

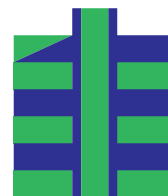
A S Y M M E T R Y

Newsletter

English Digest

Issue #1, June 2025

Unveiling, Design, and Development of Asymmetric Quantum Matters



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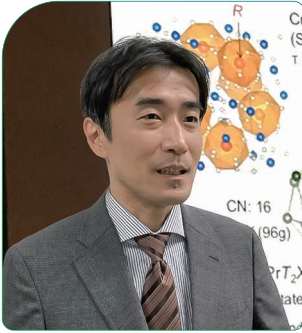
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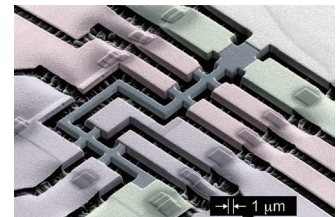


Unveiling, Design, and Development of Asymmetric Quantum Matters

Takahiro Onimaru

Professor, Graduate School of Advanced Science and Engineering, Hiroshima University, Japan

Upon examining the natural world, one concept that comes to the forefront is symmetry, the loss of which is referred to as asymmetry. Examples include the DNA double helix, which is exclusively right-handed, and elemental particles gaining their mass through spontaneous symmetry breaking. Asymmetry also triggers the realization of various material properties and functionalities. In solid crystals, breaking symmetries give electronic states various functional properties. For instance, polarization and ferroelectricity occur when spatial inversion symmetry is broken, while ferromagnetism arises in breaking time-reversal symmetry. When spatial inversion and time-reversal symmetries are broken, unique “cross-correlation” phenomena emerge, highlighting a close relationship between electricity and magnetism.



Single-crystalline sample micro-fabricated by FIB to measure transport properties.

Recent research has demonstrated that cross-correlation phenomena can be better understood with the multipole concept, which arose from asymmetric electronic states in solid crystals. With spatial inversion symmetry, only magnetization is observed as a diagonal response to magnetic fields. However, if spatial inversion symmetry is broken, odd-parity multipoles become active, and off-diagonal responses and cross-correlation functions appear. The advantage of the multipole approach is that the exploration of new cross-correlation functions is enabled with the basis set with electric and magnetic multipoles, as well as electric and magnetic toroidal multipoles [1].

To detect and investigate the tiny response of new functionality arising from these multipoles, we employ the focused ion beam technique to facilitate the study in a single domain and to achieve high current density for enhanced signals. Our advanced microscopic and macroscopic measurements enable us to capture a range of physical properties, including domain formation, non-reciprocal conductivity, and non-linear responses associated with the emergence of multipole orders. These insights help us to construct new theoretical models for evaluating the cross-correlation to design novel asymmetric quantum matters. We extend this concept to molecular clusters, artificial materials, and a broader range of targets, aiming to advance next-generation materials science and to frame the field of “Asymmetronics.”



Overview of this research area

[1] S. Hayami and H. Kusunose, J. Phys. Soc. Jpn. 93, 072001 (2024).



The Asymmetry Project: Unveiling Hidden Magnetism and Emerging Functionalities

Elena Hassinger

Professor Dr., Institute of Solid State and Materials Physics, Dresden University of Technology, Germany

Ferromagnetism and Antiferromagnetism have been known to mankind for a long time. Nevertheless, magnetism is still an active field of research, since new exciting and complex phenomena still arise. Magnets can be understood as systems of ordered small dipolar magnetic objects called magnetic moments or spins.

One of the recent research directions deals with frustrated or topological magnetic systems, in which the interactions between the magnetic moments in certain geometric arrangements (triangular geometries or competing interactions from different sites) can lead to new phenomena.

A second research direction, and this is the focus of the project “Asymmetric Quantum Matter”, kindly funded by the “Grant-in-Aid for Scientific Research on Innovative Areas”, concerns new magnetic states and functionalities that arise from the breaking a combination of different symmetries in the crystal such as inversion symmetry and time-reversal symmetry. This can lead to a magnetization distribution, that is no longer dipolar, but rather has a more complicated structure such as a multipolar or toroidal structure. These symmetries allow a coupling of different fields, such as electric and magnetic fields, or magnetic and strain fields. These types of coupling, here called cross correlation, also lead to new functionalities, for example current- or strain induced magnetization, or switching of antiferromagnetic domains with electric currents. These concepts also make it very clear how magnetic, electric, orbital and structural degrees of freedom become interrelated and lead to a certain complexity of the physical phenomena.

Theoretically, some of these phenomena are already understood, but because the effects are often expected to be small and hard to detect, material realisations and the experimental evidence are subject of immense research efforts worldwide. But vice versa, experiments also lead to new discoveries and theoretical developments.

