物性研究所セミナー

標題：Unraveling Principles of Living Phenomena via Physical Approaches
日時：2023 年 9 月 14 日(木) 午前 10 時～
場所：On Line and Lecture Room A632 , ISSP（Hybrid）
講師：Tetsuya J. Kobayashi
所属：Institute of Industrial Science the University of Tokyo: Universal Biology Institute, UTokyo
要旨：

Understanding living systems through the lens of physical principles is a cornerstone objective of biophysics. Historically, physicists have delved into this challenge by exploring a myriad of biological phenomena. As a consequence, a rich collection of theoretical methodologies has been developed. While these techniques often have their origins in other physics domains, they also have evolved in distinct ways in biology. In this talk, we demonstrate how theoretical methods, being common in physics, can be used to analyze biological phenomena, such as evolutionary processes and intracellular reactions. We place specific emphasis on the techniques of path integral method and thermodynamic structure, highlighting that these aren't merely computational tools but that they enable us to elucidate fundamental aspects of living phenomena.

標題：Progress towards Cavity-Based X-ray Free-Electron Lasers
日時：2023 年 9 月 20 日(水) 午後 3 時～午後 4 時
場所：物性研究所本館 6 階 第 5 セミナー室（A615）
講師：Rachel Margraf
所属：Stanford University and SLAC National Accelerator Laboratory, Menlo Park, USA
要旨：

Current X-ray Free-Electron Lasers (XFELs), like SACLA at RIKEN, or the LCLS at SLAC, are single-pass X-ray light sources, where electrons produce X-rays as they pass through an undulator line just once. The exponential gain of X-ray power in an XFEL occurs as X-rays act on the electron beam, causing it to form microbunches at the X-ray wavelength. In a single-pass SASE (self-amplified spontaneous emission) XFEL, the X-rays which initiate this process come from noise in the beam, and thus X-rays produced by current XFELs are transversely coherent, but longitudinally noisy. In proposed cavity-based XFELs (CBXFELs) [1], by contrast, X-rays are returned by mirrors from the end of the undulator line to the beginning, so a strong X-ray pulse is used to seed the FEL process on subsequent passes. Future X-ray light sources based on CBXFELs can thus produce longitudinally coherent pulses with improved spectral brightness, and promise to be more stable than current XFELs. This talk will give an overview of CBXFELs and show recent progress towards constructing them, including demonstration of a 14 meter hard X-ray cavity at LCLS.

標題：Formation of quantum critical 2D Bose gas in the honeycomb antiferromagnet YbCl3
日時：2023 年 9 月 21 日(木) 午後 3 時～午後 4 時
場所：物性研究所本館 6 階 第 5 セミナー室（A615）
講師：Dr. Yosuke Matsumoto
所属：Max Planck Institute for Solid State Research
要旨：

Bose-Einstein condensation (BEC) is a quantum phenomenon, where a macroscopic number of bosons occupy the lowest energy state and acquire coherence at low temperatures. It manifests itself not only in superfluid 4He and dilute atomic gases but also in quantum magnets[1]. In three-dimensional (3D) antiferromagnets, an XY-type long-range ordering (LRO) near a magnetic-field-induced transition to a fully polarized state (FP) has been successfully described as a BEC in the last few decades. An attractive extension of the BEC in 3D magnets is to make their two-dimensional (2D) analogue. In a strictly 2D system, BEC cannot take place due to the presence of a finite density of states at zero energy, but instead, a Berezinskii-Kosterlitz-Thouless (BKT) transition may emerge. In a realistic quasi-2D magnet consisting of stacked 2D magnets, a small but finite interlayer coupling stabilizes marginal LRO and BEC, but such that 2D physics is still expected to dominate. A few systems were reported to show such 2D-limit BEC, but at very high magnetic fields that are difficult to access.

YbCl3 is a pseudo-spin 1/2 honeycomb Heisenberg antiferromagnet with intra-layer coupling of J ~ 5 K and exhibits a transition to a FP state at an in-plane saturation field Hs = 5.93 T [2-4]. Here, we demonstrate that the LRO right below Hs is a BEC but close to the 2D-limit, marginally stabilized by an extremely small interlayer coupling $J_{\perp}$ of the order of 10-5J [5]. At the quantum critical point Hs, we capture 2D-limit quantum fluctuations as the formation of a highly mobile, interacting 2D Bose gas in the dilute limit. A much-reduced effective boson-boson repulsion compared with that of a prototypical 3D system indicates the presence of a logarithmic renormalization of interaction, which is unique to 2D. Thus, the old candidate for a Kitaev quantum spin liquid, YbCl3, is now established as an ideal arena for a quantum critical BEC in the 2D limit. We will further discuss the possible BKT characteristics in the thermal fluctuations. This work has been done in collaboration with S. Schnierer, J. Bruin, J. Nuss, P. Reiss, G. Jackeli, K. Kitagawa and H. Takagi.

