Trans-Scale Quantum Science Institute

PRESENTATION BOOKLET

Program Book Designed by Mingxuan Fu

ORAL ABSTRACTS

Keynote Talk

10 : 15 - 10 : 55

Kyung-Jin Lee

Korea Advanced Institute of Science and Technology (KAIST), Korea

Orbital torque and orbital pumping

The orbital Hall effect [1,2] describes the generation of the orbital current flowing in a perpendicular direction to an external electric field, analogous to the spin Hall effect. As the orbital current carries the angular momentum as the spin current does, injection of the orbital current into a ferromagnet can result in torque on the magnetization [3], which provides a way to detect the orbital Hall effect. With this motivation, we examine the current-induced spin-orbit torques in various ferromagnet/heavy metal bilayers by theory and experiment [4]. Analysis of the magnetic torque reveals the presence of the contribution from the orbital Hall effect in the heavy metal, which competes with the contribution from the spin Hall effect. In particular, we find that net torque in Ni/Ta bilayers is opposite in sign to the spin Hall theory prediction but instead consistent with the orbital Hall theory. This orbital torque can enhance net spin-orbit torque via an efficient orbital-to-spin conversion [5]. We also present a theory of orbital pumping [6], which is the Onsager reciprocity of orbital torque.

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Oral Session A1 (Tuesday, February 13)

Chair: Satoru Nakatsuji, University of Tokyo

Contributed Oral

10 : 55 - 11 : 15

Observation of current-driven fast magnetic domain-wall motion in noncollinear antiferromagnets

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Antiferromagnets have the natural advantages of ultrafast magnetization dynamics and negligible stray fields compared with ferromagnets, thus appealing for next-generation magnetic domain-wall applications. So far, however, the study of the magnetization dynamics in antiferromagnets has been challenging due to their insensitive magneto-electric responses. Recently, remarkable developments on noncollinear antiferromagnets Mn_3X (X = Sn, Ge) enabled us to detect and manipulate their antiferromagnetic domain states [1-7]. Here, we demonstrate a current-driven magnetic domain-wall motion in a single crystal Mn_3X wire by means of magneto-optical Kerr observation technique [8]. It reveals that Néel-like domain-walls can be accelerated up to 750 m/s with a current density of only 7.6×10^{10} A/m^2. It also shows extremely high mobility compared with ferromagnets and ferrimagnets. Moreover, our theory reveals that the domain-wall motion in noncollinear antiferromagnets is driven by the spin-transfer torque derived from the current-induced nonequilibrium spin accumulation. These our findings open a new route to develop a mechanism responsible for antiferromagnetic domain-wall-based applications.

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Contributed Oral

11: 15 - 11 : 35

Stroboscopic magneto-optical imaging of current-induced domain wall dynamics in ferrimagnet GdFeCo

K. Ogawa[1], N. Yoshikawa[1], M. Ishibashi[1], A. Tsukamoto[2], M. Hayashi[1] & R. Shimano[1,3]

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Current-induced domain wall motion (CIDWM) is expected to find applications in spintronic devices such as memory and logic. Recently, it is known that CIDWM in ferrimagnetic materials can exceed 1 km/s at the angular momentum compensation point temperature TA [1,2]. A method to visualize such ultrafast dynamics of CIDWM is necessary to understand its physics and achieve accurate manipulation of domain walls (DWs).

Here, we developed a stroboscopic magneto-optical imaging system capable of detecting DW displacements of sub-μm with a time resolution of approximately 160 ps [3]. In our experiment, DWs were generated in a ferrimagnetic GdFeCo/Pt wire by all-optical magnetization reversal and ns current pulses were injected to observe CIDWM. The CIDWM dynamics unveil a time varying DW velocity during the pulse, especially, an acceleration noticeable approximately 1 ns after the start of current injection. These results can largely be attributed to the gradual temperature change caused by Joule heating and an enhanced DW velocity at TA. Our method provides access to the spatial and stochastic magnetization dynamics in sophisticated structures driven by external stimuli and should be applicable to a wide range of current-driven phenomena.

References

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Oral Session A1 (Tuesday, February 13)

Chair: Satoru Nakatsuji, University of Tokyo

Keynote Talk

11: 35 - 12 : 15

Cheng Song

Korea Advanced Institute of Science and Technology (KAIST), Korea

Electrical 180° switching of Néel vector in altermagnets

Altermagnet is an emerging magnetic phase with alternating spins and spin splitting band structure, thus combining the advantages of both antiferromagnets and ferromagnets [1-3]. However, as crucial components, the electrical detection and electrical 180° switching of the Néel vector as well as the corresponding spin-splitting, are very challenging. We demonstrated that in altermagnets $Mn5Si_3$ [4] and CrSb [5], the unique anomalous Hall effect can be adopted for electrical readout of opposite Néel vectors. We proposed a new mechanism for the electrical 180° switching of the Néel vector via spin-orbit torques by designing asymmetric switching barriers and experimentally achieved it. It is made possible by the fixed chirality between Néel vector and tiny relativistic net moment due to the Dzyaloshinskii-Moriya interaction. Based on their novel readout and manipulation methods, we fabricated prototype Hall devices that can accomplish robust write and read cycles. By suitable design of crystal distortion via strain, field-free and fully electrical switching of altermagnetic Néel vector is realized. Furthermore, controllable Néel vector enables tunable spin-charge interconversion through altermagnetic and inverse altermagnetic spin splitting effect [2,3,6].

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Oral Session A2 (Tuesday, February 13)

Chair: Stefan Blügel,
Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich GmbH

Keynote Talk

14: 00 - 14 : 40

Prineha Narang

Physical Sciences, the University of California, Los Angeles (UCLA)

TBD

Contributed Oral

14 : 40 - 15: 00

Hyperuniform electron distribution in quasicrystals

Shiro Sakai

RIKEN Center for Emergent Matter Science, Japan

Electrons in a quasiperiodic potential or lattice are distributed in an aperiodic but regular manner. Although electron wavefunctions in such a system often show multifractality, other physical quantities do not necessarily have multifractal distribution. For instance, the charge distribution on a Penrose lattice is not multifractal but hyperuniform [1].
Hyperuniformity [2] is a framework to quantify the regularity of a point distribution in a *d*- dimensional space. Counting the number of the points inside a window of radius R, we define its varianceσ^2 (R) as the window moves over the space. The distribution withσ^2 (R) < O(R^d) is called hyperuniform, as it is more uniform than a random distribution. Several different hyperuniformity classes have been identified.

Using a generalization of the hyperuniformity framework to scalar fields [2], we studied a one-dimensional Aubry-Andre-Harper model in terms of hyperuniformity [3]. The charge distribution of this model was found to be either class-I or class-II hyperuniform depending on the model parameters. By calculating the total energy, we found a phase transition between the regions of different hyperuniformity classes. This is a transition between two different non-uniform charge distributions in the absence of translational symmetry

Referemces

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Oral Session A2 (Tuesday, February 13)

Chair: Stefan Blügel,
Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich GmbH

Contributed Oral

15: 00 - 15: 20

Four-index coulomb interaction beyond Hund's coupling

Steffen Backes
RIKEN iTHEMS

To study the properties of strongly correlated electron materials one usually employs an effective low-energy lattice model, such as the Hubbard model, to obtain a simplified description of the material under consideration. Such a model is fully defined by the kinetic, or electron-hopping term, and the interaction term, originating from the electron-electron Coulomb interaction. This interaction term is a two-particle operator and in general involves the interaction of 4 different electron channels. For highly symmetric orbital basis functions this term is sparse and involves terms like the density-density interaction, or pair-hopping and spin-flip terms induced by the Hund's coupling. Even though in real materials all 4-index terms can in principle provide a finite contribution, they are usually assumed to be small and thus neglected for most practical calculations.
In this talk we will discuss the symmetry constraints imposed by the symmetry group of the corresponding atom on the form of the Coulomb interaction, and how the resulting non-zero elements can be obtained for specific systems. Using the constrained random-phase approximation we will present ab-initio 4-index elements of the Coulomb interaction for real materials and discuss cases where they show a non-negligible effect on the electronic structure. Using exact diagonalization of finite systems and the dynamical mean-field theory for lattice models and real materials, we will present the impact of these terms on electronic properties such as the spectral function.

Contributed Oral

15: 20 - 15: 40

Exact quantum spin Hamiltonian for magnetic interactions

H. Katsumoto[1], F. Lux[2], Y. Mokrousov[1,3], and S. Blügel[1]

Chair: Stefan Blügel,
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2 Department of Physics, Yeshiva University, USA
3 Institute of Physics, Johannes Gutenberg-University Mainz, Germany

The intricate nature of magnetism arises from the interplay of Heisenberg interactions and higher-order exchange interactions [1, 2]. The awareness is rising that the higher-order exchange interactions depend not only on the number of magnetic sites *N* but also on the local spin magnitude *S*. Nevertheless, a definitive method for uniquely deriving a spin Hamiltonian that comprehensively captures these interactions for a given system remains elusive.

his presentation is dedicated to delving into the algebraic aspects of the spin-permutation operator offering a methodology for deriving an exact quantum spin Hamiltonian tailored for an *N*- site system of spin *S*. We showcase the construction of the exact quantum spin Hamiltonian of $S = 1/2$ and 1 and extending to higher-order interactions up to 4-site systems. Furthermore, we delve into higher-order terms related to scalar spin chirality using this algebraic approach. he magnetism in solid materials is described by the classicalization of the quantum spin Hamiltonian.

hese findings not only contribute to our understanding of magnetism in solids but also bear relevance to nuclei and cold atom systems.

We acknowledge funding from the ERC grant 856538 (project "3D MAGIC"), the Deutsche Forschungsgemeinschaft (DFG) through SPP-2137 and SFB-1238 (project C1).

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Oral Session A3 (Tuesday, February 13)

Chair: Surjeet Rajendran, Johns Hopkins University

Special Session Talk

16: 00 - 16 : 40

Maria A. H. Vozmediano

Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC)

Quantum field theory aspects of Dirac semimetals

After the synthesis of graphene (massless Dirac fermions in (2+1) dimensions), Weyl semimetals emerged as physical realization chiral particles in (3+1) dimensions. Although they can be seen as 3D graphene, a series of new phenomena arise from the fundamental differences between chiral fermions in two and three dimensions. Chiral imbalance in 3D implies a set of anomaly related transport phenomena first discussed in the context of high energy collisions (quark-gluon plasma). In particular, quantum anomalies - most prominently the chiral anomaly - have provided a novel theoretical frame for the understanding of new magneto transport features in Weyl semimetals. More recently thermal transport has taken the lead in relation with the gravitational anomaly [1,2]. In this talk I will describe some of the aspects of the cross-fertilization between condensed matter, particle physics and gravity. I will try to be pedagogical.

