QPQIS International Symposium on Quantum Physics and Quantum Information Sciences

QPQIS 2020

Theme: Advances in Novel Quantum States of Matter

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北京量子信息科学研究院
Beijing Academy of Quantum Information Sciences

About

International Symposium on Quantum Physics and Quantum Information Sciences 2020

Theme : Advances in novel quantum states of matter

Welcome to the International Symposium on Quantum Physics and Quantum Information Sciences (QPQIS2020), hosted by Beijing Academy of Quantum Information Sciences (BAQIS) on December 9, 2020. QPQIS committee decided to welcome scientists and researchers to join us online this year because of the Covid-19 pandemic.

We are going to discuss the theme of "Advances in Novel Quantum States of Matter" on this year's symposium. The knowledge of quantum states of matter is the foundation of applicable quantum technologies. In recent years, the research in various novel quantum states of matter, such as topological materials, unconventional superconductors, exotic magnetisms and low-dimensional materials, has achieved great progress. Promising quantum information applications have been conceived based on these advancements, attracting more and more attention not only inside the physics community, but also in the industry and general public.

About

We proudly present eleven invited top scientists from universities and institutes all over the world to share their latest research progress and perspective insights about novel quantum states of matter. We would also bring together a group of students, postdocs and senior scientists working on the frontier of quantum science to discuss and explore the cutting edge developments at this exciting symposium. All the talks and discussions will be broadcasted worldwide through Internet.

Organizing Committee

Chair: Dr. Qi-Kun Xue (President of BAQIS, CAS Member, Vice President of Tsinghua Univ.)

Member: Dr. Kai Chang (BAQIS), Dr. Jian-Hao Chen (BAQIS/Peking University), Dr. Hong-Yi Xie (BAQIS) and Dr. Huai-Bin Zhuang (BAQIS).

Program

9:25-9:30
Welcome Speech
Qi-Kun Xue
President of Beijing Academy of Quantum Information Sciences

Session 1

Chair: *Dr. Jian-Hao Chen* (BAQIS, Peking Univ.)

9:30-10:10
Nonlinear Hall effect and terahertz technology
Liang Fu
Associate Professor of Physics, MIT, USA

10:10-10:50
Stacking van der Waals atomic layers: quest for new quantum materials
Philip Kim
Professor of Physics and Applied Physics, Harvard University, USA

10:50-11:30
Double Majorana vortex zeromodes in superconducting topological crystalline insulators
Akira Furusaki
Chief Scientist, Condensed Matter Theory Laboratory, RIKEN, Japan

11:30-12:10
Three-Dimensional Topological Insulators and Applications
Katsumi Tanigaki
Senior Scientist, BAQIS, Beijing, China. Professor, AIMR, Tohoku University, Sendai, Japan

12:10-14:00
Break

Program

Session 2

Chair: *Dr. Kai Chang* (BAQIS)

14:00-14:40
Exploration of the Fu-Kane proposal for topological quantum computation
Li Lu
Director of Daniel Chee Tsui Laboratory, and the director of the Huairou branch, IOP-CAS.

14:40-15:20
Vortex states in the topological trivial and nontrivial FeSe-based superconductors
Donglai Feng
Professor, Hefei National Laboratory for Physical Sciences at the Microscale,and Yan Ji Ci professor of Phisics at the School of Physics, USTC

15:20-16:00
Chiral non-collinear spin textures
Stuart S. P. Parkin
Director, Max Planck Institute of Microstructure Physics, Germany

16:00-16:40
Topological materials science
Claudia Felser
Director, Max Planck Institute for Chemical Physics of Solids, Germany

16:40-17:00
Break

Program

Session 3

Chair: ***Dr. Hong-Yi Xie*** **(BAQIS)**

17:00-17:40
Less is more: a simple effective description of quantum spin liquids in terms of gravity
Jiannis K. Pachos
Professor of Theoretical Physics, University of Leeds, UK

17:40-18:20
Transport through twisted graphene layers: gaps interactions and devices
Klaus Ensslin
Director of Swiss Centre for Research in Quantum Science and Technology, ETH, Switzerland

18:20-19:00
Quantum thermoelectricity in nano-devices
Mikhail Kiselev
Research Scientist, Abdus Salam International Center for Theoretical Physics (ICTP), Italy.

