The Asia-Pacific Workshop on Strongly Correlated Systems 2014 (APW2014)

Oct.9-11, 2014

Beijing, China

Sponsored by

Key Laboratory of Condensed Matter Theory and Computation, IOP, CAS
Center for International Collaboration, IOP, CAS
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About the Workshop

The Asia-Pacific Workshop on Strongly Correlated Systems 2014 (APW2014) will be held at the Institute of Physics Chinese Academy of Sciences from October 9 to 11, 2014. The APW is a series of workshops. Since its first initiation in 2001, the APW has been held in various cities in Asia-Pacific region, including Sendai, Hong-Kong, Beijing, Taipei, Seoul, Tokyo, etc. In this workshop we will bring together experts on the research of strongly correlated systems to discuss the new progress in the following aspects:

- High Tc superconductivity
- Topological aspects of condensed matter
- Spintronics & 2D materials
- Frustrated quantum spin system
Workshop Organization

Committee members:

Yunkyu Bang  Chonnam National University, Korea
Xi Dai  IOP, CAS, China
Vic Law  Hong Kong University of Science and Technology, Hong Kong, China
Ting-Kuo Lee  Institute of Physics, Academia Sinica, Taiwan
Sadamichi Maekawa  ASRC, Japan Atomic Energy Agency, Japan
Naoto Nagaosa  RIKEN & University of Tokyo, Japan
Tao Xiang  IOP, CAS, China
Lu Yu  IOP, CAS, China
Fuchun Zhang  Zhejiang University, China

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Jianwei Qi, Tel: 86-10-82649400, jwqi@iphy.ac.cn
# Program

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<td>Welcome Speech</td>
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<td>9:00-9:30</td>
<td>Zhixun Shen, Stanford University, USA</td>
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<td>9:30-10:00</td>
<td>Ryotaro Arita, RIKEN, Japan</td>
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<td>10:00-10:30</td>
<td>Pengcheng Dai, IOP, CAS, China</td>
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<td>10:30-10:50</td>
<td>Break (Taking Picture)</td>
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<td>10:50-11:20</td>
<td>Ting-Kuo Lee, Academia Sinica, Taiwan</td>
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<td>11:20-11:50</td>
<td>Takahiro Misawa, University of Tokyo, Japan</td>
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<td>12:00-13:00</td>
<td>Lunch: Wuke Hotel Restaurant, 4th Floor, Building H, IOP</td>
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<td>13:30-14:00</td>
<td>Yunkyu Bang, Chonnam National University, Korea</td>
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<td>15:30-15:50</td>
<td>Break</td>
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<td>Nandini Trivedi, Ohio State University, USA</td>
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<td>16:20-16:50</td>
<td>Ziyang Meng, IOP, CAS, China</td>
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<td>Tao Wu, University of Science and Technology of China, China</td>
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<td>17:20-17:50</td>
<td>Stefan Kirchner, Zhejiang University, China</td>
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### The Asia-Pacific Workshop on Strongly Correlated System 2014 (APW2014)