References

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Special Session Talk

16: 40 - 17 : 20

Naoki Yamamoto

Department of Physics, Keio University

Chiral transport in the universe

In many-body systems of relativistic chiral fermions, unusual transport phenomena emerge due to the spin-momentum locking and resulting nontrivial Berry curvature. These chiral transport phenomena may appear in various physical systems, such as Weyl/Dirac semimetals, quark-gluon plasmas in relativistic heavy-ion collisions, electroweak plasma in the early universe, and neutrino matter in core-collapse supernovae. In this talk, we discuss how these chiral transport phenomena are relevant in astrophysical and cosmological systems, especially in core-collapse supernovae [1,2].

References

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Chair: Surjeet Rajendran, Johns Hopkins University

Contributed Oral

17: 20 - 17: 40

Chiral anomalies through laser-induced chiral gauge fields in disordered 3D Dirac semimetals

Hung-Hsuan Teh, Tokiro Numasawa, and Takashi Oka
The Institute of Solid State Physics, The University of Tokyo, Chiba, Japan

Inspired by a recent experiment that observed a significant photoexcited surface current in bismuth semimetal, we consider a Dirac semimetal subjected to a gradient chiral gauge field. The chiral gauge field, which can be generated for instance by circularly polarized light (CPL), is known to separate a Dirac fermion into a Weyl pair, leading to an appearance of Fermi arc states. Our study reveals that, due to the gradient, which can be achieved through the skin effect of the CPL on the semimental surface, one of the Fermi arc states leaks into the bulk, becoming a delocalized chiral Landau level state. We then introduce a homogeneous disorder and find that remarkably the chiral Landau level state exhibits greater robustness against scattering than the Fermi arc state, resulting in distinct lifetimes for two chiral states. Exploiting this asymmetry, we demonstrate an emergence of finite anomalous current, all without applications of external electric and magnetic fields. This discovery also serves as a realization of non-Hermitian topological quantum field theory within materials.

17: 40 - 18: 00

Emergent spin-momentum locking and triplet-mixed cooper pairs in a chiral organic superconductor

Takuro Sato[1, 2], and Hiroshi M. Yamamoto[1, 2, 3]

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Chirality is a novel source of several asymmetrical charge/spin transports such as electrical magnetochiral anisotropy (EMChA)[1] and chirality-induced spin selectivity (CISS)[2]. Especially, CISS gives a significant spin-rectification even at room temperature despite the negligible spin-orbit coupling (SOC) in organics, which distinguishes it from Edelstein effect that assumes large SOC from heavy elements. Both CISS and EMChA are distinct manifestations of chirality-induced spin/charge rectification effects and moreover share a similar parity-time symmetry, strongly suggesting the intimate relationship between them [Figs. 1(a, b)]. This issue, however, remains a fundamental open question.

Oral Session A3 (Tuesday, February 13)

Chair: Surjeet Rajendran, Johns Hopkins University

Here we experimentally address the issue by reporting a gigantic EMChA in a chiral organic superconductor, κ-(BEDT-TTF)2Cu(NCS)2, that exhibits a giant CISS effect as well [3]. Our study also reveals chiral superconducting diode effect and two-gap superfluid in the same device, suggesting a strong hedgehog-type spin-momentum locking and the triplet-mixed Cooper pairs as a common origin for both giant CISS and EMChA [Fig. 1(c)]. We anticipate that a similar strong spin-momentum locking in molecular orbitals can be also explored to rationalize high spin polarization in molecular CISS effect. The revealed triplet-mixed Cooper pair in chiral material may play roles in future developments of high critical field superconductors as well as novel types of quantum computers.

References

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Oral Session B1 (Wednesday, February 14)

Chair: Kyung-Jin Lee, KAIST

Keynote Talk

9: 00 - 9 : 40

Shunsuke Fukami

Research Institute of Electrical Communication, Tohoku University

Electrical control of noncollinear antiferromagnetic Mn_3Sn

Dynamics of collective spin structures induced by various electrical means has been of paramount interest in magnetics and spintronics fields, and many interesting phenomena have been revealed, leading to various opportunities of applications. Non-collinear antiferromagnet with chiral-spin structure is an attractive system showing intriguing properties that were believed to be inherent to ferromagnets such as the anomalous Hall effect [1]. Here I discuss physics and functionalities of Mn_3Sn, a representative room-temperature noncollinear antiferromagnetic system. First, I will show an epitaxial thin-film growth technique that is necessary to explore the device functionalities [2] and show basic magneto-transport properties [2,3]. Then, I will show the characteristic response of the chiral-spin structure of Mn_3Sn epitaxial heterostructures under a spin-orbit torque generated by an electric current [4]. If time allows, I will also present our studies on the domain structure [6] and thermal stability [7] of Mn_3Sn thin film and nanodot.

This work is performed under a collaboration with Y. Takeuchi, J.-Y. Yoon, T. Uchimura, Y. Sato, Y. Yamane, J. Han, S. Kanai, J. Ieda, and H. Ohno. This study is partly supported by JSPS Kakenhi 19H05622, MEXT X-NICS JPJ011438, and RIEC Cooperative Research Projects.

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Chair: Kyung-Jin Lee, KAIST

Contributed Oral

9: 40 - 10 : 00

Electrical manipulation and detection of topological antiferromagnetic state in Mn_3Sn-based epitaxial heterostructures

T. Higo[1,2], K. Kondou[3], T. Nomoto[4], X. Chen[1,5], K. Tanaka[1], M. Shiga[1,6], S. Sakamoto[2], H. Tsai[1], H. Idzuchi[1,2], H. Kosaki[2], T. Matsuo[1,8], D. Nishio-Hamane[2], R. Arita[3,4], Y. Otani[2,3,7], S. Miwa[2,7], S. Nakatsuji[1,2,7,8]

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8. IQM, Department of Physics and Astronomy, Johns Hopkins University, USA

Antiferromagnetic materials have garnered significant attention for their favorable properties in device applications, including negligible stray/demagnetizing fields and ultrafast spin dynamics [1]. The non-collinear antiferromagnet (AFM) Mn_3Sn [2], a prominent example of time-reversal symmetry-breaking AFMs, is a magnetic Weyl semimetal with unique AF ordering hosting cluster magnetic octupoles, leading to large transverse responses [2,3]. The research targets are shifting fundamental studies using bulk samples to exploring spintronic properties using thin films. This presentation focuses on our recent studies involving heterointerfaces based on Mn_3Sn. We have successfully manipulated the chiral AF order in bilayer films composed of polycrystalline Mn_3Sn and heavy metals, demonstrating the potential for spin-orbit torque (SOT) [4]. This research extends to heterostructures comprising epitaxial Mn_3Sn and heavy metals [5,6], where we have achieved SOT-induced perpendicular magnetic recording for the first time in AFMs [6], leveraging high-quality Mn_3Sn layers fabricated by MBE methods. These samples exhibit large Hall conductivity of ~40 $\Omega^{-1}cm^{-1}$ comparable to that obtained in the bulk single crystals, and the fabrication of $Mn_3Sn/MgO/Mn_3Sn$ stacks has also enabled the observation of the tunnel magnetoresistance effect at room temperature [7]. These results offer promising avenues for the development of AF spintronics.

References

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Oral Session B1 (Wednesday, February 14)

Chair: Kyung-Jin Lee, KAIST

Keynote Talk

10: 00 - 10 : 40

Stuart Parkin

Max Planck Institute of Microstructure Physics

The Josephson diode effect

We discuss a non-reciprocal Josephson diode effect in Josephson junctions, both lateral and vertical, formed from superconducting electrodes (Nb, $NbSe_2$) separated by several 2D van der Waals metals, $NiTe_2$ [1] , WTe_2 [2] , and $PtTe_2$ [3] , as well as platinum that is magnetically proximitized via a magnetic insulator [4] . Each of these materials becomes superconducting by proximity to the conventional superconducting electrodes. The superconductivity can be sustained over long distances of, in some cases, up to ~1 micron. The critical supercurrent densities for current flowing in opposite directions are distinct and can vary by up to 40% or more. For the van der Waals metals the non-reciprocity is only observed in the presence of a small magnetic field oriented perpendicular to the supercurrent, whereas for the Pt based junctions the diode effect is observed in zero field. For vertical Josephson junctions formed from WTe_2 we show that the non-reciprocity depends on the orientation of the magnetic field with respect to the crystal structure of the WTe_2, thereby proving the intrinsic origin of the Josephson diode effect. Such an effect could have important applications as a novel magnetic field detector at cryogenic temperatures, for example, to “read” magnetic domain walls in a cryogenic racetrack memory.

References

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Oral Session B2 (Wednesday, February 14)

Chair: Shinsei Ryu, Princeton University

Contributed Oral

11: 00 - 11 : 20

Ferroic multipole order in the quadrupole Kondo lattice PrV_2Al_{20} studied by magnetostriction and thermal expansion

A. Sakai[1] M. Fu[1], T. Isomae[1], M. Tsujimoto[2], Y. Nagaoka[2], N. Sogabe[2] and S. Nakatsuji[1-4]

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2. Institute for Solid State Physics, The University of Tokyo, Japan
3. Institute for Quantum Matter, Johns Hopkins University, USA
4. Trans-scale Quantum Science Institute, University of Tokyo, Tokyo, Japan

Strongly hybridized quadrupole system may induce anomalous metallic state through the two channel Kondo effect [1]. A cubic Pr-based rare-earth compound PrV_2Al_{20} can provide such quadrupole Kondo system where strong *c-f* hybridization and quadrupole active nonmagnetic crystalline electric field ground state (cubic Γ_3) are realized. Besides, PrV_2Al_{20} exhibits anomalous metallic behavior, multiple multipole orders at $T \sim 0.75$ and ~0.65 K, and superconductivity at $T_c \sim 0.05$ K [2, 3]. In this presentation, we will present our recent study for the multipole order of PrV_2Al_{20} via magnetostriction and thermal expansion.

