物性研究所セミナー

標題：赤外パルス偏光波形整形技術とその展開
日時：2025 年 7 月 3 日(木) 午後 1 時～午後 3 時
場所：物性研究所本館 6 階 第一会議室（A636）
講師：神田 夏輝
所属：理化学研究所　光量子工学研究センター
要旨：

近年の中赤外域光源の高強度化・短パルス化に伴い、固体中での極端非線形光学や超高速な物性制御の研究が盛んに行われるようになってきた。我々はこれまでにテラヘルツと中赤外の間に位置するマルチテラヘルツ帯における時間領域分光の開発を行い[1,2]、逆回り二色円偏光パルスなどの電場ベクトル軌跡を制御したパルスの発生も実現した[3]。この技術を用いることで、物質との相互作用において過渡的な対称性の操作が可能になると期待される。また、電場ベクトル軌跡を制御したパルス光の概念は中赤外高強度光源と組み合わせて高次高調波の円偏光制御への展開も考えられる。講演ではこれまでの成果と今後の展望について述べた。

[1] NK et al., Opt. Express 29, 3479 (2021).
[2] NK et al., Nano Lett. 22, 2358 (2022).
[3] K. Ogawa, NK et al., Nat. Commun. 15, 6310 (2024).

標題：Quantum reservoir probing: exploration of quantum many-body physics via computational performance
日時：2025 年 7 月 4 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）及び Online（Hybrid）
講師：小林 海翔
所属：東京大学 工学系研究科 物理工学専攻
要旨：

Over the past decade, the integration of quantum information science with quantum many-body physics has yielded new insights into quantum phenomena. In this talk, we further advance this synergy by focusing on the computational performance of quantum systems, beyond traditional quantum information metrics.

Our starting point is quantum reservoir computing (QRC) [1, 2], a quantum machine learning paradigm in which the natural dynamics of a quantum system (“quantum reservoir”) serve as a feature map for information processing. A key aspect of QRC is that training is limited to the classical post-processing stage, while the quantum reservoir itself remains fixed. Therefore, the computational performance of QRC directly reflects the characteristics of the quantum many-body system acting as the reservoir.

By inverting this relationship, we introduce quantum reservoir probing (QRP) [3,4], a novel framework to explore quantum many-body physics through its computational capabilities. We demonstrate the applicability of QRP by investigating two key phenomena: (i) information propagation, where QRP discerns distinct propagation dynamics reflecting the system’s inherent nature [3], and (ii) quantum phase transitions, where enhanced critical fluctuations leave clear signatures in the computational performance [4]. Our results highlight the versatility of QRP for probing a plethora of exotic quantum many-body phenomena.

[1] K. Fujii and K. Nakajima, Phys. Rev. Applied 8, 024030 (2017).
[2] K. Kobayashi, K. Fujii, N. Yamamoto, PRX Quantum 5, 040325 (2024).
[3] K. Kobayashi and Y. Motome, arXiv:2308.00898 (to appear in SciPost Phys.).
[4] K. Kobayashi and Y. Motome, Nat. Commun. 16, 3871 (2025).

標題：X 線レーザーによるエキゾチックな物質状態の生成と応用
日時：2025 年 7 月 9 日(水) 午後 2 時～午後 3 時
場所：物性研究所本館 6 階 第 4 セミナー室（A614）
講師：井上 伊知郎
所属：新領域物質系専攻
要旨：

X 線と物質との相互作用は非常に弱く、X 線計測は試料の状態を変えない「非破壊測定」として広く利用されてきた。しかし、X 線自由電子レーザーの登場によって、物質中の電子励起や緩和と同程度の時間幅（フェムト秒）を持つ高強度 X 線パルスが利用可能となり、この前提は必ずしも成立しない状況が生まれている。本発表では、X 線レーザーが引き起こす物質中の電子状態や構造の超高速変化[1]について紹介した。また、この過渡的な状態変化を利用した X 線光学素子の開発についても触れた[2]。最後に、大強度 X 線照射と無損傷計測を両立させるために行っている、アト秒 X 線自由電子レーザーを用いた研究[3]についても紹介した。

[1] I. INOUE ET AL., PRL 126, 117403 (2021), PRL 128, 223203 (2022), PRL 131, 163201 (2023), OPTICA 12, 530 (2025).
[2] I. INOUE ET AL, PRL 127, 163903 (2021), T. M. LINKER ET AL., ACCEPTED TO NATURE.
[3] I. INOUE ET AL., OPTICA 12, 309 (2025), ARXIV:2506.07968. J. YAN ET AL., NATURE PHOTON. 18, 1293 (2024).

標題：Large-scale first-principles DFT calculations on metallic nanoparticle catalysts
日時：2025 年 7 月 18 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：Dr. Ayako Nakata
所属：National Institute for Materials Science (NIMS)
要旨：

Controlling the shape and size of metallic nanoparticles (NPs) is a crucial challenge in catalyst development. Miniaturization of the NPs can enhance catalytic activity and reduce the usage of noble metal, while extremely small particles (e.g., sub-nano particles) have distinct differences electronic structures and stabilities compared to larger “nano” particles.

