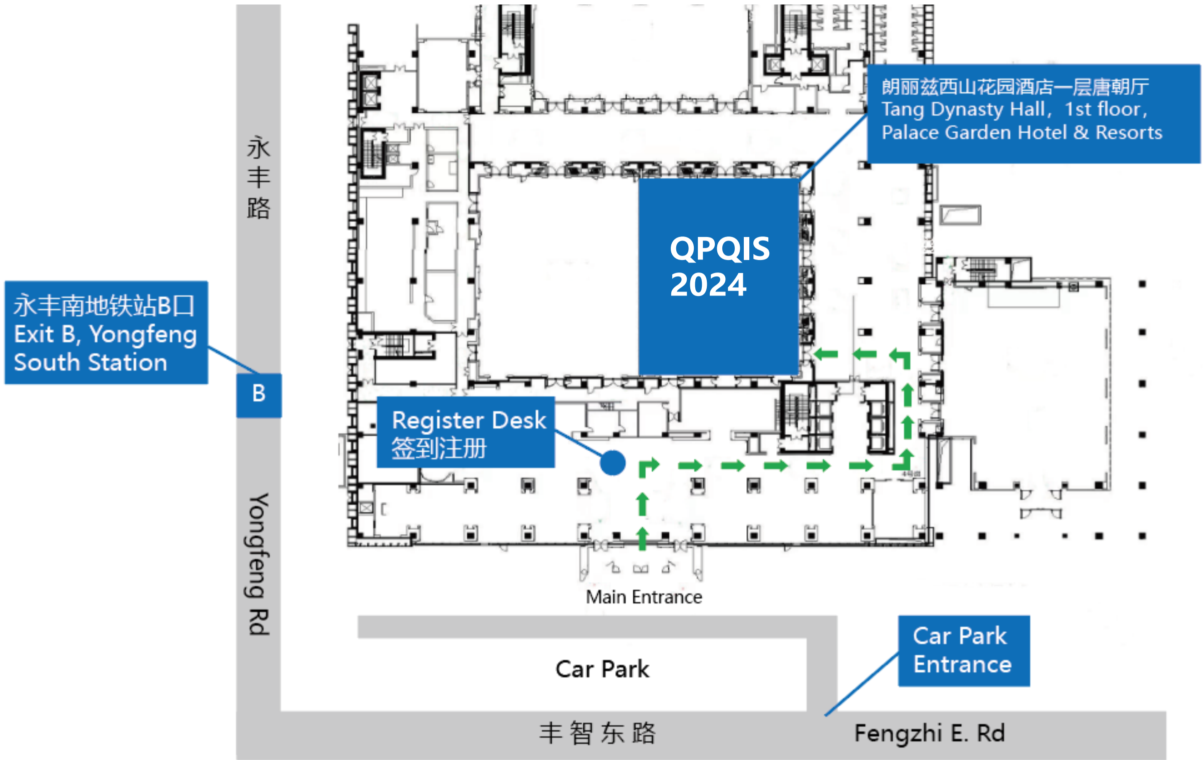

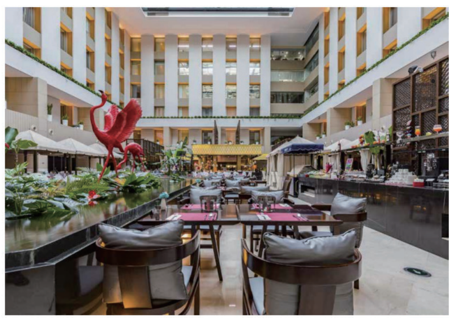

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