References

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11: 20- 11 : 40

Versatile magnetic hedgehog lattice phases induced by anisotropic interactions in centrosymmetric systems

S. Okumura[1] S. Hayami[2], Y. Kato[1], and Y. Motome[1]

1. The University of Tokyo, Japan
2. Hokkaido University, Japan

Oral Session B2 (Wednesday, February 14)

Chair: Shinsei Ryu, Princeton University

Recently, a new generation of topological spin textures has been discovered in centrosymmetric metals, where the Dzyaloshinskii-Moriya interaction is absent. For instance, a three-dimensional topological spin texture composed of four spin helices, called the quadruple-Q hedgehog lattice (4Q-HL), was observed in the simple cubic perovskite $SrFeO_3$ [1]. While the 4Q-HLs have been studied theoretically by using effective spin models reflecting the itinerant nature of electrons [2, 3], the origin of the experimentally observed topological Hall effect has not been clarified.

In this work, we investigate the effects of the Q-dependent anisotropic interactions on the 4Q-HL, which originate from the spin-orbit coupling for the itinerant electrons in the centrosymmetric systems. By using simulated annealing for the effective spin model, we find that the anisotropic interactions modify the ellipticity of the composed spin helices and result in the other types of the 4Q-HL with four spin sinusoidal waves hosting a larger number of hedgehogs and antihedgehogs than the isotropic case [3] [Figure 1(a)]. Furthermore, in an external magnetic field, we find that the anisotropic interactions induce nonzero scalar spin chirality not only in the 4Q-HL states but also in topologically trivial phases [Figure 1(b)].

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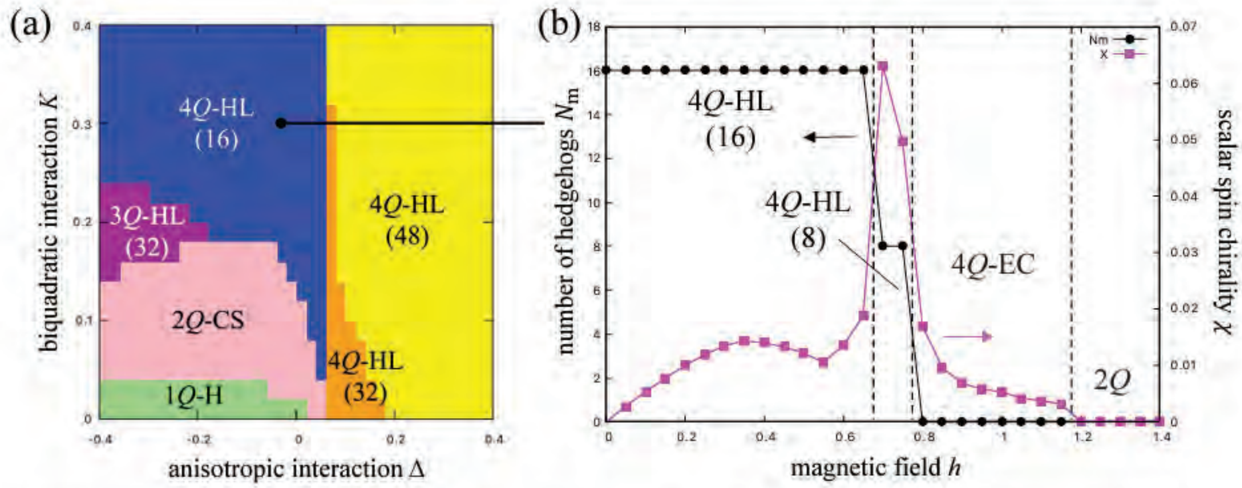

Figure 1: (a) Phase diagram for the anisotropic interaction Δ and the biquadratic interaction K at zero field. The numbers in parentheses represent the number of hedgehogs and antihedgehogs in the magnetic unit cell. (b) Magnetic field dependence of the number of hedgehogs and the scalar spin chirality for $(K, \Delta) = (0.3, -0.03)$.

Oral Session B2 (Wednesday, February 14)

Chair: Shinsei Ryu, Princeton University

Contributed Oral

11: 40 - 12 : 00

Emergent inductance from spin fluctuations in strongly correlated magnets

Taekoo Oh[1], and Naoto Nagaosa[1]

1. RIKEN CEMS, Japan

Recently, the intriguing phenomenon of emergent inductance has been theoretically proposed and experimentally observed in nanoscale spiral spin systems subjected to oscillating currents. Building upon these recent developments, we put forward the concept of emergent inductance in strongly correlated magnets in the normal state with spin fluctuations. It is argued that the inductance shows a positive peak at temperatures above the ordering temperature. As for the frequency dependence, in systems featuring a single-band structure or a gapped multi-band, we observe a Drude-type, while in gapless multi-band systems, a non-Drude inductance with a sharp dip near zero frequency. These results offer valuable insights into the behavior of strongly correlated magnets and open up new possibilities for harnessing emergent inductance in practical applications.

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12: 00 - 12 : 20

Majorana-mediated spin transport in the Kitaev model at finite temperatures

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2. Center for Emergent Matter Science, RIKEN, Wako 351-0198, Japan

Spin transport mediated by Majorana fermions is one of the interesting phenomena realized in the Kitaev model [1], where spin excitations flow in the quantum spin liquid (QSL) region without the oscillations in spin moments [2]. This nontrivial phenomenon originates from the fact that the S=1/2 spins are fractionalized into the itinerant and localized Majorana fermions in the Kitaev system. It is known that these Majorana fermions have distinct energy scales, leading to the double peaks in the specific heat [3]. Therefore, it is unclear how stable the Majorana-mediated spin transport in the Kitaev model is against thermal fluctuations.

In this study, we examine finite-temperature spin dynamics in the Kitaev model by means of the thermal pure quantum state method [4]. At low temperatures, the spin excitation propagates in a similar way to that for the ground state. At intermediate temperatures, larger oscillations in the spin moments are induced in the other edge, compared to the results at the ground state. At higher temperatures, excited localized Majorana fermions disturb the coherent motion of the itinerant Majorana fermions, which suppresses the spin propagation. Our results demonstrate an important role of thermal fluctuations in the Majorana-mediated spin transport [5].

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12: 20 - 12 : 40

Field control of quasiparticle decay in a quantum antiferromagnet

S. Hasegawa[1], H. Kikuichi[1], S. Asai[1], Z. Wei[1], B. Winn[2], G. Sala[2], S. Itoh[3], and **T. Masuda**[1, 3, 4]

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Dynamics in a quantum material is described by quantized collective motion: a quasiparticle. The single-quasiparticle description is useful for a basic understanding of the system, whereas a phenomenon beyond the simple description such as quasiparticle decay which affects the current carried by the quasiparticle is an intriguing topic. The instability of the quasiparticle is phenomenologically determined by the magnitude of the repulsive interaction between a single quasiparticle and the two-quasiparticle continuum. Although the phenomenon has been studied in several materials, thermodynamic tuning of the quasiparticle decay in a single material has not yet been investigated. Here we show, by using neutron scattering, magnetic field control of the magnon decay in a quantum antiferromagnet $RbFeCl_3$, where the interaction between the magnon and continuum is tuned by the field [1]. At low fields where the interaction is small, the single magnon decay process is observed. In contrast, at high fields where the interaction exceeds a critical magnitude, the magnon is pushed downwards in energy and its lifetime increases. Our study demonstrates that field control of quasiparticle decay is possible in the system where the two-quasiparticle continuum covers wide momentum-energy space, and the phenomenon of the magnon avoiding decay is ubiquitous.

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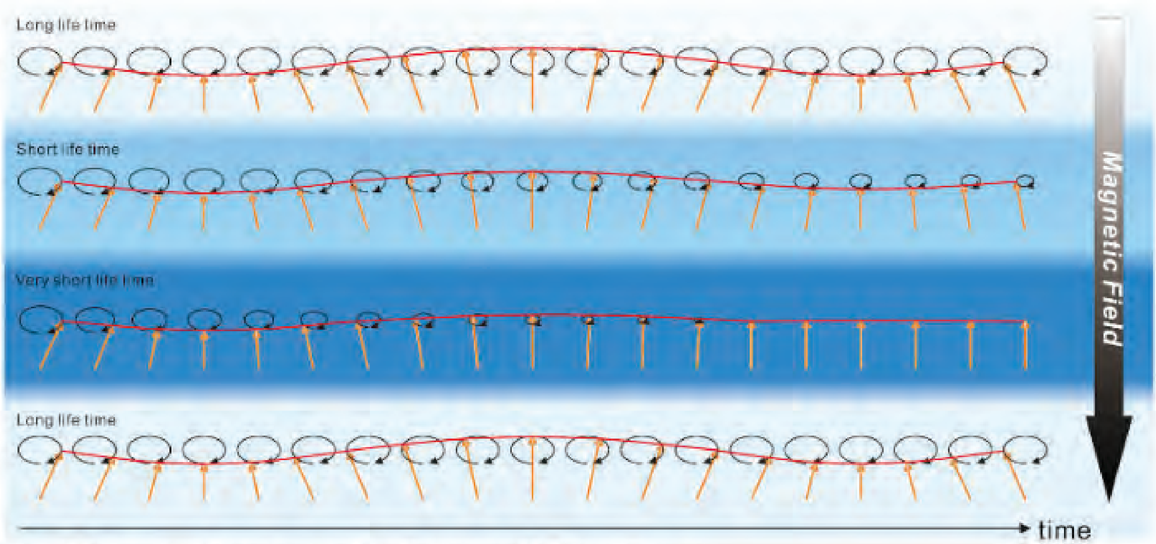
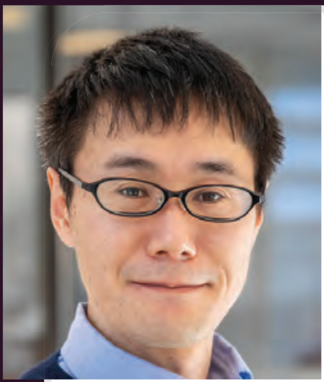


Fig. 1: Representative image for the control of magnon.