The researchers of the Asymmetry project will join their outstanding expertise by development of cutting edge methods of growth of new materials, theoretical models and precise measurements of bulk properties as well as scattering techniques in a wide range of temperature, magnetic field and pressure. A special advantage is also on the potential provided by microstructures, since small devices allow for mono-domains and high current densities. Both well established as well as rising new generation researchers are involved in the project.

The project has already lead to and still promises novel experimental discoveries and substantial further technical developments of experimental and theoretical techniques. This will put Japan at the forefront of worldwide research on quantum materials. The Asymmetry project thereby significantly contributes to our understanding of quantum materials in general so that in the future, the possibilities for new technologies based on new functionalities can be utilized, for example for spintronic devices.



Symmetry Breaking as a Gateway to Novel Quantum Functionalities

Ernst Bauer

Professor Dr., Institute of Solid State Physics, TU Wien, Austria

In physics and even in daily life, asymmetry is a state of an object which misses balance – or symmetry – but could be, in principle, symmetric. While in daily life the difference of left and right like that of the human body is colloquial, in physics and mathematics well defined terms are employed, including translation, rotation, reflection and glide reflection, comprising the main types of symmetry operations. Symmetry and breaking thereof are guiding many physical properties. Well known is superconductivity, which breaks the $U(1)$ -gauge symmetry upon the condensation of electrons into Cooper pairs. In case of unconventional superconductors, additional symmetries, such as time reversal symmetry, can be broken. Typically, the Cooper-pair wave function in such systems has a different rotational symmetry than the underlying crystal lattice. Breaking of symmetries does not mean that any symmetry is absent; rather, the state with a certain broken symmetry is characterized by a lower symmetry than the original one. Thus, the initial symmetry group passes over to one of its subgroups. Symmetry breaking can be parametrized by order parameters. The latter is quite obvious in case of ferromagnetism: At the phase transition temperature (Curie temperature T_C) disordered magnetic moments start to align into well arranged structures. The resulting magnetisation represents the order parameter, vanishing above T_C . The paramagnetic state of the material ($T > T_C$) with higher symmetry transforms into the magnetically ordered state ($T < T_C$) with lower symmetry. Symmetry breaking and thus the appearance of asymmetry is the origin of a large number of material functionalities. By combining several of such symmetry breaking scenarios, unconventional material properties are expected to occur. The Japanese-based research project “Asymmetric Quantum Matters” primarily intends to find and rigorously characterise – and eventually - understand novel, unconventional material properties, resulting from certain combinations of symmetry breakings. “Asymmetric Quantum Matters” is based on solid grounds on achievements acquired in terms of the previously completed research project “J-Physics” .

The aim of the present 5-years project “Asymmetric Quantum Matters” , starting mid of 2023, is the exploration of yet unknown physical properties in asymmetric quantum materials, its manipulation and control, the relevance for technical applications and the respective theoretical description in terms of augmented multipoles. The latter takes into account electrical, magnetic, electric-toroidal and magnetic-toroidal multipoles. This description allows linking electronic degrees of freedom, such as charge, spin or orbital with macroscopic symmetries. It yields a combined description of electronic orderings, cross correlations and transport properties in solids, just to name a few. The very strength of this project is the cooperation of several highly skilled research teams throughout Japanese Universities and Research Facilities, as well as the involvement of most recent sample preparation techniques and their respective characterisation, the evaluation of a wide range of physical

properties of asymmetric quantum materials in an extended phase space of temperature, pressure and magnetic fields, together with strong theoretical support in terms of analytical and computational methods in solid state physics.

To ensure the success of the present research project, a well thought out organisational structure was chosen, with 5 research teams under the umbrella of the central “Research Management” . Each of these groups is headed by a principal investigator, while research work is carried out in 4 or 5 sub-groups each, with competences and know-how covering up the needs in the forefront of a mostly unexplored terrain. A young generation of scientists is already the backbone in this work and responsible for a substantial part of the research proposed. This project provides, in addition, an appealing environment for students to carry out and complete their PhD theses in highly topical areas of research.

Although the research program started only 2 years ago, members of the project have already published about 40 papers in well acknowledged international journals (e.g., Nature, J. Phys. Soc. Jpn., PRL or PRB), distributed among the five research teams. Several of these publications received awards such as “hot-topic” or “editor’ s choice” , like a PRL publication in 2023. In 2024, a very remarkable review article was published in J. Phys. Soc. Jpn. 93, 072001 (2024), summarizing the theoretical progress of the multipole representation, describing electronic ordering and cross-correlations of asymmetric materials. Likely, this review will serve the entire community as a solid reference for further research in this field. A large number of contributions to national and international conferences and workshops complement the achievements accomplished already in this field.