**Friday, Oct. 10, 2014, Room 234, Building M, IOP, CAS**

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| Session IV | 9:00-9:30 | Fang-Cheng Chou, National Taiwan University, Taiwan  
Conjugated pi-bonds and electron crystals in topological insulators |
| | 9:30-10:00 | Thomas Lang, Boston University, USA  
Mott Transitions of Correlated Fermions from SU(2) to SU(N) |
| Sadamichi Maekawa  
ASRC, Japan Atomic Energy Agency, Japan | 10:00-10:30 | Bohm-Jung Yang, RIKEN, Japan  
Quantum Criticality of Topological Phase Transitions in 3D Interacting Electronic Systems |
| | 10:30-10:50 | Break |
| | 10:50-11:20 | Yi Zhou, Zhejiang University, China  
Quantum spin liquids at the vicinity of Mott transition |
| | 11:20-11:50 | Young Sang Lee, MIT, USA |
| | 12:00-13:00 | Wuke Hotel Restaurant, 4th Floor, Building H, IOP |
| Session V | 13:30-14:00 | Sadamichi Maekawa, ASRC, Japan Atomic Energy Agency, Japan  
Spin Mechatronics: Mechanical Generation of Spin and Spin Current |
| Nandini Trivedi  
Ohio State University, USA | 14:00-14:30 | Changqing Jin, IOP, CAS, China  
New Diluted Magnetic Semiconductors with Decoupled Charge & Spin Doping |
| | 14:30-15:00 | Fanlong Ning, Zhejiang University, China  
From Fe-based high Tc superconductors to Zn-based high Tc Diluted Ferromagnetic Semiconductors |
| | 15:00-15:30 | Takeshi Mizushima, Okayama University, Japan  
Dirac-Fermion-Induced Parity Mixing in Superconducting Topological Insulators |
| | 15:30-15:50 | Break |
| Session VI | 15:50-16:20 | Atsushi Tsukazaki, Tohoku University, Japan  
Transport properties of the surface states in (Bi_{1-x}Sb_x)2Te3 thin film devices |
| Shunqing Shen  
The University of Hong Kong, Hong Kong, China | 16:20-16:50 | Zhiyuan Xie, IOP, CAS, China  
Tensor Network Algorithm and Its Applications |
| | 16:50-17:20 | Wang Yao, The University of Hong Kong, Hong Kong, China  
Valley and spin currents of electrons and charged excitons in 2D transition metal dichalcogenides |
| | 17:20-17:50 | Tong Zhang, Fudan University, China  
ARPES and STM investigation of the superconductivity in single layer FeSe: the role of substrate and the pairing symmetry |
<p>| | 18:30-19:30 | Banquet: The Jade Palace Hotel |</p>
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<td>Shunqing Shen, The University of Hong Kong, Hong Kong, China, Many-body localization of the surface electrons in topological insulators</td>
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<td>9:30-10:00</td>
<td>Rui-Rui Du, Peking University, China</td>
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<td>10:00-10:30</td>
<td>Lu Li, University of Michigan, USA, Quantum Oscillations in Kondo Insulator SmB$_6$</td>
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<td>10:30-10:50</td>
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<td>10:50-11:20</td>
<td>Jeil Jung, National University of Singapore, Singapore, Pseudospin order in 2D Dirac materials: the role of short vs long-range interactions</td>
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<td>11:50-12:00</td>
<td>Summary</td>
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Invited Speakers

Ryotaro Arita, RIKEN, Japan
Yunkyu Bang, Chonnam National University, Korea
Fang-Cheng Chou, National Taiwan University, Taiwan
Pengcheng Dai, IOP, CAS, China
Rui-Rui Du, Peking University, China
Bo Gu, ASRC, Japan Atomic Energy Agency, Japan
Shaolong He, IOP, CAS, China
Wanzheng Hu, Max Planck Institute, Germany
Changqing Jin, IOP, CAS, China
Jeil Jung, National University of Singapore, Singapore
Stefan Kirchner, Zhejiang University, China
Thomas Lang, Boston University, USA
Young S. Lee, MIT, USA
Ting-Kuo Lee, Institute of Physics, Academia Sinica, Taiwan
Lu Li, University of Michigan, USA
Zhongyi Lu, Renmin University, China
Sadamichi Maekawa, ASRC, Japan Atomic Energy Agency, Japan
Ziyang Meng, IOP, CAS, China
Takahiro Misawa, University of Tokyo, Japan
Takeshi Mizushima, Okayama University, Japan
Fanlong Ning, Zhejiang University, China
Zhixun Shen, Stanford University, USA
Shunqing Shen, The University of Hong Kong, Hong Kong, China
Nandini Trivedi, Ohio State University, USA
Atsushi Tsukazaki, Tohoku University, Japan
Tao Wu, University of Science and Technology of China, China
Zhiyuan Xie, IOP, CAS, China
Bohm-Jung Yang, RIKEN, Japan
Wang Yao, The University of Hong Kong, Hong Kong, China
Tong Zhang, Fudan University, China
Yi Zhou, Zhejiang University, China
Abstract

Fully non-empirical calculation of superconducting transition temperature in alkali-doped C$_{60}$ solids

Ryotaro Arita

RIKEN Center for Emergent Matter Science
Isobe Degenerate π-Integration Project, Tohoku University

Fully non-empirical calculation of superconducting transition temperature ($T_c$) is a fascinating challenge in condensed matter physics, especially when the pairing mechanism is unconventional. Among a wide variety of exotic superconductors, alkali-doped C$_{60}$ compounds are of great interest, in which the kinetic energy, Coulomb correlations, and electron-phonon coupling severely compete with each other. Recently, we formulated an ab initio downfolding scheme to derive effective low-energy Hamiltonians for electron-phonon coupled systems [1]. We applied it to alkali-doped C$_{60}$ and constructed a realistic model for the $t_{1u}$ band. We estimated the key parameters in the model such as the Hubbard $U$, off-site Coulomb repulsions, Hund’s coupling, electron-phonon coupling and so on. We then solve the model by means of the extended dynamical mean field theory. We explicitly treat the anomalous Green’s function and calculated $T_c$ as a function of the volume of the unit cell. We show that the obtained phase diagram (left panel) agrees well with the experiment (right panel) quantitatively.