[1] V. Zapf, M. Jaime, and C. D. Batista, Rev. Mod. Phys. 86, 563 (2014).
[2] G. Sala et al., Phys. Rev. B 100, 180406(R) (2019).
[3] J. Xing et al., Phys. Rev. B 102, 014427 (2020).
[4] G. Sala et al., Nat Commun 12, 171 (2021).
[5] Y. Matsumoto et al., arXiv:2207.02329.

標題：Closest Wannier functions to a given set of localized orbitals
日時：2023 年 9 月 22 日(金) 午後 4 時～午後 5 時
場所：物性研究所 6 階第 5 セミナー室（A615）及び Hybrid 開催
講師：尾崎 泰助
所属：東京大学物性研究所
要旨：

Wannier functions (WFs) play a pivotal role in analyzing the electronic structures of real materials and in furthering electronic structure methods, alongside density functional theory (DFT) and other electronic structure theories [1]. In this talk, I will present a novel method to calculate the closest Wannier functions (CWFs) to a given set of localized

guiding functions, such as atomic orbitals, hybrid atomic orbitals, and molecular orbitals, based on minimization of a distance measure function [2]. It is shown that the minimization is directly achieved by a polar decomposition [3] of a projection matrix via singular value decomposition, making iterative calculations and complications arising from the choice of the gauge irrelevant. The disentanglement of bands is inherently addressed by introducing a smoothly varying window function and a greater number of Bloch functions, even for isolated bands. In addition to atomic and hybrid atomic orbitals, we introduce embedded molecular orbitals in molecules and bulks as guiding functions, and demonstrate that the Wannier interpolated bands accurately reproduce the targeted conventional bands of a wide variety of systems including Si, Cu, the TTF-TCNQ molecular crystal, and a topological insulator of Bi2Se3 [4]. We further show the usefulness of the proposed method in calculating effective atomic charges. These numerical results not only establish our proposed method as an efficient alternative for calculating WFs, but also suggest that the concept of CWF can serve as a foundation for developing novel methods to analyze electronic structures and calculate physical properties.

[1] N. Marzari and D. Vanderbilt, Phys. Rev. B 56, 12847 (1997).
[2] T. Ozaki, arXiv:2306.15296.
[3] K. Fan and A. J. Hoffman, Proc. Amer. Math. Soc. 6, 111 (1955).
[4] https://www.openmx-square.org/cwf/

標題：Spin-lattice glass transition without quenched disorder on pyrochlore magnet
日時：2023 年 9 月 22 日(金) 午後 1 時～午後 2 時
場所：物性研究所 6 階第 4 セミナー室（A614）及び Hybrid 開催
講師：光元 亨汰
所属：東京大学生産技術研究所
要旨：

In the community of magnetism, it has been generally assumed that spin glass transitions occur due to frustration from random interactions, so-called quenched disorder. However, disorder-free spin glass transitions are observed experimentally in a geometrically frustrated pyrochlore magnet. So far, there are no convincing theoretical explanations for the mechanism of this spin glass transition without quenched disorder.

A recent experiment suggested that lattice distortions play important roles in the spin glass transition on the prototypical geometrically frustrated spin glass Y2Mo2O7[1]. This lattice distortion results from the selection of the electron orbitals[2], i.e., Jahn-Teller distortion. Being motivated by the experiment, we introduced a model which includes not only the spin degrees of freedom but also the lattice distortions as dynamical variables. This model doesn't include any quenched disorder, but both spins and lattice distortions are geometrically frustrated. We performed extensive numerical simulations for the model and analyzed a mean-field model which can be solved exactly in the infinite dimension.

In the numerical simulations[3], we found that spins and lattice distortions simultaneously freeze at a common finite temperature. Both degrees of freedom do not exhibit any long range order below the freezing temperature. In the mean-field analysis in the spherical limit using the replica method[4], we found that replica symmetry breaking appears only in the phase where both spins and lattice distortions are frozen, implying that a complex free-energy landscape is induced by the spin-lattice coupling

[1] P. M. Thygesen, et al., Phys. Rev. Lett. 118, 067201 (2017)

[2] KM, C. Hotta and H. Yoshino, Phys. Rev. Research 4, 033157 (2022)
[3] KM, C. Hotta and H. Yoshino, Phys. Rev. Lett. 124, 087201 (2020)
[4] KM and H. Yoshino, Phys. Rev. B 107, 054412 (2023)

標題：有機ラジカル系を活用したスピン配列制御による量子現象の開拓
日時：2023 年 9 月 29 日(金) 午前 11 時～午後 0 時
場所：On Line
講師：山口 博則 准教授
所属：大阪公立大学大学院理学研究科
要旨：