Oral Session B3 (Wednesday, February 14)

Chair: Maria A. H. Vozmediano,
Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC)

Special Session Talk



14: 00 - 14 : 40

Shinsei Ryu

Department of Physics, Princeton University

Topological phenomena out of equilibrium and time-reversal symmetry

Time reversal symmetry plays a crucial role in topological phenomena in many-body quantum physics. One of the prime examples include topological insulators that have been studied extensively in modern condensed matter physics. Recent investigations have expanded the scope to include non-equilibrium settings, such as driven (Floquet) systems, and topological phenomena in open quantum systems. In this talk, I will discuss the implication of time-reversal symmetry in out-of-equilibrium quantum many-body systems. In particular, we discuss the so-called Kubo-Martin-Schwinger (KMS) symmetry, and the role it plays in drive/open quantum many-body systems. Specifically, we discuss topological phenomena protected by the KMS symmetry and quantum anomalies associated to the KMS symmetry with applications to the Lieb-Schultz-Mattis type theorem.

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Oral Session B3 (Wednesday, February 14)

Chair: Maria A. H. Vozmediano,
Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC)

Special Session Talk

14: 40 - 15 : 20

Takashi Oka

The Institute for Solid State Physics (ISSP), The University of Tokyo

Heterodyne Hall effect in oscillating magnetic fields

Floquet engineering [1] introduces new dynamical functions within quantum materials. The process of heterodyning, a signal processing technique, produces output signals by combining an input signal with the dynamics of a designated multiplier [2]. This multiplier operates as a Floquet system, which is periodically influenced by an external drive over time [2, 3]. By designating electrons in oscillating magnetic fields as this multiplier, the Heterodyne Hall effect can be achieved [2]. We have recently broadened this concept to encompass 2D Dirac electrons, leading to the discovery of Floquet Landau levels and an effect reminiscent of the chiral magnetic effect [4].

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Chair: Maria A. H. Vozmediano,
Instituto de Ciencia de Materiales de Madrid (ICMM - CSIC)

Contributed Oral

15: 20 - 15 : 40

Nonlinear optical responses in α-type organic salt

Keisuke Kitayama[1] and Masao Ogata[1, 2]

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2. Trans-scale Quantum Science Institute, University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan

Nonlinear optical responses, such as shift current, have been extensively explored from the perspectives of both fundamental science and electronic applications. However, nonperturbative effects in multiband systems are not well understood.

In this talk, we investigate the shift current induced by linearly polarized light in α-(BEDT-TTF)$_2$I$_3$ [see Fig. (a)] [1]. In our previous studies, we have theoretically predicted various photoinduced topological phase transitions in this material [2-5]. By applying the perturbation theory, we determine the dependencies of the shift current on the frequency of light. Notably, we discover that the direction of the shift current strongly depends on the frequency of light, and this unique dependence is attributed to multiband effects. Furthermore, we explore the nonperturbative effects of the shift current using the Floquet Hamiltonian [see Fig. (b)]. Our findings reveal a sign change in this response, a phenomenon not observable when considering only the second-order response. We discuss the limitations of both the equation derived by the perturbation theory and the one derived by Morimoto and Nagaosa [6] when the light intensity is large.

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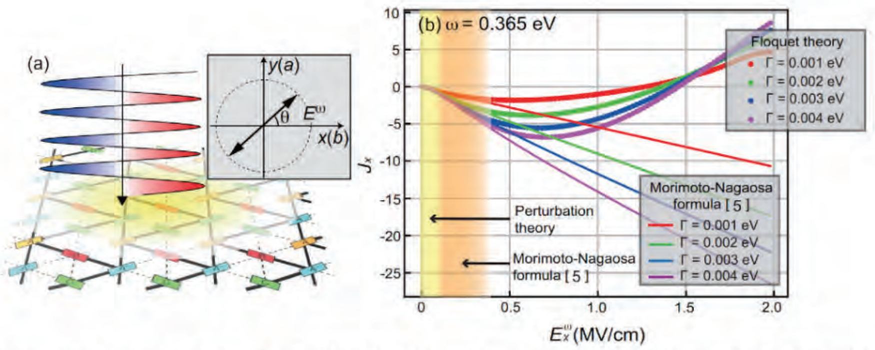

Fig. (a) Schematic illustration of α-(BEDT-TTF)$_2$I$_3$ irradiated with linearly polarized light. (b) Nonlinear optical responses in photodriven α-(BEDT-TTF)$_2$I$_3$.

Oral Session C1 (Thursday, February 15)

Chair: Shunsuke Fukami, Tohoku University

Keynote Talk

9: 00 - 9 : 40

Daniel C. Worledge

IBM Research

Spin-transfer-torque MRAM: the next revolution in memory

Spin-Transfer-Torque MRAM (STT-MRAM) was invented at IBM by John Slonczewski in the early 1990s, using a spin-polarized current, instead of a magnetic field, to write a magnetic free layer in a magnetic tunnel junction. The discovery of perpendicular magnetic anisotropy in thin CoFeB/MgO layers at IBM and independently by Tohoku University enabled a dramatic reduction in the switching current, and opened the way to practical perpendicular magnetic tunnel junctions for dense STT-MRAM.

This talk will provide an overview of STT-MRAM, including the two basic building blocks described above. I'll give an introduction to the physics of spin-transfer torque and applications of STT-MRAM. Then I will review why perpendicular magnetic anisotropy is advantageous for STT-MRAM compared to in-plane anisotropy. I will discuss the research at IBM in 2009 that led to our discovery of perpendicular anisotropy in thin CoFeB/MgO layers, and our use of these layers to make the first practical perpendicular magnetic tunnel junctions and the first demonstration of reliable writing in STT-MRAM [1]. Finally I will review our recent results on methods to lower the switching current of STT-MRAM by using optimized magnetic materials and double magnetic tunnel junctions, including our recent demonstration of reliable 250 ps switching [2].

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Chair: Shunsuke Fukami, Tohoku University

Keynote Talk

9: 40 - 10 : 20

Evgeny Y. Tsymbal

Department of Physics and Astronomy, University of Nebraska-Lincoln (UNL)

Antiferromagnetic tunnel junctions for spintronics

Antiferromagnetic (AFM) spintronics has emerged as a subfield of spintronics, where an AFM Néel vector is used as a state variable. Due to being robust against magnetic perturbations, producing no stray fields, and exhibiting ultrafast dynamics, antiferromagnets can serve as promising functional materials for spintronic applications. To realize this potential, efficient electric control and detection of the AFM Néel vector are required. This keynote talk features fundamental properties of AFM tunnel junctions (AFMTJs) as spintronic devices where such electric control and detection can be realized [1]. We emphasize critical requirements for observing a large tunneling magnetoresistance (TMR) effect in AFMTJs with collinear [2] and noncollinear [3,4] AFM electrodes, such as crystallinity of the junction, AFM metals exhibiting momentum-dependent spin polarization [2,3], and/or AFM metals supporting Néel spin currents [5]. We further discuss the unique property of non-collinear antiferromagnets to sustain virtually 100% spin polarization [4], the possibility of magnetic tunnel junctions (MTJs) with a single ferromagnetic electrode [6], and spin torques that are capable of Néel vector switching [5]. Overall, AFMTJs have potential to become a new standard for spintronics providing larger magnetoresistive effects, few orders of magnitude faster switching speed, and much higher packing density than conventional MTJs.

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Contributed Oral

10: 55 - 11 : 15

Anisotropic spin polarized current and magnetoresistance in an antiferromagnetic tunnel junction

Xianzhe Chen[1, 2,] Tomoya Higo[1, 2], Katsuhiro Tanaka[2, 3], Takuya Nomoto[3], Hanshen Tsai[2], Hiroshi Idzuchi[2], Masanobu Shiga[1], Shoya Sakamoto[1], Hidetoshi Kosaki[1], Takumi Matsuo[2], Daisuke Nishio-Hamane[1], Ryotaro Arita[3, 4,] **Shinji Miwa**[1, 5], and Satoru Nakatsuji[1, 2, 5, 6]

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2. Department of Physics, The University of Tokyo, Japan
3. Research Center for Advanced Science and Technology, The University of Tokyo, Japan
4. Center for Emergent Matter Science (CEMS), RIKEN, Japan
5. Trans-scale Quantum Science Institute, The University of Tokyo, Japan
6. Institute for Quantum Matter, Johns Hopkins University, USA

Tunnel magnetoresistance (TMR) and spin-transfer torque (STT), due to longitudinal spin-polarized current, provide the read and write protocols for the two-terminal magnetoresistive devices. In addition to the well-established ferromagnetic spintronics, antiferromagnets have attracted considerable interest as next-generation active elements for further improvements in operating speed and integration density. Therefore, it is important to develop both TMR and STT using all-antiferromagnetic tunnel junctions. In principle, TMR effect in all-antiferromagnetic tunnel junction is feasible in terms of momentum-dependent spin polarization [1]. However, it is difficult to prepare such time-reversal odd and controllable spin state in collinear antiferromagnet. Therefore, no reports have been published on the TMR effect using an all-antiferromagnetic tunnel junction. In addition, the observation and manipulation of the longitudinal spin-polarized current is necessary as a basis for the design of the memory device based solely on antiferromagnets, but, again, it has never been carried out for antiferromagnets. In this talk, we show that high-quality epitaxial thin films of the Weyl antiferromagnet Mn_3Sn [2] could be prepared by molecular beam epitaxy [3]. We clarify the existence of anisotropic, longitudinal spin-polarized current [4] using Fe/MgO/Mn_3Sn-MTJ and achieve TMR in an all-antiferromagnetic tunnel junction comprising Mn_3Sn/MgO/Mn_3Sn [5].

This work was supported by JST-MIRAI Program, JST-CREST, JSPS-KAKENHI , Spin-RNJ, and MEXT-XNICS.

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Contributed Oral

11: 15 - 11 : 35

First-principles study on tunnel magnetoresistance effect with antiferromagnets

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2. Research Center for Advanced Science and Technology, The University of Tokyo, Japan
3. Center for Emergent Matter Science (CEMS), RIKEN, Japan

Recent studies have shown that the antiferromagnets macroscopically breaking the time-reversal symmetry can exhibit a finite tunnel magnetoresistance (TMR) effect [1–4]. Particularly, we have focused on Mn_3Sn, a noncollinear antiferromagnet whose time-reversal breaking magnetic structure can be regarded as the ferroic order of the cluster magnetic octupole moments [5]. We have shown that Mn_3Sn can have a finite TMR effect from first principles, and we have actually observed the TMR effect in experiments [3].

