MA 34: Focus Session: Emerging Magnetic Phenomena from Chiral Phonons I (joint session MA/TT)

Contemporary efforts in spintronics focus on utilizing and controlling electronic angular momentum for possible applications in data storage and processing. Only recently, an alternative has arisen in the form of angular momentum generated by circularly polarized (chiral) phonons. Chiral phonons have been shown to lead to a variety of novel magnetic phenomena, including a phonon Hall, phonon Einstein-de Haas, phonon Barnett, and phonon Zeeman effect. Phonon angular momentum can be utilized to control the magnetic state of solids and even to induce magnetization in nonmagnetic materials. These discoveries make the angular momentum of chiral phonons a promising tool for the control of magnetic materials and an emerging quantity of interest for spintronic applications. The goal of this focus session is to highlight topical research on novel magnetic phenomena arising from chiral phonons and to connect this rapidly developing field to the broader audience working in magnetism and spintronics.

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Time: Thursday 9:30–12:15 Location: H 1058

Invited Talk MA 34.1 Thu 9:30 H 1058

Giant effective magnetic fields from chiral phonons — •Dominik M. Juraschek — Tel Aviv University, Tel Aviv 6997801, Israel

Chiral phonons conventionally describe circularly polarized lattice vibrations that carry angular momentum. In dielectric materials, the circular motions of the ions create a macroscopic magnetic field when driven with an ultrashort laser pulse, which has previously been shown to reach the order of millitesla. Here, we predict that this magnetic field can effectively reach up to the tesla scale, when enhanced by orbit-lattice coupling [1,2]. Our predictions have been experimentally confirmed in a recent study [3]. We demonstrate theoretically that these giant phono-magnetic fields can be utilized to generate nonequilibrium spin configurations in antiferromagnets, leading to a light-induced weak ferromagnetic state [4]. Finally, whereas the above phenomena are based on circularly polarized chiral phonons, we further demonstrate that the crystal structure can be transiently made chiral with linearly polarized phonons that are quasistatically displaced by nonlinear phonon coupling [5]. These "linearly polarized chiral phonons" make it possible to create chiral crystal structures on demand with implications for chiral magnetic and electronic properties.

[1] Juraschek et al., PRResearch, 4, 013129 (2022) [2] S. Chaudhary, D. M. Juraschek, et al., arXiv:2306.11630 (2023) [3] J. Luo et al., Science 382, 698 (2023) [4] T. Kahana, D. A. Bustamante Lopez, and D. M. Juraschek, arXiv:2305.18656 (2023) [5] C. Romao and D. M. Juraschek, arXiv:2311.00824 (2023)

Invited Talk MA 34.2 Thu 10:00 H 1058

Chiral phonons in quantum materials revealed by the thermal Hall effect — •Gael Grissonnanche — Ecole Polytechnique, Palaiseau, France

It is becoming surprisingly clear that phonons can produce a large thermal Hall effect across a wide range of quantum materials, from cuprate superconductors [1,2] to titanates [3], iridates [4], and frustrated magnets [5]. The thermal Hall effect represents the deflection of a heat current by a perpendicular magnetic field. It is usually interpreted as coming from mobile hot electrons deflected by the Lorentz force. While trivial in metals, this effect is now found in insulators, and phonons that carry no charge are responsible for it. Phonons are the most common low-energy excitations in solids. Yet the handedness they acquire in a magnetic field * which triggers the thermal Hall effect * remains an enigma. In this talk, I will present the results that have led to the emergence of a new field of research aimed at discovering the origin of the thermal Hall effect of phonons and how this might relate to the question of chiral phonons measured by other probes.