量子スピン系の研究は、1980 年代以降、無機物を主体として精力的に取り組まれてきた。一方で無機物の対称性・安定性の制約により、未だに現実のモデル物質の多様性は乏しい。私たちは、有機ラジカル系の設計性・多様性に着目して独自の物質開発に試みてきた。物理と化学の複合領域においてスピン配列制御という新たな技術を開拓し、量子スピン系の物質開発にブレイクスルーをもたらしている。有機分子特有の低対称性と分子軌道の柔軟性により、これまでに報告されていなかった新たな量子現象を実現することができている。本セミナーでは、強磁場を活用した量子物性の検証を中心に、最近の研究成果を紹介する。

標題：溶液散乱による生体高分子の構造・ダイナミクス・システムの研究
日時：2023 年 10 月 4 日(水) 午後 3 時～午後 4 時
場所：物性研究所本館 6 階 第 2 セミナー室（A612）
講師：杉山 正明
所属：京都大学複合原子力科学研究所
要旨：

溶液散乱（小角散乱）は、溶液中のタンパク質の様態を観測することにおいて有用な手法である。この手法は、他の構造測定法や分光法に比べると時間空間分解能は劣るが、溶液中の全ての分子の時間・集団平均のデータを与える。この特徴を生かして、講演者は高純度（＝単分散）試料を用いた生体高分子の構造・ダイナミクス研究と複数分子が織り成す生体系の動態研究を進めている。

今回は、最もシンプルな生体時計であるシアノバクテリアの Kai タンパク質を取り上げて、揺らぎを含む巨大な 3 者複合体の構造解析と概日振動を起こす系の構成分子の動態解析を紹介する。いずれの研究においても、X 線小角散乱に加えて試料重水素化を用いた中性子小角散乱が解析において決め手となるデータを与えている。この点も踏まえ、時間が許せば福井県のもんじゅ跡地に建設が決まっている新試験研究炉プロジェクトの概要等も紹介した。

標題：Highly transmissive InSb nanoflag Josephson junctions
日時：2023 年 10 月 5 日(木) 午後 3 時
場所：物性研究所本館 6 階 第 2 セミナー室（A612）
講師：Dr. Stefan Heun
所属：NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Italy
要旨：

High-quality III–V narrow bandgap semiconductor materials with strong spin–orbit coupling and large Landé g-factor provide a promising platform for next-generation applications in the field of high-speed electronics, spintronics,

and quantum computing. InSb offers a narrow bandgap, high carrier mobility, and small effective mass and, thus, is very appealing in this context. In fact, this material has attracted tremendous attention in recent years for the implementation of topological superconducting states. An attractive pathway to obtain two-dimensional (2D) InSb layers is the growth of freestanding single-crystalline InSb nanoflags [1].

We have demonstrated fabrication of ballistic Josephson-junction devices based on these InSb nanoflags with Ti/Nb contacts that show a gate-tunable proximity-induced supercurrent and a sizable excess current [2]. The devices show clear signatures of subharmonic gap structures, indicating phase-coherent transport in the junction and a high transparency of the interfaces.

The high quality of the devices has allowed the observation of the Josephson diode effect in these Josephson junctions [3]. Indeed, when an in–plane magnetic field is applied, the devices are driven into a non-reciprocal transport regime, where we observe an asymmetry between the positive and negative critical current. The asymmetry is modulated by the angle between the in-plane field and the current direction, and strongly depends on temperature. Our experimental evidence demonstrates that these devices can work as Josephson diodes, with dissipation–less current flowing in only one direction.

Under microwave irradiation, we observe half-integer Shapiro steps that are robust to temperature, suggesting their possible nonequilibrium origin [4]. Our results demonstrate the potential of ballistic InSb nanoflags Josephson junctions as a valuable platform for understanding the physics of hybrid devices and investigating their nonequilibrium dynamics.

References

[1] I. Verma et al., ACS Appl. Nano Mater. 4 (2021) 5825−5833.
[2] S. Salimian et al., Appl. Phys. Lett. 119 (2021) 214004.
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[4] A. Iorio et al., Phys. Rev. Res. 5 (2023) 033015.

This research activity was partially supported by the FET-OPEN project AndQC (H2020 Grant No. 828948) and by PRIN MUR (Grant No. 2022PH852L).

標題：MOF における Kitaev 磁性体と強磁場誘起相の探索
日時：2023 年 10 月 13 日(金) 午前 11 時～午後 0 時
場所：On Line
講師：石川 孟　助教
所属：金道研究室
要旨：

MOF(金属有機構造体)は金属と有機配位子がネットワーク構造を形成する物質で、ガス吸着や触媒といった機能物性を示す材料として注目を集めている。遷移金属が興味深い幾何学格子を組むことがあり磁性研究の対象としても興味深いが、その観点からはあまり注目されていない。我々はプロトン伝導体として知られている MOF において、遷移金属が三次元ハニカム格子を組むことに着目した。類似の状況は物性研の理論グループにおいて研究され、Kitaev スピン液体の実現が提案されているが[1]、我々の知る限り実験的な研究は行われていない。我々は対象物質の試料を合成し、パルス強磁場領域まで物性測定を行い、温度や磁場変化に伴い様々な相が現れることを発見した[2]。セミナーではこの物質の磁性を紹介し、MOF において Kitaev 磁性体を探索することの利点や今後の展望を議論する。時間があれば関連する有機無機ハイブリッド磁性体の強磁場磁化過程についても紹介した。

[1] M. G. Yamada et al. Phys. Rev. Lett. 119, 057202 (2017).
[2] H. Ishikawa et al. under review.

