Preface

Magnetism is a quantum-mechanical phenomenon that can be observed at room temperature. Depending on the structure of electron-exchange interactions, various ordered phases, such as ferromagnetic and antiferromagnetic, can appear. In symmetric structures, a typical Heisenberg exchange (scalar product of spins) occurs. The symmetry constraint significantly affects the properties of a material. In 1957–60, Igor Dzyaloshinskii in his seminal paper, "A thermodynamic theory of "weak" ferromagnetism of antiferromagnets" J. Phys. Chem. Solids **4**, 241 (1958), pointed out that breaking the inversion symmetry leads to an antisymmetric exchange interaction between magnetic moments (the vector product of spins) based on crystal symmetry consideration. Toru Moriya clarified its microscopic origin theoretically in his articles, "New Mechanism of Anisotropic Superexchange Interaction," Phys. Rev. Lett. **4**, 228 (1960); "Anisotropic Superexchange Interaction and Weak Ferromagnetism," Phys. Rev. **120**, 91 (1960). He gave a more comprehensive explanation in "Weak ferromagnetism," ed. G. T. Rado and H. Suhl, Magnetism Vol. **1**, 85 (1963), where the condition for the appearance of the Dzyaloshinskii–Moriya interaction (DMI) under the breaking of inversion symmetry is explained in detail. These pioneering studies kindled the physics of broken inversion-symmetry systems. We extend our sincere thanks to Professor Moriya for his kind encouragement regarding the present Special Topics.

DMI was initially introduced to explain the origin of weak ferromagnetism (parasitic ferromagnetism with non-collinear spin configurations) in magnetic physics. This concept has been extensively studied and has found applications in various research areas, including quantum spin systems, multiferroics, and spintronics. For instance, it was widely investigated in early publications such as that of Moriya and Miyadai, Solid State Commun. **42**, 209 (1982), and has become a key concept in these fields, shaping our current understanding of magnetic phenomena in diverse materials and systems.

In the present Special Topics, we survey the contemporary significance of the DMI in various fields and delve into the advancements DMI physics in diverse directions. Although the physics of inversion-symmetry broken systems has been developed in various contexts, our focus here is on the magnetic properties arising from DMI, as this is already a rich subject. We anticipate that this topic will play a pivotal role for further research developments in future studies.

In Special Topics, Fert, Chshiev, Thiaville, and Yang provided a theoretical and experimental overview of the DMI, from the context in which they were first postulated to generalization to interface phenomena and their impact on spin textures and the design of contemporary magnetic devices.

Nagaosa discusses the physics of time-reversal and inversion symmetry breakings, as well as reviews related topics, including emergent inductance in spiral magnets, nonreciprocal nonlinear resistivity, superconducting multiferroics, and skyrmions in chiral magnets.

Ohta provided a review of the impact of DMI in quantum spin systems, with an emphasis on the dynamic aspects revealed by electron spin resonance in exotic quantum magnets with low-dimensional strongly fluctuating systems based on chain, Kagome, and honeycomb geometries.

Mazurenko, Iakovlev, Sotnikov, and Katsnelson provided a comprehensive review of their past work along with exciting new results (e.g., neuromorphic calculation schemes), which offer promising perspectives for the future advancements of quantum magnetism.

Mostovoy discussed the physical consequences of electric charges and dipoles induced by topological magnetic defects (e.g., magnetic skyrmions) via the inverse Dzyaloshinskii–Moriya mechanism of magneto-electric coupling.

Togawa, Ovchinnikov, and Kishine provided a comprehensive review of recent advancements in the study of magnetic, electronic, spintronic, and phononic properties of chiral crystals with a focus on the connection between the DMI and chirality in such materials.

Kammerbauer, Freimuth, Frömter, Kläui, and Mokrousov provided a review of the origin of DMI in multiple systems. This included bulk DMI in B20 materials, gradient-induced DMI via interfacial DMI, its post-growth tuneability towards the recently discovered interlayer DMI, and the current-induced DMI from both experimental and theoretical perspectives.

Tokunaga, Kimura, and Arima provided a review of studies on magnetoelectric multiferroics and skyrmion hosts, with a focus on the inverse effect of the DMI and its contributions to magnetoelectric couplings.

We express our gratitude to all the authors who have contributed to the Special Topics, and we hope their valuable insights will serve as "starting point" for future research.

Editors of this Special Topics section:
Jun'ichi Ieda (Japan Atomic Energy Agency)
Efim Kats (Landau Institute for Theoretical Physics)
Tsuyoshi Kimura (University of Tokyo)
Jun-ichiro Kishine (Open University of Japan)
Timothy Ziman (Institut Laue-Langevin and CNRS)