CPh 2025

International Conference on Chiral Phonons

Program

and

Book of Abstracts

June 17 to 22, 2025 Nanjing, China

Organizer: Nanjing Normal University

Co-organizers: University of Science and Technology of China, Nanjing University of Posts and Telecommunications

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Welcome speech from conference chairs

Dear Participants, Colleagues, and Friends,

It is our great pleasure and honor to welcome you to **the International Conference on Chiral Phonons (CPh2025)** held in Nanjing, historically renowned as the capital city of six ancient Chinese dynasties. Chiral phononics, an emerging frontier of scientific inquiry, is transforming our understanding of quantum materials, topological phenomena, and pioneering technological advancements. This conference serves as a critical global platform, designed to facilitate the exchange of groundbreaking research, foster meaningful collaborations, and accelerate innovations in quantum computing, spintronics, and symmetry-driven materials science.

We express our sincere gratitude to the international scientific community for your enthusiastic engagement and contributions. The strong response, marked by **over 40 abstract submissions from researchers across 12 countries**, has resulted in an impressive scientific program. CPh2025 will showcase **24 invited lectures** highlighting significant recent advances, complemented by **13 contributed talks** and diverse **poster presentations**. Your active participation underscores the rapidly expanding global interest and progress in chiral phonon research.

We also extend our heartfelt appreciation to our **100+ delegates** and distinguished sponsors—Nanjing Normal University, the University of Science and Technology of China, Nanjing University of Posts and Telecommunications, and the National Natural Science Foundation of China—for their generous support. Your commitment greatly enhances the collaborative environment crucial for pioneering scientific discovery.

We hope this conference stimulates insightful academic discussions, strengthens international partnerships, and significantly advances our field. May your time at CPh2025 be intellectually rewarding and your stay in Nanjing memorable, a city where historical splendor meets scientific innovation.

With warm regards,

Lifa Zhang (Conference Chair, Nanjing Normal University)
Qian Niu (Conference Co-Chair, University of Science and Technology of China)

Conference Committees

LOCAL ORGANIZING COMMITTEE

- Lifa ZHANG, Nanjing Normal University, China (Conference Chair)
- Qian NIU, University of Science and Technology of China, China (Conference Co-Chair)
- Hao CHEN, Nanjing University of Posts and Telecommunications, China (Vice Chair)
- Tingting WANG, Nanjing Normal University, China (Secretary)
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- Jun ZHOU, Nanjing Normal University, China

Conference website: https://conferences.koushare.com/CPh2025

Conference Website

Sponsors

The organizers would like to express their deepest gratitude toward the following institutions for their support:

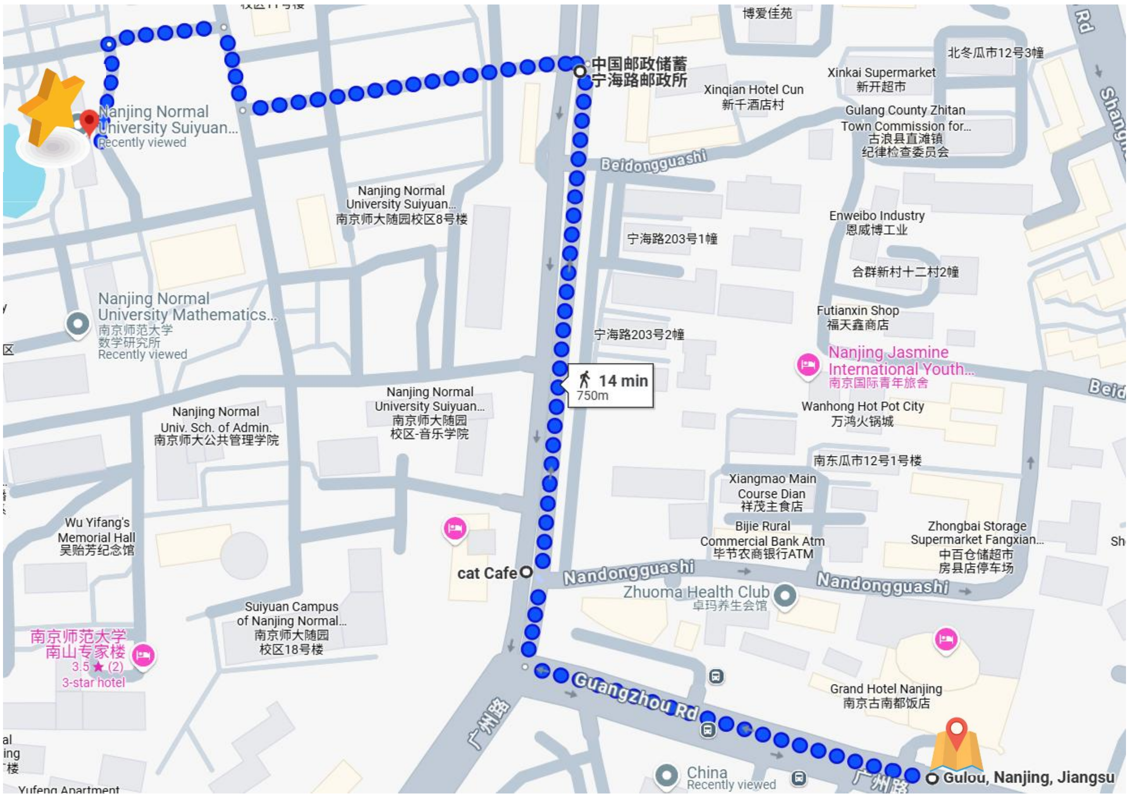
- Nanjing Normal University
- University of Science and Technology of China
- Nanjing University of Posts and Telecommunications
- National Natural Science Foundation of China