標題：Quantum solids, hidden patterns, and dark-field x-ray microscopy at APS-U
日時：2023 年 10 月 17 日(火) 午前 10 時 30 分～午前 11 時 30 分
場所：物性研究所本館　大講義室（A632）/ ZOOM 同時開催
講師：Zahir Islam
所属：X-ray Science Division, Advanced Photon Source, Argonne National Laboratory
要旨：

Novel opportunities are emerging at third-generation synchrotron x-ray facilities ushered in by their coherence upgrade as well as at x-ray free-electron-laser facilities worldwide. These sources afford researchers to go far beyond 'average' reciprocal-space investigations by x-ray diffraction, which has been a mainstay methodology of research on quantum materials. In this talk contemporary research efforts to exploit multitude of contrasts accessible via diffraction germinating a novel imaging modality called dark field x-ray microscopy (DFXM) [1] and its outlook at future sources (e.g., APS-U) are presented. DFXM technique provides real-space images of 'mesoscale' features [2-4] that give rise to deviations from an average order. In DFXM, a diffracted beam from an ordered material is used to form a two-dimensional full-field image of these features by passing it through an x-ray objective lens. Mesoscale information is encoded on a crystal Bragg peak, a super-lattice (e.g., due to charge, magnetic, or orbital order) peak, or an epitaxial-film peak, in the form of intensity contrasts, revealing an incisive real-space picture over many orders-of-magnitude in length scales. In this talk, some recent illustrative cases are reviewed along with state-of-the-art technical advances of this methodology. Examples include a role of local actors across a magneto-structural phase transition [2], a set of imaging studies of three dimensionally ordered charge-density waves in superconductors, a search for long-range modulations below a nematic transition, and an exploration of neomorphism in metal-insulator-transition based memristor devices. Finally, new directions to leverage increased coherence in DFXM studies are sketched.

Work performed at the Advanced Photon Source was supported by the DOE, under Contract No. DE-AC02-06CH11357

▸ References

[1] Zhi Qiao, Xianbo Shi, Peter Kenesei, Arndt Last, Lahsen Assoufid, and Zahir Islam, "A large field-of-view high-resolution hard x-ray microscope using polymer optics", Rev. Sci. Instrum. 91, 113703 (2020); https://doi.org/10.1063/5.0011961
[2] Jayden Plumb, Ishwor Poudyal, Rebecca L. Dally, Samantha Daly, Stephen D. Wilson, Zahir Islam, "Dark Field X-ray Microscopy Below Liquid-Helium Temperature: The Case of NaMnO2," Materials Characterization 204, 113174 (2023).
[3] Elliot Kisiel, Ishwor Poudyal, Peter Kenesei, Mark Engbretson, Arndt Last, Rourav Basak, Ivan Zaluzhnyy, Uday Goteti, Robert Dynes, Antonino Miceli, Alex Frano, Zahir Islam, "Full-Field Nanoscale X-ray Diffraction-Contrast Imaging using Direct Detection", arXiv:2212.07303 physics.ins-det cond-mat.mes-hall (2022).
[4] Omar Abulshohoud, Ishwor Poudyal, Jessica McChesney, Zhan Zhang, Zhi Qiao, Ulrich Welp, Zahir Islam, "A general method for multiresolutional analysis of mesoscale features in dark-field x-ray microscopy images", arXiv:2210.15757 cond-mat.mtrl-sci (2022).

標題：Seeking Robust Quantum Bit Memory: Topological and Fracton Order
日時：2023 年 10 月 20 日(金) 午後 4 時～午後 5 時
場所：物性研究所本館 6 階 第 5 セミナー室 (A615)
講師：Han Yan
所属：ISSP, the Univ. of Tokyo
要旨：

I will introduce the topological and fracton order from the quantum information perspective. That is, how a qubit can be stored, and manipulated in these models, and how robust they are. I will also introduce our work on fracton orders in hyperbolic space, which shows new behaviors of fractionalized particles, and partially improved protection of qubits stored there.