This work was done in collaboration with Yusuke Nomura (Univ. Tokyo), Shiro Sakai (RIKEN), Kazuma Nakamura (Kyushu Inst. Technology) and Massimo Capone (SISSA).

Anomalous behavior of the Specific Heat jump ($\Delta C$) vs. $T_c$ and its understanding with the $\pm S$-wave pairing state in Fe-based superconductors

Yunkyu Bang
Department of Physics, Chonnam National University, Kwangju 500-757, and Asia Pacific Center for Theoretical Physics, Pohang 790-784, Korea.
E-mail address: ykbang@jnu.ac.kr

So called BNC scaling ($\Delta C \sim T_c^3$) -- Bud’ko, Ni, and Canfield, PRB, 79, 220516 (2009) -- have been observed in the wide-range of the Fe-based superconducting compounds such as Ba(Fe$_{1-x}$Co$_x$)$_2$As$_2$, Ba(Fe$_{1-x}$Ni$_x$)$_2$As$_2$, BaFe$_2$(AsP)$_2$, and Ba$_{1-x}$Na$_x$Fe$_2$As$_2$ And there are several theoretical proposals to explain this anomalous non-BCS behavior. More recently, however, Canfield and coworkers reported that Ba$_{1-x}$K$_x$Fe$_2$As$_2$ compound severely deviates from this scaling when $x>0.7$ and argued that this is an indication for the Lifshitz transition in Ba$_{1-x}$K$_x$Fe$_2$As$_2$ compound at higher hole-doping. In this talk, I will demonstrate that the BNC scaling as well as its strong deviation, as observed in Ba$_{1-x}$K$_x$Fe$_2$As$_2$, are an intrinsic property of the $\pm S$-wave pairing state with various strength of impurity scattering.
Conjugated $\pi$ bonds and electron crystals in topological insulators

Fang-Cheng Chou

Center for Condensed Matter Sciences, National Taiwan University, Taiwan

A novel chemical bond model is proposed to allow interpretation of the unique chemical and physical properties of topological insulator Bi$_2$Se$_3$ and topological crystalline insulator Pb$_{1-x}$Sn$_x$Se. The quintuple layer of Bi$_2$Se$_3$ is composed of hybridized $s$-$p$-$d$ orbitals in octahedral coordination through directional $\sigma$-bond formation, and the unpaired electrons of Se on the surface form a conjugated $\pi$ bond system. Pb$_{1-x}$Sn$_x$Se is composed of $\sigma$ bond connected covalent chains within each (001) plane plus additional conjugated $\pi$ bonds exist among the Pb/Sn atoms. The existence of $\pi$ bonds was identified under the proposed chemical bond model and verified successfully with electron energy-loss spectroscopy (EELS) and electron density (ED) through an inverse Fourier transform of X-ray diffraction. An electron crystal constructed by the conjugated $\pi$ bond electrons is proposed.
The spin Hall effect, which converts charge current into spin current, is one of the key phenomena for the further development of spintronic devices. A difficulty in exploiting the effect is that it depends on spin-orbit interaction which, as a relativistic effect, is intrinsically weak except in heavy elements. The challenge is how to enhance the spin Hall effect. In this presentation, we discuss the effects of electron correlations in spin Hall effect.

First, we show that the spin Hall effect is sensitive to collective spin fluctuations in a ferromagnetic metal [1, 2]. Our theory extends Kondo’s theory of the anomalous Hall effect to include short-range spin-spin correlations. We find a relation between the inverse spin Hall effect and the four-spin correlations near the Curie temperature. Such four-spin correlations do not contribute to the anomalous Hall effect, which relates to the three-spin correlations. Thus our theory shows an essential difference between the inverse spin Hall effect and anomalous Hall effect in metals. A comparison between theory and a recent experiment in ferromagnetic PdNi alloys is discussed.

Second, we show that the spin Hall effect is sensitive to electron correlations in CuBi alloys [3]. A recent experiment in CuBi alloys obtained a large spin Hall angle of -0.24. Our calculations show that the spin Hall effect can be dramatically enhanced by Bi impurities close to the Cu surface. The mechanisms of this enhancement are two-fold. One is that the localized impurity state on surface has a decreased hybridization and combined with Coulomb correlation effect. The other comes from the low-dimensional state of conduction electrons on surface, which results in a further enhancement of skew scattering by impurities.