Attendance Instructions

Conference Check-in&Accommodation

Time: 2025-06-17 09:00-21:00

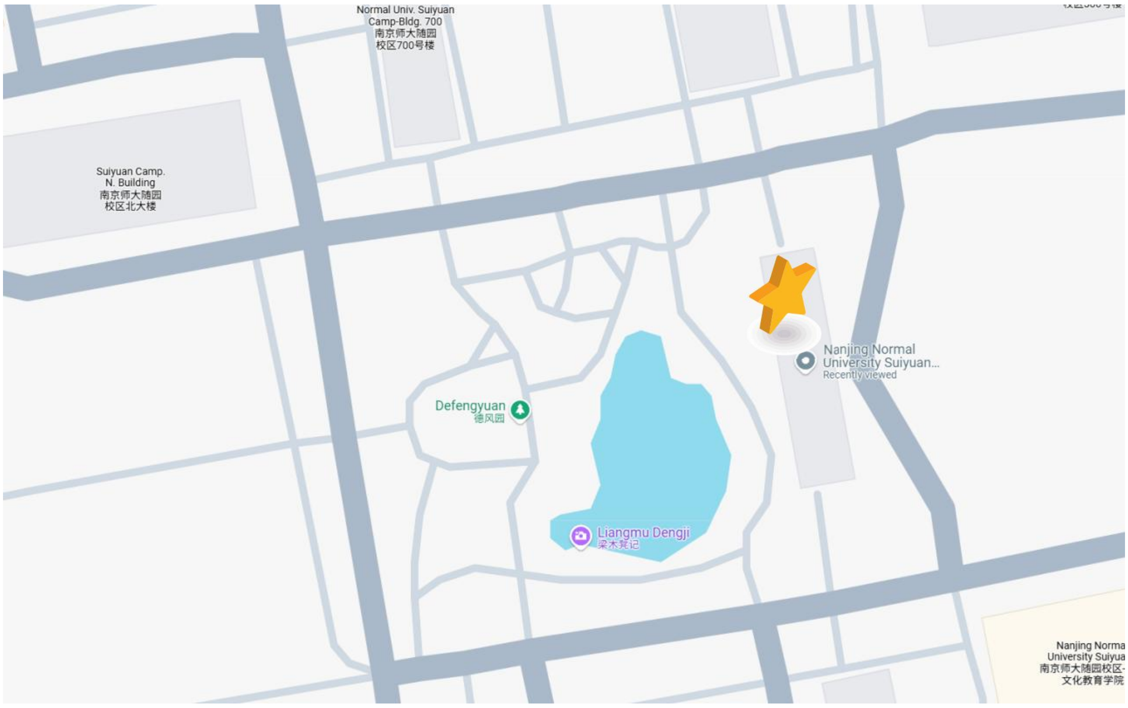
Location: Grand Hotel Nanjing (208 Guangzhou Rd, Nanjing, China)