Based on work: arXiv:2306.07203

標題：A tale about discovery of quantum E8 particles in quantum material BaCo2V2O8
日時：2023 年 10 月 24 日(火) 午後 2 時～午後 3 時
場所：物性研究所本館 6 階 第 3 セミナー室 (A613)
講師：Prof. Jianda Wu
所属：Shanghai Jiao Tong University
要旨：

Exotic thermodynamics and excitations can emerge in the vicinity of a quantum phase transition. In the talk, I will first detailedly discuss the unique quantum criticality for the Grüneisen ratio in the transverse field Ising chain (TFIC) [1]. The unique quantum criticality of the Grüneisen ratio then serves as a smoking gun to identify the underlying TFIC universality observed in quasi-1D antiferromagnetic materials BaCo2V2O8 with transverse field applied along [110] direction [2]. From systematic quantum critical analysis for the effective model of the material SrCo2V2O8 [3], we confirm the material with field applied along [100] direction can also accommodate the TFIC universality with much weaker magnetic field [4]. Furthermore, when the quantum critical point of the TFIC is perturbed by a longitudinal magnetic field, it was predicted that its massive excitations are precisely described by the exceptional E8 Lie algebra. Here we first discuss non-trivial low temperature local spin dynamics of the exotic E8 model [5]. Then we show an unambiguous experimental realization of the E8 physics in the material BaCo2V2O8, via nuclear magnetic resonance and inelastic neutron scattering measurements, and detailed theoretical analysis [6 – 9]. The large separation between the masked 1D and 3D quantum critical points of the system allows us to identify, for the first time, the full 8 single-particle E8 excitations, various multi-E8-particle states [7, 8] as well as the dispersion of E8 particles [9] in the spin excitation spectrum. Our results open new experimental and theoretical routes for exploring the dynamics of quantum integrable systems and physics beyond integrability, and thus bridge key physics in condensed matter and statistical field theory.

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[3] H. Zou, R. Yu & J. Wu, J. Phys.: Condens. Matter. 32, 045602 (2020).
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[5] J. Wu, M. Kormos, Q. Si, Phys. Rev. Lett. 113, 247201 (2014).

[6] X. Wang, H. Zou, K. Hódsági, M. Kormos, G. Takács & J. Wu, Phys. Rev. B 103, 235117 (2021).
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[8] H. Zou, Y. Cui, X. Wang, Z. Zhang, J. Yang, G. Xu, A. Okutani, M. Hagiwara, M. Matsuda, G. Wang, G. Mussardo, K. Hódsági, M. Kormos, Z. Z. He, S. Kimura, R. Yu, W. Yu, J. Ma & J. Wu, Phys. Rev. Lett. 127, 077201 (2021).
[9] X. Wang, K. Puzniak, K. Schmalzl, C. Balz, M. Matsuda, A. Okutani, M. Hagiwara, J. Ma, J. Wu, & B. Lake, submitted (2023).

標題：Magnetic frustration in octahedral lattices: emergent complexity in applied field
日時：2023 年 10 月 30 日(月) 午後 4 時～午後 5 時
場所：物性研究所本館 6 階 第 5 セミナー室 (A615)
講師：Mike Zhitomirsky
所属：IRIG, CEA, Grenoble, France; IMR, Tohoku Univ.
要旨：

Geometrically frustrated magnets typically consist of either triangular or tetrahedral blocks of magnetic ions. A novel frustrated motif is provided by octahedral blocks. Magnetic ions form a corner-sharing network of octahedra in antiperovskites and Mn3X intermetallics, whereas edge-shared octahedra emerge for the J1–J2 spin model on a face-centered cubic (fcc) lattice for a special ratio of two exchanges J2/J1 = 0.5. We illustrate an emergent complex behavior of octahedral antiferromagnets by studying the magnetization process of the classical J1–J2 fcc antiferromagnet. Up to eight different phases exist in magnetic field including two fractional magnetization plateaus at M/Msat = 1/3 and 2/3. An unusual twist in the quantum order-by-disorder effect due to magnon-magnon interactions is also found for the nearest-neighbor fcc antiferromagnet in zero field.

標題：理論・ナノサイエンス合同セミナー
日時：2023 年 10 月 31 日(火) 午後 3 時～午後 5 時
場所：物性研究所本館 6 階 第 5 セミナー室 (A615)
要旨：

Coherent few-electron states in interacting low-dimensional systems

Lecturer : Dr. Flavio Ronetti
Affiliation : Centre de Physique Théorique, CNRS

The on-demand generation of single- and few-electron states in mesoscopic systems has opened the way to the fascinating field of electron quantum optics (EQO), where individual fermionic quantum states are manipulated with methods borrowed from photonic quantum-optical experiments. In this framework, a train of Lorentzian voltage pulses represents one of the most reliable experimental protocol to inject coherent single-electronic states, known as Levitons, into ballistic channels of meso-scale devices. These fascinating results open up the possibility of investigating the dynamics of single-electron states in one-dimensional systems. Indeed, it is well known that, in contrast with photons, electronic systems are drastically affected by electron-electron correlations. In this talk, we will discuss how the propagation of Levitons is affected by the presence of correlations between electrons and how these effects can be exploited in potential applications for quantum electronics and quantum information.