To understand the TMR effect with antiferromagnets more closely, we have dealt with simple lattice models with collinear magnets. We have found that the local density of states inside the tunneling barrier can be an easy probe to discuss the TMR effect qualitatively [6]. As its application to first-principles calculations, we will discuss the TMR effect with Cr doped RuO_2; the rutile-type RuO_2, an antiferromagnet, shows intriguing phenomena thanks to its magnetic structure [1, 7], and its magnetism is reinforced by doping Cr into RuO_2 [8].

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Contributed Oral

11: 35 - 11 : 55

Magnetic tunnel junction-based readout for spin Hall nano-oscillators

Akash Kumar[1, 2], Takaaki Dohi[2], Mohammad Zahedinejad[1], Roman Khymyn[1]
Shun Kanai[2], Shunsuke Fukami[2] and Johan Åkerman[1, 2]

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2. Laboratory for Nanoelectronics and Spintronics, Research Institute of Electrical Communication, Tohoku University, Sendai, Japan

Since their demonstration, nano-constriction spin Hall nano-oscillators (NC-SHNOs) have gained substantial attention for their easy nano-fabrication, coherent signal, and large frequency-tunability[1]. Their superiority in mutual synchronization exhibited in both onedimensional chains [2,3] and two-dimensional arrays [4] positions these oscillators as building-blocks in diverse unconventional computing schemes, including reservoir/neuromorphic computing [4,5], and Ising machines [6]. Despite their potential, the low anisotropic magneto-resistance (AMR) of ferromagnetic materials limits their practical applications. Various efforts have been undertaken to enhance the output power of NC-SHNOs, such as incorporating large easy-plane anisotropy [7] and exploiting giant magneto-resistance [8].
This study introduces a groundbreaking approach by integrating a magnetic tunnel junction (MTJ)-based read-out for SHNO devices, resulting in MTJ-SHNOs with superior spectral characteristics. These devices exhibit large output power due to significant tunnelling magnetoresistance (>70%) while maintaining a low linewidth and preserving original magnetodynamical mode of SHNOs. Experiments demonstrate a remarkable 10^4 increment in output power (>5 nWs from 0.5 pW) without additional input. Moreover, the MTJ pillars provide a means for individual control of SHNOs through an additional current path and enable local probing/control within large chains or arrays. These advancements not only overcome NC-SHNOs' output power limitations but also enables additional control, facilitating their effective integration into practical applications.

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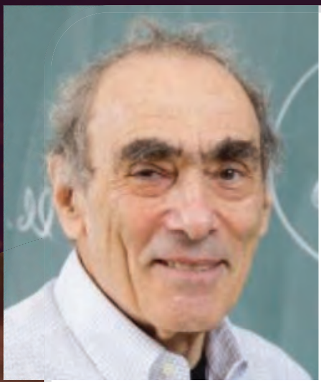
Oral Session C3 (Thursday, February 15)

Chair: Naoki Yamamoto, Keio University

Special Session Talk



13: 30 - 14 : 10

Gordon Baym

The University of Illinois at Urbana-Champaign (UIUC)

Matter under extreme conditions in neutron stars

Neutron stars -- of masses up to a little more than twice that of the sun, and yet compressed by gravity down to tens of kilometers -- are the densest objects in the universe [1]. As such they are natural laboratories for studying the properties of matter under extreme conditions of density and pressure not readily achievable on Earth. Indeed, very shortly after the discovery of the BCS theory of superconductivity, familiar ideas of condensed matter physics began to play an important role in unraveling the physics of neutron stars -- from the existence of a solid crust to superfluid states of the nucleons, neutrons and protons, in the interior. In this talk I will give a general overview of the condensed matter physics in neutron stars interiors, including cutting edge questions of the role of quarks (the internal constituents of neutrons and protons) in the deep interior. For example, how does a superfluid of neutrons and protons transition to superfluid quark matter in the deep interior, and how can such superfluid quark matter carry angular momentum [2].

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Contributed Oral

14: 10 - 14 : 30

Nonrelativistic trace anomaly and its impact on equation of state in dense fermionic matter: Toward understanding hadron-quark crossover via analogue quantum simulation

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2. Department of Mathematics and Physics, Kochi University, Japan
3. Interdisciplinary Theoretical and Mathematical Sciences Program (iTHEMS), RIKEN, Japan

Recent observations of neutron stars suggest that nuclear matter gradually changes into dense quark matter with increasing density [1]. A remarkable feature of this structural change lies in the presence of a sound velocity peak in the hadron-quark crossover regime [2]. However, the microscopic mechanism of the hadron-quark crossover is elusive because it is observationally difficult to obtain detailed information on the properties of matter in the star. Recent lattice two-color quantum chromodynamics simulation [3] shows the existence of such a peak and implies similarities with the Bose-Einstein-condensation (BEC) to Bardeen-Cooper-Schrieffer (BCS) crossover realized in ultracold atoms. In this regard, analogue quantum simulation could be a promising route to elucidate the crossover mechanism. According to the quantum Monte Carlo simulation of one-dimensional three-component nonrelativistic Fermi gases [4], this system simultaneously exhibits a sound velocity peak and a crossover from deeply to loosely bound trimers, which has been discussed in connection with the three-body counterpart of Cooper pairs, namely, Cooper triples [5]. In this contribution, we discuss effects of trace anomaly involving three-body correlations on the equation of state in this system by using the Brueckner G-matrix approach known to successfully describe the equation of state in the BCS-BEC crossover [6].

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Oral Session C3 (Thursday, February 15)

Chair: Naoki Yamamoto, Keio University

Special Session Talk

14: 30 - 15 : 10

Surjeet Rajendran

Department of Physics and Astronomy, Johns Hopkins University

Fundamental physics with quantum sensors

The search for new physical laws and particles has largely been driven by the expectation that the new physics lies at high energies with reasonably strong interactions with the standard model. However, the existence of dark matter and dark energy, as well as the potential new physics that could be discovered using gravitational waves, suggests that there is a strong case to search for phenomena that do not interact much with the standard model. The discovery of such phenomena requires precision sensing. The remarkable advances that have occurred in the field of quantum metrology in the past three decades have made it possible to deploy a wide variety of quantum sensors to detect such ultra-weakly coupled physics. In this talk, I will discuss a variety of new experimental methods that can be used to detect gravitational waves in the 1 Hz frequency band between LIGO and LISA and probe a wide variety of dark matter candidates in the laboratory.

Oral Session C3 (Thursday, February 15)

Chair: Naoki Yamamoto, Keio University

Contributed Oral

15: 10 - 15 : 30

Braiding and fusion of Majorana fermions in minimal Kitaev spin liquid on a single hexagon with 5 qubits

Motohiko Ezawa

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We propose the minimal Kitaev spin liquid on a single hexagon with three Ising-type exchange interactions proportional to K_x, K_y and K_z. In the limit K_z=0, we find 32-fold zero-energy states, leading to 10 free Majorana fermions, and hence, 5 qubits are constructed. These qubits are protected by particle-hole symmetry even for $K_z \neq 0$. Braiding of these Majorana fermions is possible by temporally controlling a spin-correlation Hamiltonian. In addition, the fusion is possible by measuring spin correlations. By switching on the Heisenberg interaction together with magnetic field, only one zero-energy state persists, which can be used as an initialization of qubits. Furthermore, it is shown that $3L$+2 qubits are constructed on the Kitaev spin liquid model on connected L hexagons. All the processes of initialization, operation and readout of qubits are executable in terms of spin operators.

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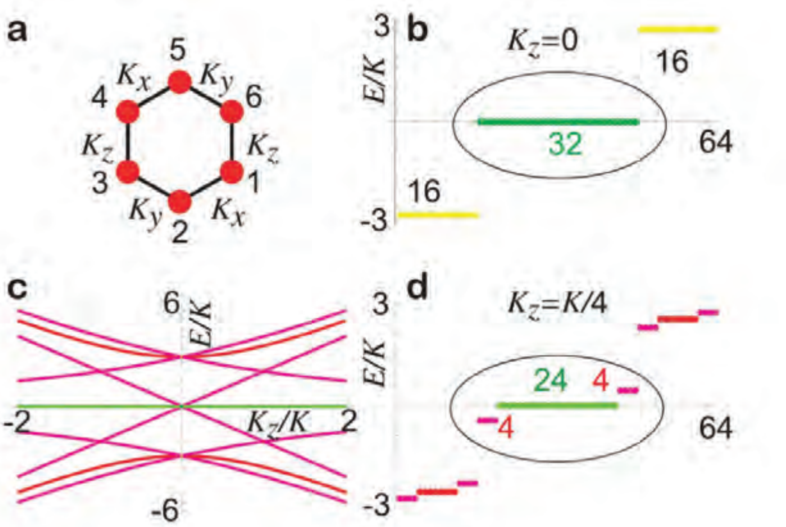

Contributed Oral

15: 30 - 15 : 50

Integrating ultrafast switches into a single molecule

Hirofumi Yanagisawa

Shizuoka University, Japan

Irradiating a sharp metallic needle with femtosecond light pulses generates electron emissions from the apex[1], as depicted in Figure 1(a). These emissions serve as ultrafast switches, significantly surpassing the speed of current computer switching devices by three to six orders of magnitude. Concurrent plasmonic effects enable precise spatial control of electron emission on a 10-nm scale[2]. Leveraging this phenomenon allows the selection of emission sites A or B in Figure 1(b), resembling two integrated transistor switches independently controlled by light in the accompanying diagram. Consequently, this site selectivity aids switch integration. However, further miniaturization of such an electron source through plasmonics poses challenges. Here, we propose a new approach utilizing the quantum nature of a single-molecule. In this setup, fullerene molecules are positioned on a metallic substrate[3], as illustrated in Figure 1(c). Electrons, supplied from the substrate, are emitted from the single molecules after traversing specific molecular orbitals (MOs). Depending on the involved MOs, the emission sites vary. Our research demonstrates the potential to optically manipulate the MOs that electrons pass through, thus enabling the creation of an electron source with subnanometric emission site-selectivity[4]. This technique facilitates the integration of switches into a single molecule.

