Topological Matter & Quantum Computing

Kavli ITS Workshop

May 4-6, 2018
Kavli Institute for Theoretical Sciences, at
University of Chinese Academy of Sciences
Beijing, China

中国科学院大学卡弗里理论科学研究所
Kavli Institute for Theoretical Sciences at UCAS

中国科学院拓扑量子计算卓越创新中心
CAS Center for Excellence in Topological Quantum Computation

中国科学院大学
University of Chinese Academy of Sciences

Conference Program

May 4, Friday

	[Session 1] Chair: Fu-Chun Zhang (Kavli ITS)	
09:00-09:10	**Fu-Chun Zhang** (Kavli ITS)	[Opening session]
09:10-09:40	**Xiao-Gang Wen** (MIT)	Non-Abelain Topological Orders
09:40-10:10	**Liang Fu** (MIT)	(TBA)
10:10-10:40	**Hao Zhang** (Delft Univ. Technol)	Majorana nanowires and topological quantum computation
10:40-11:00	*Coffee Break*	
	[Session 2] Chair: Yi Zhou (ZJU)	
11:00-11:30	**Jin-Feng Jia** (SJTU)	Majorana zero mode inside vortex of topological superconductors
11:30-12:00	**Hong Ding** (IOP, CAS)	Majorana bound state in iron-based superconductor Fe(Te, Se)
12:00-12:30	**Xiao Hu** (NIMS, Japan)	Topological metamaterials towards robust quantum computation
12:30-14:00	*Lunch*	
	[Session 3] Chair: Zheng-Yu Weng (Tsinghua)	
14:00-14:30	**Hong-Wen Jiang** (UCLA)	Experimental creation/detection of single skyrmions and its possible applications in quantum computing
14:30-15:00	**Sadamichi Maekawa** (RIKEN, Japan)	Spin mechatronics – Mechanical effects on spintronics
15:00-15:30	**Yu-Lin Chen** (Oxford)	Topological electronic structures in metallic phases
15:30-16:00	*Coffee Break*	
	[Session 4] Chair: Heng Fan (IOP, CAS)	
16:00-16:30	**Li Lu** (IOP, CAS)	Search for Majorana zero modes in Josephson devices constructed on Bi2Te3 surface
16:30-17:00	**Bob Joynt** (Kavli ITS/Wisconsin)	Speedup of the Quantum Adiabatic Algorithm by Topological Cancellation
17:00-17:30	**Hao-Hua Wang** (Zhejiang Univ.)	Multi-qubit superconducting quantum circuits

May 5, Saturday

	[Session 1] Chair: Tao Xiang (IOP, CAS)	
09:00-09:30	**Qi-Kun Xue** (Tsinghua Univ.)	New progress in quantum anomalous Hall effect
09:30-10:00	**Rui-Rui Du** (PKU)	Quantum spin hall effect in InAs/GaSb quantum wells
10:00-10:30	**Xin Liu** (HUST)	Braiding Majorana zero modes in spin space: from worldline to worldribbon
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	[Session 2] Chair: Xin-Cheng Xie (Peking U)	
11:00-11:30	**Shou-Cheng Zhang** (Stanford Univ.)	Discovery of chiral Majorana fermion and its application to topological quantum computing
11:30-12:00	**Qing-Lin He** (PKU)	Quantization of chiral Majorana fermions: Quantum transport and Interference
12:00-12:30	**Jing Xia** (UC Irvine)	Evidence for chiral Majorana edge modes
12:30-14:00	*Lunch*	
	[Session 3] Chair: Jiang-Ping Hu (IOP, CAS)	
14:00-14:30	**Meng Cheng** (Yale Univ.)	Symmetry-enforced genons
14:30-15:00	**Xi Dai** (UKUST)	Chiral hinge states and surface quantum anomalous Hall effect in ferromagnetic axion insulators
15:00-15:30	**Bing-Hai Yan** (Weizmann Inst. of	Berry phase induced higher order responses in topological materials
15:30-16:00	*Coffee Break*	
	[Session 4] Chair: Hong Yao (Tsinghua)	
16:00-16:30	**Zhen-Yu Zhang** (USTC)	Towards Materials Realization of Topological Superconductivity
16:30-17:00	**Shun-Qing Shen** (HKU)	Intrinsic Magnetoresistivity in Three-Dimensional Dirac Materials
17:00-17:30	**Chen Fang** (IOP, CAS)	Quantitative mappings from symmetry to topology in band structures
18:00-21:00	Banquet	