Ultrafast control of correlated systems
Wanzheng Hu
Max Planck Institute for the Structure and Dynamics of Matter, 22761 Hamburg, Germany
wanzheng.hu@mpsd.mpg.de

Conventional infrared spectroscopy is a well-developed technique, which provides rich information about the electronic dynamics in solids. Time-resolved optical spectroscopy greatly strengthens the power of infrared spectroscopy, that it can control the properties and explore new phenomena by using a tailored pump beam to excite the system. These light-induced novel phenomena sometimes cannot be achieved by using conventional stimulation, like heating/cooling, changing pressure or doping. Studying the non-equilibrium properties not only benefits the understanding of the equilibrium properties, but also illuminates a new path towards engineering materials with specific properties at equilibrium.

In this talk, I will present two examples to show the power of ultrafast control of correlated systems. The first example is a phonon-driven non-equilibrium state in underdoped YBa$_2$Cu$_3$O$_{6.5}$. We used mid-infrared pulses to drive the apical oxygen phonon. We found optical evidence for a c-axis coherent transport above Tc in underdoped YBa$_2$Cu$_3$O$_{6+d}$. Broadband THz probe showed that the enhancement of the inter-bilayer coherence happened at the expense of the intra-bilayer coherence, while keeping the total c-axis spectral weight unchanged. Mid-infrared pump, X-ray probe experiment illustrates a dynamic structure picture for the phonon-driven state. The second example is a novel light-induced state in NdNiO$_3$/LaAlO$_3$ heterostructure. Our previous study on NdNiO$_3$ thin film on LaAlO$_3$ substrate showed that when the phonon of the LaAlO$_3$ substrate was excited by the mid-infrared pump pulses, an insulator-to-metal transition was induced in the NdNiO$_3$ thin film. Recent broadband data shows that such a non-equilibrium state is completely different from the thermal driven insulator-to-metal transition.

New Diluted Magnetic Semiconductors with Decoupled Charge & Spin Doping
Changqing Jin
Institute of Physics, Chinese Academy of Sciences

Diluted magnetic semiconductor (DMS) combines both charge and spin quantum freedoms promising for developing new generation information technologies [1]. So far several type of diluted magnetic semiconductor systems are found [1~5]. In prototypical systems based on III-V semiconductors, such as (Ga, Mn)As, substitution of divalent Mn$^{2+}$ atoms into trivalent Ga$^{3+}$ induced local magnetic moment but simultaneously generated hole type charge carriers. This type of spin & charge doping leads to severely limited chemical solubility, available only as thin films fabricated at low temperature [2]. Moreover the integrated doping results in impossible tuning spin versus charge separately. In this talk we report our recent works on new types DMS featured with individual charge and spin doping. The highest Curie temperature ($T_C$) of the bulk form of the new DMS is comparable to that of typical (Ga, Mn)As, making room temperature ferromagnetism within reach [6~8].

Acknowledgments: We would like to thank all collaborators especially to Profs. T. Uemura, S. Maekawa, S. Uchida, F. L. Ning, Dr. Z. Deng, Dr. B. Gu, Dr. K. Zhao for their contributions through the research.

[6]. Z. Deng et al., Nature Communications 2, 422 (2011)
[7]. Z. Deng et al., Review B 88, 81203(R) (2013)
Pseudospin order in 2D Dirac materials: the role of short vs long-range interactions

Jeil Jung

Graphene Research Centre and Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117551

The advent of a new class of 2D Dirac materials, among which graphene is a paradigmatic example, has opened up a new frontier in materials research. Their reduced dimensionality makes these systems especially susceptible to electron-electron interactions and their simple stoichiometry makes them ideal platforms to explore in detail the complex role of many-body effects in configuring ordered phases. In this presentation I will use the example of single and few layers graphene to illustrate the role of short vs long-range electron-electron interactions in defining the ground-state properties in Dirac materials, where (layer/valley/spin) pseudospin order and band gap enhancements can take place. Whereas short-range interactions that favor antiferromagnetic spin order can explain a number of experimental observations in zero and finite field Hall measurements, the non-locality of long-ranged interactions can lead to a competition between ground-states exhibiting spontaneous orbital moments that should be tunable through external system parameters and distinguished through transport and spectroscopy measurements.