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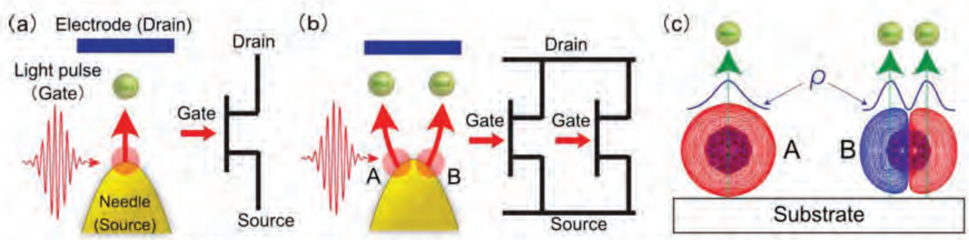

Fig. 1: Conceptual diagrams illustrating the ultrafast emission of electrons from a nano-object upon irradiation with a light pulse (a) and the optical control of emission sites (b). (c) Conceptual diagram showcasing the spatial modulation of an electron source through resonant electron emissions using a molecule.

Oral Session D1 (Friday, February 16)

Chair: Tomas Jungwirth,
Academy of Sciences of the Czech Republic (ASCR)

Keynote Talk

9 : 00 - 9 : 40

Stefan Blügel

Peter Grünberg Institute and Institute for Advanced Simulation,
Forschungszentrum Jülich and JARA

From the Fermi surface to topological magnetization textures

Topological magnetization textures such as skyrmions are solutions of nonlinear field equations. They are typically metastable and in the past mostly stabilized by the Dzyaloshinskii-Moriya interaction (DMI), recently increasingly also by frustrated exchange, and sometimes with higher-order exchange interactions. In this context, centrosymmetric intermetallic rare-earth compounds (e.g. Gd_2PdSi_3 $GdRu_2Si_2$, $EuAl_4$) constitute a very flexible play-ground for the realization of topological magnetization textures (e.g. skyrmion lattices) relying on the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction between the localized 4*f*-moments [1-3] which directly depend on the details of the Fermi surface. We perform a systematic first-principles analysis in the framework of the DFT+U and relate the Fermi-surface and electronic properties to magnetic interaction parameters of spin models. Since the exchange interaction is much larger than the DMI, the skrymions are so small that transport properties beyond the adiabatic approximation are considered [4]. We employ atomistic spin-dynamics simulations and identify the magnetic phases that are stabilized in the presence of an external magnetic field. Our analysis aims at drawing a direct connection between the topology of the electronic band structure and the spin structures in real space.

We acknowledge funding from ERC grant 856538 (project "3D MAGIC"), the Deutsche Forschungsgemeinschaft (DFG) through SPP-2137 and SFB-1238 (project C1).

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Chair: Tomas Jungwirth,
Academy of Sciences of the Czech Republic (ASCR)

Contributed Oral

9 : 40 - 10 : 00

Observation of cluster magnetic octupole domains in the antiferromagnetic Weyl semimetal Mn_3Sn nanowire using an atomic force microscope

H. Isshiki[1, 2], N. Budai[1], A. Kobayashi[1], R. Uesegi[1], Z. Zhu[1], T. Higo[1, 2, 3], S. Nakatsuji[1, 2, 3, 5] and Y. Otani[1, 2, 4, 5]

1. Institute for Solid State Physics, The University of Tokyo, Japan
2. CREST, Japan Science and Technology Agency (JST), Japan.
3. Department of Physics, The University of Tokyo, Japan
4. Trans-scale Quantum Science Institute, The University of Tokyo, Japan.
5. Center for Emergent Matter Science RIKEN, Japan

The antiferromagnetic Weyl semimetals such as Mn_3Sn [1] have recently attract wide attention due to their anomalous transverse transport properties despite having barely any net magnetization. In this study, we visualized the cluster magnetic octupole domains in a (0001)textured Mn_3Sn nanowire using an atomic force microscope. Our technique involves establishing a tip-sample contact, inducing a localized vertical temperature gradient, and measuring the thermoelectric voltages due to the anomalous Nernst effect at the wire's ends [2,3] as illustrated in Figs. 1(a). We show a topographic image of the Mn_3Sn wire in Fig. 1(b). After the application of a magnetic field 2 T along the y-direction, we obtained the corresponding anomalous Nernst voltage map at 0 T as shown in Fig. 1(c). This represents the distribution of the y-component of the cluster magnetic octupole moments in a remanent state. The inhomogeneous voltage signal reflects the presence of the grains with tilted Kagome planes about the x-axis. Not like the magnetic imaging by the stray field measurement, our approach directly maps the distribution of the cluster magnetic octupole moments in Mn_3Sn. Our work provides a solid methodology to investigate the magnetic structures of the antiferromagnetic Weyl semimetals.

References

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Oral Session D1 (Friday, February 16)

Chair: Tomas Jungwirth,
Academy of Sciences of the Czech Republic (ASCR)

Contributed Oral

10 : 00 - 10 : 20

Topological magneto-optical effect from skyrmion lattice

Y. Okamura[1], Y. D. Kato[1], M. Hirschberger[1,2], Y. Tokura[1,2,3], and Y. Takahashi[1,2]

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3. Tokyo College, University of Tokyo, Japan

Magnetic skyrmions are nanometric whirlpools of spins, where the directions of the constituent spins wrap the unit sphere [1], attracting enormous attention as potential information carriers in next-generation memory/logic devices. Due to their non-coplanar spin arrangement, the resultant scalar spin chirality gives rise to the fictious magnetic field (emergent magnetic field) acting on the conduction electrons, which leads to unique transport phenomena such as the topological Hall effect. However, other emergent electromagnetic phenomena, for example, skyrmion-driven optical response have yet to be reported.
In this presentation, we show the observation of the topological magneto-optical Kerr effect in the centrosymmetric material Gd_2PdSi_3 [2,3]. Magneto-optical effects are polarization rotation phenomena under breaking of time-reversal symmetry, whose magnitude is usually proportional to the magnetization. In Gd_2PdSi_3, the Kerr effect in the mid-infrared region exhibits a significant enhancement in the skyrmion lattice phase, demonstrating the existence of a topological Kerr signal (Fig. 1). The topological Kerr effect is observed up to the sub-eV region, which indicates that the formation of the skyrmion lattice causes a reconstruction of the electronic band structure. Our findings establish novel emergent optical phenomena, which enables noncontact, fast and efficient readout of skyrmions.

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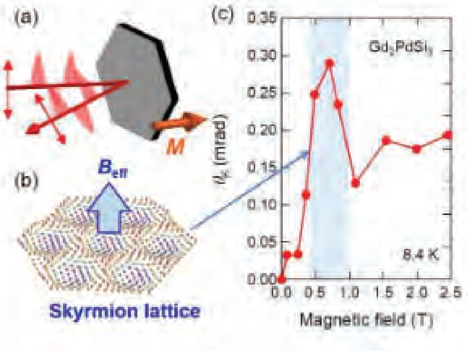

Fig. 1: (a,b) Schematic illustration of magneto-optical Kerr effect (MOKE) (a) and skyrmion lattice (b). (c) Magnetic-field dependence of the MOKE

Oral Session D1 (Friday, February 16)

Chair: Tomas Jungwirth,
Academy of Sciences of the Czech Republic (ASCR)

Contributed Oral

10 : 20 - 10 : 40

First principles calculation of topological Hall conductance in the skyrmion lattice

Hsiao-Yi Chen[1], Takuya Nomoto[2], and Ryotaro Arita[1, 2]

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Noncoplanar topologically protected spinor excitations, such as Skyrmions, have attracted significant attention in the field of spintronics, due to their stability and low energy costs in manipulation, as a prospective candidate for information storage. While experimentalists have made strides in advancing our understanding of Skyrmions through measurements of the unique topological Hall conductance (THC) and real-space imaging using the Lorentz TEM technique, theoretical investigations have predominantly relied on empirical modeling, lacking a comprehensive predictive tool.

In response to this gap, we developed a first-principle approach for computing the transport properties of Skyrmionic systems. In this presentation, we introduce our method for calculating the THC in the Skyrmion lattice, employing density functional theory. Our approach incorporates the magnetic field induced by noncoplanar spinors into the current scheme that utilizes the Kubo formula within the wannier tight-binding model [1]. To validate our formalism, we apply it to investigate the THC of the Skyrmion lattice phase in the Gd_2PdSi_3 crystal and achieve a remarkable agreement with experimental measurements [2]. Additionally, we analyze the spin on the Fermi surface, obtaining polarization consistent with those derived from a phenomenological model, thereby confirming the reliability of the theoretical discussion adopted in the literature.

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Oral Session D2 (Friday, February 16)

Chair: Evgeny Y. Tsymbal , University of Nebraska-Lincoln (UNL)

Keynote Talk

11 : 00 - 11 : 40

Tomas Jungwirth

Institute of Physics, Czech Academy of Sciences
School of Physics and Astronomy, University of Nottingham,

Altermagnets: An unconventional magnetic class

Conventional magnets can be divided in two basic classes – ferromagnets and anti-ferromagnets. In the first part of the talk, we will recall that the ferromagnetic order offers a range of phenomena for energy efficient IT, while the vanishing net magneti-zation in antiferromagnets opens a possibility of combining ultra-high energy efficiency, capacity and speed of future IT [1-4]. In the main part of the talk we will move on to our recent predictions of instances of strong time-reversal symmetry breaking and spin splitting in electronic bands, typical of ferromagnetism, in crystals with antiparallel com-pensated magnetic order, typical of antiferromagnetism [5-8]. We resolved this apparent fundamental conflict in magnetism by symmetry considerations that allowed us to classify and describe a third basic magnetic class [6,7]. Its alternating spin polarizations in both crystal-structure real space and electronic-structure momentum space suggested a term altermagnetism. A *d*-wave spin-polarization order in altermagnets is a direct counterpart of the unconventional d-wave superconducting order in cuprates. We will discuss predic-tions and initial experimental verifications [9,10] in which altermagnets combine merits of ferromagnets and antiferromagnets, that were regarded as principally incompatible, and have merits unparalleled in either of the two conventional magnetic classes. We will introduce the broad materials landscape of altermagnetism and show how its unconven-tional nature enriches fundamental concepts in condensed matter physics, such as the Kramers theorem [10]. We will show that this underpins a development of a new avenue in spintronics, elusive within the two conventional magnetic classes, based on strong and conserving spin phenomena, without magnetization imposed scalability limitations.

