

Chiral phonon-spin conversion in rare-earth and 2D materials

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Abstract: The electronic and magnetic properties of solids are fundamentally determined by the crystal structures. When the structure keeps evolving, the properties are usually determined by the instantaneous lattice configurations, but this may not always be true. Typical lattice vibration involves atoms oscillating back and forth around their equilibrium positions, and one would expect the perturbation on electronic properties to largely cancel out. But a qualitative change might be possible with coherent atomic motions called “chiral phonons”, which break time-reversal symmetry and have been predicted to cause unexpected magnetic, topological, and transport phenomena. Notably, chiral phonons with quantized angular momentum are simply guaranteed by multi-fold rotational symmetry, and thus are rather common in materials. In this talk, I will first briefly introduce the concept of chiral phonons, which kept evolving after the first theoretical proposal in 2015 and experimental confirmation in 2018 for 2D semiconductors, followed by a briefly overview of recent exciting development of the field of chiral phonons and there possible relevance in energy and information transport. I will then give an example on chiral phonon-controlled spin polarization in rare earth halides, based on our recently developed time-resolved terahertz-optical spectroscopy. Finally, I will introduce quantum coherent spin-phonon coupling in 2D antiferromagnets, leading to magnon-phonon hybridization, nontrivial topology, and possible chiral edge states, showing phonons’ impact on spin properties without any external fields. Together, these phenomena demonstrate a new paradigm of dynamic structural-property relationship in quantum materials, as well as possible routes towards low-loss bosonic transport.

Introduction: Dr. Hanyu Zhu is an assistant professor of Materials Science and NanoEngineering at Rice University, with joint appointment in Physics and Astronomy, as well as Electrical and Computer Engineering. He earned his B.S. in Mathematics and Physics in Tsinghua University in China, when he got into the field of nanomaterials. He obtained his Ph.D. in Applied Science and Technology in the University of California at Berkeley for studying electromechanics of atomically thin crystals. After postdoctoral research at Berkeley developing new optical spectroscopy for phonons, he started the Emerging Quantum and Ultrafast Materials Lab in 2018, with a focus on bosonic excitations of quantum materials. He has a joint appointment in the department of Physics and Astronomy, and is part of the Rice Center for Quantum Materials. He received the ORAU Ralph E. Powe Junior Faculty Enhancement Award in 2019, the NSF CAREER Award in 2023, and the AFOSR Young Investigator Award in 2024.

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