Critical Exponents of Strongly Correlated Fermion Systems from Diagrammatic Multi-Scale Methods
Stefan Kirchner

Center for Correlated Matter, Zhejiang University, Hangzhou
Department of Physics & Astronomy, Rice University, Houston

Self-consistent dynamical approximations for strongly correlated fermion systems are particularly successful in capturing the dynamical competition of local correlations. In these, the effect of spatially extended degrees of freedom is usually only taken into account in a mean field fashion or as a secondary effect. As a result, critical exponents associated with phase transitions of the model have mean field character. Here, we demonstrate that a particular diagrammatic multi-scale method, the dual fermion method, anchored around local approximations are indeed capable of capturing the non mean-field nature of the critical point of the lattice model and to correctly describe the transition to mean field like behavior as the number of spatial dimensions increases[1, 2]. The dual fermion approach thus is suitable to capture the dynamic interplay between electronic correlation and geometric frustration [3].

Mott Transitions of Correlated Fermions from SU(2) to SU(N)
Thomas C. Lang

*Boston University, MA, USA*

We discuss the instabilities upon the introduction of local Coulomb repulsion and explicit SU(N)-symmetric Heisenberg-like spin exchange to Dirac Fermi-surfaces, quadratic band touching point-like Fermi-surfaces and full Fermi-surfaces. The extension to higher symmetries allows us to study the melting of phases as a function of correlations as well as symmetry. We explore the quantum phases and phase transitions emerging in the SU(N)-symmetric Hubbard and Heisenberg models by means of projective quantum Monte Carlo simulations from SU(2) to the large-N limit for even values of N. Correlation ratios provide us with new insights into the semi-metal insulator transition at SU(2) and the potential of a direct Neel to valence bond solid quantum phase transition at higher N.
Origin of variety of low-energy “competing” states in cuprates
Wei-Lin Du and T. K. Lee
Institute of Physics, Academia Sinica, Taiwan

One of the most puzzling facts about the cuprate high temperature superconductors is the observation of a variety of low-energy states in coexistence with the superconductivity and/or antiferromagnetism in the underdoped regime. These states could have a one-dimensional charge density wave like structure or a two-dimensional checkerboard structure. Some of them like the stripe state could also have an intertwined charge density and spin density waves together. Can all these different states caused by different mechanisms and competing with the superconducting state? In this talk we will present reasons to show that these states are all originated from the same strong correlation inherent in the cuprates.
Quantum Oscillations in Kondo Insulator SmB$_6$

Lu Li

*University of Michigan, USA*

In Kondo insulator samarium hexaboride SmB$_6$, strong correlation and band hybridization lead to a diverging resistance at low temperature. The resistance divergence ends at about 3 Kelvin, a behavior recently demonstrated to arise from the surface conductance. However, questions remain whether and where a topological surface state exists. Quantum oscillations have not been observed to map the Fermi surface. We solve the problem by resolving the Landau Level quantization and Fermi surface topology using torque magnetometry. The observed angular dependence of the Fermi surface cross section suggests two-dimensional surface states on the (101) and (100) plane. Furthermore, similar to the quantum Hall states for graphene, the tracking of the Landau Levels in the infinite magnetic field limit points to -1/2, the Berry phase contribution from the 2D Dirac electronic state.
Spin Mechatronics
-Mechanical Generation of Spin and Spin Current-
Sadamichi Maekawa

Advanced Science Research Center,

A. Einstein and W. J. de Haas discovered experimentally the equivalence of magnetic moment and mechanical rotation in 1915 [1]. In the same year, S.J. Bernett showed that the mechanical rotation can generate a magnetic field, i.e., the so-called Bernett field, even in a body with no electric charge [2]. These phenomena are caused by the angular momentum conservation between electron spin and mechanical rotation, which has been proved in the general relativistic quantum mechanics [3]. We introduce mechanical effects in spintronics and propose a variety of novel spintronics phenomena. In particular, the coupling between nuclear spin and mechanical rotation is demonstrated [4]. Since the Bernett field is enhanced more than three orders of magnitudes in nuclei than electron spins, the mechanical nuclear-magnetic-resonance (NMR) may provide new applications of NMR. We also observe the generation of spin current by the flow of liquid metals. Combining this effect with the spin Hall effect [5], the spin-hydrodynamic generation of electricity is obtained [6]. The mechanical generation of spin and spin current opens a door from “Spintronics” to “Spin-Mechatronics”.