Conference Venue

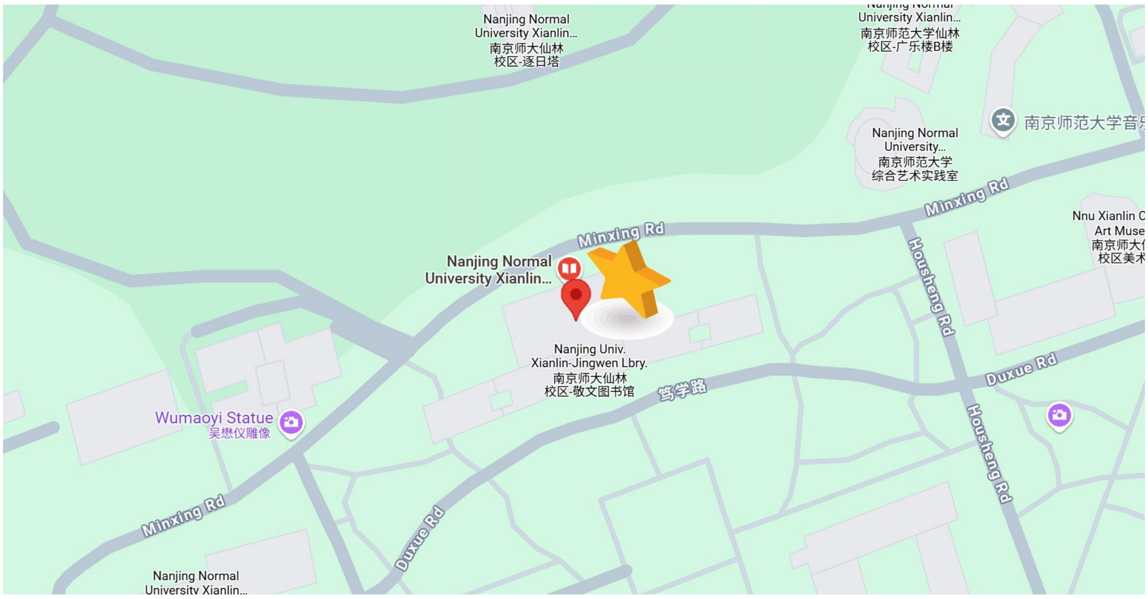
Time: June 18 to 20, 2025

Location: Nanjing Normal University Suiyuan Campus Conference room on the second floor of Building 100



Time: June 21,2025

Location: Nanjing Normal University Xianlin Campus East Auditorium on the second floor of Jingwen Library



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Traffic Guide

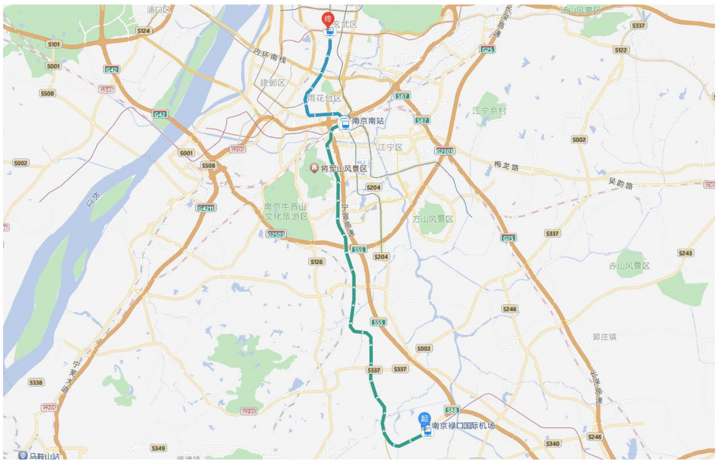
Nanjing Lukou Airport

Taxi / Online - Hailed Car

Cost: It's about 110 yuan.
Duration: It takes around 43 minutes to arrive.

Metro:

Cost: Around 7 yuan.
Duration: The whole journey takes approximately 1 hour and 40 minutes. The specific route is to walk to the metro station from the airport first, and then take Metro Line S1 (from Lukou Airport to Nanjing South Station). After getting off at Nanjing South Station, transfer to Metro Line 1 (from China Pharmaceutical University to Maigaoqiao). Get off at Xinjiekou Station and exit from Exit 6. Then walk 100 - 500 meters to the hotel.