[1] Grissonnanche et al. Nature 571, 376 (2019) [2] Grissonnancheet al. Nat. Phys. 16, 1108 (2020) [3] Li et al. Phys. Rev. Lett. 124, 105901 (2020) [4] Ataei et al. Nat. Phys. (2023) [5] Lefrançois et al. Phys. Rev. X 12, 021025 (2022)

Invited Talk MA 34.3 Thu 10:30 H 1058

Phonon chirality and thermal Hall transport — •Benedetta Flebus[1] and Allan H. MacDonald[2] — [1]Department of Physics, Boston College, 140 Commonwealth Avenue, Chestnut Hill, Massachusetts 02467, USA — [2]Department of Physics, the University of Texas at Austin, Austin, Texas 78712, USA

In recent years, a rapidly increasing amount of studies has reported novel physical phenomena arising from lattice vibrations that carry angular momentum, i.e., chiral phonons. In this talk, I will discuss both intrinsic and extrinsic sources of chiral phonon transport. First, I will show that in ionic crystals a phonon Hall viscosity contribution can emerge as a result of the Lorentz forces on moving ions [1]. I will then explain how phonon scattering from defects that break time-reversal symmetry, such as charged impurities, can yield giant thermal Hall effects that are consistent with recent experimental observations [2].

[1] B. Flebus and A. H. MacDonald, The phonon Hall viscosity of ionic crystals, Phys. Rev. Lett. (in press). [2] B. Flebus and A. H. MacDonald, Charged defects and phonon Hall effects in ionic crystals, Phys. Rev. B 105 (22), L220301 (2022).

15 min. break

Invited Talk MA 34.4 Thu 11:15 H 1058

Orbital magnetic moment of phonons in diamagnetic and paraelectric perovskites — Filip Kadlek[1], Christelle Kadlek[1], •Martina Basini[2,3], Sergey Kovalev[4], Jan-Christoph Deinert[4], Stefano Bonetti[1,5], and Stanislav Kamba[1] — [1]Institute of Physics of the Czech Academy of Sciences, Praha, Czech Republic — [2]Department of Physics, Stockholm University, Stockholm, Sweden — [3]Deparment of Materials and Nanophysics, KTH Royal Institute of Technology, Stockholm Sweden — [4]Helmholz Zentrum Dresden-Rossendorf, Germany — [5]Department of Molecular Sciences and Nanosystems, Ca' Foscari University of Venice, Venice, Italy

In the present work, we demonstrate transient magnetism in $KTaO_3$ induced by chiral phonons. In particular, the infrared-active soft phonon was circularly excited by means of intense quasi-monochromatic THz pulses produced by the TELBE facility and the magnetic moment was probed by magneto-optical Faraday effect. The evidence will be compared with our previous results on $SrTiO_3$. We anticipate that, contrary to $SrTiO_3$, $KTaO_3$ does not undergo any structural phase transition at low temperature so that we could efficiently excite the soft phonon below 100K, where the phonon effective charge is larger and a higher value of the induced orbital magnetic moments per unit cell is expected.

Invited Talk MA 34.5 Thu 11:45 H 1058

Spin-lattice coupling in multiscale modeling — •Markus Weissenhofer[1,2], Sergiy Mankovsky[3], Svitlana Polesya[3], Hannah Lange[3], Akashdeep Kamra[4], Hubert Ebert[3], and Ulrich Nowak[5] — [1]Uppsala University, Uppsala, Sweden — [2]Freie Universität Berlin, Berlin, Germany — [3]LMU Munich, Munich, Germany — [4]Universidad Autónoma de Madrid, Madrid, Spain — [5]University of Konstanz, Konstanz, Germany

In recent years, it has been shown that it is not only possible to transfer angular momentum from the spin system to the lattice on ultrashort time scales, but also that this process can be reversed by using circularly polarized terahertz light pulses [1].

To contribute to the understanding of angular momentum transfer between spin and lattice degrees of freedom, we have developed a theoretical multiscale framework for spin-lattice coupling [2], which is linked to ab-initio calculations on the one hand and magnetoelastic continuum theory on the other. Here I will discuss how this framework can be used to calculate magnon-phonon coupling parameters, emphasizing the importance of a Dzyaloshiskii-Moriya type interaction for angular momentum transfer in iron, and to perform simulations to study the combined magnetic and mechanical motion of ferromagnetic nanoparticles.

[1] Dornes et al., Nature (London) 565, 209 (2019); Tauchert al., Nature (London) 602, 73 (2022); Luo et al., Science 382, 698 (2023). [2] Mankovsky et al., PRL 129, 067202 (2022); Weißenhofer et al., PRB 108, L060404 (2023).