May 6, Sunday

	[Session 1] Chair: Kai-Chang (IOS, CAS)	
09:00-09:10	[Kavli ITS Ceremony]	
09:10-09:40	**Wei Pan** (Sandia Nat Lab, USA)	New Results in Dirac Semimetals
09:40-10:10	**Kun Yang** (Florida State Univ.)	Interplay of Topology and Geometry in Fractional Quantum Hall Liquids
10:10-10:35	**Xi Lin** (PKU)	3/2 fractional quantum Hall plateau in a single layer two-dimensional electron gas
10:35-10:55	*Coffee Break*	
	[Session 2] Yong-Qing Li (IOP, CAS)	
10:55-11:20	**Jian-Hua Zhao** (IOS, CAS)	Robust manipulation of magnetic property of (Ga, Mn)As & high-quality low dimensional semiconductor-based topological quantum materials
11:20-11:45	**Mamoru Matsuo** (Kavli ITS)	Spin hydrodynamic generation in graphene
11:45-12:10	**Kai-You Wang** (IOS, CAS)	Evidence for chiral Majorana edge modes
12:10-12:35	**Long Zhang** (Kavli ITS)	Characterizing quantum phase transitions of symmetry protected topological phases with surface critical behavior
12:35-12:40	[Closing remark]	
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14:00-17:00	[Discussion of special topics]	

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Majorana nanowires and topological quantum computation

Hao Zhang (Delft Univ. Technol)

Hybrid superconductor-semiconductor nanowires is a prime platform to realize, control and manipulate Majorana quasi-particles in topological quantum information processing. Since the first report of the Majorana signatures, as a zero-bias-conductance-peak in 2012 [1], substantial advances has been achieved in this system over the last few years, from material growth, device processing and measurement, to theoretical understanding. In this talk, I will discuss our efforts together with Microsoft, following two paths. The first path is a series of experiments to find better and stronger evidence on the existence of Majorana modes [2-4], while the second path focuses on the efforts toward realizing the first Majorana qubit for the future topological quantum computers. [5]

References:

[1] Mourik, Zuo *et al*, Science **336**, (2012)

[2] Deng *et al*, Science **354,** (2016)

[3] Gul, Zhang, Bommer *et al*, Nature Nanotech. **13**, (2018)

[4] Zhang *et al*, Nature **556**, (2018)

[5] Gazibegovic, Car, Zhang *et al*, Nature **548**, (2017)

Majorana bound state in iron-based superconductor Fe(Te, Se)

Hong Ding

Institute of Physics, Chinese Academy of Sciences

In this talk I will report our recent discoveries of topological superconductivity and Majorana bound state in Fe-based superconductor Fe(Te, Se). We have obtained convincing ARPES evidence of superconducting topological surface state of Fe(Te, Se) single crystal with Tc ~ 14.5K. By using low-temperature STM on this maeteial, we clearly observe a pristine Majorana bound state inside a vortex core, well separated from non-topological bound states away from zero energy due to the high ratio between the superconducting gap and the Fermi energy in this material. This observation offers a new, robust platform for realizing and manipulating Majorana bound states at a relatively high temperature.