Abstract

9:30-10:10

Nonlinear Hall effect and terahertz technology

Liang Fu
Associate Professor of Physics, MIT, USA

I will describe recent theories and experiments on nonlinear Hall effect in nonmagnetic materials at zero magnetic field, where an applied electric field induces a transverse current at second order. This effect arises from anomalous velocity due to Berry curvature in a current-carrying state in inversion-breaking systems. Technological applications of nonlinear Hall effect in terahertz detection and wireless power transmission will be discussed.

Abstract

10:10-10:50

Stacking van der Waals atomic layers: quest for new quantum materials

Philip Kim
Professor of Physics and Applied Physics, Harvard University, USA

Modern electronics heavily rely on the technology to confine electrons in the interface layers of semiconductors. In recent years, scientists discovered that various atomically thin van der Waals (vdW) layered materials can be isolated. In these atomically thin materials, quantum physics allows electrons to move only in an effective 2-dimensional (2D) space. By stacking these 2D quantum materials, one can also create atomic-scale heterostructures with a wide variety of electronic and optical properties. We demonstrate the enhanced electronic and optoelectronic performances in the vdW heterostructures, suggesting that these a few atom thick interfaces may provide a fundamental platform to realize novel physical phenomena. In this talk, we will discuss several research efforts to realize unusual quasiparticle pairing mesoscopic devices based on stacked vdW interfaces between 2-dimensional materials.

Abstract

10:50-11:30

Double Majorana vortex zeromodes in superconducting topological crystalline insulators

Akira Furusaki
Chief Scientist, Condensed Matter Theory Laboratory, RIKEN, Japan

Majorana fermions bound to a superconducting vortex have received great attention, and recent experiments have reported evidence for Majorana zero modes localized at vortex cores in superconducting topological insulators such as Bi2Te3 and iron-based superconductors. In this talk I will report our recent theoretical study of Majorana zero modes bound to a vortex in superconducting topological crystalline insulators protected by rotation symmetry. The proximity-induced s-wave superconductivity on the surface of topological crystalline insulators protected by time-reversal and n-fold rotation (n=2, 4, 6) symmetries yields a topological superconducting state in which two Mjorana zero modes are bound to a vortex. Accordingly, the n-fold rotation symmetry enriches the topological classification of a superconducting vortex from Z2 to (Z2)2.

Abstract

Abstract

11:30-12:10

Three-Dimensional Topological Insulators and Applications

Katsumi Tanigaki
Senior Scientist, BAQIS, Beijing, China.
Professor, AIMR, Tohoku University, Sendai, Japan