First-principles density functional theory (DFT) calculation is a powerful tool for investigating atomic and electronic structures of materials, but conventional DFT applications have been limited to small systems, comprising tens to hundreds of atoms due to significant computational costs. In this study, using our large-scale DFT calculation method in the CONQUEST code [1], we investigate the size and site dependencies of atomic and electronic structures in metallic NPs of a few nanometers in diameter, which is comparable to particle sizes in practical applications.

We optimized the structures of the NPs with diameters ranging from 0.5 nm (13 atoms) to 5.5 nm (3871 atoms) and found that the electronic structure of the NPs becomes metallic when particle sizes become larger than about 2 nm. Clear site dependence of local density of states was found in large NPs, particularly for atoms at the vertex and in the

(111) face. To analyze massive data calculated for large systems efficiently, we have proposed a method for quantitatively and systematically comparing differences in local electronic structures in large systems by statistical analysis [2]. With this method, we analyzed the interactions between the NPs and the oxide substrate, summarizing which atom in the NP is affected by the substrate how largely. The relationship between the analyzed results and the catalytic properties were also investigated.

[1] A. Nakata, D. R. Bowler, T. Miyazaki, J. Phys. Soc. Jpn. 91, 091011 (2022).

[2] S. Li, T. Miyazaki, A. Nakata, Phys. Chem. Chem. Phys. 26, 20251 (2024).

標題：A universal model of Floquet operator Krylov Space

日時：2025 年 7 月 24 日(木) 午前 10 時～午後 0 時

場所：物性研究所本館 6 階 第 5 セミナー室 (A615)

講師：Aditi Mitra

所属：New York University

要旨：

Recursion methods such as Krylov techniques map complex dynamics to an effective non-interacting problem in one dimension. We show that the operator Krylov space for Floquet dynamics can be mapped to the dynamics of an edge operator of the one-dimensional Floquet inhomogeneous transverse field Ising model (ITFIM), where the latter, after a Jordan-Wigner transformation, is a Floquet model of non-interacting Majorana fermions, and the couplings are angles that we dub the Krylov angles. We present an application of this showing that a moment method exists where given a stroboscopic autocorrelation function, one can construct the corresponding Krylov angles, and from that the corresponding Floquet-ITFIM. Consequently, when no solutions for the Krylov angles are obtained, it indicates that the autocorrelation is not generated by unitary dynamics. We relate our approach to those developed using orthogonal polynomials on the unit circle. We present several applications such as the study of stable m-period dynamics as well as decaying dynamics in chaotic systems.

標題：キラリティが駆動する有機超伝導体の巨大スピン軌道物性

日時：2025 年 7 月 29 日(火) 午後 3 時～午後 4 時

場所：物性研究所本館 6 階 大講義室 (A632)

講師：佐藤　拓朗　氏

所属：分子科学研究所

要旨：

スピン軌道相互作用が空間反転対称性の破れと結びつくとき、物質中の電磁気応答に非相反性が誘起される。このスピン軌道相互作用に基づいた解釈は、ポーラーな系の非相反応答をよく記述できるが、同じく反転対称性を破る系であるキラルな空間群に対しては、その非相反応答を説明しきれないことが分かってきている。キラルな有機分子中で観測されたキラル誘起スピン選択性（Chirality-induced spin selectivity : CISS）はその典型例であり、スピン軌道相互作用が無視できるほど小さい有機系であるにも関わらず、無機系を凌駕するほどの巨大なスピン偏極流が生成される[1]。このことから、キラリティに固有な有効スピン軌道相互作用の存在が強く示唆されているものの、それを定量的に検証した実験は非常に限られている。

本セミナーではキラルな結晶構造を有する有機超伝導体 κ-(BEDT-TTF)$_2$Cu(NCS)$_2$ における非相反電荷応答に着目し、キラリティによって駆動される巨大有効スピン軌道相互作用を実証した実験結果を紹介する[2]。CISS 効果一般の現状を整理しつつ、有機キラル超伝導における最新の実験と今後の展望について議論した。

[1] R. Naaman, et al., Nat. Rev. Chem. 3, 250 (2019).
[2] T. Sato, et al., Phys. Rev. Res. 7, 023056 (2025).

標題：Fast and high-fidelity transfer of edge states via dynamical control of topological phases and effects of dissipation
日時：2025 年 7 月 30 日(水) 午後 2 時～午後 3 時
場所：物性研究所本館 6 階 第 5 セミナー室 (A615)
講師：Hideaki Obuse
所属：Hokkaido University
要旨：

Topological edge states are robust against symmetry-preserving perturbations and noise, making them promising for quantum information and computation, particularly in topological quantum computation through braiding operations of Majorana quasiparticles. Realizing these applications requires fast and high-fidelity dynamic control of edge states. In this work, we theoretically propose a high-fidelity method for transferring topological edge states by dynamically moving a domain wall between two regions of different topological numbers in one dimension. This method fundamentally relies on Lorentz invariance and relativistic effects, because the moving the domain wall at a constant speed is described by a mass term with the uniform linear motion in the Dirac equation. We demonstrate effectiveness of our method in transferring edge states with high fidelity using a one-dimensional quantum walk with two internal states, which is feasible with current experimental technology. We also investigate how bit-flip and dephasing dissipation to environment affects transfer efficiency. Remarkably, bit (dephasing) dissipation does not affect the efficiency at slow (fast) transfer limits, which can be explained by the relativistic effects on the edge states.