Nanjing South Station

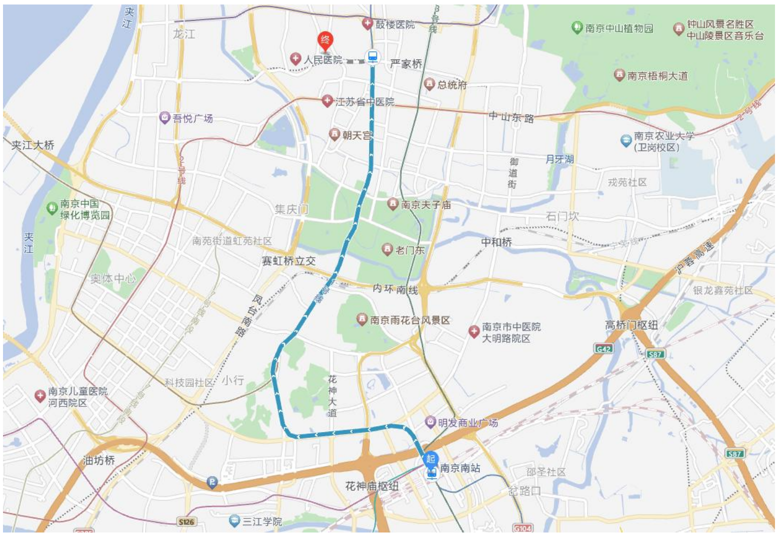
Taxi/Online - Hailed Car

Cost: It's about 60 yuan.
Duration: It takes around 25 minutes to arrive.

Metro:

Cost: Around 4 yuan.

Duration: Find the entrance of Metro Line 1 at Nanjing South Station, follow the signs and walk to the platform. Then take Metro Line 1 (in the direction of South of Bagua Zhou Bridge). After passing through 9 stations, get off at Zhujiang Road Station and exit from Exit 1.



Shanghai Pudong

High-speed Rail: Go from Shanghai Pudong International Airport to Shanghai Hongqiao Station or Shanghai Station, and then take a high-speed rail or bullet train to Nanjing South Station. The second-class seat fare of the high-speed rail is about 139 yuan, and that of the bullet train is about 93 yuan. After arriving in Nanjing South Station, you can refer to the above metro or taxi methods to get to the hotel.

Shanghai Hongqiao

High-speed Rail: Take a high-speed rail at Shanghai Hongqiao Station and head for Nanjing South Station.The journey usually takes about 1.5 hours.After arriving in Nanjing South Station, you can refer to the above metro or taxi methods to get to the hotel.

Schedule----CPh2025

June 17th【Nanjing Grand Hotel】			
---------------- Check in ----------------			
June 18th **Suiyuan Campus: Conference room on the second floor of Building 100**		**June 19th** **Suiyuan Campus: Conference room on the second floor of Building 100**	
Session Chair	**Lifa ZHANG**	**Session Chair**	**Hiroki UEDA**
8:30 - 8:50	**Opening Ceremony**	8:30 - 9:10	Shuichi MURAKAMI
8:50 - 9:30	Andrei KIRILYUK	9:10 - 9:50	Benedetta FLEBUS(online)
9:30 - 10:10	Takuya SATOH	9:50 - 10:10	Jun ZHOU
10:10 - 10:50	Coffee Break	10:10 - 10:50	Coffee Break
Session Chair	**Takeo KATO**	**Session Chair**	**Andrei KIRILYUK**
10:50 - 11:30	Yoshihiko TOGAWA	10:50 - 11:30	Yafei REN(online)
11:30 - 12:10	Hiroki UEDA	11:30 - 12:10	Bumchul PARK(online)
12:10 - 14:00	Lunch Time & Break	12:10 - 14:00	Lunch Time & Break
Session Chair	**Takuya SATOH**	**Session Chair**	**Jie REN**
14:00 - 14:40	Dominik JURASCHEK(online)	14:00 - 14:40	Taekoo OH(online)
14:40 - 15:20	Takeo KATO	14:40 - 15:00	Jing-Tao LÜ
15:20 - 15:40	Yizhou LIU	15:00 - 15:20	Eiichi OISHI
15:40 - 16:20	Coffee Break	15:20 - 16:00	Coffee Break
Session Chair	**Yoshihiko TOGAWA**	**Session Chair**	**Tiantian ZHANG**
16:20 - 17:00	Rembert DUINE(online)	16:00 - 16:40	Urs STAUB(online)
17:00 - 17:40	Luis FOA TORRES(online)	16:40 - 17:20	Matteo CALANDRA(online)
17:40 - 18:00	Fernando GÓMEZ-ORTIZ(online)	17:20 - 17:40	Peng CHEN
18:00 -	Dinner Time & Break	18:00	Dinner Banquet