Topological metamaterials towards robust quantum computation

Xiao Hu (NIMS, Japan)

Recently there are tremendous interests and significant progresses in realizing topological states and functionality in various platforms. In this talk, I wish to discuss our recent works on several interesting topological systems towards the ultimate goal of robust quantum computation. (1) We reveal a novel relation among the energy, orbital angular momentum and spin for quasiparticle excitations inside superconducting vortex at the surface of a hybrid system of an s-wave superconductor and a 3D topological insulator. This relation can be used to nail down the Majorana bound state experimentally in terms of the spin-resolved STM/STS technique. (2) We propose a universal gate for manipulating qubits formed by zero-energy Majorana modes at the ends of 1D topological superconductors. This is based on a Landau-Zener-Stuckelberg interference between the parity states induced by bias voltage across the Majorana-Josephson junction between two 1D topological superconductors. (3) We demonstrate a synthetic quantum spin Hall effect in dielectric photonic crystals by exploring the C6v symmetry of honeycomb structure, which can be used for realizing topological photon transportation, topological microwave optics and topological laser. Generalizing this idea to electronic systems, we show that in graphene patchwork formed by regular arrays of nano-holes one can achieve topological interface states protected by energy gaps over 1 eV.

Topological electronic structures in metallic phases

Yu-Lin Chen (Oxford)

Following the discovery of 2D and 3D topological insulators, in the past few years, topological electronic structures in metallic phases were discovered and actively investigated, such as the topological Dirac/Weyl semimetals and topological line-node semimetals. These new topological phases can host interesting exotic particles and unusual physical phenomena (such as Weyl fermions, surface Fermi-arcs, negative magnetoresistance, chiral magnetic effects and topological superconductivity, etc.) which are not only interesting in fundamental physics, but also attractive to novel future applications. In this talk, I will discuss how to identify the nontrivial bulk and surface topological electronic structures in these interesting metallic phases by angel resolved photoemission spectroscopy (ARPES). Furthermore, I will also briefly introduce the recently advances of ARPES (with spatial, spin and time resolution) which can be used in the future investigations on topological electronic structures.

Speedup of the Quantum Adiabatic Algorithm by Topological Cancellation

Bob Joynt (Kavli ITS/Wisconsin)

Transitions in a time-dependent quantum system can be suppressed by adding a topological cancellation term to the Hamiltonian. We use this technique to improve the quantum adiabatic algorithm, using the random-field Ising model as an illustrative case. For strong disorder the cancellation significantly enhances the probability for the system to remain in the ground state. The new technique opens up a broad avenue for the improvement of the quantum adiabatic algorithm.

Multi-qubit superconducting quantum circuits

Hao-Hua Wang (Zhejiang Univ.)

Here I will review our recent activities with our collaborators on designing and fabricating superconducting circuits for scalable quantum information processing. In particular, I will introduce a superconducting quantum processor featuring 10 individually-accessible Xmon qubits that are controllably coupled to a bus resonator, based on which we deterministically produce the Greenberger-Horne-Zeilinger states with up to 10 qubits. With the excellent control of Xmon qubits, we further present an experiment of demonstrating the path independent nature of anyonic braiding statistics, where we dynamically create the ground state of the 7-qubit version of the toric code model and subsequently implement single-qubit rotations for braiding operations.

Braiding Majorana zero modes in spin space: from worldline to worldribbon

Xin Liu (HUST)

Quantum states in solids inevitably have internal degrees of freedom of spin, including Majorana zero modes (MZMs). In this talk, I will first give an intuitive introduction of the unique spin properties of MZMs. A brief summary of the proposals for detecting and braiding MZMs and their spin counterparts will be present. I then focus on our recent work, proposing a scheme to braid MZMs by locally winding the Majorana spins, which topologically corresponds to twisting two associated worldribbons, equivalent to worldlines that track the braiding history of MZMs. We demonstrate the feasibility of applying the current scheme to the superconductor/2D-topological-insulator/ferromagnetic-insulator (SC/2DTI/FI) hybrid system. The braiding operation by winding Majorana spins is robust against local imperfections such as irregular winding paths, the static and dynamical disorder effects, which is a natural consequence of the intrinsic connection of our scheme to topological charge pumping.

Discovery of chiral Majorana fermion and its application to topological quantum computing

Shou-Cheng Zhang (Stanford Univ.)

