

論文の内容の要旨

Topological properties of magnon excitation in magnetic skyrmion systems

(磁性スカーミオン系のマグノン励起と そのトポロジカルな性質)

氏名 廣澤 智紀

Magnetic skyrmion is a topological soliton characterized by an integer topological charge, which is realized in non-centrosymmetric magnetic systems. Since the first discovery in chiral magnets, they have attracted considerable attention for future spintronic applications. As an isolated single object, they are stable due to the topological protection. In addition, they can be nucleated, annihilated, and driven by external fields. This property makes them an attractive candidate for future information carriers.

They also form a periodic structure with hexagonal rotational symmetry, known as skyrmion crystals. Since the noncoplanar spin textures of skyrmions induces an emergent gauge field on magnons, which are quanta of spin waves, they provide a rich platform for topological magnonics. With the bulk-boundary correspondence as a guiding principle, the nontrivial magnon band topology leads to topologically protected chiral edge states. Crucially, the magnonic chiral edge states are robust against impurities due to the absence of backscattering, thus promising for dissipationless spin transports. Furthermore, the recently discovered higher-order topological phases in electronic systems open up a new possibility of magnonic corner states, which could broaden functionalities of topological magnonics.

In this thesis, we investigate the topological properties of magnon excitations in magnetic skyrmion crystals. The central idea of the thesis is to propose an external control over the magnon band topology, which can be experimentally realized. The main result of the thesis is divided into three research projects: (i) Magnetic-field driven topological phase transition; (ii)

Laser-driven skyrmion motion and topological phase transition; (iii) Magnonic corner states protected by the magnonic quadrupole moment.

In (i), we study the magnetic field dependence of magnon band structures in skyrmion crystals. We find that the magnonic topological phase transition occurs at the critical magnetic field, which is associated with the band inversion between characteristic magnetic excitations of skyrmions. We also show that the chiral magnetic edge states can be turned on and off by external magnetic fields.

In (ii), we discuss the classical spin dynamics of skyrmion crystals under circularly polarized lasers with terahertz frequencies, focusing on a skyrmion-hosting multiferroic material. We show that skyrmions carrying the in-plane electric polarization are driven by circularly polarized laser, with its direction controlled by the chirality of laser. We also demonstrate the laser driven topological phase transition arising from the effective magnetic field induced by the laser, which is consistent with the Floquet theory applied to magnons.

In (iii), we extend the magnonic topological phases to higher order topology by introducing the magnonic quadrupole moment. We show that skyrmion crystals support a nontrivial magnonic quadrupole moment, whose hallmark signature is the topologically protected magnonic corner states. We demonstrate that the magnonic corner states emerge with edge-localized objects carrying fractional topological charges, which are stabilized at low magnetic fields.