June 20th Suiyuan Campus: Conference room on the second floor of Building 100		June 21th Xianlin Campus: East Auditorium on the second floor of Jingwen Library	
Session Chair	**Felix HERNANDEZ**	**Session Chair**	**Xiao LI**
8:30 - 9:10	Jie REN	9:00 - 9:40	Qi ZHANG
9:10 - 9:50	Andrey BAYDIN(online)	9:40 - 10:20	Hanyu ZHU
9:50 - 10:10	Takehito YOKOYAMA	10:20 - 11:00	Qian NIU
10:10 - 10:50	Coffee Break	11:00 - 11:20	Closing Ceremony
Session Chair	**Sinisa COH**	11:20 - 14:00	Lunch Time & Break
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11:30 - 11:50	Weikang WU		
11:50 - 12:10	Qingyong REN		
12:10 - 14:00	Lunch Time & Break		
Session Chair	**Qi ZHANG**	14:00 - 18:00	Visit the campus & Free Discussion
14:00 - 14:40	Tiantian ZHANG		
14:40 - 15:20	Felix HERNANDEZ		
15:20 - 15:40	Fangliang WU		
15:40 - 16:20	Coffee Break		
Session Chair	**Hanyu ZHU**		
16:20 - 17:00	Sinisa COH		
17:00 - 17:20	Tingting WANG		
17:20 - 17:40	Xiangping ZHAO		
17:40 - 18:00	Xiaozhe LI		
18:00 -	Dinner Time & Break	18:00 -	Dinner Time & Break
June 22th【Nanjing Grand Hotel】			
--------------- Check out ---------------			

Timetable - Presentations

June 18th - Wednesday morning

Suiyuan Campus: Conference room on the second floor of Building 100

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9:30 - 10:10	Chiral Phonons in Circularly Polarized Raman Scattering **Takuya SATOH**	3
Session Chair : Takeo KATO		
10:50 - 11:30	Chirality-Induced Selectivity and Polarization of Electron Spins and Chiral Phonons in Chiral Materials **Yoshihiko TOGAWA**	4
11:30 - 12:10	Spectroscopy on chiral phonons **Hiroki UEDA**	5

June 18th - Wednesday afternoon

Suiyuan Campus: Conference room on the second floor of Building 100

Session Chair : Takuya SATOH		
14:00 - 14:40	Phonon chirality beyond circular atomic motion **Dominik JURASCHEK (online)**	6
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15:20 - 15:40	Topological Phononics: From Fundamental Models to Real Materials **Yizhou LIU**	8
Session Chair : Yoshihiko TOGAWA		
16:20 - 17:00	Phonon Amplification via Magnetoelastic Klein Scattering **Rembert DUINE (online)**	9
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June 19th - Thursday morning

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Extended Abstracts

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Shaken or stirred: ultrafast phono-magnetism

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Abstract: Excitations of the crystal lattice have a significant impact on the orbital dynamics of the electrons, and through it, also on spins. Recently, ultrafast optical techniques have provided new insights into the spin-lattice coupling including angular momentum transfer from magnetization to phonons [1,2]. It should therefore be possible to realize the opposite process, by driving the lattice and thus controlling the magnetization, on the same (femtosecond) time scale.

We have recently demonstrated how the resonant excitation of circularly-polarized optical phonons in paramagnetic substrates can permanently reverse the magnetic state of the overlayer [3]. With the handedness of the phonons steering the direction of switching, such effect offers a selective and potentially universal method for ultrafast non-local control over magnetic order.

Moreover, a different and ultimately universal behaviour, characterized by displacive modification of crystal potentials, is driven by linearly-polarized excitation. The magnetic switching was shown to create very peculiar quadrupolar spatial patterns [4], confirming the mechanism. The mechanism appears to be very universal, as observed in variety of systems [5]. The dynamics of the domain formation was shown to proceed via a strongly inhomogeneous magnetic state resulting in a self-organization of magnon-polarons [6] and formation of magneto-elastic solitons.

Keywords: Magnetization dynamics; phono-magnetism; infrared and THz spectroscopy.

References:

[1] C. Dornes et al, Nature 565, 209 (2019).
[2] S.R. Tauchert et al, Nature 602, 73 (2022).
[3] C.S. Davies, F.G.N. Fennema, A. Tsukamoto, I. Razdolski, A.V. Kimel & A. Kirilyuk, Nature 628, 540 (2024).
[4] A. Stupakiewicz, C.S. Davies, K. Szerenos, D. Afanasiev, K.S. Rabinovich, A. V. Boris, A. Caviglia, A.V. Kimel, & A. Kirilyuk, Nature Phys. 17, 489 (2021).
[5] M. Kwaaitaal, D.G. Lourens, C.S. Davies & A. Kirilyuk, Nature Phot. 18, 569 (2024).
[6] 6. M. Gidding, T. Janssen, C.S. Davies & A. Kirilyuk, Nature Commun. 14, 2208 (2023).