Reference:
Y. Kanda, Y. Fujisawa, K. Yakubo, N. Kawakami, and H. Obuse, arXiv:2505.16606

標題：強磁場が切り開くレーザー核融合プラズマの新展開
日時：2025 年 7 月 31 日(木) 午前 11 時～午後 0 時
場所：Online
講師：藤岡 慎介 教授
所属：大阪大学レーザー科学研究所
要旨：

核融合プラズマと磁場は不可分の関係である。国際熱核融合実験炉 ITER に代表される磁場閉じ込め方式では、強力な磁場を「かご」として用い、高温・高密度プラズマを長時間保持してエネルギーを取り出す。一方、レーザー核融合(ICF)の世界では、プラズマ圧が磁場圧をはるかに上回るため、長らく磁場は重要視されてこなかった。しかし近年、米国 NIF での点火・燃焼実証を契機に、電子やアルファ粒子のエネルギー輸送を強磁場で制御し、熱閉じ込めを強化する「磁化レーザー核融合(Magnetized ICF)」が脚光を浴びている。磁場により熱損失が抑制されれば、レーザーエネルギーからプラズマへの変換効率が飛躍的に向上し、フュージョンエネルギー実用化への道筋を大きく短縮できる可能性がある。本講演では、強磁場とレーザー核融合プラズマの相互作用を軸に、点火領域で期待される磁場効果の理論的背景、パルス電流コイルやレーザー駆動磁場などによる強磁場発生技術の進展、熱閉じ込めとアルファ粒子閉じ込めの実験的検証などの、最新の研究動向を概観した。強磁場がもたらす次世代フュージョンエネルギー開発に向けた新たな展望と課題を共有した。

標題：Simulation and Applications of Acoustoelectric Effects in SAW Devices

日時：2025 年 8 月 4 日(月) 午前 10 時～午後 0 時

場所：物性研究所本館 6 階 第 5 セミナー室 (A615)

講師：Prof. Wei Luo

所属：華中科技大学

要旨：

The acoustoelectric effect refers to the electron-phonon interactions between the electronic charge carriers in the semiconductor and the SAW phonons, which results in acoustic velocity change and attenuation. This effect plays a crucial role in various applications within SAW devices, including gas sensing, optoelectronic detection, and integrated devices for surface acoustic wave filtering and amplification. This lecture provides a detailed overview of the research conducted by our team in the realm of acoustoelectric effects, encompassing precise modeling techniques, the design and fabrication of high-performance SAW gas and UV sensors, and the development of a novel, highly sensitive PT gas sensor based on engineering acoustic wave losses. Finally, we offer insights into potential future directions and trends in this research field.

Biography

Wei Luo received the B.S. degree in electronic science and technology and the Ph.D. degree in microelectronics and solid state electronics from the Huazhong University of Science and Technology, Wuhan, China, in 2004 and 2009, respectively. From 2009 to 2012, he was a Postdoctoral Fellow in the Department of Electrical and Information Engineering, Huazhong University of Science and Technology. In 2012, he joined the School of Optics and Electronic Information, Huazhong University of Science and Technology. From 2014 to 2016, he was a visiting scholar in the University of Michigan, Ann Arbor, USA. He is currently a Professor and assistant Dean of the School of Integrated Circuits, Huazhong University of Science and Technology. His research interests include high-frequency acoustic MEMS sensors for application in harsh environment, intelligent microsystems.

標題：Misfit compounds as a platform for engineering doping, charge density waves and Ising superconductivity

日時：2025 年 8 月 18 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)及び Online

講師：Prof. Tristan Cren

所属：Institut des NanoSciences de Paris, Sorbonne University and CNRS, Paris, France

要旨：

In the current quest of superconducting materials which combine two-dimensionality and strong spin-orbit coupling, transition metal dichalcogenides (TMD) misfit materials appear as extremely promising. They are constituted by sandwiching rocksalt layers, such as LaSe, and TMD layers, such as $NbSe_2$. TMD misfits are a new platform that allows achieving unprecedented high doping levels in TMD materials [1, 2]. We will show how we have succeeded adjusting finely the chemical potential over a very wide range in $NbSe_2$ using a Pb_xLa_{1-x} rocksalt, and how this can be used for stabilizing several charge density waves orders (2 × 2, 3 × 3) and tuning the superconducting transition temperature over a wide range [2]. Superconductivity in these compounds exhibits a huge in-plane critical field which is much higher than the paramagnetic limit [3, 4, 5] due to a very strong Ising spin-orbit coupling. We will show some hint of non-conventional pairing in misfit compounds.

References:

[1] Raphaël T. Leriche et al., Advanced Functional Materials 31, 2007706 (2021).

[2] L. Zullo, G. Marini, T. Cren, M. Calandra, Nano Letters 23, 6658 (2023).

[3] P. Samuely et al., Physical Review B 104, 224507 (2021).

[4] T. Samuely et al., Physical Review B 108, L220501 (2023).

[5] L. Engström, L. Zullo, T. Cren, A. Mesaros, P. Simon, arXiv:2504.20775 (2025).

