Oral Session D1 (Friday, February 16)

Chair: Tomas Jungwirth,
Academy of Sciences of the Czech Republic (ASCR)

Keynote Talk

9 : 00 - 9 : 40

Stefan Blügel

Peter Grünberg Institute and Institute for Advanced Simulation,
Forschungszentrum Jülich and JARA

From the Fermi surface to topological magnetization textures

Topological magnetization textures such as skyrmions are solutions of nonlinear field equations. They are typically metastable and in the past mostly stabilized by the Dzyaloshinskii-Moriya interaction (DMI), recently increasingly also by frustrated exchange, and sometimes with higher-order exchange interactions. In this context, centrosymmetric intermetallic rare-earth compounds (e.g. Gd_2PdSi_3 $GdRu_2Si_2$, $EuAl_4$) constitute a very flexible play-ground for the realization of topological magnetization textures (e.g. skyrmion lattices) relying on the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction between the localized 4*f*-moments [1-3] which directly depend on the details of the Fermi surface. We perform a systematic first-principles analysis in the framework of the DFT+U and relate the Fermi-surface and electronic properties to magnetic interaction parameters of spin models. Since the exchange interaction is much larger than the DMI, the skrymions are so small that transport properties beyond the adiabatic approximation are considered [4]. We employ atomistic spin-dynamics simulations and identify the magnetic phases that are stabilized in the presence of an external magnetic field. Our analysis aims at drawing a direct connection between the topology of the electronic band structure and the spin structures in real space.

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Contributed Oral

9 : 40 - 10 : 00

Observation of cluster magnetic octupole domains in the antiferromagnetic Weyl semimetal Mn_3Sn nanowire using an atomic force microscope

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The antiferromagnetic Weyl semimetals such as Mn_3Sn [1] have recently attract wide attention due to their anomalous transverse transport properties despite having barely any net magnetization. In this study, we visualized the cluster magnetic octupole domains in a (0001)textured Mn_3Sn nanowire using an atomic force microscope. Our technique involves establishing a tip-sample contact, inducing a localized vertical temperature gradient, and measuring the thermoelectric voltages due to the anomalous Nernst effect at the wire's ends [2,3] as illustrated in Figs. 1(a). We show a topographic image of the Mn_3Sn wire in Fig. 1(b). After the application of a magnetic field 2 T along the y-direction, we obtained the corresponding anomalous Nernst voltage map at 0 T as shown in Fig. 1(c). This represents the distribution of the y-component of the cluster magnetic octupole moments in a remanent state. The inhomogeneous voltage signal reflects the presence of the grains with tilted Kagome planes about the x-axis. Not like the magnetic imaging by the stray field measurement, our approach directly maps the distribution of the cluster magnetic octupole moments in Mn_3Sn. Our work provides a solid methodology to investigate the magnetic structures of the antiferromagnetic Weyl semimetals.

References

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Contributed Oral

10 : 00 - 10 : 20

Topological magneto-optical effect from skyrmion lattice

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Magnetic skyrmions are nanometric whirlpools of spins, where the directions of the constituent spins wrap the unit sphere [1], attracting enormous attention as potential information carriers in next-generation memory/logic devices. Due to their non-coplanar spin arrangement, the resultant scalar spin chirality gives rise to the fictious magnetic field (emergent magnetic field) acting on the conduction electrons, which leads to unique transport phenomena such as the topological Hall effect. However, other emergent electromagnetic phenomena, for example, skyrmion-driven optical response have yet to be reported.

In this presentation, we show the observation of the topological magneto-optical Kerr effect in the centrosymmetric material Gd_2PdSi_3 [2,3]. Magneto-optical effects are polarization rotation phenomena under breaking of time-reversal symmetry, whose magnitude is usually proportional to the magnetization. In Gd_2PdSi_3, the Kerr effect in the mid-infrared region exhibits a significant enhancement in the skyrmion lattice phase, demonstrating the existence of a topological Kerr signal (Fig. 1). The topological Kerr effect is observed up to the sub-eV region, which indicates that the formation of the skyrmion lattice causes a reconstruction of the electronic band structure. Our findings establish novel emergent optical phenomena, which enables noncontact, fast and efficient readout of skyrmions.

References

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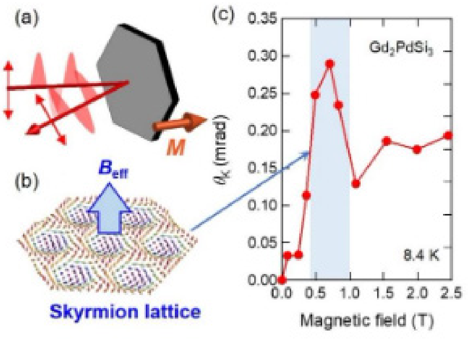

Fig. 1: (a,b) Schematic illustration of magneto-optical Kerr effect (MOKE) (a) and skyrmion lattice (b). (c) Magnetic-field dependence of the MOKE

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Contributed Oral

10 : 20 - 10 : 40

First principles calculation of topological Hall conductance in the skyrmion lattice

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Noncoplanar topologically protected spinor excitations, such as Skyrmions, have attracted significant attention in the field of spintronics, due to their stability and low energy costs in manipulation, as a prospective candidate for information storage. While experimentalists have made strides in advancing our understanding of Skyrmions through measurements of the unique topological Hall conductance (THC) and real-space imaging using the Lorentz TEM technique, theoretical investigations have predominantly relied on empirical modeling, lacking a comprehensive predictive tool.

In response to this gap, we developed a first-principle approach for computing the transport properties of Skyrmionic systems. In this presentation, we introduce our method for calculating the THC in the Skyrmion lattice, employing density functional theory. Our approach incorporates the magnetic field induced by noncoplanar spinors into the current scheme that utilizes the Kubo formula within the wannier tight-binding model [1]. To validate our formalism, we apply it to investigate the THC of the Skyrmion lattice phase in the Gd_2PdSi_3 crystal and achieve a remarkable agreement with experimental measurements [2]. Additionally, we analyze the spin on the Fermi surface, obtaining polarization consistent with those derived from a phenomenological model, thereby confirming the reliability of the theoretical discussion adopted in the literature.

References

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