MA 40: Focus Session: Chiral phonons and crystals coupled to magnetic order II

Conventional magnetism arises from electron spin and orbital angular momentum, forming the basis of spintronics and orbitronics. Recent advances, however, have revealed that magnetism is also intimately linked to the chirality and angular momentum of the crystal lattice itself, often mediated by circular lattice vibrations known as chiral or axial phonons. These discoveries have uncovered novel mechanisms of spin and phonon transport and enabled direct access to phonon chirality and angular momentum as fundamental physical quantities. These developments prompt a re-examination of angular momentum coupling in solids, including well-established phenomena such as the Einstein-de Haas and Barnett effects, as well as the role of phonon angular momentum in the equilibrium state of magnetic materials. Chiral and axial phonons emerge as a powerful new platform for controlling magnetic order and dynamics, bridging lattice, spin, and angular momentum physics. This focus session aims to highlight recent breakthroughs in phonon angular momentum and magnetism and to connect the rapidly expanding field of chiral phononics with the broader magnetism community, spanning both experimental and theoretical perspectives.

As part of this focus session, we offer an excursion to the high-field THz user facilities at HZDR with an introduction to the planned Dresden Advanced Light Infrastructure (DALI). See MA 32 for details.

Organizers: Dominik Juraschek, d.m.juraschek@tue.nl; Michael Fechner, michael.fechner@mpsd.mpg.de; Sebastian Maehrlein, s.maehrlein@hzdr.de

Time: Thursday 9:30–12:45 Location: HSZ/0002

Invited Talk MA 40.1 Thu 9:30 HSZ/0002

Magnetic order induced chiral phonons in a ferromagnetic Weyl semimetal — •Luyi Yang — Tsinghua University, Beijing, China

Chiral phonons are vibrational modes in a crystal that possess a well-defined handedness or chirality, typically found in materials that lack inversion symmetry. Here we report the discovery of chiral phonon modes in the kagome ferromagnetic Weyl semimetal $Co_3Sn_2S_2$, a material that preserves inversion symmetry but breaks time-reversal symmetry. Using helicity-resolved magneto-Raman spectroscopy, we observe the spontaneous splitting of the doubly degenerate in-plane E_g modes into two distinct chiral phonon modes of opposite helicity when the sample is zero-field cooled below the Curie temperature, in the absence of an external magnetic field. As we sweep the out-of-plane magnetic field, this E_g phonon splitting exhibits a well-defined hysteresis loop directly correlated with the material's magnetization. The observed spontaneous splitting reaches up to 1.27 cm^{-1} at low temperatures, progressively diminishes with increasing temperature, and completely vanishes near the Curie temperature. Our findings highlight the role of the magnetic order in inducing chiral phonons, paving the way for novel methods to manipulate chiral phonons through magnetization and vice versa. Additionally, our work introduces new possibilities for controlling chiral Weyl fermions using chiral phonons.

Ref: [1] M. Che et al., Magnetic order induced chiral phonons in a ferromagnetic Weyl semimetal, Physical Review Letters 134, 196906 (2025).

MA 40.2 Thu 10:00 HSZ/0002

The effect of lattice vibrations on the Curie temperature — •Thorben Pürling[1,2,3] and Stefan Blügel[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute for Theoretical Physics, RWTH Aachen University, 52074 Aachen, Germany — [3]Science Institute and Faculty of Physical Sciences, University of Iceland, 107 Reykjavík, Iceland

Lattice vibrations, or phonons, are important degrees of freedom that are excited in every magnet operating at finite temperatures. This is particularly true for magnets used in practical applications, which typically operate above room temperature. When predicting critical temperatures – a key property of magnets – from *ab initio* calculations lattice vibrations are typically neglected in favor of fluctuations only in the magnetic degrees of freedom. Conversely, in experiments at room temperature the lattice does contribute to the thermal properties of the system. We aim to close the gap between theory and experiment at room temperature by taking lattice vibrations into account explicitly. We present a numerical method based on the atomistic spin model and showcase how the lattice vibrations can be integrated out to an effective spin Hamiltonian that inherently depends on lattice fluctuations.

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MA 40.3 Thu 10:15 HSZ/0002

Universal phonon angular momentum Hall effect — •Daniel Bustamante Lopez[1,2], Verena Brehm[2], and Dominik Juraschek[2] — [1]Boston University, Boston, MA, USA — [2]Eindhoven University of Technology, Eindhoven, Netherlands

The phonon angular momentum Hall effect was recently proposed as a phononic analogue of the spin and orbital Hall effects. Here, we demonstrate that a temperature gradient universally drives a transverse flow of phonon angular momentum in harmonic lattices. Using an exact Green's function method together with nonequilibrium molecular dynamics, we obtain closed-form expressions for the local phonon angular momentum density, bond-resolved current, and a corresponding conductivity kernel that ties them to spatial temperature variations. The Hall response originates from bath-induced mode mixing encoded in off-diagonal phonon correlations and does not require lattice chirality, Berry curvature, or inversion-symmetry breaking. It persists in the most simple centrosymmetric geometries, including square and honeycomb lattices. We predict robust edge accumulation and a tunable Hall angle for phonon angular momentum in various materials with quantitative agreement between analytic theory and simulations. Our results establish the phonon angular momentum Hall effect as a universal channel for transverse angular-momentum transport in crystalline solids.