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Chiral Phonons in Circularly Polarized Raman Scattering

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Abstract: In chiral crystals, truly chiral phonons—phonons for which the inner product of the wave vector and angular momentum is nonzero—can exist [1]. These phonons are known to be detectable using circularly polarized Raman spectroscopy. Such phenomena have been reported in crystals with a threefold helical structure, including α-HgS [1], Te [2], and α-quartz [3]. In contrast, $CrSi_2$ is an inorganic chiral crystal featuring a sixfold helical structure. It exhibits two enantiomorphic forms depending on the handedness of the helix: a right-handed form (space group $P6_222$) and a left-handed form ($P6_422$).

We conducted circularly polarized Raman spectroscopy on single-crystalline $CrSi_2$ and observed that, similar to chiral crystals with threefold helicity, the Raman shifts of doubly degenerate phonon modes differ between RL and LR polarization configurations. Furthermore, first-principles calculations were performed to determine the selection rules for circular polarization and the phonon angular momentum. These results confirm that genuine chiral phonons have also been successfully observed in $CrSi_2$.

In addition, we explored the excitation of chiral phonons in an achiral crystal.

Keywords: circularly polarized Raman scattering, truly chiral phonon, chiral crystals

References:

[1] K. Ishito, H. Mao, Y. Kousaka, Y. Togawa, S. Iwasaki, T. Zhang, S. Murakami, J. Kishine, and T. Satoh, Nat. Phys. 19, 35 (2023).

[2] K. Ishito, H. Mao, K. Kobayashi, Y. Kousaka, Y. Togawa, H. Kusunose, J. Kishine, and T. Satoh, Chirality 35, 338 (2023).

[3] E. Oishi, Y. Fujii, and A. Koreeda, Phys. Rev. B 109, 104306 (2024).

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Chirality-Induced Selectivity and Polarization of Electron Spins and Chiral Phonons in Chiral Materials

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Abstract: A role of chirality is discussed, being inspired by recent studies on chirality-induced dynamic phenomena with chiral materials. As a manifestation of time-even pseudo scalar, which works as a microscopic chiral term in chiral media and hybridizes translational and rotational degrees of freedom, a polarization of angular momenta appears under charge or thermal flow. Notably, such a polarized state of electron spins or atomic vibrations (chiral phonons) is detectable electrically and its robust protection enables non-local spin detection over micrometers and even centimeters in chiral materials. In the talk, I would focus on recent experimental progress on the key findings made with various kinds of chiral inorganic materials [1-8]. A comprehensive understanding of these nontrivial features will clarify the mystery of chirality-induced spin selectivity (CISS).

Keywords: Chirality, Angular Momenta, Electron Spins, Chiral Phonons, CISS

References:

[1] A. Inui *et al.*, Phys. Rev. Lett. 124, 166602 (2020).
[2] K. Shiota *et al.*, Phys. Rev. Lett. 127, 126602 (2021), featured in Physics 14, s113.
[3] H. Shishido *et al.*, Appl. Phys. Lett. 119, 182403 (2021).
[4] Y. Kousaka *et al.*, Jpn. J. Appl. Phys. 62, 015506 (2023).
[5] H. Shishido *et al.*, J. Chem. Phys. 159, 064502 (2023).
[6] K. Ishito *et al.*, Nat. Phys. 19, 35 (2023); Chirality 35, 338 (2023).
[7] K. Ohe *et al.*, Phys. Rev. Lett. 132, 056302 (2024).
[8] Y. Togawa *et al.*, J. Phys. Soc. Jpn. 92, 081006 (2023), Special Topics DMI.

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Spectroscopy on chiral phonons

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Abstract: Three different types of circular phonons have been referred to as chiral phonons in the community: (1) circular rotation modes at the Γ point [1], (2) circular rotation modes propagating in the rotational plane [2, 3], and (3) circular rotation modes propagating out of the rotational plane [4, 5]. From the symmetry point of view, however, only the last type is chiral because of the dimensionality. Here, I will show our direct demonstration of the last type of chiral phonons in a chiral crystal α-SiO_2 [5] and a polar crystal $LiNbO_3$ [6] by resonant inelastic X-ray scattering (RIXS) with circularly polarized X-rays. Angular momentum transfer between a circularly polarized photon and a chiral phonon imposes the selection rule in the RIXS process and allows us to observe chiral phonons as a circular contrast in a phonon excitation peak. Our demonstration will clarify the symmetry requirement to possess chiral phonons.