A new scheme to calculate superconductivity instabilities in correlated electronic systems beyond single-site DMFT

Ziyang Meng

Institute of Physics, Chinese Academy of Sciences

In this talk, I will present a new numerical scheme to calculate the non-local, two-particle vertex functions beyond the dynamical mean field theory (DMFT) simulations, in which one first measures the local vertex functions in DMFT, then introduces the momentum-dependence into the two-particle vertex and correlation functions with the help of two-particle diagrammatic techniques-Bethe-Salpeter equation and Parquet equations. After that, I will present the application of such scheme to the measurement of superconductivity instabilities in several strongly correlated systems: in Hubbard model on square lattice with type-II van Hove singularity, a topological p+ip triplet pairing instability is found; in the t_{2g} multi-orbital correlated system with strong spin-orbit coupling, a two-fold degenerate, odd-parity, p-wave triplet pairing instability is observed when Hund's coupling is comparable with spin-orbit coupling, and a d-wave singlet pairing state is found in when Hund's coupling is small.
Ab initio studies on mechanism of superconductivity in electron-doped LaFeAsO
Takahiro Misawa
Department Applied Physics, University of Tokyo

In iron-based superconductors, although it is believed that electron correlations and orbital degrees of freedom play key roles in stabilizing high-temperature superconductivity, their roles are not fully understood yet. To clarify microscopic mechanism of superconductivity in iron-based superconductors, we study the ab initio low-energy effective models for iron-based superconductor [1], particularly for LaFeAsO by using many-variable variational Monte Carlo (mVMC) method, which properly takes into account both spatial and dynamical quantum fluctuations. We show that the calculated magnetic order was shown to correctly reproduce the experimental material dependences [2, 3]. By extending these normal state studies, we show that superconductivity emerges in the ab initio model of an electron-doped iron-based superconductor LaFeAsO in essential agreement with the experimental results. The pairing satisfies gapped s± symmetry and the specific orbital (X^2-Y^2) is shown to play a key role in stabilizing the superconducting phase as well as the antiferromagnetic phase. Then, we find a one-to-one correspondence between superconductivity and enhanced uniform charge fluctuations. This one-to-one correspondence is also found in the Hubbard model [4], which is one of the simplest models for cuprates. Despite many differences between iron-based superconductors and cuprates, our study suggests that the enhanced uniform charge fluctuations play a key role in stabilizing the superconductivity in both materials.

This work was done in collaboration with Masatoshi Imada.

Dirac-Fermion-Induced Parity Mixing in Superconducting Topological Insulators

Takeshi Mizushima,1 Ai Yamakage,2 Masatoshi Sato,2 and Yukio Tanaka2

1Department of Physics, Okayama University, Okayama 700-8530, Japan
2Department of Applied Physics, Nagoya University, Nagoya 464-8603, Japan

Recently, the newly discovered superconductor Cu-doped Bi2Se3 has been considered as one potential topological superconductor candidate [1,2]. Here, we self-consistently study surface states of the superconducting topological insulator [3]. We demonstrate that, if a topologically trivial bulk $s$-wave pairing symmetry is realized, parity mixing of pair potential near the surface is anomalously enhanced by surface Dirac fermions, opening an additional surface gap larger than the bulk one. In contrast to classical $s$-wave superconductors, the resulting surface density of state hosts an extra coherent peak at the induced gap besides a conventional peak at the bulk gap but no such surface parity mixing is induced by Dirac fermions for topological odd-parity superconductors. Recent point-contact experiments have revealed a pronounced zero-bias conductance peak supporting a topological odd-parity superconductivity [2], while the STM spectroscopy indicates a simple U-shaped tunneling conductance for Cu$_x$Bi$_2$Se$_3$ [4]. Our calculation suggests that the simple U-shaped STM spectrum does not originate from $s$-wave superconductivity, but can be explained by topological odd-parity superconductivity with a Fermi-surface evolution [5].

From Fe-based high $T_c$ superconductors to Zn-based high $T_C$ Diluted Ferromagnetic Semiconductors
Fanlong Ning

*Department of Physics, Zhejiang University*
ningfl@zju.edu.cn

After nearly 20 years of research, the Curie temperature of a prototypical diluted magnetic semiconductor (DMS) III-V (Ga, Mn)As has been improved to 210 K [1]. This temperature is still far below the room temperature requested for practical application. Inspired by the research of Fe-based high temperature superconductors, we extend our research to the fabrication and characterization of a series of novel DMS materials. These materials are “111” type Li(Zn, Mn)As with $T_C \sim 50$ K [2], “122” type (Ba, K)(Zn, Mn)$_2$As$_2$ with $T_C \sim 180$ K [3], “1111” type (La$_{1-x}$Ba$_x$) (Zn$_{1-x}$Mn$_x$)AsO with $T_C \sim 40$ K [4], “32522” type (Sr$_3$La$_2$O$_5$)(Zn$_{1-x}$Mn$_x$)$_2$As$_2$ with $T_C \sim 40$ K [5] and “42622” type (Sr$_{1-x}$K$_x$)$_4$Ti$_2$O$_{6}$Zn$_{1-x}$Mn$_x$)$_2$As$_2$ with $T_C \sim 25$ K [6]. Note that each of these “1111”, “111”, “122”, “32522” and “42622” ferromagnetic system have their counterpart Fe-based superconductor families, anti-ferromagnetic variants, and the lattice matching is within 5%, which enables to make various junctions through As layers.