Majorana fermion is a hypothetical fermionic particle which is its own anti-particle. Intense research efforts focus on its experimental observation as a fundamental particle in high energy physics and as a quasi-particle in condensed matter systems. We have theoretically predicted the chiral Majorana fermion in a hybrid structure of quantum anomalous Hall thin film coupled with a conventional superconductor, and have proposed the half-integer quantized conductance plateau as its compelling signature. Recently, this theoretical prediction has been experimentally realized in magnetically doped topological insulator coupled with Nb superconductor and the half plateau quantization has been observed. I shall discuss a new proposal to braid the chiral Majorana fermion in a Corbino device geometry. The discovery of the chiral Majorana fermion leads to new avenues towards topological quantum computing, which could be much faster compared to Majorana zero modes.

Quantization of chiral Majorana fermions: Quantum transport and Interference

Qing-Lin He (PKU)

In a quantum anomalous Hall insulator coupled to an s-wave superconductor, the surface Dirac fermion at the interface forms a px+ipy superconductor, which accommodates one-dimensional chiral Majorana fermion modes propagating along the edges when the topological order is carefully controlled. Experimental signatures of this mode is captured by the magneto-electric transport measurements in a hybrid system of a quantum anomalous Hall insulator [Cr-doped (Bi,Sb)2Te3] thin film partially capped by a superconductor layer (Nb). The external magnetic field serves as a “knob” to tune the system into different topological regimes that allow the degenerate and non-degenerate propagation of Majorana edge modes. This tuning was signified as quantized conductance transitions among e2/h, 0.5e2/h, and 0 as the external magnetic field was swept, which correspond to the topological superconducting phases with Chern numbers of 2, 1, and 0. This phase transition was recently further investigated by the edge tunneling spectra, which show the interference signature of the chiral Majorana fermions. When the Chern number is odd, the single chiral Majorana fermion contributes to a tunneling conductance quantized to 2e2/h. Otherwise conductance dips appear, which is attributed to the destructive interference of the degenerate Majorana fermions.

Evidence for chiral Majorana edge modes

Jing Xia (UC Irvine)

An emerging approach to quantum computing seeks to utilize topologically protected quantum states as Qubits to solve the error-correction problem, as the information encoded in such a "topological quantum computer" cannot be easily corrupted. A recent focus in condensed matter physics has been finding and fabricating such topological materials. In this talk, I will discuss two material systems that could host chiral Majorana modes and may have potential applications in topological quantum computing. The first system is the interface between a magnetically doped topological insulator and a superconductor, where we found experimental transport evidence for a chiral edge state of Majorana Fermions, which were proposed theoretically by Ettore Majorana in the 1930s by remained elusive. The second system is the ultra-thin bilayer film of bismuth and nickel, where we found experimental optical evidence for a superconducting state that breaks time-reversal symmetry, pointing to a 'd+id' superconducting state. Theories suggest that this state may have two chiral Majorana edge modes propagating around the sample edge, either clockwise or counterclockwise. These Majorana edge states, with further engineering and manipulation, could be useful for topological quantum computing.

Symmetry-enforced genons

Meng Cheng (Yale Univ.)

Genons are lattice dislocations in crystalline topological phases which carry non-Abelian zero modes. We will discuss general symmetry conditions for genons to emerge in strongly interacting systems. In the first part of the talk, we present a Lieb-Schultz-Mattis type theorem for translation-invariant non-degenerate fermions with particle-hole symmetry. The theorem implies that if the system is gapped and preserves all symmetries, there must be genons. In the second part, we turn to a more realistic system, topological Hoftstadter bands with Chern number C > 1 in 2D superlattices. They can be engineered, e.g. in Moire pattered graphene. We show that the magnetic translation symmetry is enlarged to a translation symmetry and an internal "color" symmetry. The color symmetry, together with the filling constraint, imply that certain candidate topological states must host genons.

Chiral hinge states and surface quantum anomalous Hall effect in ferromagnetic axion insulators

Xi Dai (UKUST)

A universal mechanism to generate chiral hinge states in the ferromagnetic axion insulator phase is proposed, which leads to an exotic transport phenomena, the quantum anomalous Hall effect on some particular surfaces determined by both the crystalline symmetry and the magnetization direction. A realistic material system Sm doped Bi_2Se_3 is then proposed to realize such exotic hinge states by combing the first principle calculations and the Green’s function techniques. A physically accessible way to manipulating the SQAHE is also proposed, which makes it very different with the QAHE in ordinary 2D systems.