標題：三次元ベクトル強磁場とFIB微細加工を用いた物性研究

日時：2025年8月22日(金) 午前11時～午後0時

場所：Online

講師：木俣 基 研究副主幹

所属：日本原子力研究開発機構

要旨：

磁場の角度を精密に制御することは、磁性体や超伝導体における異方的応答の解明に極めて重要です。私たちはこれまで、東北大学金属材料研究所における定常強磁場に二軸回転機構を組み込み、20 テスラを超える強磁場を任意の方向に印加できる「三次元ベクトル強磁場」環境を構築してきました。この装置を活用し、さまざまな量子物質の研究を展開しています。

本セミナーでは、その応用例として、スピン三重項超伝導体 UTe2 における角度依存磁気抵抗振動(AMRO)測定の結果を紹介しました。AMRO は、擬二次元伝導体において面間方向の電気抵抗が磁場の角度に対して周期的に変化する現象であり、これを結晶の全方位で測定することで、フェルミ面の詳細な形状を明らかにできます。UTe2 の実験では、こうした手法を用いて、擬二次元的なフェルミ面の構造を精密に決定することに成功しました。

さらに時間が許せば、FIB (Focused Ion Beam) による微細加工技術を活用し、単結晶微細デバイスで測定した非相反磁気抵抗の角度依存性からフェルミ面のスピン偏極状態（スピンテクスチャ）を明らかにした研究や、25T-CSM 用の希釈冷凍機の導入状況など、最新の技術的取り組みについてもご紹介しました。

標題：Quantum Dynamics in Complex Molecular Systems & Chiral Phonons in the CISS Effect

日時：2025年9月12日(金) 午後2時～午後3時

場所：物性研究所本館6階 第5セミナー室 (A615)

講師：Dr. Hanggai Nuomin

所属：Duke University

要旨：

Part I: Quantum Dynamics in Chemical Systems

As chemistry increasingly probes ultrafast and complex processes, capturing quantum effects such as coherence and entanglement becomes crucial. I introduce new computational methods—building on tensor network algorithms, path integral resummation, and quantum master equations that enable accurate simulations of quantum dynamics in electronically and environmentally rich settings. Applications to electron and energy transfer in *multi-acceptor* systems illustrate how molecular structure and environmental coupling shape chemical reactivity, with implications for catalysis, materials, and biology.

Part II: Chiral Phonons and the CISS Effect

The chiral induced spin selectivity (CISS) effect produces spin polarization without strong spin-orbit coupling, raising the question of its microscopic origin. I present a tight-binding helical model showing how directional current flow can generate chiral phonons carrying angular momentum. An analysis of the Berry potential in a current-carrying Born-Oppenheimer Hamiltonian shows that these current-induced chiral phonons mirror the symmetry properties of the CISS effect. This connection suggests that chiral phonons may contribute to the observed spin selectivity.

標題：Nonlinear vibrational spectroscopy of aqueous surfaces and interfaces using spectral maps
日時：2025 年 9 月 24 日(水) 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 Online（Hybrid）
講師：Prof. Amalendu Chandra
所属：東京科学大学
要旨：

We will present our recent theoretical work on nonlinear vibrational spectroscopy of aqueous surfaces and interfaces using a combination of techniques involving molecular dynamics simulations, quantum chemical calculations and theories of nonlinear vibrational spectroscopy. The calculations are based on use of spectral maps for various quantities that are obtained from quantum chemical calculations considering electric field as the primary order parameter. Specifically, we will present calculations of one-dimensional and two-dimensional vibrational sum frequency generation (1D-VSFG and 2D-VSFG) spectroscopy of aqueous surfaces and interfaces of different kinds [1-3]. The results of various dynamical features of the 2D-VSFG spectra will be connected to various underlying dynamical modes of the hydrogen-bonded and non-hydrogen-bonded OH groups of surface and interfacial water [3]. Some preliminary results will also be discussed using machine learning methods where, in addition to electric field, other structural descriptors are also considered for obtaining the spectral maps [4].

References:
1.B. Das and A. Chandra, Phys. Chem. Chem. Phys. 24 , 7374-7386 (2022).
2.B. Das and A. Chandra, ChemPhysChem 24, e202200604 (2022).
3.R. Malik, Abhilash Chandra, B. Das and A. Chandra, J. Phys. Chem. B 127, 10880-10895 (2023).
4.S. Poddar, R. Malik, B. Das and A. Chandra, to be published.

標題：重い電子系物質で観測された室温でも安定な磁気形状記憶効果
日時：2025 年 10 月 2 日(木) 午後 1 時 30 分～午後 2 時 30 分
場所：東北大学金属材料研究所強磁場超伝導材料研究センター会議室での対面および Online
講師：三宅 厚志 准教授
所属：東北大学金属材料研究所
要旨：

重い電子系物質 CeSb2 において、室温でも安定な磁気形状記憶効果を発見した[1]。
この物質は強磁場を印可することで磁化容易軸が切り替わり、その記憶が室温でも保持される。
さらに、磁場印加方向を変えることで容易軸方向を繰り返し切り替えることができる。
この変化は磁歪や偏光顕微鏡観察から結晶軸の変化を伴うことも明らかになった。
磁気異方性が大きな Ce 原子が特徴的な「パンタグラフ」構造を有しており、Ce 原子間距離を保ったままパンタグラフの伸縮により軸切り替えが起きていると考えられる。
PrSb2 や NdSb2 でも同様の現象を観測している。

本セミナーでは、それらの結果を紹介するとともに、類似の記憶効果を有するメタ磁性形状記憶合金やRCu2 (R: 希土類)と比較を行い、RSb2 での磁気形状記憶効果を議論した。

[1] A. Miyake et al., J. Phys. Soc. Jpn. 94, 043702 (2025).