Lecture2 15:50~

Andreev-like reflection in the Pfaffian fractional quantum Hall effect

Lecturer：**大橋　良伊 氏**

Affiliation：**大阪大学基礎工学研究科**

In the edge of a fractional quantum Hall state and an integer quantum Hall state point contact, Andreev-like reflection occurs similar to superconducting Andreev reflection [1]. This reflection scenario is due to a mismatch between fractional charge ve and normal charge e. Recently, Andreev-like reflection has been detected for the Laughlin fractional quantum Hall system [2]. We study tunnel transport between the edge of a Pfaffian fractional quantum Hall state and that of an integer quantum Hall state [3]. Based on the duality argument between strong and weak tunnelings, we find that Andreev-like reflection appears for a strong tunneling regime with fractional charge e/4. We also evaluate charge conductance in the weak and strong tunneling regimes for the low-voltage limit.

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Lecture3 16:25~

Pairing symmetry of Josephson current flowing through a spin-polarized quantum anomalous Hall insulator

Lecturer：**仲井　良太 氏**

Affiliation：**九州大学理学研究院**

Superconducting proximity effect for topological materials works effectively in engineering topological electronic structures [1]. However, this is not the case for quantum (anomalous) Hall insulators as time-reversal partners of the chiral edge modes are absent. In this talk, I will discuss a Josephson junction through a spin-polarized quantum anomalous Hall insulator [2], which is robust against the proximity effect and hence is a highly opaque conductor of spin-singlet Cooper pairs. We showed that supercurrent in this system is carried by Cooper pairs with (i) equal-spin triplet, (ii) a combination of even and odd frequencies, and (iii) a finite momentum (the Fulde-Ferrell state). Experimentally, these features can be examined by the Josephson effect. Specifically, we showed that the triplet spins can be detected by the interface-magnetization dependence of the equilibrium phase difference, and the Cooper-pair momentum can be detected by the width dependence of the critical current.

[1] L. Fu and C. L. Kane, Phys. Rev. Lett. 100, 096407 (2008); A. R. Akhmerov, J. Nilsson, and C. W. J. Beenakker, Phys. Rev. Lett. 102, 216404 (2009).

[2] RN, K. Nomura, and Y. Tanaka, Phys. Rev. B 103, 184509 (2021).

標題：Magnetic, superconducting, and topological surface states on FeTeSe superconductor

日時：2023 年 11 月 10 日(金) 午後 1 時 30 分～午後 2 時 30 分

場所：物性研究所本館 6 階 第 5 セミナー室（A615）及び Hybrid 開催

講師：Dr. Igor Zaliznyak

所属：Brookhaven National Laboratory

要旨：

The idea of employing non-Abelian statistics for error-free quantum computing ignited interest in recent reports of topological surface superconductivity and Majorana zero modes (MZMs) in iron chalcogenide superconductor FeTe 1-x Se x (x=0.45). An associated puzzle, however, is that the topological features and superconducting properties are not observed uniformly across the sample surface. Understanding and practical control of these electronic inhomogeneities present a prominent challenge for potential applications. In this work, we combine neutron scattering, scanning angle-resolved photoemission spectroscopy (ARPES), and microprobe composition and resistivity measurements to characterize the electronic state of Fe 1+y Te 1−x Se x . We establish a phase diagram in which the superconductivity is observed only at sufficiently low Fe concentration, in association with distinct antiferromagnetic correlations, while the coexisting topological surface state occurs only at sufficiently high Te concentration. We find that FeTe 0.55 Se 0.45 is located very close to both phase boundaries, which explains the inhomogeneity of superconducting and topological states. Our results demonstrate the compositional control required for use of topological MZMs in practical applications.

References:

[1] Y. Li, N. Zaki, V. O. Garlea, A. T. Savici, D. Fobes, Z. Xu, F. Camino, C. Petrovic, G. Gu, P. D. Johnson, J. M. Tranquada, I. A. Zaliznyak. Magnetic, superconducting, and topological surface states on Fe 1+y Te 1−x Se x . Nature Materials 20, 1221–1227 (2021).

[2] J. M. Tranquada, G. Xu, I. A. Zaliznyak. Magnetism and superconductivity in Fe 1+y Te 1−x Se x . Journal of Physics: Condensed Matter 32, 374003 (2020).

標題：多モード・多色ナノ解析に向けた 色収差無しで軟X線を 20 nm 集光する超小型ミラー/Shining a light on the superconductivity in CsV3Sb5-derived kagome metals

日時：2023 年 11 月 20 日(月) 午後 1 時～午後 3 時

場所：On Line

講師：島村 勇徳 氏　ZHONG Yigui（钟 益桂）氏

所属：物性研究所　原田研究室　岡﨑研究室

要旨：講師（1）：島村 勇徳 氏

題目：多モード・多色ナノ解析に向けた色収差無しで軟X線を 20 nm 集光する超小型ミラー

概要：

光の波長に応じて集光素子の焦点位置が変化する現象を色収差と呼ぶ。色収差は像を滲ませるため、高分解能観察において克服する必要がある。しかし、色収差が無い集光素子（集光鏡）を高開口数で作製することは、軟 X 線域（0.3 – 2 keV）では難しい。