Topological insulators (TIs) have currently been attracting large attention from the viewpoint of contemporary materials science generating new electronic states of helical massless Dirac fermions with spin momentum locking and high mobility on the two-dimensional (2D) surface or the one-dimensional (1D) edge. Many theoretical studies suggest exotic physical properties as well as novel applications of TIs. In order to unveil the intrinsic physical properties of topological surface states (TSS) in TIs, it is required to grow high quality ultra-thin films and minimize the contribution of the bulk carriers by tuning the Fermi level (EF) inside the bulk gap. The EF of three-dimensional (3D) TIs is known to be engineered by the concept of charged defects control in the phase diagram of tetradymites consisting of III(Sb,Bi)-VI(Se,Te) elements. Bi2Se3 and Bi2Te3 are known to be n-type 3D-TIs, while Sb2Te3 is p-type one, while Sb2Se3 is still debated as to whether this is trivial or nontrivial as 3D-TIs. Since it has been difficult to observe the intrinsic TSS properties, ternary (Bi,Sb)2Te (BST) or (Bi,Sb)2Se3 (BSS) grown by molecular beam epitaxy crystal growth are frequently employed. Highly bulk insulating quaternary tetradymites 3D-TIs of (Bi,Sb)2(Te,Se)3 (BSTS) and Sn-(Bi,Sb)2(Te,,S)3 (Sn-BSTS) are recently proposed for 3D-TIs with larger band gap and are intensively studied. We have been focusing on BSTS by non-catalytic vapor phase epitaxial (NC-VPE) growth and Sn-BSTS via the exfoliation (EXF) technique widely used for graphene. These techniques provide large-size thin films with high quality and can be transferred to a various kind of substrates with free of damage. In this seminar, I will talk on our recent advancements in high quality thin films of BSTS and Sn-BSTS 3D-TIs [1-5]. We can observe integer quantum spin Hall effects for high quality samples without gate control [5]. In this

seminar, I will give a talk focusing on 3D-TIs of BSTS and Sn-BSTS and their applications to electronic devices, such as field effect transistors [1], topological pn-junction [2] and thermoelectrics [4] in addition to other achievements in my research group of AIMR.

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Abstract

14:00-14:40

Exploration of the Fu-Kane proposal for topological quantum computation

Li Lu
Director of Daniel Chee Tsui Laboratory, and the director of the Huairou branch, IOP-CAS.

In 2008, Fu and Kane proposed to induce p-wave-like superconductivity at the interface of an s-wave superconductor and a topological insulator. Since then, many hybrid structures have been proposed/tested. Signatures of Majorana zero modes (MZMs) have been observed in structures containing semiconducting nanowires, topological insulators, Chern insulators, iron chains, etc. However, the original proposal of Fu and Kane – to construct Josephson trijunctions on topological insulators, which could potentially serve as the building blocks for topological quantum computers – remains largely unexplored experimentally. In this talk, I will report our systematic studies on the Josephson devices constructed on the surface of Bi2Te3. We demonstrate that the Majorana phase diagram for Josephson trijunction proposed by Fu and Kane is correct. The minigap at the center of the trijunction was found to close linearly when the devices enter into the MZM regions of the phase diagram, yet re-open slightly inside the MZM regions due to the finite width effect of the junctions. Our result is in favor of the Fu-Kane proposal of searching for scalable topological quantum computing on two-dimensional platforms.

Abstract

14:40-15:20

Vortex states in the topological trivial and nontrivial FeSe-based superconductors

Donglai Feng
Professor, Hefei National Laboratory for Physical Sciences at the Microscale,and Yan Ji Ci professor of Phisics at the School of Physics, USTC

Majorana zero modes (MZM) are the building blocks for potential topological quantum qubits. MZM could live in the vortices of topological superconductors (TSC). Here we present the vortex states in several FeSe-based superconductors and a heterostructure with scanning tunneling microscopy (STM). (Li0.84Fe0.16)OHFeSe has a superconducting transition temperature (Tc) of 42 K. We show that it possesses non-trivial band inversion and topological surface states with band calcu lations and angle-resolved photoemission spectroscopy. Moreover, via low-temperature STM, we found a zero-bias conduction peak (ZBCP) well separated from other discrete Caroli-de Gennes-Matricon (CdGM) states exists ubiquitously in all unpinned vortex cores [1]. This ZBCP has distinct spatial distributions from the other CdGM states [2], and its conductance is quantized at 2e2/h [3]. It thus can be naturally attributed to an MZM arising from the chiral topological surface states of a bulk super conductor.

For single layer FeSe film on STO substrate, we show that neither MZMs exist in the vortex cores nor do they show up on the iron impurities [4], which suggests it is topologically trivial and thus band inversion induced by interlay coupling is critical for realizing topological superconductivity in FeSe based systems, such as (Li,Fe)OHFeSe..