MA 40.4 Thu 10:30 HSZ/0002

Phonon Angular Momentum Transfer Torque — •Verena Brehm[1], Daniel Bustamante Lopez[2], Shu Zhang[3], and Dominik Juraschek[1] — [1]Department of Applied Physics and Science Education, Eindhoven University of Technology, Eindhoven, Netherlands — [2]Department of Physics, Boston University, Boston, USA — [3]Okinawa Institute of Science and Technology, Okinawa, Japan

Angular momentum can be carried by a variety of (quasi)particles, including magnons, photons, and phonons, whose interplay has recently opened new directions in spintronics and optoelectronics. In this talk, we demonstrate the transfer of angular momentum from a phononic system to a magnetic system via an interfacial transfer torque, which we call the Phonon Angular Momentum Transfer Torque (PAMTT). We estimate the magnitude of phonon angular momentum originating from different mechanisms, among them the recently discovered phonon angular momentum Hall effect, and explore the possible magnetization dynamics that can be induced by the resulting PAMTT. Our analysis shows that both the precessional and relaxation components of the PAMTT can be detected as shifts in frequency and broadening of the linewidth in ferromagnetic resonance (FMR) experiments.

MA 40.5 Thu 10:45 HSZ/0002

The phonomagnet: Spontaneous order of phonon angular momentum — •Maike Fahrensohn and Matthias Geilhufe — Condensed Matter and Materials Theory Division, Department of Physics, Chalmers University of Technology, 41258 Göteborg, Sweden

Magnetism arises from the collective order of electron spin and orbital angular momentum. Here, we introduce a new type of magnetism, which appears due to spontaneous order of the phonon angular momentum. We consider a Hamiltonian containing an interaction term that couples the phonon angular momentum to the electronic spin density. Using an imaginary-time Dyson expansion, we evaluate the spin partition function and obtain an effective phonon Hamiltonian.

To first order in the coupling strength, this approach yields a Zeeman-like term, which couples the electronic magnetization to the phonon angular momentum and leads to a spin-induced bias of phonon chirality.

To second order, we obtain a bilinear interaction between ionic angular momentum modes on different sites, mediated by the Matsubara spin susceptibility. Decomposing the tensor into isotropic and anisotropic parts, we identify emergent phononic analogues of the Heisenberg (isotropic), Γ-model (symmetric, anisotropic), and Dzyaloshinskii-Moriya (antisymmetric, anisotropic) interactions.

Similarly to the conventional Heisenberg model for electronic spins, our model exhibits a phase transition in which ions spontaneously develop angular momentum at elevated temperatures.

15 min break

Invited Talk MA 40.6 Thu 11:15 HSZ/0002

Thermal Hall Effects of Magnons and Phonons — •Alexander Mook — Universität Münster

Thermal Hall transport in insulating magnets provides a powerful probe of topology, interactions, and spin-lattice coupling in charge-neutral quantum matter. I will discuss the magnon thermal Hall effect arising from Berry curvature in altermagnets, and show how symmetry and band geometry control transverse heat currents carried by spin waves [1]. Going beyond single-particle pictures, I highlight recent theoretical results demonstrating that magnon-magnon interactions can generate intrinsic thermal Hall responses even in topologically trivial magnon bands [2]. I then turn to magnetoelastic systems, where magnon-phonon coupling produces hybrid excitations whose combined Berry curvature and scattering processes can strongly enhance or even invert the thermal Hall signal [3,4]. Together, these results establish thermal Hall transport as a genuinely many-body phenomenon governed by topology, interactions, and spin-lattice hybridisation.

[1] Hoyer et al., PRB 111 (2), L020412 (2025) [2] Chatzichrysafis, Mook, PRB 111 (13), 134405 (2025) [3] Li et al., PRB 108 (14), L140402 (2023) [4] Nawwar et al., Reports on Progress in Physics 88 (8), 080503 (2025)

MA 40.7 Thu 11:45 HSZ/0002

Electrical conductivity from the axial phono-magnetic effect — •Natalia Shabala and Matthias Geilhufe — Department of Physics, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Axial, or circularly polarized phonons, are characterized by the collective vibrations of atoms in circular patterns. These phonons have been shown to induce large magnetization in a phenomenon referred to as the phono-magnetic effect [1,2]. The mechanism behind this effect is believed to be the electron-phonon interaction. In combination with circular polarization of phonons this interaction leads to the time-reversal symmetry breaking and causes splitting of electronic energy levels. In this work, we aim to study the effect of this splitting on other physical phenomena. In particular, we are interested in the electrical conductivity, which can be studied through the Hubbard model. Additionally, we investigate whether the time-reversal symmetry breaking leads to the emergence of the anomalous Hall effect, as can be expected in 2D materials.