Microscopic Visualization of Asymmetric Quantum Matters Using Quantum Beam Techniques

Chihiro Tabata

Scientist, Materials Sciences Research Center, Japan Atomic Energy Agency, Japan

A01 specializes in visualizing asymmetric quantum states at the microscopic level using advanced quantum beam techniques. We focus on quantum beam experiments, leveraging properties such as wave-particle duality, polarization, and energy tunability. These properties enable precise visualization of charge, spin, and orbital degrees of freedom, with ongoing efforts to observe asymmetric quantum states (Fig. 1). Asymmetric quantum states incorporate complex electronic degrees of freedom influenced by multiple symmetries in solids, commonly referred to as “multipoles”. While some observations have been made, a systematic approach has yet to be established. A01 aims to pioneer methodologies for systematic quantum beam-based observations.

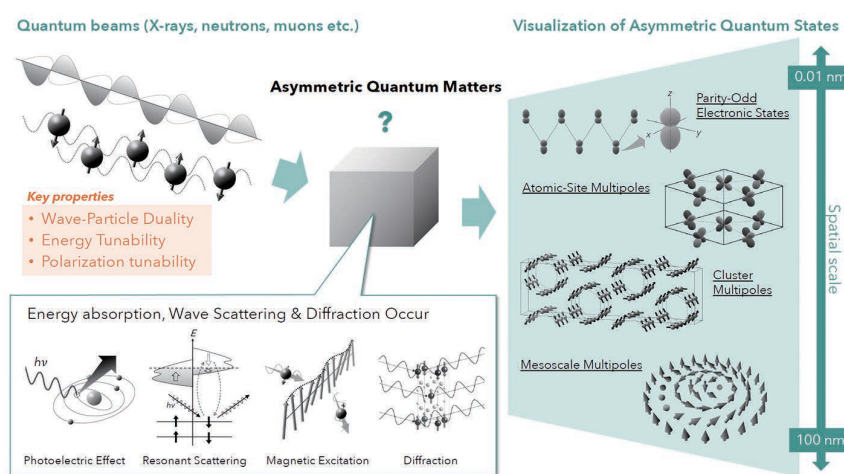


Fig.1 Schematic diagram of planned research A01

Understanding material functionality requires bridging micro- and macroscale structures through mesoscale analysis. Some asymmetric quantum matters exhibit mesoscale ordering, such as magnetic skyrmions. We investigate visualization techniques across multiple scales to connect microscopic ordering with macroscopic material properties.

Our targets:

- Crystal Symmetry and Cluster Structures

Re-examining known magnetic materials with modern quantum beam techniques may reveal previously overlooked symmetry-breaking features. Neutron and synchrotron X-ray diffraction will provide structural analysis to support macroscopic measurements and theoretical designs.

- Higher-Order and Parity-Odd Multipoles

Resonant X-ray scattering enables observation of higher-order multipoles, including recently detected extended magnetic octupoles. A01 seeks to establish detection methods for parity-odd multipoles and hybridized orbitals.

- Cluster Multipoles

Topological magnetic materials, such as skyrmions, exhibit large periodic structures (~100 nm). Small-angle X-ray and neutron scattering will be used to visualize these structures, with sample preparation supported by FIB processing.

- Multifaceted Analysis of Symmetry Breaking

X-ray spectroscopy will analyze electronic states at atomic sites, while inelastic X-ray and neutron scattering will probe interactions governing multipole ordering. Muon spin rotation (μ SR) experiments will detect weak internal magnetic fields associated with time-reversal symmetry breaking.

By integrating quantum beam experiments with newly synthesized materials from C01 and C02, we aim to systematically elucidate the microscopic nature of asymmetric quantum states while collaborating with multiple research groups to expand the possibilities for microscopic visualization.



Exploring Novel Functionalities in Asymmetric Quantum Matters through Precise Measurements

Tatsuya Yanagisawa

Professor, Department of Physics, Graduate School of Science, Hokkaido University, Japan

Our mission is the quantitative observation of multipolar susceptibilities and the visualization of anisotropic multipolar degrees of freedom in matter, focusing on the emergence of spontaneous multipolar order and/or collective modes induced by asymmetry. In this research, "asymmetry" encompasses not only inversion symmetry in time and space but also crystal symmetries such as mirror and rotational symmetries, as well as symmorphic and non-symmorphic properties.

We conduct precise macroscopic measurements of various cross-correlation responses and nonrelativistic conductions under diverse external fields, including not only electrical currents but also heat currents, strain, lattice rotation, and magnetic fields, in asymmetric quantum materials. Additionally, establishing fundamental technologies for domain control and exploring new material functionalities are key aspects of this work. This involves integrating microfabrication techniques using high-power focused ion beam (FIB) technology with real-space magnetization imaging. The ultimate goal of this project is to gain the ability to control such novel functionalities at will.

To achieve this mission, diversifying cross-correlation responses is an essential cornerstone for the visualization of multipoles. Therefore, members of the A02 team are specialists in a broad range of macroscopic physical property measurements (Fig. 1).

- **Dr. Tatsuo Kobayashi** (Okayama Univ.):

Investigates odd-parity electric multipole order and its fluctuation-induced superconductivity through transport measurements under high pressure and low temperatures.