In this talk, I will give an introduction of these new DMS materials, and discuss recent muSR and NMR results. Both muSR and NMR results provide unequivocal experimental evidences that the ferromagnetic ordering is indeed caused by randomly substituted Mn in Zn sites, instead of Mn cluster or other magnetic impurities. MuSR measurements demonstrate that all of these DMS systems including (Ga, Mn)As share a common mechanism for the ferromagnetic exchange interaction [2-6]. The availability of bulk DMS specimens enables us to conduct NMR measurements. In Li(Cd$_{1-x}$Mn$_x$)P and Li(Zn$_{1-x}$Mn$_x$)P, we successfully identified new $^7$Li NMR peak induced by Mn doping, which enabled us to probe local static and dynamic properties of Mn spins with NMR for the first time [7]. We present the first experimental information on Mn spin dynamics in DMS, and establish that Mn-Mn ferromagnetic interactions are not limited to the near-neighbor sites, but extend over many unit cells, mostly likely due to the p-d Zener interactions.

[7]. Ding et al, Physical Review B, 88, 041108(R), (2013)
Many-body localization of the surface electrons in topological insulators
Shun-Qing Shen

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The electronic transport experiments on topological insulators exhibit a dilemma. A negative cusp in magnetoconductivity is widely believed as a quantum transport signature of the topological surface states, which are immune from localization and exhibit the weak antilocalization. However, the measured conductivity drops logarithmically when lowering temperature, showing a typical feature of the weak localization as in ordinary disordered metals. Here, we present a conductivity formula for massless and massive Dirac fermions as a function of magnetic field and temperature, by taking into account the electron-electron interaction and quantum interference simultaneously. The formula reconciles the dilemma by explicitly clarifying that, the temperature dependence of the conductivity is dominated by the interaction, while the magnetoconductivity is mainly contributed by the quantum interference. The low temperature behaviors of conductivity in topological insulators indicate the localization of surface electrons in topological insulators. This demonstrates the breakdown of topological protection of surface states in an interacting topological insulator. The theory paves the road to quantitatively study the transport in topological insulators, and can also be extended to other two-dimensional Dirac-like systems, such as graphene, transition metal dichalcogenides, and silicene.

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Quantum materials today can be classified as a function of the strength of Coulomb interactions $U$ and spin orbit coupling $\lambda$, in units of the bandwidth $W$. At large $U$ lie the 3d transition metal oxides that show phenomena such as colossal magneto-resistance and high Tc superconductivity. In the opposite quadrant we encounter topological band insulators with large $\lambda$ but in weakly correlated s- and p- band materials. I will discuss the next frontier of 4d and 5d oxide materials in the central region of such a phase diagram and show how novel phases and phenomena arise from the close interplay of all three scales-- $\lambda$, $U$ and $W$. I will critically review the combination of computational methods that are necessary to address the richness of the 4d and 5d materials. The role of advanced spectroscopies such as angle resolved photoemission, inelastic neutron scattering, THz spectroscopy, and resonant x-ray scattering using circularly polarized photons, to identify different response functions of complex oxides will also be discussed.
NMR study on doped Kondo insulator SmB$_6$
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In this talk, I will introduce our recent NMR results on doped Kondo insulator SmB$_6$. We systematically measure the spin-lattice relaxation (1/T$_1$) for Yb and La doped SmB$_6$ single crystals. It is found that the nature of 4f electrons is controlled by the average valence of Sm ions and could be tuned between local and itinerant nature. Moreover, a systematic evolution of bulk “in-gap” state with chemical doping is also observed. Furthermore, a possible pseudogap scenario is proposed to understand the insulating behavior in this system instead of primary Kondo insulator picture.
Tensor network algorithm is a novel class of numerical renormalization group methods, which satisfies the area law of the entanglement entropy and can be roughly considered as the higher dimensional extension of the density matrix renormalization group. This talk will talk about some basics of the tensor network algorithm, and demonstrate its potential power by showing its application on the statistical Ising model and Kagome lattice spin-1/2 antiferromagnetic Heisenberg model.
Quantum Criticality of Topological Phase Transitions in 3D Interacting Electronic Systems
Bohm-Jung Yang
RIKEN, Japan