Keywords: RIXS, chiral crystal, polar crystal

References:

[1] J. Luo, T. Lin, J. Zhang, X. Chen, E. R. Blackert, R. Xu, B. I. Yakobson, and H. Zhu, Science 382, 698-702 (2023).
[2] L. Zhang and Q. Niu, Phys. Rev. Lett. 115, 115502 (2015).
[3] H. Zhu, J. Yi, M.-Y. Li, J. Xiao, L. Zhang, C.-W. Yang, R. A. Kaindl, L.-J. Li, Y. Wang, and X. Zhang, Science 359, 579-582 (2018).
[4] K. Ishito, H. Mao, Y. Kousaka, Y. Togawa, S. Iwasaki, T. Zhang, S. Murakami, J.-I. Kishine, and T. Satoh, Nat. Phys. 19, 35-39 (2023).
[5] H. Ueda, M. García-Fernández, S. Agrestini, C. P. Romao, J. van den Brink, N. A. Spaldin, K.-J. Zhou, and U. Staub, Nature 618, 946-950 (2023).
[6] H. Ueda, A. Nag, C. P. Romao, M. García-Fernández, K.-J. Zhou, and U. Staub, arXiv 2504.03330.

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Phonon chirality beyond circular atomic motion

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Abstract: Chiral phonons are generally inseparably associated with circular or elliptical motion of atoms in a crystal lattice, which leads to angular momentum and an associated magnetic moment. Here, we present different cases of phonons that defy this conventional picture and lead to new forms of phonon angular momentum and chirality. In particular, we show that (i) phonon angular momentum can arise from purely linear atomic motion [1], (ii) phonon angular momentum and phonon magnetic moment can be noncollinear [1], (iii) multicolor phonons lead to staggered angular momentum and magnetization [2], and (iv) nonlinear excitation of phonons can make structurally achiral materials chiral [3-5]. Our findings provide new insight into the fundamentals of phonon chirality and angular momentum and a novel toolkit for advanced light-induced control of functional properties in quantum materials.

Keywords: Geometric chiral phonons, multicolor phonons, nonlinear phononics

References:

[1] S. Chaudhary, C. P. Romao, D. M. Juraschek, arXiv: 2504.19121.

[2] O. Yaniv, D. M. Juraschek, arXiv:2504.03323.

[3] C. P. Romao, D. M. Juraschek, ACS Nano 18, 29550 (2024).

[4] Z. Zeng, M. Först, M. Fechner, M. Buzzi, E. Amuah, C. Putzke, P. J. W. Moll, D. Prabhakaran, P. Radaelli, and A.Cavalleri, Science 387, 431 (2025).

[5] C. P. Romao, D. M. Juraschek, Chirality à la carte Science 387, 361 (2025).

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Spin-Chiral Phonon Interconversion at Metal-Chiral Insulator Interfaces

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Abstract: Recently, phonon-spin interconversion phenomena have attracted considerable attention as manifestations related to chirality-induced spin selectivity (CISS). Despite numerous theoretical and experimental investigations [1], the microscopic mechanism governing the interconversion between chiral phonons and electron spins remains unresolved. In this study [2], we develop a theoretical framework for this interconversion by considering the gyromagnetic effect, which describes angular momentum transfer between electron spin and rigid-body rotation.

We analyze a junction system composed of a nonmagnetic metal (NM) and a chiral insulator (CI) and focus particularly on "microscopic rotations" induced in the presence of chiral phonons. This leads us to derive a spin-microscopic rotation coupling at the interface. Importantly, this coupling does not require spin-orbit interaction and plays a crucial role in mediating spin–chiral phonon interconversion. By treating the interfacial spin–phonon coupling perturbatively, we calculate the spin current injected into the NM under a temperature bias. We demonstrate that a non-equilibrium distribution of chiral phonon modes, induced by a temperature gradient, can generate a spin current across the NM/CI interface. Furthermore, we estimate the magnitude of this spin current and compare it with experimental results [3].