Towards Materials Realization of Topological Superconductivity

Zhenyu Zhang

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The recent discoveries of topological insulators as a new class of quantum materials offer various new design schemes for potential definitive realization of topological superconductors and unambiguous detection of Majorana fermions. In this talk, I will present some of our latest findings surrounding topological superconductors, focusing on their potential materials realization. We first briefly review on the robust nature of the topological surface states at the interfaces of topological heterojunctions within the contexts of their intriguing emergent functionalities and potential technological applications. We then show that proper introduction of dilute magnetic dopants at the interfaces of topological insulators and conventional superconductors can effectively convert the systems into chiral topological superconductors. We next shift to two-dimensional (2D) Rashba spin-orbit coupled superconductors, and explore how magnetic or Anderson disorders can induce topological phase transitions in such systems. Beyond such microscopic model studies, we also use first-principles calculations to explore several candidate systems that may favor 2D topological superconductivity.

Intrinsic Magnetoresistivity in Three-Dimensional Dirac Materials

Shun-Qing Shen (HKU)

Recently, negative longitudinal and positive in-plane transverse magnetoresistance have been observed in most topological Dirac/Weyl semimetals, and some other topological materials. Here we present a quantum theory of intrinsic magnetoresistance for three-dimensional Dirac fermions at a finite and uniform magnetic field B. In a semi-classical regime, it is shown that the longitudinal magnetoresistance is negative and quadratic of a weak field B while the in-plane transverse magnetoresistance is positive and quadratic of B. The relative magnetoresistance is inversely quartic of the Fermi wave vector and only determined by the density of charge carriers, irrelevant to the external scatterings in the weak scattering limit. This intrinsic anisotropic magnetoresistance is measurable in systems with lower carrier density and high mobility. In the quantum oscillation regime a formula for the phase shift in Shubnikov-de Hass oscillation is present as a function of the mobility and the magnetic field, which is useful for experimental data analysis.

Reference:

H. W. Wang, B. Fu, S. Q. Shen

Intrinsic Magnetoresistance in Three-Dimensional Dirac Materials arXiv:1804.00246

Quantitative mappings from symmetry to topology in band structures

Chen Fang (IOP, CAS)

The study of spatial symmetries in solids, or the crystallographic space groups, was accomplished during the last century, and had greatly improved our understanding of electronic band structures in solids. Nowadays, the ``symmetry data'' of any band structure, i.e., the irreducible representations of all valence bands, can be readily extracted from standard numerical calculations based on first principles. On the other hand, the topological invariants, the defining quantities of topological materials, are in general considerably difficult to calculate ab initio. While topological materials promise robust and exotic physical properties both scientifically intriguing and favorable for the designs of new quantum devices, their numerical prediction and discovery have been critically slowed down by the involved calculation of the invariants. It has long been hoped that quantitative relations exist between symmetry data and topological invariants, but examples are extremely scarce (e.g., the famous Fu-Kane formula relating inversion eigenvalues to time-reversal Z2-invariants) and discovered in ad hoc ways. In this work, we combine the technique of layer construction and the theory of symmetry-based indicators and derive, in each of the 230 space groups, all the relations that exist between symmetry representations and topological invariants in bands. For each set of symmetry eigenvalues of space group operations, we find all six types of topological invariants corresponding to it in a gapped band structure, and we give the types (lines or points), topological charges, numbers and configurations of all robust topological band crossings if the bands are gapless.

Interplay of Topology and Geometry in Fractional Quantum Hall Liquids

Kun Yang (Florida State Univ.)

Fractional Quantum Hall Liquids (FQHL) are the ultimate strongly correlated electron systems, and the birth place of topological phase of matter. Early theoretical work has emphasized the universal or topological aspects of quantum Hall physics. More recently it has become increasingly clear that there is very interesting bulk dynamics in FQHL, associated with an internal geometrical degree of freedom, or metric. The appropriate quantum theory of this internal dynamics is thus expected to take the form of a "quantum gravity", whose elementary excitations are spin-2 gravitons. After briefly reviewing the topological aspect of FQHL, I will discuss in this talk how to couple and probe the presence of this internal geometrical degree of freedom experimentally in the static limit [1], and detect the graviton excitation in a spectroscopic measurement [2].