Recently, we fabricated MnTe/Bi2Te3/Fe(Te,Se) heterostructure, and observed robust ZBCP and discrete bound states without applying external magnetic field [5]. These systems provide platforms for studying the properties of MZMs and explore their applications in topological quantum computing.

References:

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Abstract

15:20-16:00

Chiral non-collinear spin textures

Stuart S. P. Parkin
Director, Max Planck Institute of Microstructure Physics, Germany

Magnetic non-collinear spin textures that have chiral structures are of great current interest. The same type of Dzyaloshinskii-Moriya (DMI) vector exchange interactions that stabilize chiral Néel domain walls in magnetic multilayers1-3 results in the formation of topological spin textures in bulk compounds. We recently discovered magnetic antiskyrmions in a tetragonal inverse Heusler compound Mn1.4Pt0.9Pd0.1Sn using Lorentz transmission electron microscopy (LTEM)4. Unlike skyrmions in B20 compounds, that have been extensively studied, the size of the anti-skyrmion can be tuned by varying the thickness of the host material allowing for sizes varying from nanometer to microns in the same material5. This is due to long range magneto-dipole interactions that are important in this compound that has a complex DMI interaction with a symmetry that follows the D2d symmetry of its crystalline structure. The same symmetry ensures that anti-skyrmions are robust to temperature and magnetic field6. The magnetic dipole-dipole interactions also allow for the formation of metastable "elliptical skyrmions" in this same material7. These have Bloch-like boundaries that we can directly observe using LTEM. Finally, we discuss novel Néel like skyrmions in a metallic compound that exist almost to room temperature and that are also tunable in size8. Chiral spin textures in ferro-, ferri- and anti-ferrimagnetic materials and thin film heterostructures are of fundamental interest with potential for spintronic applications especially Racetrack Memory.

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Abstract

16:00-16:40

Topological materials science

Claudia Felser
Director, Max Planck Institute for Chemical Physics of Solids, Germany

Topology, a mathematical concept, recently became a hot and truly transdisciplinary topic in condensed matter physics, solid state chemistry and materials science. Since there is a direct connection between real space: atoms, valence electrons, bonds and orbitals, and reciprocal space: bands, Fermi surfaces and Berry curvature, a simple classification of topological materials in a single particle picture should be possible [1]. Binary phosphides are an ideal material class for a systematic study of Dirac, Weyl and new Fermion physics, since these compounds can be grown as high-quality single crystals. A new class of topological phases that have Weyl points was also predicted in the family that includes NbP, NbAs. TaP, MoP and WP2. [3-5]. Beyond Weyl and Dirac, new fermions can be identified in compounds that have linear and quadratic 3-, 6- and 8- band crossings that are stabilized by space group symmetries [2]. Crystals of chiral topological materials CoSi, AlPt and RhSi were investigated by angle resolved photoemission and show giant unusual helicoid Fermi arcs with topological charges of ±2 [6,7]. In agreement with the chiral crystal structure two different chiral surface states are observed. In magnetic materials the Berry curvature and the classical anomalous Hall (AHE) and spin Hall effect (SHE) helps to identify potentially interesting candidates. As a consequence, the magnetic Heusler compounds have already been identified as Weyl semimetals: for example, Co2YZ [8-11], and Co3Sn2S2 [12-15]. The Anomalous Hall angle also helps to identify materials in which a QAHE should be possible in thin films. Heusler compounds with non-collinear magnetic structures also possess real-space topological states in the form of magnetic antiskyrmions, which have not yet been observed in other materials [16].