従来、X 線集光鏡の設計は最長 1 m で低開口数だった。作製精度・視野の観点から、長さ 2 mm と極めて短い設計が高開口数に有利なことを示し[1, 2]、超小型ミラーを提案した。本講演では、その形状を数 nm 精度で作製する手法の開発[3]、及び集光サイズ 20.4 nm の達成（色収差無しとして軟X線域最小）を扱う。また、超小型ミラーが可能にした軟X線多色ナノプローブを使い、軟X線吸収・蛍光顕微鏡を神経細胞に応用した例[1,4]を示す。

[1] T. Shimamura et al., accepted at Nat. Commun. (2023). doi:10.21203/rs.3.rs-2876568/v1

[2] T. Shimamura et al., Opt. Express 31, 38132 (2023).

[3] T. Shimamura et al., Rev. Sci. Instrum. 94, 043102 (2023).

[4] T. Shimamura et al., under review at Spectrochim. Acta B. (2023).

講師（2）：ZHONG Yigui（钟 益桂）氏

題目：Shining a light on the superconductivity in CsV3Sb5-derived kagome metals

概要：

The newly discovered kagome superconductors AV3Sb5 (A=K, Rb, Cs) provide a promising platform for investigating the interplay between band topology, electronic order, and lattice geometry [1-2]. Despite extensive research efforts on this system, the nature of the superconducting ground state remains elusive and a consensus on the electron pairing symmetry has not been achieved so far. During the long-term research of superconductors, angle-resolved photoemission spectroscopy (ARPES) has been proven to be a powerful tool to directly measure the superconducting gap in the momentum space. In this talk, I will report our ultrahigh resolution and low-temperature ARPES studies on two exemplary CsV3Sb5-derived kagome superconductors — Cs(V0.93Nb0.07)3Sb5 with the appearance of charge order and Cs(V0.86Ta0.14)3Sb5 without charge order in the normal state [3]. Our new updated results of the superconducting gap in pristine CsV3Sb5 will be also presented in this talk. Additionally, I will present our studies of electronic kinks in the band structure [4] and temperature- dependent muon spin relaxation rate. Finally, the possible pairing mechanisms for these kagome superconductors based on these results will be discussed.

[1] T. Neupert, M. Denner, J.-X. Yin et al., Nat. Phys. 18, 137 (2021).
[2] J.-X. Yin, B. Lian, M.Z. Hasan, Nature 612, 647 (2022).
[3] Y. Zhong, J. Liu, X. Wu et al., Nature 617, 488 (2023).
[4] Y. Zhong, S. Li, H. Liu et al, Nat. Commun. 14, 1945 (2023)

標題：Theoretical studies on dichroism in X-ray absorption and photoemission spectroscopy of nanomaterials

日時：2023 年 11 月 20 日(月) 午後 1 時 30 分

場所：物性研究所本館 6 階 第 5 セミナー室 (A615)

講師：Prof. Peter Krüger

所属：Chiba University, Materials Science Department

要旨：

I present some recent studies on the electronic and geometrical structure of nanomaterials using polarization-dependent X-ray absorption (XAS) and photoemission spectroscopy and first-principles calculations.
First, the crystal phase transformations observed in titanium dioxide nanoribbons, going from NaHTi3O7 titanate over the TiO2–B to the anatase phase is analyzed using polarization-dependent XAS in scaning transmission X-ray microscopy [1,2]. The oxygen K-edge spectra of the three phases display marked differences which are well reproduced with DFT calculations. Strong linear dichroism is observed in single nanoribbons, reflecting preferential O-2p to Ti-3d bond orientation in the low symmetry crystal structures. A simple bond counting model is developed which semi-quantitatively accounts for the major dichroic effect. It is shown how the crystal orientation in the nanoparticles can be inferred from the polarization-dependent XAS spectra.

Next, I present theoretical advances in the theory of angle resolved photoemission spectroscopy (ARPES). For ARPES of graphite, we reproduce and explain the strong circular dichroism (CD) in angular distribution and show that final state photoelectron scattering plays a substantial role in the formation of the dichroic signal [3].

Finally I discuss the CD at the photoelectron diffraction peaks (the so-called Daimon effect) that was recently observed in ARPES of Ni and Cu at the 2p-3d resonance. The intensity of the CD is strongly binding-energy-dependent and indicates reversed angular momentum transfer from the photon to the electron in some cases. To explain these findings we have developed a theory of resonant ARPES, combining atomic multiplet and multiple scattering theory [4] and we obtained excellent agreement with the data.

[1] Individual Titanate Nanoribbons Studied by 3D-resolved Polarization Dependent X-ray Absorption Spectra Measured with Scanning Transmission X-ray Microscopy, Xiaohui Zhu, Adam Hitchcock, Carla Bittencourt, Polona Umek and Peter Krüger, J. Phys. Chem. C 119, 24192-24200 (2015).