標題：マグノン誘起ブリルアン散乱における光渦発生の観測
日時：2025 年 10 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 2 セミナー室 (A612)
講師：久富 隆佑
所属：京都大学化学研究所 材料機能化学研究系
要旨：

光は物質と相互作用することによりその性質を変化させます。とくに物質中の素励起による光の性質変化は、ブリルアン散乱として理解されています。今回我々は強磁性体中の素励起マグノンが誘起するブリルアン散乱によって、光の持つ軌道角運動量が変化し光渦が発生することを見出しました [1]。さらに、その変化が光と物質全体の角運動量保存を満たすように発生していることも確認しました。本セミナーでは、本現象の発見の経緯と詳細について説明しました。

[1] R. Hisatomi et al., arXiv:2505.03152

標題：From submission to publication in a high impact journal – discussion with a Nature Nanotechnology editor
日時：2025 年 10 月 16 日(木) 午前 9 時 25 分～午前 9 時 50 分
場所：物性研究所本館 6 階 大講義室(A632)
講師：Benjamin Heinrich
所属：Nature Nanotechnology
要旨：

This seminar provides insights into the world of academic publishing from the perspective of Benjamin Heinrich, a senior editor at Nature Nanotechnology, one of the leading journals in the field of nanoscience and nanotechnology. The session discusses the scope and breath of Nature Nanotechnology and aims to demystify the publishing process, from manuscript submission over peer review to publication.
The discussion will cover:

- Criteria for article selection: Understand what editors (or researchers beyond your immediate field) look for in an article.
- Defining novelty: All research is new, but the degree of novelty varies. What are critical factors for publication in high-impact journals?
- Path to editorship: The qualifications and experiences that can help you become an editor.
- A day in the life: A look at the typical daily tasks and responsibilities of a Nature Nanotechnology editor.
- Questions and informal discussion are appreciated.

標題：Manipulation of single polarons at atomic scale
日時：2025 年 10 月 23 日(木) 午前 11 時～
場所：物性研究所本館 6 階 第 6 セミナー室（A616）& Online
講師：Prof. Ying-Shuang Fu
所属：Huazhong university of science and technology, China
要旨：

Short Biography:

Ying-Shuang Fu is a physics professor affiliated with Huazhong University of Science and Technology in China. He earned his Ph.D. from the Institute of Physics, Chinese Academy of Sciences in 2008. From 2008 to 2014, he worked as a postdoctoral researcher at Hamburg University and RIKEN, respectively. Since 2014, he has been a professor in the School of Physics at Huazhong University of Science and Technology. He has focused on the study of correlated states in low-dimensional quantum systems using molecular beam epitaxy and spectroscopic- imaging scanning tunneling microscopy under ultralow-temperature and high-magnetic-field conditions. During the recent five years, he has published 36 papers as a corresponding author, including Phys. Rev. Lett. (1), Phys. Rev. X (1), PNAS (1), Nat. Commun. (7), JACS (5), etc.

Abstract:

Polarons are composite quasiparticles comprising an excess electron or hole surrounded by local lattice distortions−an effect driven by anti-adiabatic displacements of adjacent ions arising from strong electron-phonon coupling. These quasiparticles play a pivotal role in a broad range of physicochemical processes, influencing charge transport, superconductivity, colossal magnetoresistance, surface reactivity, thermoelectricity and multiferroicity, among others. Traditionally, polarons have been studied using ensemble-averaged techniques. Investigating single polarons at the atomic scale is critical to unraveling the correlated electron-phonon mechanisms underlying polaron formation, which however remains a longstanding challenge. In this talk, I will present our recent research on the discovery and manipulation of individual polarons in monolayer atomic and molecular crystals. Our works encompass single polarons and multipolarons, and have identified several novel polaron types, including van der Waals polarons in Sb_2O_3, spin-flip polarons in MnTe, and Jahn-Teller polarons in molecular magnet. Additionally, we have leveraged polaron manipulation to uncover new correlated states, including a Hubbard-type Coulomb blockade effect and a phason-polaron effect in one-dimensional nanowires. Our studies open a new avenue for exploring polarons and are expected to inspire efforts to harness polaron behavior for tailoring diverse physicochemical processes.

標題：From pairs to quadruplets: a new class of electron condensates
日時：2025 年 10 月 23 日(木) 午後 4 時～午後 5 時
場所：物性研究所本館 4 階セミナー室（A424）
講師：Dr. Ilaria Maccari
所属：ETH Zürich
要旨：

Recent experimental results have revealed signatures of unconventional electron condensates that go beyond the standard Cooper pair paradigm.

In multicomponent and unconventional superconductors, the proliferation of topological phase excitations can indeed destroy the phase coherence among Cooper pairs while preserving coherence among pairs of Cooper pairs. The resulting beyond-mean-field phases are characterized by a four-electron order parameter and accompanied by spontaneous symmetry breaking.

In this talk, I will discuss recent theoretical and experimental advances on electron quadruplet condensates in multiband superconductors and twisted bilayer graphene, and present new results on possible electron quadruplets emerging from a nematic superconducting ground state.