- **Dr. Koichi Izawa** (Osaka Univ.):

Develops a real-space magnetization imaging system using a scanning SQUID microscope and quantifies multipole susceptibility via nonlinear and nonreciprocal transport measurements.

- **Dr. Motoi Kimata** (JAEA):

Specializes in microfabrication using a high-power FIB system and conducts physical property measurements under a three-dimensional vector high magnetic field.

- **Dr. Shunichiro Kittaka** (Univ. of Tokyo):

Focuses on visualizing asymmetric quantum materials through thermal measurements, angle-resolved magnetostriction, and specific heat measurements.

- **T. Y.** responsible for observing electric multipole responses using ultrasonic measurement techniques.

To seamlessly achieve the quantitative evaluation of multipole responses across microscopic, mesoscopic, and macroscopic regimes, we collaborate closely with other planned research teams and publicly offered researchers. We will leverage complementary experimental results from the A01 team's microscopic experiments using quantum beams. The C01 and C02 material synthesis teams provide us with high-quality samples, while the B01 theorists offer critical insights and continue to work closely with experimentalists to refine our approach. Our ultimate goal is to establish a new scientific principle, which we term “*asymmetronics*”. This groundbreaking concept aims to open new avenues and drive fundamental transformations in the field of condensed matter physics through strong collaboration and cooperation with researchers worldwide.

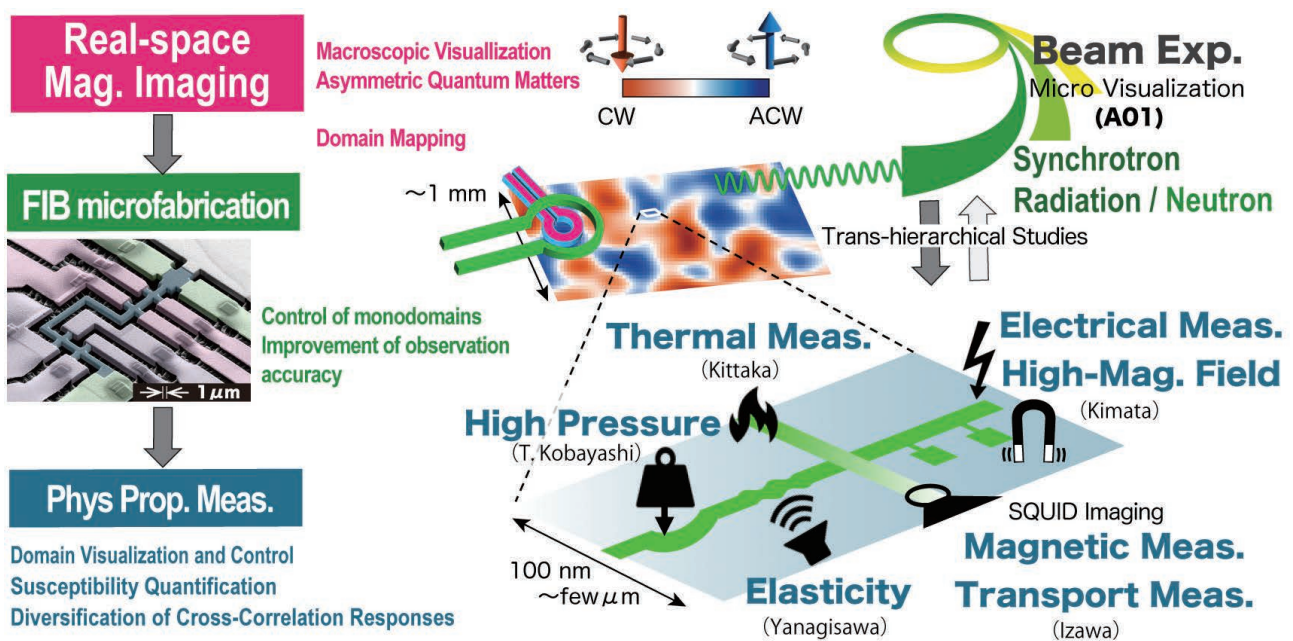


Fig.1 Schematic diagram of planned research A02



Fundamental Theories and Theoretical Design of Asymmetric Quantum Matters

Junya Otsuki

Associate Professor, Research Institute for Interdisciplinary Science, Okayama University, Japan

The B01 research group, the only theoretical group in this project, is strategically positioned between experimental groups A and C, reflecting its important role.

In the preceding J-Physics project, significant progress has been made regarding multipole physics. Multipole descriptions, previously limited to atomic wavefunctions, have been extended to encompass multiple atoms and orbitals. This expansion broadens the traditional multipole framework—comprising electric (E) and magnetic (M) multipoles—to include electric toroidal (ET) and magnetic toroidal (MT) multipoles. Together, these four types form a complete basis capable of describing any electronic configuration. Symmetry classification based on these multipoles offers a significant advantage, enabling predictions of cross-correlated responses to external fields [1]. The B01 group seeks to uncover undiscovered cross-correlations while advancing theoretical developments, with a particular focus on quantitative descriptions of phase transitions and responses arising from symmetry breaking.

