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Chiral phononics: Controlling magnetic order with phonon angular momentum

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Chiral phonons are circularly polarized lattice vibrations, in which the atoms move along circular orbits around their equilibrium positions in a solid. In dielectric materials, the orbital motions of the ions generate atomistic charge currents and therefore an effective magnetic moment carried by the chiral phonon [1,2]. In this talk, I show that chiral phonons are able to induce giant effective magnetic fields in solids when driven with an ultrashort laser pulse, and I present three examples of how these fields can be utilized to control the magnetic order of materials. First, we demonstrate that chiral phonons in paramagnetic rare-earth trihalides are able to create giant effective magnetic fields of potentially up to 100 T that polarize the spins in the material [3,4], a prediction that has been successfully verified by a recent experiment [5]. Second, we predict that the effective magnetic field produced by chiral phonons can rectify spin precession in antiferromagnets, leading to the generation of a quasistatic magnetization through a nonequilibrium weak ferromagnetic state [6]. Third, the phonon magnetic moment can resonantly couple to the magnetic field component of light, which leads to an intriguing variety of new phenomena, including the excitation of circularly polarized phonons with linearly polarized light, phononic frequency up-conversion spanning several orders of magnitude, and the excitation of Raman-active phonons without Raman scattering [9].

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[4] S. Chaudhary, D. M. Juraschek, M. Rodriguez-Vega,G. A. Fiete, arXiv:2306.11630 (2023).
[5] J. Luo, T. Lin, J. Zhang, X. Chen, E. R. Blackert, R. Xu, B. I. Yakobson and H. Zhu, arXiv:2306.03852 (2023).
[6] T. Kahana and D. M. Juraschek, arXiv:2305.18656 (2023).
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