標題：Exploring the Magnetism of Hexagonal Perovskites
日時：2025 年 10 月 29 日(水) 午後 2 時～午後 3 時
場所：物性研究所本館 6 階 第 5 セミナー室 (A615)
講師：Professor Patrick Woodward
所属：Department of Chemistry and Biochemistry, Ohio State University
要旨：

Hexagonal perovskites share the ABX3 stoichiometry and cation coordination environments of the more widely studied “cubic” perovskite family, but unlike their cubic counterparts, hexagonal perovskites feature face-sharing linkages between metal-centered octahedra. When transition-metal ions occupy these sites there can be sufficient overlap of d-orbitals on neighboring metals to form metal-metal bonds. In such cases the clusters of face-sharing octahedra can be treated as having an electronic structure akin to a molecule. In this talk I will discuss the structure, bonding, and magnetism of various oxide and chloride hexagonal perovskites. Depending on the identity of the cations that occupy the octahedral holes and the nature of the anion, various degrees of metal-metal bonding occur. Furthermore, by controlling the composition we can magnetically isolate the face-sharing clusters to accentuate the molecule-like behavior. In such instances the frustrated triangular network that is characteristic of hexagonal perovskites can lead to exotic low temperature magnetic phenomena, such as quantum spin liquids. Alternatively, we can the face-sharing clusters can be linked by octahedra containing magnetic ions, in which case strong superexchange interactions lead to high-temperature magnetic ordering.

標題：Low-energy optical sum-rules
日時：2025 年 10 月 29 日(水) 午後 1 時～午後 2 時
場所：物性研究所本館 6 階　第 6 セミナー室（A616）
講師：Dr. Dan Mao
所属：Paul Scherrer Institut　(PSI)
要旨：

The superconducting properties of materials are inherently rooted in the quantum mechanical wavefunctions of electrons and the interactions that govern their behavior. However, our understanding of superconductivity in the regime of extremely narrow electronic bands remains elusive due to the lack of a comprehensive microscopic theory. I will present a novel theoretical framework for computing a critical fundamental characteristic – the superconducting phase stiffness – without relying on the conventional Bardeen-Cooper-Schrieffer (BCS) approximation, which is not applicable to narrow-band superconductivity. Without prior knowledge of the underlying pairing symmetry, our method can give an upper bound on the superconducting phase stiffness, which is related to the superconducting transition temperature in 2D.

Furthermore, we find a relationship between the superconducting phase stiffness and the optical absorption, which leads to the discovery of the so-called projected optical sum rule, which puts fundamental constraints on how much light the system can absorb. I will discuss two types of projected optical sum rule: the f-sum rule and the Souza-Wilkens-Martin sum rule. While the connection between quantum geometry and optical absorption is well-established in the non-interacting limit, whether an analogous connection can be established for the low-energy projected optical sum rules in strongly interacting systems remains an open question.

From the study of twisted bilayer graphene and fractional Chern insulators, we obtain non-perturbative results on the projected optical sum rules, pointing out the intriguing interplay between the “many-body” quantum geometry, symmetry and topology.

標題：Ferroic behavior of 2D materials
日時：2025 年 10 月 31 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 Online（Hybrid）
講師：Salvador Barraza-Lopez **氏**
所属：University of Arkansas & ISSP, The University of Tokyo
要旨：

Until a decade ago, people believed that ferroelectricity should not exist on materials below a certain critical thickness (of a few nanometers) due to depolarization fields induced at exposed faces. Furthermore, most known ferroelectrics were insulators. Nevertheless, members of a family of binary orthorhombic (layered) materials were known to be antipolar (i.e., they have intrinsic electric dipoles changing orientation among consecutive layers). The ground state of a single monolayer of those materials is degenerate. Structural degeneracies give rise to domains and structural transformations at finite temperature [1,2] and those materials are 2D ferroelectrics [3]. This field became further invigorated by the observation that intrinsic electric dipoles can be created by rotating successive monolayers, and also by the observation of ferroelectricity in elemental materials [4]. Currently, the field is gearing toward (i) the creation of multiferroic 2D materials by the adequate stacking of 2D magnets [5], (ii) the discovery of novel ferroic orders and their intercouplings, (iii) and toward coupling ferroic orders to other orders such as superconductivity.

[1] M. Mehboudi, et al., Nano Letters **16**, 1704 (2016).
[2] M. Mehboudi, et al., Physical Review Letters **117**, 246802 (2016).
[3] S. Barraza-Lopez, et al., Reviews of Modern Physics **93**, 011001 (2021).
[4] G. G. Naumis, S. A. Herrera, S. P. Poudel, H. Nakamura, S. Barraza-Lopez. Reports on Progress in Physics **87**, 016502 (2024).
[5] S. P. Poudel, et al., Physical Review B **107**, 195128 (2023).