Reference:

[1] Kun Yang, Geometry of compressible and incompressible quantum Hall States: Application to anisotropic composite-fermion liquids, Phys. Rev. B 88, 241105 (2013).

[2] Kun Yang, Acoustic Wave Absorption as a Probe of Dynamical Gravitational Response of Fractional Quantum Hall Liquids, Phys. Rev. B 93, 161302 (2016).

3/2 fractional quantum Hall plateau in a single layer two-dimensional electron gas

Xi Lin (PKU)

In a single layer two-dimensional electron gas, we observed a new even-denominator fractional quantum Hall plateau quantized at (h/e^2)/(3/2) under confinement, at a bulk filling factor of 5/3. This unexpected plateau develops below 300 mK with a quantization of 0.02%. The conductance transmitting through the confined region is also quantized at 3/2 e^2/h, and the conductance of 1/6 e^2/h is backscattered. A new elemental excitation with e/6 effective charge, the further fractionalization of the e/3 quasi-particles, through topological soliton and topological phase transition is proposed as a tentative explanation.

Robust manipulation of magnetic property of (Ga, Mn)As & high-quality low dimensional semiconductor-based topological quantum materials

Jian-Hua Zhao (IOS, CAS)

(Ga,Mn)As is a presentative material in the family of magnetic semiconductors, with a well-accepted intrinsic ferromagnetism. Through modulation of the hole density, electrical gating has been shown to alter the magnetic properties of (Ga,Mn)As films, but with limited electric-field effects on the Curie temperature (T_c) about 10 K. In this talk, I will present our recent work on modulation of magnetism in (Ga,Mn)As. We have realized a robust manipulation of the magnetism in (Ga,Mn)As ultra-thin films via electric field with the assistance of a special dielectric, ionic liquid. The maximum modulation of T_c is over 100 K. On the other side, the high-quality narrow-bandgap semiconductor nanostructures are highly desired for searching for and manipulating Majorana Fermions in solid state, a fundamental research task in physics today. Here I will also provide the MBE growth of high material quality InSb, InAs and GaSb nanowire/nanosheet in my group recently.

Spin hydrodynamic generation in graphene

Mamoru Matsuo (Kavli ITS)

Generation of spin current is a key issue in the field of spintronics. In particular, spin current generation in non-magnetic materials has been repeatedly demonstrated by utilizing the spin-orbit interaction known as the spin Hall effect [1-3].

Recently, an alternative route for generating spin current has been proposed by exploiting spin-rotation coupling or spin-vorticity coupling [4,5], which expands the choice of materials for spin-current generation such as liquid metals [6] as well as materials with a weak spin-orbit coupling like Cu [7]. In this stream, it suggests that a graphene, a typical nonmagnetic material with a weak spin-orbit coupling, could be a candidate for generating spin current. In particular, viscous hydrodynamic behaviors of electrons in graphene have been demonstrated experimentally[8-11]. However, a spin current generation via the spin-vorticity coupling in graphene has not been studied so far.

In this talk, we propose a spin-current generation by using hydrodynamic electron flow in graphene [12]. By combining the Navier-Stoke equation for the electron flow and the spin diffusion equation in the presence of the spin-vorticity coupling, spin current generation has been shown in the case of the typical configurations, and we have obtained a variety of spin-current generation and spin accumulation by controlling the parameters such as the bias voltage, carrier number density, and the geometry of the samples. Our result reveals a new functionality of graphene as a suitable material for spin-current generation.