The research plan consists of the following three components:

1. **Fundamental Theory:** In collaboration with experimental groups, we explore novel cross-correlations and identify multipole order parameters in materials. Notably, toroidal multipoles are recognized to naturally emerge in materials with magnetic ordering involving multiple magnetic elements. Revisiting existing materials from a multipolar perspective may reveal previously unrecognized phenomena. Observing unique cross-correlations, such as current-induced magnetization, could provide indirect methods for identifying hidden order parameters that are challenging to detect directly.
2. **Quantitative Descriptions:** While symmetry classifications provide broad insights into the existence of cross-correlated responses, their quantitative descriptions require detailed electronic structure and many-body calculations. Recent advancements in integrating band structure calculations with many-body calculations enable precise quantitative descriptions of electronic structure and response functions, despite computational challenges. We will establish a practical framework for quantitative evaluations of multipole properties and cross-correlated responses.
3. **Material Design:** Computational approaches have revolutionized material development. However, designing materials with multipole-related phenomena often demands sophisticated theoretical frameworks capable of incorporating many-body effects. By collaborating with experimental groups, we apply our quantitative methods to a wide range of correlated materials, validating and advancing material design for strongly correlated systems.

[1] S. Hayami, H. Kusunose, J. Phys. Soc. Jpn. **93**, 072001 (2024)



Development of Archetypal Asymmetric Quantum Matters

Shigeo Ohara

Professor, Department of Physical Science and Engineering, Nagoya Institute of Technology, Japan

In the planned research C01, the primary focus is on the development of archetypal asymmetric quantum materials. These materials are distinguished by unique electronic and magnetic states arising from the breaking of spatial inversion and/or time-reversal symmetry. The ultimate goal of this research is to create representative asymmetric quantum material systems where asymmetry is intrinsically connected to their functional properties. This will enable systematic advancements in understanding and controlling their functionalities.

To achieve this objective, we will systematically enhance the synthesis of asymmetric quantum materials by refining crystal growth methods and expanding the synthesis environment. Additionally, we aim to control the functionality of these materials through precise manipulation of their structure and composition.

Chiral materials serve as prototypical examples of asymmetric quantum materials, showcasing distinctive properties such as nonreciprocal conduction, chirality-induced spin selectivity, chiral phonons, chiral helimagnetism, current-induced magnetization, optical rotation, and so on. We are actively advancing the synthesis of novel chiral compounds and conducting comprehensive investigations into their crystal structures, conductivity, magnetism, and Fermiology.

Moreover, crystal structures with locally broken inversion symmetry, combined with charge or magnetic moment ordering, represent another category of asymmetric quantum materials. For example, when magnetic ions in zigzag, honeycomb, kagome, or diamond networks exhibit charge or antiferromagnetic order, spatial inversion symmetry can disappear. This phenomenon can be conceptualized as a ferroic ordering of extended multipoles, offering the potential for novel functionalities such as nonreciprocal conduction, anomalous Hall effect, current-induced magnetization, and others.

To support these efforts, we employ various crystal synthesis methods, including the Czochralski method, Bridgman method, chemical transport, and flux method, carefully selecting the most suitable technique for each material. Furthermore, we optimize the mixing ratios of starting materials and the temperature profiles for crystal growth to achieve superior quality. As part of enhancing the synthesis environment, we place special emphasis on high-pressure synthesis. At present, three research institutions are equipped to perform material synthesis under high-pressure conditions, with one facility specifically capable of synthesizing uranium compounds. This expansion of capabilities allows for the exploration of novel material systems that are otherwise inaccessible under ambient conditions.

We have also established equipment designed to control the stacking of layered chalcogenides by the metal element reaction method. This specialized setup enables the growth of polytypes and misfit-layered chalcogenides, with plans to synthesize layered chalcogenides featuring tunable symmetry. These efforts aim to advance the synthesis of materials with customizable symmetry and functionality.