標題：亜酸化銅励起子の基礎物性の理論計算：「歪誘起エネルギーシフト」と「スピン転換機構」
日時：2025 年 11 月４日(火) 午後１時～午後２時
場所：物性研究所本館６階 第２セミナー室（A612）
講師：灰田 悠希
所属：東京大学大学院工学系研究科物理工学専攻
要旨：

亜酸化銅(Cu2O)単結晶中の励起子ボース・アインシュタイン凝縮(BEC)は、多体ボース粒子の開放系における BEC を理解するための格好の舞台である。2022 年に、希釈冷凍機による冷却を通じて温度 100 mK 台の 1s パラ励起子集団が生成され、歪トラップ中で安定な BEC が実現された[1]。この際、1s-2p 吸収イメージングにより、凝縮体自体の信号が初めて観測された。現在、1s-2p 吸収イメージの時間分解測定を通じて、凝縮体の形成・緩和ダイナミクスを調べる実験が進行中である。しかし、このような実験から励起子 BEC の本質に迫るには、励起子の基礎物性の徹底的な理解が前提となる。この観点から、私は以下２テーマに取り組んできた。

1. 取得される吸収イメージをもとに系を正確に把握するには、歪トラップ中の1s-2p吸収スペクトルの位置依存性の評価が必要である。まず、任意歪下の任意の励起子状態を扱える理論的枠組みを構築した。次に、変形ポテンシャルの値を決定した。これにより、任意歪下の 2p 励起子のエネルギー・波動関数を計算できるようになり、歪トラップ中の 1s-2p 吸収スペクトルの位置依存性の評価が可能になった。
2. パラ励起子は、光生成可能なオルソ励起子からのスピン反転(オルソ-パラ転換)により生成する。オルソ-パラ転換は約 50 年前から知られており[2]、複数のモデルが提案されてきたが、どのモデルもフォノンによりスピンが反転することを説明できなかった。私は「バンドの非放物性」に着目することで、音響フォノンによりスピン反転が起きることを明らかにした。また、転換レートの実験値をほぼ定量的に説明できた。

[1] Y. Morita, K. Yoshioka and M. Kuwata-Gonokami, Nat. Commun. 13, 5388 (2022).
[2] F. I. Kreingold and V. L. Makarov, Fiz. Tverd. Tela 15, 1307 (1973) [Sov. Phys.–Solid State 15, 890 (1973)].

標題：2D in-plane ferroelectric semiconductors and ultra-narrow lateral heterostructures
日時：2025 年 11 月 5 日(水) 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：Kai Chang **氏**
所属：北京量子信息科学研究院
要旨：

2D ferroelectric and ferromagnetic materials discovered in the recent decade have opened a new era for the construction and tuning of heterostructures for electronic and computing applications. Semiconducting 2D ferroic materials are especially interesting as their electronic structures deeply intertwine with the spontaneously broken symmetry, thus new freedoms like spin, orbital and electronic valleys are generated. In this talk, I will mainly focus on the development of group-IV monochalcogenide 2D ferroelectric semiconductors, from the discovery, ferroelectric mechanism, spin-valley correlation in the electronic structures, to the recently realized 2D lateral heterostructures and superlattices. The most interesting advancement is the design and in situ molecular beam epitaxial growth of a new type of valley-controlled ferroelectric sandwich heterostructure that is analogous to the classical spin valve, in which the transmission probability of electronic states is determined by the alignment of the polarization of two ferroic layers separated by a thin barrier. The mechanism of this ferroelectric valley valve relies on the polarization-tuned hole valleys in group-IV monochalcogenide ferroelectric semiconductors. The creation of such device is enabled by our ability of precisely controlling the growth mode of these materials, which eventually generates SnTe-PbTe monolayer superlattices with 2-nm wide material section, the narrowest ever 2D lateral superlattices to the best of our knowledge. Based on such structures, we plan to further develop novel non-volatile logic and storage devices, as well as topological qubits.

Biography: Kai Chang obtained his Ph.D. in 2015 from Tsinghua University, focusing on the molecular beam epitaxial growth and scanning tunneling microscopy characterization of low-dimensional quantum materials. He worked as a postdoctoral staff in Max Planck Institute of Microstructure Physics from 2015 to 2019, and then joined Beijing Academy of Quantum Information Sciences (BAQIS) by the end of 2019. He is currently the executive president of BAQIS and the Principal Investigator of the Low-Dimensional Quantum Materials Team. His research focuses on the molecular beam epitaxial growth and scanning tunneling microscopy characterization of 2D ferroic heterostructures, involving the combinations of 2D ferroelectrics, ferromagnets, superconductors and semiconductors, particularly on the design and construction of novel non-volatile logic/memory devices and topological qubits based on 2D ferroic semiconductors

標題：Magneto-optical detection of time-reversal symmetry breaking in antiferromagnets
日時：2025 年 11 月 6 日(木) 午前 11 時～午後 0 時
場所：物性研究所本館 6 階 第 5 セミナー室 (A615)
講師：Veronika Sunko
所属：Institute of Science and Technology Austria
要旨：

Optical probes are naturally well suited to detecting broken symmetries, including time-reversal symmetry (T), and are frequently used in this way, for example, to map ferromagnetic domains. But the conditions under which optics can detect T – breaking in antiferromagnets with no net magnetization are far more subtle. The key distinction is whether the effect of T can be undone by a simple translation (S_(1/2)); if it can, the product TS_(1/2) is a symmetry of the system and T-breaking is usually invisible to bulk probes. In contrast, antiferromagnets that do not preserve TS_(1/2) display a range of T- breaking phenomena, such as the magnetoelectric and piezomagnetic effect.