[1] N. Shabala, and R. M. Geilhufe, Phys. Rev. Lett. 133.26 (2024): 266702

[2] N. Shabala, F. Tietjen, R. M. Geilhufe, arXiv:2511.03329 (2025)

MA 40.8 Thu 12:00 HSZ/0002

Magnetic field induced pseudo angular momenta, chiral phonons, and anomalous EP interactions in some Weyl semimetals — Vladimir Gnezdilov[1], Florian Büscher[2], •Peter Lemmens[2], Angela Möller[3], Dirk Wulferding[4], Claudia Felser[5], and Chandra Shekar[5] — [1]ILTPE, Kharkiv, Ukraine — [2]IPKM, TU-BS, Braunschweig — [3]Dept. Chemistry, JGU, Mainz — [4]Dept. Physics and Astr., Sejong Univ., Korea — [5]MPI-CPfS, Dresden

Applying magnetic fields excite phonon chirality and induce angular momenta due to the time-reversal breaking [1]. This allows to study effects usually restricted to the boundary of the Brillouin zone. We show such results for several Weyl semimetals [2] with uncommon spin-phonon interactions and discuss novel possibilities for the transfer and interaction between the angular momenta of photons and phonons [3].

[1] T. Wang, H. Sun, X. Li, L. Zhang, Chiral Phonons: Prediction, Verification, and Application, Nano Lett. 24, 15, 4311 (2024).

[2] P. Sessi, et al., Handedness-dependent quasiparticle interference in the two enantiomers of the topological chiral semimetal $PdGa$, Nature Comm. 11, 3507 (2020).

[3] R. Rao, et al., Anomalous Raman scattering in layered $AgCrP_2Se_6$: Helical modes and excitation energy-dependent intensities, https://arxiv.org/abs/2501.17565 (2025).

MA 40.9 Thu 12:15 HSZ/0002

Phonon Polariton Hall Effect — •Omer Yaniv[1] and Dominik Juarschek[1,2] — [1]Tel Aviv University, Tel Aviv, Israel — [2]Eindhoven University of Technology, Eindhoven, Netherlands

The phonon Hall effect conventionally describes the generation of a transverse heat current in an applied magnetic field. In this work, we extend the effect to hybrid light matter excitations and demonstrate theoretically that phonon polaritons, formed by coupling optical phonons with terahertz radiation, support transverse energy flow when coherently driven in an applied magnetic field. Using the example of PbTe, which exhibits strongly coupled phonon polaritons, we show that the magnetic field splits the phonon-polariton branches into left and right-handed circular polarization, obtaining unequal group velocities. We derive the energy current operators for propagating phonon polaritons and show how their mixed phononic-photonic nature enables controllable transverse phonon-polariton transport in the terahertz regime. Our results demonstrate bending of light through a phonon polariton Hall effect, which provides a route towards terahertz polaritonic devices.

MA 40.10 Thu 12:30 HSZ/0002

Phonon angular momentum in ultrafast demagnetization and hybrid quasiparticles — •Markus Weissenhofer[1], MS Mrudul[1], Philipp Rieger[1], Luca Mikadze[1], Ulrich Nowak[2], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Universität Konstanz, Konstanz, Germany

Transfer and manipulation of angular momentum is a key aspect in spintronics. Recently, it has been shown that angular momentum transfer between spins and phonons is possible even on ultrashort timescales [1]. To contribute to the understanding of this transfer, we investigate spin-phonon coupling using two different fully ab-initio based methods [2,4]. Using Ehrenfest nuclear dynamics simulations combined with time-dependent density functional theory, we demonstrate that after ultrafast demagnetization of FePt optical phonons carrying finite angular momentum are created [2]. In addition, we show how a novel framework [3] can be used to calculate magnon-phonon coupling parameters and hybridization from first principles, revealing the existence of chiral phonons in Fe arising from a chirality-selective magnon-phonon coupling [4].

[1] Tauchert al., Nature 602, 73 (2022); Luo et al., Science 382, 698 (2023). [2] Mrudul et al., PRB 112, L180407 (2025). [3] Mankovsky et al., PRL 129, 067202 (2022). [4] Weißenhofer et al., PRL 135, 216701 (2025).