Development of Novel Asymmetric Quantum Matters

Hiroyuki K. Yoshida

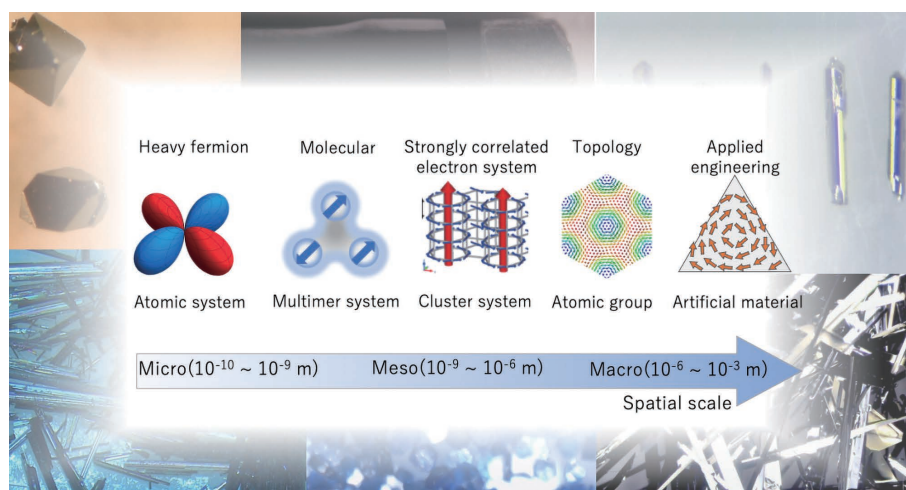
Professor, Department of Physics, Faculty of Science, Hokkaido University, Japan

“Asymmetries” in electronic states can lead to a wide variety of functionalities in solid-state materials, just like the breaking of space- and time-reversal symmetries leads to ferroelectricity and ferromagnetism. Asymmetry is the main concept in this research area, and it is important to develop asymmetric quantum materials to understand asymmetric quantum physics.

Planned research C02 aims to promote interdisciplinary research based on asymmetry in crystal structures and electronic states, to establish strategic material search methods, and to create innovative cross-correlational materials, through the development of a wide variety of materials and the evaluation of their precise physical properties.

We will develop spatially scale-seamless asymmetric quantum materials by utilizing basic synthesis methods and characteristic chemical techniques such as hydrothermal and high-pressure synthesis under extreme conditions, and by precisely evaluating local asymmetries by combining NMR and structural analysis. Based on the asymmetry of matters, we facilitate interdisciplinary study by achieving a unified understanding of material systems across various fields, including inorganic and organic compounds, molecular clusters, and metamaterials, which have been developed independently due to differences in spatial scale.

Recently, we have succeeded in observing anomalous Hall effects due to even-parity multipoles in metallic antiferromagnets NbMnP [1] and Ce_2CuGe_6 [2], and electric toroidal dipole order in transition metal oxide $\text{Ca}_5\text{Ir}_3\text{O}_{12}$ [3], flexoelectric effect in topological semimetals [4], etc. In addition, we are developing a variety of materials such as zigzag and pseudo-kagome compounds, Tsai-type approximant crystals and asymmetric topological materials. We will collaborate with other planned researches to search for novel cross-correlation phenomena on these compounds and explore the frontier of asymmetric materials science.

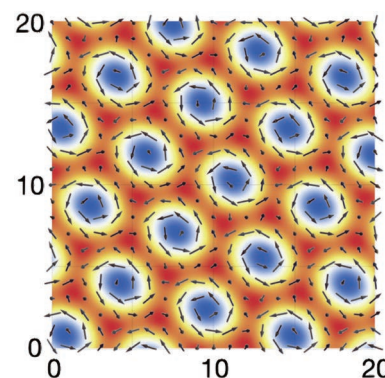


Unified helicity of the magnetic skyrmion lattices in EuPtSi and EuNiGe₃

Takeshi Matsumura

Professor, Department of Quantum Matter, Graduate School of Advanced Science and Engineering, Hiroshima University, Japan

The magnetic skyrmion lattice is a crystallization of spin-swirling, particle-like objects formed by multiple helimagnetic modulation waves with identical helicity. Although this striking structure has been widely observed, direct experimental confirmation of unified helicity had remained elusive. Using circularly polarized resonant x-ray diffraction, we demonstrated that the skyrmion lattice in the chiral helimagnet EuPtSi indeed exhibits unified helicity. This likely results from its chiral crystal structure and a single-oriented Dzyaloshinskii–Moriya interaction (DMI). In contrast, EuNiGe₃, which lacks inversion symmetry but retains mirror planes, hosts opposite DMI. Nonetheless, we found that all three helimagnetic components in its skyrmion lattice also share the same helicity. Notably, one component reversed its helicity from the zero-field state, and another, expected to form a longitudinal cycloid, instead adopted a helical structure matching the others. These results suggest that the energetic advantage of unified helicity can overcome competing antisymmetric interactions.



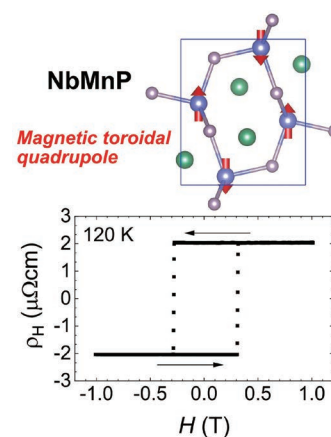
T. Matsumura et al., Phys. Rev. B **109**, 174437 (2024); T. Matsumura et al., J. Phys. Soc. Jpn. **93**, 074705 (2024).