Abstract

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Abstract

17:00-17:40

Less is more: a simple effective description of quantum spin liquids in terms of gravity

Jiannis K. Pachos
Professor of Theoretical Physics, University of Leeds, UK

It is widely accepted that topological superconductors can only have an effective interpretation in terms of curved geometry rather than gauge fields due to their charge neutrality. Nevertheless, it is not known how accurately curved geometry can describe actual microscopic models. In this talk I will demonstrate that the low-energy properties of the Kitaev honeycomb lattice model, a topological superconductor that supports localized Majorana zero modes at its vortex excitations, are faithfully described in terms of Riemann-Cartan geometry. This approach gives the opportunity to accurately predict dynamical properties of the Kitaev model from its effective geometric description.

Abstract

17:40-18:20

Transport through twisted graphene layers: gaps interactions and devices

Klaus Ensslin
Director of Swiss Centre for Research in Quantum Science and Technology, ETH, Switzerland

Twisting graphene layers with a twist angle larger than 10 degrees results in electronically decoupled systems. This can be used to extract the electronic thickness of graphene from transport experiments. For twisted double bilayer graphene a gap opens without applied top and back gate voltages. The gap formation is caused by crystal fields between the layers. For tilt angles around 2 degrees the overlap between gaps and wave functions in the two double layer systems can be controlled by top and back gates. This intermediate angle is small enough for the minibands to form and large enough such that the charge carrier gases in the layers can be tuned independently. We use this property to generate an energetic overlap between narrow isolated electron and hole bands with good nesting properties. Our measurements reveal the formation of ordered states with reconstructed Fermi surfaces, consistent with density-wave states, for equal electron and hole densities.

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Abstract

18:20-19:00

Quantum thermoelectricity in nano-devices

Mikhail Kiselev
Research Scientist, Abdus Salam International Center for Theoretical Physics (ICTP), Italy.

In this talk I review a recent progress in theoretical understanding of quantum thermoelectric phenomena on nano-scale. In particular, I discuss effects of strong electron-electron interaction and resonance scattering on quantum thermal transport in nano-devices. For illustration I consider manifestation of exotic Fermi-liquid regimes in thermoelectricity of single wall carbone nanotubes [1,2,3] and numerous examples of the non-Fermi liquid regimes in the thermoelectric transport through a circle implementation of multi-channel charge Kondo model quantum simulators [4,5] and quantum dot-based implementation of the over-screened spin Kondo model [6]. Finally, I discuss the non-Fermi liquid regimes in thermoelectric transport through possible realization of the complex Sachdev-Ye-Kitaev (SYK) model in irregularly shaped graphene flake quantum dots [7]. In my talk I focus on theoretical challenges (parafermions, fractionalized zero modes etc) and experimental applications including but not limited by power output and experimental control on the thermopower signal.

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About BAQIS

Beijing Academy of Quantum Information Sciences (BAQIS) was established on December 24, 2017. Partnering with top research institutions such as Tsinghua University, Peking University, and Chinese Academy of Sciences, etc., BAQIS is taking advantages of the most favorable strength for quantum information research in Beijing.

BAQIS aims at developing the world first class innovative research institution, standing at the forefront of quantum physics and quantum information sciences research. It runs with a management model of international standard, integrates strength resources from all partnering institutions, vigorously introduces global top talents to form the research teams. The research teams are to be led by scientists with potential for strategic scientific and technological innovations, and supported by highly expertized engineers, and provided with world class experimental platforms. It strives to achieve world class results in the fundamental research of quantum state of matter, quantum communication and computation, quantum materials and devices, quantum precision measurement.

For more information please visit our website: http://www.baqis.ac.cn/

Contact

For further information please forward all enquiries to:

Dr. Min ZHOU
Email: qpqis2020@baqis.ac.cn

QPQIS2020 website: http://qpqis2020.baqis.ac.cn/

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Beijing Academy of Quantum Information Sciences

West Bld #3, No.10 Xi-bei-wang East Rd.,
Haidian District, Beijing 100193
P.R.CHINA
Tel: (86)10-83057401
Fax: 010-83057512
Email: info@baqis.ac.cn