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Chair: Evgeny Y. Tsymbal , University of Nebraska-Lincoln (UNL)

11 : 40 - 12 : 00

Symmetry of emergent physical phenomena free from relativistic spin-orbit coupling

Hikaru Watanabe[1], Kohei Shinohara[2], Takuya Nomoto[1], Atsushi Togo[3], and Ryotaro Arita[1,4]

1. Research Center for Advanced Science and Technology, University of Tokyo, Meguro, Tokyo 153-8904, Japan
2. Department of Materials Science and Engineering, Kyoto University, Sakyo, Kyoto 606-8501, Japan
3. Center for Basic Research on Materials, National Institute for Materials Science, Tsukuba, Ibaraki 305-0047, Japan
4. RIKEN, Center for Emergent Matter Science, Saitama 351-0198, Japan

This study explores spin-order-driven phenomena, especially in systems with light magnetic atoms, revealing unique physical properties linked to the spin degree of freedom. Our approach, which decouples spin and orbital degrees of freedom, offers a deeper understanding of the relationship between spin structure dimensionality and physical properties arising from the spin order. Unlike traditional magnetic space group symmetry analyses, the spin crystallographic group exhibits richer symmetries including spin translation symmetry. We discuss the geometrical nature of the anomalous Hall effect and magnetoelectric effect arising from nonrelativistic spin-charge coupling. This method serves as a systematic tool for exploring significant electromagnetic responses rooted in spin order. Overall, our work advances the understanding of spin-driven phenomena, paving the way for realizing giant responses associated with the spin degree of freedom in various magnetic materials.

12 : 00 -12: 20

Acoustically driven magnon-phonon coupling in a layered antiferromagnet

T.P. Lyons[1], **J. Puebla**[1], K. Yamamoto,[2,1] R.S. Deacon,[3,1] Y. Hwang,[4,1] K. Ishibashi,[3,1] S. Maekawa ,[1,2,5] and Y. Otani,[1,4]

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2. Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki 3191195, Japan
3. Advanced Device Laboratory, RIKEN, Wako-shi, Saitama 351-0198, Japan
4. Institute for Solid State Physics, University of Tokyo, Kashiwa, Chiba 277-8581, Japan
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Oral Session D2 (Friday, February 16)

Chair: Evgeny Y. Tsymbal , University of Nebraska-Lincoln (UNL)

Contributed Oral

Harnessing the causal relationships between mechanical and magnetic properties of Van der Waals materials presents a wealth of untapped opportunity for scientific and technological advancement, from precision sensing to novel memories. This can, however, only be exploited if the means exist to efficiently interface with the magnetoelastic interaction. Here, we demonstrate acoustically driven spin-wave resonance in a crystalline antiferromagnet, chromium trichloride, via surface acoustic wave irradiation. The resulting magnon-phonon coupling is found to depend strongly on sample temperature and external magnetic field orientation, and displays a high sensitivity to extremely weak magnetic anisotropy fields in the few mT range. Our work demonstrates a natural pairing between power-efficient strainwave technology and the excellent mechanical properties of Van der Waals materials, representing a foothold toward widespread future adoption of dynamic magnetoacoustics.

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12 : 20 - 12 : 40

Emergent isotropic spin fluctuations from a diluted 2D anisotropic antiferromagnet

Hidemaro Suwa[1], Junyi Yang[2], Lin Hao[3], and Jian Liu[2]

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2. Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA
3. Anhui Key Laboratory of Condensed Matter Physics at Extreme Conditions, High Magnetic Field Laboratory, HFIPS, Chinese Academy of Sciences, Hefei, Anhui 230031, China

A prominent characteristic of two-dimensional magnetic systems is the enhanced spin fluctuations, which reduce the ordering temperature [1]. We have proposed a novel mechanism for obtaining an extreme magnetic response of emergent isotropic spin fluctuations from two-dimensional anisotropic antiferromagnets. Using a diluted antiferromagnet built in the iridate superlattice thin film [$(SrIr_{1-\delta}Ti_{\delta}O_3)/(SrTiO_3)_2$] (Fig. 1), we have demonstrated that a magnetic field of only 1000th of the spin exchange coupling can increase the crossover (ordering) temperature by 600% [2]. Such an extraordinary magnetic response is enabled because the system directly enters the antiferromagnetically ordered state from the isotropic disordered state, skipping the intermediate anisotropic stage. The underlying mechanism is achieved on the pseudospin-half square lattice realized in the superlattice thin film that is designed to linearly couple the staggered magnetization to external magnetic fields by virtue of the rotational symmetry-preserving Dzyaloshinskii–Moriya interaction. Our model analysis shows that the skipping of the anisotropic regime despite finite anisotropy is due to the characteristic length scale switch under moderate dilution. The demonstrated field-tunable antiferromagnetic ordering temperature is expected to be useful in antiferromagnetic spintronics.

Oral Session D2 (Friday, February 16)

Chair: Evgeny Y. Tsymbal , University of Nebraska-Lincoln (UNL)

References

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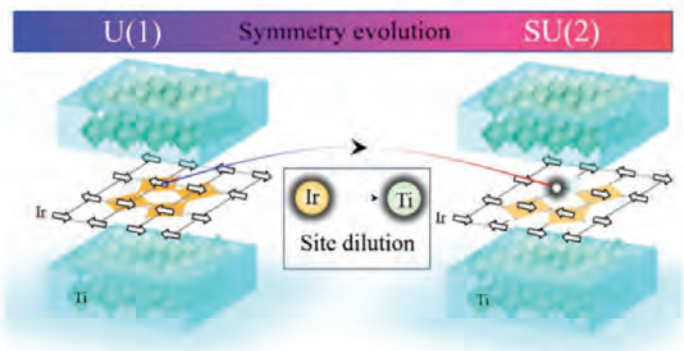

Fig. 1 Symmetry evolution in the magnetic response to external fields upon site dilution.

POSTER
PRESENTATION LIST

Session 1 (Day 2, February 14)

Registration No.	Presenter	Title
U_0005	Yangming Wang	Anomalous Nernst effect in topological $Fe_3Ga_{1-x}Al_x$ polycrystals
U_0007	Kohei Hattori	Effect of Collective Spin Dynamics on Anomalous Transverse Transport: Real-Time Calculation
U_0011	Jieyi Chen	Effect of alkali halide insertion on magnetic anisotropy at the Fe/MgO interface
U_0032	Yoshitaka Okuyama	Aspects of critical phenomena with boundary and defect
U_0033	Hironobu Yoshida	Uniqueness of the non-equilibrium steady state in open quantum many-body systems
U_0035	Yurina Nakazato	Formation and evolution of galaxies in the early Universe by 3D hydrodynamics simulation
U_0045	Ming-Chun Jiang	Possible Rattling and Anharmonicity Enhanced Superconductivity in Sc_6MTe_2 (M=Fe, Co, Ni)
U_0047	Masaki Yama	Theory of the Inverse Edelstein Effect using Boltzmann Equation
U_0058	Tik Tsun Yeung	Decay spectroscopy and delayed-neutron measurements of neutron-rich nuclei from Os to Po at RIBF
U_0059	Zijun Wei	Spin Dynamics in an Easy-plane Antiferromagnet $CsFeCl_3$ in Magnetic Field
U_0066	Yunyoung Hwang	On-chip strong coupling between spin waves and surface acoustic waves
U_0069	Raigo Nagashima	Classification of Lifshitz invariant in multiband superconductors and its application to Leggett modes
U_0071	Moeta Tsukamoto	Observation of domain wall in chiral antiferromagnet
U_0073	You Ba	Resonant surface acoustic wave absorption in YIG
U_0080	Tatsuto Hatanaka	First-principles derivation of classical spin models based on the spin cluster expansion
U_0083	Junna Sugiyama	Precipitable Water Vapor Measurement using GNSS Data in the Atacama Desert for Millimeter and Submillimeter Astronomical Observations
U_0090	Moritz M. Hirschmann	Fundamental Laws of Chiral Band Crossings
U_0091	Akihiro Hokkyo	No-Go Theorem from Eigenstate Thermalization Hypothesis about Work Extractability in Locally Interacting Systems
U_0092	Yuka Oshima	Development of Torsion Pendulums and Readout Optics for Gravity Gradient Observation
U_0096	Hibiki Matsunaga	Calculation method for the coherence length at low temperatures

Session 1 (Day 2, February 14)

Registration No.	Presenter	Title
U_0098	Ken Inayoshi	Energy Flow during Relaxation in an Electron-Phonon System with Multiple Modes: A Nonequilibrium Green's Function Study
U_0101	Hiromu Ushihara	Microscopically-derived quantum master equation for a boundary-driven Hubbard model and its application to nonlinear thermoelectric effect
U_0106	Dongxue Han	Nanoscale imaging of magnetic texture dynamics by ultrafast Lorentz transmission electron microscopy
U_0108	Ryota Uesugi	Giant anomalous Nernst effect in the epitaxial and polycrystalline films of the Weyl ferromagnet Co_2MnGa
U_0113	Shinichi Inoue	Robust two-qubit entangling gate scheme for collision-free scalable quantum computer
U_0116	Yuchen Wang	Large Photoelasticity in Topological Antiferromagnet Mn_3Sn Studied by Coherent Acoustic Phonon
U_0120	Shohei Imai	Systematic construction of unconventional η-pairing states in multi-body interacting systems
U_0124	Mihiro Asakura	Observation of the exchange bias at polycrystalline chiral-antiferromagnet/collinear-antiferromagnet interface
U_0127	Diego Catala	Observation of orbital Hall effect in Ru/FM nanostructures
U_0129	Yukihiro Marui	The accuracy of the harmonic Hall measurements on spin orbit torques in W/CoFeB
U_0131	Shota Namerikawa	First-Principles Electrical Conductivity Calculations of Ag-Pd Alloy based on Wannier-CPA Method
U_0146	Aakanksha Sud	Spin-pumping driven by non-linear harmonic generation
U_0081	Patrick Zellekens	Flux-periodic supercurrent oscillations in GaAs/InAs/Al core/shell/halfshell nanowire Josephson junctions
U_0149	Akiyoshi Yamada	Quantum-classical correspondence and dissipative to dissipationless crossover in magneto-transport phenomena
U_0150	Shaocong Lu	Superconductivity in Hole-Doped Perovskite Hydride $KMgH_3$
U_0156	Zhiyi Duan	Ti-Doping Effect in Weyl Antiferromagnet Mn_3Sn
U_0157	Kana Sakaguri	The Status of the Simons Array Experiment and the Science Cases with Circular Polarization Measurements
U_0158	Shunsuke Nishimura	Magnetic imaging of quantum vortices in microfabricated superconductor using diamond quantum sensor
U_0160	Zoe Jeandupeux	Stochastic Reaction-Diffusion System of Biological Chemical Reaction Network
U_0165	Hua Bai	Charge-spin conversion in antiferromagnetic RuO_2