[2] Chemical Bond Modification upon Phase Transformation of TiO2 Nanoribbons Revealed by Nanoscale X-ray Linear Dichroism, P. Krüger, M. Sluban, P. Umek, P. Guttmann and C. Bittencourt, J. Phys. Chem. C 121, 17038-17042 (2017).

[3] Observation and theory of of strong circular dichroism in angle-resolved photoemission from graphite, Peter Krüger and Fumihiko Matsui, J. Electron Spectrosc. Related Phenom. 258, 147219 (2022).

[4] Theory of circular dichroism in angle-resolved resonant photoemission from magnetic surfaces,, Ryunosuke Sagehashi, Godeung Park and Peter Krüger, Physical Review B 107, 075407 (2023).

標題：Defining a quantum active particle using a non-unitary quantum walk

日時：2023 年 11 月 28 日(火) 午後 4 時～午後 5 時

場所：Seminar Room 5 (A615), Hybrid

講師：Manami Yamagishi

所属：Department of Physics, The University of Tokyo; RIKEN

要旨：

The main aim of the present work is to define an active matter in a quantum framework and investigate difference and commonalities of quantum and classical active matters. We here propose a truly deterministic quantum active-matter model with a non-unitary quantum walk as minimal models of quantum active matter [1]. We aim to reproduce similar results that Schweitzer et al. (1998) obtained with their classical active Brownian particle [2]. With our quantum active particle, we successfully observe that the movement of the quantum walker becomes more active in a non-trivial way as we increase the non-Hermiticity parameter, which is similar to the classical active Brownian particle (Schweitzer et al., 1998). Meanwhile, we also observe three unique features of quantum walks, namely, ballistic propagation of peaks in one dimension, the walker staying on the constant energy plane in two dimensions, and oscillations originating from the resonant transition between the ground state and excited state both in one and two dimensions. I also plan to explain more technical sides of quantum walks in higher dimensions [3] and with interactions [4] if time allows.

References

[1] M. Yamagishi, N. Hatano and H. Obuse, arXiv:2305.15319 (2023).

[2] F. Schweitzer, W. Ebeling and B. Tilch, Phys. Rev. Lett. 80, 5044 (1998).

[3] M. Yamagishi, N. Hatano, K.-I. Imura and H. Obuse, Phys. Rev. A 107, 042206 (2023).

[4] M. Yamagishi, N. Hatano, A. Nishino, F. Nori and H. Obuse, in preparation.

標題：機能性材料ホイスラー合金の磁性と電子状態
日時：2023 年 11 月 29 日(水) 午後 1 時 30 分～午後 2 時 30 分
場所：On Line
講師：梅津 理恵 教授
所属：東北大学金属材料研究所
要旨：

ホイスラー合金は、応用に直結する様々な機能を有することで知られている。本セミナーでは、磁性形状記憶特性を有する Ni 基合金とスピントロニクスの分野で注目されている、ハーフメタル型電子状態を有する Co 基合金の磁気特性について紹介する。前者においては、パルス磁場を組み合わせた X 線磁気円二色性実験を行い、磁場誘起構造相変態の様子を観測した。後者においては、バルク単結晶試料を育成し、共鳴非弾性 X 線散乱や光電子分光による電子状態の観測に成功している。ライフイベントを乗り越えながらの研究生活についても触れた。

標題：Microwave transport in topological edge states
日時：2023 年 12 月 4 日(月) 午後 3 時～午後 4 時
場所：物性研究所本館 6 階 第 5 セミナー室 (A615)
講師：Erwann Bocquillon
所属：Institute for Physics II, University of Cologne, Germany
要旨：

Research on helical edge states in 2D topological insulators is motivated by exotic fundamental physics, prospects for robust topological quantum computation and novel spinorbitronics. However, topological transport is often visible only on short distances. On larger distances, microwave techniques offer powerful tools to investigate the origin of this fragility, as well as the possibility to generate and control excitations in the topological edge states.

In this talk, we report on first results on microwave transport in HgTe 2D topological insulators [1, 2, 3]. Via microwave capacitance spectroscopy [1], we highlight the response of the edges. We find that they have a rather large density of states but host mobile carriers, while bulk carriers are present as puddles but are drastically slowed down in the gap. This suggests that edge states can be selectively addressed on timescales over which bulk carriers are frozen. In a second study [3], we measure the velocity of edge states in both the quantum Hall and quantum spin Hall regime. We observe low plasmon velocities corresponding to large transverse widths, which we ascribe to the prominent influence of charge puddles forming in the vicinity of edge channels. Both works point towards the prominent role of charge puddles in the topological gap, which probably constitute a hurdle on the way to clean and robust edge transport.

C. Dartiailh et al., Phys. Rev. Lett. 124, 076802 (2020).
Gourmelon et al., Phys. Rev. Res. 2, 043383 (2020).
Gourmelon et al., Phys. Rev. B 108, 035405 (2023).