But what exactly does "bulk" mean? And more specifically, are optical probes "bulk" : can they detect T-breaking in TS_(1/2) – invariant antiferromagnets? We address these questions by directly comparing two antiferromagnets: EuIn2As2 that breaks in TS_(1/2) and MnBi2Te4 that does not. In the first case, we show how an unconventional optical probe, linear magneto-birefringence, can reveal symmetry breaking invisible to more standard measurements. In the second, we demonstrate how perhaps the most standard optical probe of magnetism, reflection circular dichroism, can in fact detect antiferromagnetism even when TS_(1/2) is preserved.

Together, these experiments demonstrate both the power and the versatility of optics as a probe of symmetry breaking in quantum materials.

標題：Majorana-Based Topological Qubits: A Path to Fault-Tolerant Quantum Computing
日時：2025 年 11 月 7 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：Dr. Bela Bauer
所属：Microsoft Station Q
要旨：

Microsoft's tetron qubit—built from hybrid superconductor-semiconductor nanowires hosting pairs of Majorana zero modes-marks a key advance in topological quantum computing. This talk presents the latest experimental results, including the first demonstration of two distinct fermion parity measurements in a Majorana-based system. It also outlines our roadmap from single tetrons to multi-qubit arrays capable of quantum error correction, charting a concrete path toward scalable, reliable quantum computation.

標題：Uncovering signals of the Sordi transition in the doped κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$
日時：2025 年 11 月 11 日(火) 午前 10 時～午前 11 時
場所：物性研究所本館 6 階 第 5 セミナー室 (A615)
講師：Mr. Pierre-Olivier Downey
所属：Physics department of Université de Sherbrooke and Quantum Institute
要旨：

The first report that doping a Mott insulator reveals a first-order transition between the pseudogap and a correlated Fermi liquid [1] has triggered intensive research. It was predicted that this transition could be at the origin of many of the surprising properties of doped cuprates, such as the fall in the Knight shift.

However, this transition has never been directly observed experimentally. Furthermore, many have suggested that the transition might be an artifact of numerical methods, such as the small clusters in cluster dynamical mean field theory, or of clusters that favor antiferromagnetic fluctuations.

Following the recent proofs that the transition still exists with larger clusters without antiferromagnetic fluctuations [2,3], we used the dynamical cluster approximation to propose experiments for the 11% doped organic superconductor κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$ [4]. Using the concept of Widom lines, namely of crossover lines originating from the Sordi transition, we predicted that both the resistivity and the Seebeck coefficient should exhibit detectable signals of the transition at 11% doping, representing the first-ever observation of a consequence of the Sordi transition in a doped spin liquid.

In collaboration with Prof. Kazushi Kanoda and Dr. Hiroshi Oike, we now report preliminary evidence consistent with this scenario, including a resistivity crossover and a Seebeck coefficient feature that may correspond to the predicted Widom line. These results suggest that κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$, could provide a unique platform to observe the fingerprints of the Mott-driven Sordi transition in real materials.

References

[1]. G. Sordi et al. Phys. Rev. Letters, 104, 226402, 2010.
[2]. P.-O. Downey et al. Phys. Rev. B, 107, 125159, 2023.
[3]. P.-O. Downey et al. Phys. Rev. B, 110, L121109, 2024.
[4]. H. Oike et al. Nat. Comm. 8, 756, 2017.

標題：Sim2Real マテリアルインフォマティクスによる生分解性高分子設計：MD データベースと転移学習の融合に向けて
日時：2025 年 11 月 12 日(水) 午後 4 時～午後 5 時
場所：Online 及び物性研究所 6 階第 5 セミナー室（A615）
講師：篠田 恵子
所属：統計数理研究所
要旨：

近年、マテリアルインフォマティクス(MI)の進展により、実験・シミュレーション・機械学習を統合した材料設計が注目されている。本研究では、生分解性高分子材料を対象として、分子動力学(MD)によるデータベース構築と、機械学習による物性・生分解性予測を連携させる Sim2Real 型アプローチを目指している。まず、ポリエステル系化合物を題材に、複数物性(Tg など)を同時学習するマルチタスク事前学習モデルを構築し、特徴抽出型の転移学習により生分解性(二値分類)を予測した。今後は、富岳を用いて得られるセルロース誘導体の MD シミュレーションデータをソースとして活用し、実験的生分解性との対応を通じて、仮想設計空間から実材料設計への橋渡しを目指す。本講演では、高分子 MI の理論的基盤と Sim2Real 転移の展望について議論する。

標題：空間反転対称性の破れた磁性体における磁場応答
日時：2025 年 11 月 12 日(水) 午前 11 時～午後 0 時
場所：Online
講師：木村健太 准教授
所属：大阪公立大学工学研究科
要旨：

空間反転対称性が破れた磁性体では、電気磁気効果や非相反光学応答など、多彩な電磁応答が現れることが知られている。本セミナーでは、講演者らがこれまで開発してきた空間非対称磁性体を例に、「強磁場」下での測定によって「弱磁場(ゼロ磁場)」領域の物性を読み解いた研究を紹介する。また、磁気特性の磁場応答を、誘電特性や光応答を調べることによって明らかにした最近の研究についても取り上げる。さらに、40 代前半の研究者として、子育てと研究を両立する中で感じてきたことについても話す。