Session 1 (Day 2, February 14)

Registration No.	Presenter	Title
U_0166	Jun Oike	Detection of magnetic octupolar order by nonlinear magnetoelectric effect
U_0168	Masahiko Yunokizaki	Fabrication of tunnel junction with the antiferromagnetic Weyl semimetal Mn_3Sn dot down to sub-micron scale
U_0177	Hiroki Yoshida	Thermal Hall measurements to detect spontaneous thermal Hall effect in kagome superconductor CsV_3Sb_5
U_0199	Yuto Kajiwara	Anisotropic thermoelectric properties in $CaZn_2Sb_2$ zintl compounds
U_0004	Yuta Toga	Substitution-Driven Enhancement of the Neel Temperature in Noncollinear Magnet Mn_3Sn: A Theoretical Study
U_0084	José Maria Cruz	Hollow Lattice Tensor Gauge Theories with Bosonic Matter
U_0064	Rikuto Oiwa	Construction of symmetry-adapted Closest Wannier models using multipole basis
U_0086	Masaki Imamura	Non-negative Matrix Factorization Analysis for Angle-Resolved Photoemission Spectra of Graphene
U_0087	Kazutoshi Takahashi	Electronic band structure of ultraflat hexagonal bismuthene
U_0097	Takahiro Ishikawa	Search for superconductivity in La-N-H by evolutionary algorithm, neural network potential, and density functional theory
U_0107	Hirokazu Tanaka	Roll-to-Roll Printing of Anomalous Nernst Thermopiles for Perpendicular Heat Flux Sensing
U_0136	Junji Fujimoto	Anti-Poiseuille flow by spin Hall effect
U_0137	Shoya Sakamoto	Surface and bulk magnetic structure of Mn_3Sn epitaxial thin films studied by x-ray magnetic circular dichroism
U_0142	Koudai Sugimoto	Wannier-Stark ladders emerging in the single-particle excitation spectra of the Hubbard model
U_0154	Katarzyna Gas	Magnetic studies of epitaxial thin films of noncollinear Weyl antiferromagnet Mn_3Sn
U_0164	Takashi Koretsune	X-ray magnetic circular dichroism arising from the magnetic dipole moment in Mn_3Sn and Mn_3Ir
U_0188	Noriyuki Hatakenaka	Analogue Hawking radiation with reverse Doppler shift in Josephson metamaterial transmission lines
U_0196	Hanshen Tsai	Large Hall Signal due to electrical Switching at Mn_3Sn/heavy metal multilayers
U_0102	Rihito Kondo	Octupole polarization switching in Mn_3Sn probed by magnetoresistance through magnetic tunnel junction with different sizes

Session 2 (Day 3, February 15)

Registration No.	Presenter	Title
U_0009	Soma Takemori	Unconventional non-Hermitian superfluid phase transition induced by the interplay between exceptional manifolds and van Hove singularity
U_0012	Hongchao Li	Yang-Lee Zeros, Semicircle Theorem, and Nonunitary Criticality in BCS Superconductivity
U_0024	Erkang Wei	Magnetic damping of epitaxial Fe/Pt multilayer characterized by time-resolved magneto-optical Kerr effect
U_0034	Takahiro Anan	Time-dependent Gutzwiller simulation of Floquet topological superconductivity
U_0037	Junta Iguchi	Bulk photovoltaic effect in antiferromagnet: Role of collective spin dynamics
U_0050	Yutaro Tanaka	Anomalous crystal shapes induced by topological phases protected by crystal symmetries
U_0060	Liyang Liao	Valley-Selective Phonon-Magnon Scattering in Magnetoelastic Superlattices
U_0072	Haruto Yoshimochi	Multi-step topological transitions among meron and skyrmion crystals in a centrosymmetric magnet
U_0077	Manabu Sato	Ideal Spin-Orbit-Free Dirac Semimetal RE_8CoX_3 (RE = rare earth elements, X = Al, Ga, or In)
U_0078	Yutaro Tsushima	Cr-doping effects on the magneto-thermoelectric properties of the antiferromagnetic Weyl semimetal Mn_3Sn thin film
U_0079	Nico Budai	Magnetic imaging by the anomalous Nernst effect using atomic force microscopy
U_0085	Weiguang Gao	Nonlocally Detected Diffusive Orbital Current Generated via Orbital Edelstein Effect
U_0088	Hikaru Fukuda	Thermal fluctuation induced anisotropic topological Hall effect in pyrochlore-type $Eu_2Mo_2O_7$
U_0089	Nanse Esaki	Theoretical studies of the electric field induced thermal Hall effect in the quantum dimer magnets $XCuCl_3$ (X = Tl, K)
U_0094	Ryotaro Suda	Development of Quantum Sensing under High Pressure: Visualization of Pressure and Magnetic Field
U_0100	Tonghua Yu	Topological interface states of magnetic half-Heusler materials
U_0104	EMK Ikball Ahamed	Dynamic control of spin-wave by electric field in rare-earth iron functional oxide thin films
U_0110	Junhyeok Jeong	The doping-dependent evolution of superconductivity in the multilayered cuprate
U_0147	Kotaro Tanaka	Nonlinear optical response of a s-wave superconductor NbN with using terahertz vortex beam

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Registration No.	Presenter	Title
U_0114	Takumi Chida	Calculation of the Green function and ionization energy based on the transcorrelated method
U_0125	Takuya Matsumoto	Magneto transport properties of Ferri magnet $GdCo_2$
U_0126	Shunichiro Kurosawa	Magneto-Thermoelectric Effect in Epitaxial Thin Film of Topological Nodal Plane Kagome Ferromagnet Fe_3Sn
U_0128	Hidetoshi Kosaki	Pump-probe spectroscopy of NiFe film grown on chiral antiferromagnet Mn_3Sn
U_0132	Kaiki Shibata	Theoretical study on anomalous Nernst effect enhanced at van Hove singularity in two-dimensional materials
U_0135	Md. Shamim Sarker	Dynamic Redox Reaction-Driven Electrically Tunable Magnon FET
U_0138	Ryota Ono	Electrical control of skyrmionic lattice in centrosymmetric non-frustrated insulating magnets
U_0139	Takumi Fukushima	Supercurrent Distrubution on Superonducting Quasicrystals
U_0140	Hiroki Yoshida	Shift current responses of a two-dimensional system approaching the Weyl semimetal phase
U_0144	Keisuke Sobue	Long spin diffusion length in epitaxial Pt wires.
U_0145	Shunya Chiba	Spin-orbit and orbital torque in (W or Cr)/CoFeB/MgO stacks for SOT-MRAM application
U_0151	Shunsaku Nagasawa	Developing Innovative Hard X-ray Spectral Imager for Studies of Particle Acceleration in Solar Flare
U_0152	Tomohiro Fujimoto	Observation of Spin Hall Conductivity Spectrum of GaAs in the Terahertz Frequency Regime
U_0153	Hiroto Saito	Efficient calculation of magnetocrystalline anisotropy using symmetry-aware Wannier Hamiltonian
U_0155	Hiroyuki Sudo	3D Topological insulator in a strong magnetic field
U_0159	Lin Huang	Antiferromagnetic magnonic charge current generation via ultrafast optical excitation
U_0162	Yuki Yamazaki	Magnetic Raman spectroscopy for Majorana edge states in Kitaev spin liquids
U_0167	Po-Kuan TUNG	Effect of Y-doping on the high-temperature antiferromagnet $Ba_5Co_5ClO_{13}$
U_0184	Fang Lyu	Development of low temperature relaxation-method calorimetry for small samples
U_0185	Hang Su	NbReSi: a noncentrosymmetric superconductor with large upper critical field and nodeless superconductivity

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Registration No.	Presenter	Title
U_0187	Masaki Roppongi	Development of a circular polarized microwave cavity and microwave Hall effect measurements
U_0189	JIWON YANG	Defect density effect on scattering times in a γ-$A_{l2}O_3/SrTiO_3$ 2DEG
U_0192	Gakuto Kusuno	Polarized Raman study of antiferromagnet FePS3
U_0195	Kouki Mikuni	Magnetic resonance frequencies in a two-sublattice ferrimagnet with a magnetic compensation point
U_0197	Takachika Isomae	Extremely Large Magnetoresistance and Anisotropic Transport in Multipolar Kondo System $PrTi_2Al_{20}$
U_0198	Yuki Kobayashi	Composition variation behavior of galvanomagnetic effect in GdFe collinear coupled ferrimagnetic alloy thin films
U_0213	Takaharu Kaji	Quantum Phases of Helium Three on Graphite Plated with Bilayer of HD
U_0170	Michele Dall'Arno	Data-driven self-calibration of quantum circuits
U_0051	Kentaro Ueda	Colossal negative magnetoresistance in field-induced Weyl semimetal of magnetic half-Heusler compound
U_0112	Kunihiko Yamauchi	DFT Calculations on Spin-Splitting Phenomena in Altermagnetic $CaCrO_3$
U_0119	Takuya Matsuda	Intense photoexcitation exposes 2000-times higher-mobility carriers in correlated kagome antiferromagnet Mn_3Sn
U_0133	Vu Thi Ngoc Huyen	Topological degeneracy and emergence of transport phenomena in antiferromagnetics
U_0141	Junyeon Kim	Current-induced orbital polarization at Cu/Oxide interface
U_0143	Nguyen Thi Phuong Thao	Microscopic Mechanism of Magnetic Stability in Monolayer Transition-Metal Dihalides
U_0191	Hena Das	Anisotropic thermal expansion phenomena in Ca2RuO4 type systems
U_0194	Hikaru Takeda	Thermal Hall effect in the antiferromagnetic Skyrmion lattice
U_0122	Yuki Hibino	Energy-Efficient SOT-MRAMs Using Spin Hall Effect of Amorphous W-Ta-B Alloys
U_0109	Hitoshi Kubota	Observation of magnetization process in artificial honeycomb spin ice through tunnel magnetoresistance effect
U_0300	Xufeng Kou	Large Spin Orbit Coupling Systems for Emerging Physics and Spintronics Applications