In this talk, I am going to talk about the novel physics at the quantum critical point of topological phase transitions in three dimensions. Topological phase transitions in condensed matters accompany emerging singularities of the electronic wave function, often manifested by gap-closing points in the momentum space. In conventional topological insulators in three dimensions (3D), the low energy theory near the gap-closing point can be described by relativistic Dirac fermions coupled to the long range Coulomb interaction, hence the quantum critical point of topological phase transitions provides a promising platform to test the novel predictions of quantum electrodynamics. Here we show that a new class of quantum critical phenomena emanates in topological materials breaking either the inversion symmetry or the time-reversal symmetry. At the quantum critical point, the theory is described by the emerging low energy fermions, dubbed the anisotropic Weyl fermions, which show both the relativistic and Newtonian dynamics simultaneously. The interplay between the anisotropic dispersion and the Coulomb interaction brings about a new screening phenomenon distinct from the conventional Thomas-Fermi screening in metals and logarithmic screening in Dirac fermions.
Valley and spin currents of electrons and charged excitons in 2D transition metal dichalcogenides

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The recent emergence of two-dimensional transition metal dichalcogenides (TMDs) provides a new laboratory for exploring the internal quantum degrees of freedom of electrons for new electronics [1]. These include the real electron spin and the valley pseudospin that labels the degenerate band extrema in momentum space. The generation and control of spin and valley pseudospin currents are at the heart of spin and valley based electronics. We will discuss two mechanisms for generating spin and valley currents of electrons in 2D transition metal dichalcogenides: (I) the valley and spin Hall current arising from the Berry curvatures [2, 3]; and (II) the nonlinear valley and spin currents arising from Fermi pocket anisotropy [4]. The two effects have distinct scaling with the field and different dependence of the current direction on the field direction and crystalline axis. We discuss the possibility to observe and distinguish the two effects as distinct patterns of polarized electroluminescence at pn junction in monolayer TMDs. We show that the nonlinear current response from the Fermi pocket anisotropy allow two unprecedented possibilities to generate pure spin and valley flows without net charge current, either by an AC bias or by an inhomogeneous temperature distribution. This points to a new route towards electrical and thermal generations of spin and valley currents for spintronic and valleytronic applications. We will also discuss the valley Hall effect of charged excitons in monolayer TMDs, where the excitons can acquire valley dependent Berry curvature from two origins [5]. The first is the inheritance of the Berry curvature from the Bloch band [3]. The second is from the exchange interaction between the electron and hole constituents of the exciton which give rises to an effective coupling of the excitonic valley pseudospin to its center of mass motion [5]. The two mechanisms can dominate respectively for positively and negatively charge excitons. The valley Hall effect of charge excitons can be detected from the light emission with contrasted circular polarization on the opposite edges, which leave behind valley and spin polarised electrons or holes.

ARPES and STM investigation of the superconductivity in single layer FeSe: the role of substrate and the pairing symmetry


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Recently, in single layer FeSe films grown on SrTiO$_3$ substrates, signs for $T_c$ up to 65 K have been reported [1-3]. However, besides doping electrons and imposing strain, whether and how the substrate facilitates the superconductivity are still unclear. Here we report the growth of various single layer FeSe films on BaTiO$_3$/KTaO$_3$ substrates, with signs for $T_c$ up to 75 K. ARPES measurements revealed that high $T_c$ only exists in the films on the substrate and their band structure strongly depends on the substrate. Our results highlight the profound role of substrate on the high-$T_c$ of FeSe, and provide new clues for understanding its mechanism. Besides, I’ll also show our recent STM results on single layer FeSe/STO. We have grown FeSe films with large grain size and we studied the quasiparticle interference (QPI) and impurity induced in-gap states, possible paring symmetry will be discussed.

Quantum spin liquids at the vicinity of Mott transition
Yi Zhou

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We study quantum spin liquid states (QSLs) at the vicinity of metal-insulator transition. Assuming that the low energy excitations in the QSLs are labeled by “spinon” occupation numbers with the same Fermi surface structure as in the corresponding metal (Fermi-liquid) side, we propose a phenomenological Landau-like low energy theory for the QSLs and show that the usual U(1) QSLs with spinon Fermi surface is a representative member of this class of spin liquids. Based on our effective low energy theory, an alternative picture to the Brinkman-Rice picture of Mott metal-insulator transition is proposed. The charge, spin and thermal responses of QSLs are discussed under such a phenomenology.