Large anomalous Hall effect in an antiferromagnet NbMnP

Hisashi Kotegawa

Professor, Department of Physics, Faculty of Science, Kobe University, Japan.

The anomalous Hall effect is a phenomenon in which a Hall voltage arises even in the absence of an external magnetic field. It was long believed to be a characteristic unique to ferromagnets. However, recent studies have revealed that antiferromagnetism can also derive the anomalous Hall effect, prompting an active search for materials with large responses. A key factor is the presence of specific symmetries in the antiferromagnetic structure, which can be described by even-parity magnetic multipoles. The magnetic structure of NbMnP can be characterized by one such multipole, “the magnetic toroidal quadrupole”, which has been shown to give rise to a remarkably large anomalous Hall effect.



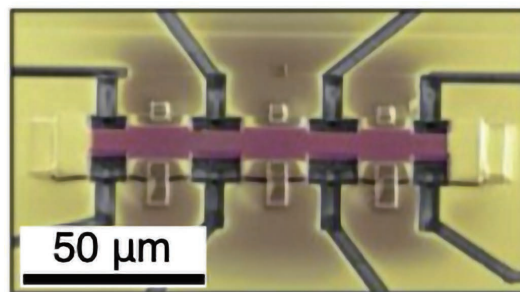
H. Kotegawa et al., npj Quantum Mater. **56**, 8 (2023).

Unveiling Superconductivity Beyond the Metamagnetic Transition: Insights from FIB-Processed UTe_2 Microdevices

Motoi Kimata

Assistant Principal Researcher, Advanced Science Research Center, Japan Atomic Energy Agency

This study investigates reentrant superconductivity in UTe_2 , triggered by a metamagnetic transition under a magnetic field tilted 30° from the b- to the c-axis. To achieve high-resolution measurements in pulsed magnetic fields up to 70 T, we employed focused ion beam (FIB) microfabrication to prepare micron-scale single-crystal devices. This enabled precise magnetotransport, revealing a record-high upper critical field ($\mu_0 H_{C2} \approx 73$ T). Notably, a strong angular suppression of the Hall effect near 30° suggests a significant reduction in band polarization. This supports the interpretation that a Jaccarino–Peter-type compensation between the applied and internal exchange fields is a likely mechanism for the reentrant superconductivity above the metamagnetic transition. The work highlights the essential role of microstructured devices in probing quantum phenomena in correlated electron systems.



Toni Helm, Motoi Kimata, *et al.*, Nature Communications **15**, 37 (2024).



Multipole description for Altermagnetism

Satoru Hayami

Professor, Department of Physics, Faculty of Science, Hokkaido University

Altermagnetism is described more precisely by multipole moments. Figure 1 completes all the correspondence between “altermagnetic” point group and the multipole moments. Each magnetic point group is classified also by the presence/absence of its spatial inversion P and time-reversal symmetry T ; **A**: (P , T , PT)=(yes, no, no) or **B**: (P , T , PT)=(no, no, no). In literatures, altermagnetism is characterized by

- ✓ Finite anomalous Hall effect (AHE) in collinear antiferromagnets (AFMs).
 - ↔ Anisotropic magnetic dipole (M dipole) $\sim T$ vector in XMCD, different from conventional M dipoles, spin-orbit-coupling (SOC) is required [1,2].
- ✓ Finite spin splitting without SOC under spontaneously-broken symmetry.
 - ↔ Even-rank magnetic toroidal (MT) (MT quadrupole, hexadecapole, etc.) or M octupole moments [3].

Importantly, the concept of multipoles covers more intriguing situations, such as emergent antisymmetric SOC in noncollinear AFMs and nonreciprocal transport in noncoplanar AFMs [4].