[1] S. O. Valenzuela and M. Tinkham, Nature (London) 442, 176 (2006).
[2] E. Saitoh, M. Ueda, H. Miyajima, and G. Tatara. Appl. Phys. Lett. 88, 182509 (2006). [3] T. Kimura, Y. Otani, T. Sato, S. Takahashi, and S. Maekawa, Phys. Rev. Lett. 98, 156601 (2007); L. Vila, T. Kimura, and Y. Otani, Phys. Rev. Lett. 99 226604 (2007).
[4] M. Matsuo, J. Ieda, K. Harii, E. Saitoh, and S. Maekawa, Phys. Rev. B 87, 180402(R) (2013).
[5] M. Matsuo, Y. Ohnuma, and S. Maekawa, Phys. Rev. B 96, 020401(R) (2017).
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[7] D. Kobayashi et al., Phys. Rev. Lett. 119, 077202 (2017). [8] D. A. Bandurin et al., Science 351, 1055 (2016).
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[10] J. W. Moll et al,, Science 351, 1061 (2016).
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[12] M. Matsuo, D. A. Bandurin, Y. Ohnuma, and S. Maekawa, in preparation.

Towards all electrically control ferromagnets by spin orbit torques at room temperature

Kai-You Wang (IOS, CAS)

Electrically control the spin in solids is the core of spintronics. Spin-orbit torques (SOTs) induced magnetization switching, as an effective way to manipulate spins by electric current, has attracted considerable attentions in recent years due to its high speed and low power advantages.

By design the device structrue, we demonstrate a strong damping-like torque from the spin Hall effect and unmeasurable field-like torque from Rashba effect. The spin-orbit effective fields due to the spin Hall effect were investigated quantitatively and were found to be consistent with the switching effective fields after accounting for the switching current reduction due to thermal fluctuations from the current pulse[1]. The spin-orbit torque switching controllablly in above structures have to have the assistant of the external magnetic field. Utilizing interlayer exchange coupling from another in-plane ferromagnetic layer, adjustable electrical current-induced magnetization switching in a magnetic multilayer structure without external magnetic field has been realized [2].

Without breaking the symmetry of the structure of the thin film, we realize the deterministic magnetization switching in a hybrid ferromagnetic/ferroelectric structure with Pt/Co/Ni/Co/Pt layers on PMN-PT substrate. The effective magnetic field can be reversed by changing the direction of the applied electric field on the PMN-PT substrate, which fully replaces the controllability function of the external magnetic field[3].

[1] Meiyin Yang, Kaiming Cai, Hailang Ju et al., Scientific Reports, 6, 20778 (2016).
[2] Yu Sheng, Kevin William Edmonds, Xingqiao Ma, Kaiyou Wang, Submitted.
[3] Kaiming Cai, Meiyin Yang, Hailang Ju et al., Nature Materials, 12, 712 (2017).

Characterizing quantum phase transitions of symmetry protected topological phases with surface critical behavior

Long Zhang (Kavli ITS)

In this talk, unconventional surface critical behavior is introduced to characterize the (2+1)-dimensional quantum phase transitions (QPT) from a symmetry-protected topological (SPT) phase to the Neel order. A plethora of unconventional surface critical behaviors emerge by engineering the Heisenberg model on different lattices in particular.

We first study the physical consequence of gapless surface states of a symmetry-protected topological phase at the bulk QPT that spontaneously breaks these symmetries. With large-scale quantum Monte Carlo simulations, we show that even though the bulk QPTs are governed by the conventional Landau phase transition theory, the gapless surface state induces unconventional universality classes of the surface critical behaviors.

In our recent work, we further show that three types of SCB classes are realized in the dimerized Heisenberg models at the (2+1)-dimensional O(3) quantum critical points by engineering the surface configurations. In particular, an extraordinary transition is induced by the ferrimagnetic order on the surface of the staggered Heisenberg model, in which the surface critical exponents violate the general scaling law and thus seriously challenge our current understanding of extraordinary transitions.

References:

[1] L. Zhang and F. Wang, Phys. Rev. Lett. 118, 87201 (2017).

[2] C. Ding, L. Zhang, and W. Guo, arXiv:1801.10035.

Registration List

Note: The contact information is provided for the convenience of attendees to collaborate and keep in touch. This information should not be shared with non-registered attendees and please respect the privacy of other attendees by not compiling this list for the purpose of sending unsolicited emails, or by sharing personal information without approval. Thank you.

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