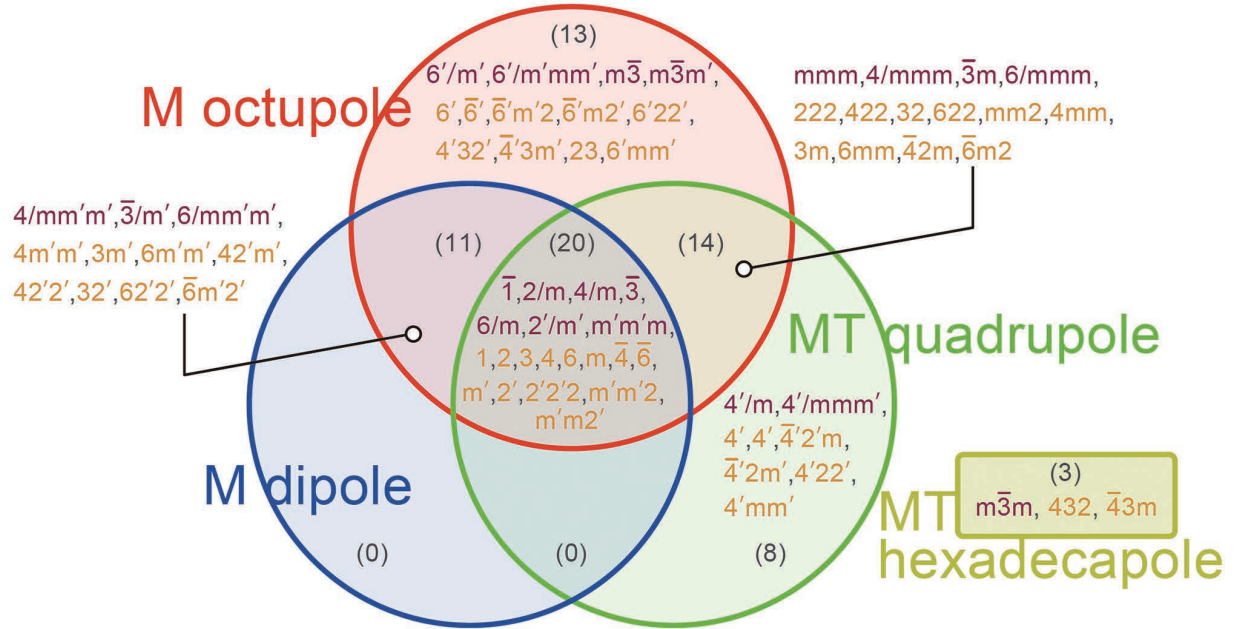


Figure 1: Multipole moments and 69 “altermagnetic” point group. The color of Hermann–Mauguin notation [5] indicates the P/T properties: **A** or **B**. 31(=11+20) groups exhibit AHE and 38(=13+14+8+3) possess spin splittings without AHE.

[1] S. Hayami and H. Kusunose, Phys. Rev. B **103**, L180407 (2021), Y. Yamasaki *et al.*, J. Phys. Soc. Jpn. **89**, 083703 (2020).

[2] This includes the non-collinear orders in Mn_3Sn ($m'm'm$), since the “cluster” anisotropic M dipole includes them.

[3] M. Naka *et al.*, Nat. Commun. **10**, 4305 (2019), S. Hayami, Y. Yanagi, and H. Kusunose, J. Phys. Soc. Jpn. **88**, 123702 (2019).

[4] S. Hayami *et al.*, Phys. Rev. B **101**, 220403(R) (2020); **102**, 144441 (2020), S. Hayami and M. Yatsushiro, Phys. Rev. B **106**, 014420 (2022).

[5] For magnetic space (point) group, see for example, “Symmetry and Magnetism” Robert R. Birss, (North-Holland Publishing Co., 1964).

Upcoming Events

■ International Workshop on Unveiling, Design, and Development of Asymmetric Quantum Matters (Asymmetry 2026)

Date: September 24 - September 26, 2026

Venue: Osaka University, Osaka, Japan

■ International Conference on Strongly Correlated Electron Systems (SCES2026)

Date: September 27 - October 2, 2026

Venue: Toyama International Conference Center, Toyama, Japan

■ Summer School: “Quantum Matter: from strong correlations to cross correlations”

Date: September 26 - October 1, 2027

Venue: Les Houches, France

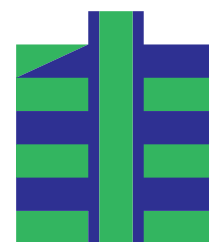
About the ASYMMETRY Project Logo

The logo featured on the cover of this newsletter carries a uniquely Japanese story. It consists of two parts: a blue segment and a green segment. When you focus on the blue area, you will notice the character “非” (pronounced hi), meaning “asymmetry” in Japanese. However, this is not just a static symbol—its upper-left part is deliberately missing, introducing an intentional asymmetry.

This missing part allows a second character to emerge from the green section: “生” (sei), meaning “life” or “birth.” This transformation expresses the central idea of our project: new physical phenomena and functionalities are born out of asymmetry.

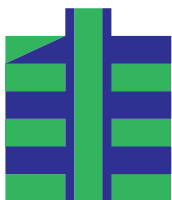
Symbolically, this reflects a reduction in symmetry—from mmm to m —a change that allows for the emergence of ferroelectricity, ferroelasticity, and other intriguing properties central to asymmetric quantum matters.

We hope this logo grows to become a true symbol of the new science we aim to create together through the ASYMMETRY Project.



A S Y M M E T R Y

Unveiling, Design, and Development of
Asymmetric Quantum Matters



A S Y M M E T R Y

Unveiling, Design, and Development of
Asymmetric Quantum Matters

Unveiling, Design, and Development of Asymmetry Quantum Matters

Grant-in-Aid for Transformative Research Areas (A) (FY2023 – FY2027)

Research Area Number: 23A202

Newsletter English Digest, Issue #1

Published: June 2025

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Publisher: Takahiro Onimaru

Published by:

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