Keywords: chiral phonon, gyromagnetic effect, phonon-spin conversion

References:

[1] Y. Togawa et al., J. Phys. Soc. Jpn. 92 (2023) 081006.
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Topological Phononics:
From Fundamental Models to Real Materials

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Abstract: Phonons are one of the most important excitations in condensed matter physics and are also main carriers of heat in solids. Inspired by recent success of topological quantum matter, concepts of band topology such as Berry connection and curvature are introduced into phononic systems, which brings a new branch called topological phononics [1].
In this talk, I will share our investigations of topological phononics in crystalline solids. By comparison with electronic band theory, we obtained a Schrödinger-like equation for phonons based on which the phononic Haldane model with nonzero Chern number can be derived [2,3]. We find phononic pseudospin degree of freedom in 2D Kekulé lattice based on which various exotic phenomena are proposed including quantum spin-Hall like states of phonon, phononic pseudospin Zeeman effect, and pseudospin contrasting optical selectivity [4]. We further generalize the concept of pseudospin to 3D lattices and realize the three-dimensional topological phononic insulator [5]. Finally, we find various crystalline solids which can support topological phonons. Among them, silicon emerges as a model material which can support both topological nodal-line phonons and topological nexus phonons [6].

Keywords: Topological phonons; Berry phase; Pseudospin

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Phonon Amplification via Magnetoelastic Klein Scattering

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Abstract: Materials exhibit various wave-like excitations, among which phonons (lattice vibrations) and magnons (oscillations in ferromagnetic ordering) hold significant promise for future nanoscale technologies. Exploring the interaction between these excitations may pave the way for innovative devices that leverage their complementary strengths. This article presents a set-up designed to amplify an incoming phononic current, potentially enhancing the phonon lifetime. The set-up consists of a nonmagnetic and ferromagnetic insulator. The ferromagnet is polarized opposite to the external magnetic field with spin-orbit torque, which allows for negative-energy magnons. Phonons that are incoming from the nonmagnetic side will interact with the negative-energy magnons via magnetoelastic coupling. The reflected phonon will increase in amplitude as a result of energy conservation. This interaction between negative-energy magnons and phonons is an example of Klein scattering. This work opens new avenues for the development of advanced devices that capitalize on the combined properties of phonons and magnons.

Keywords: phonons, magnons, spin waves, magnonics, spintronics

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Surprises from electron-phonon interactions in two-dimensional materials

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Abstract: Since the early days of the quantum theory of solids, the interaction between electrons and lattice vibrations has provided a long list of exciting discoveries. Examples include the role played by electron-phonon (e-ph) interaction in the development of the theory of superconductivity and conducting polymers, where charge doping is used to circumvent the Peierls transition. In the last decade, the theoretical prediction and observation of phonons with intrinsic chirality in two-dimensional materials brought a new ingredient to this long standing problem. In this talk I will present our recent results on the effects of the interaction between electrons and phonons in two-dimensional materials [1,2,3]. By using a non-perturbative solution, we demonstrate that electron-phonon interactions trigger inelastic Umklapp processes, leading to peculiar edge states. These states exhibit a distinctive locking among propagation direction, valley, and phonon mode, allowing for the generation of electron–phonon entangled states whose parts can be easily split. We discuss the effect of the chiral atomic motion in the zone boundary phonons leading to this efft. Our findings shed light on harnessing these unconventional states in quantum research.

Keywords: electron-phonon interaction; edge states; graphene

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Pathways to crystal chirality: A systematic procedure to identify new displacive chiral phase transitions

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Abstract: We present an algorithm that integrates pseudosymmetry search with first-principles calculations to systematically identify achiral parent structures and establish potential chiral displacive transitions linking them to their corresponding chiral phases within the 22 enantiomorphic space groups. This approach enables a robust exploration of structural relationships, offering new insights into symmetry-driven properties.

Chirality has seen a resurgence in materials science research due to its critical applications in high-impact areas such as topological insulators, chiral phonons in two-dimensional materials, and altermagnetism, as highlighted in recent studies [1,2,3].

Moreover, symmetry arguments [4] demonstrate that symmetry breaking phase transitions between chiral and achiral phases exist and should be observed in nature. A case of special interest occurs when such transitions are driven by a soft phonon mode. However, despite considerable experimental and theoretical effort, only K_3NiO_2 has been recently proposed [5] to show such transitions, even though numerous chiral phases are documented in the Inorganic Crystal Structure Database as noted in a recently published review on the topic [6]. This gap raises fundamental questions about whether these transitions are constrained by physical or chemical limitations or have simply been overlooked due to limitations in current search methodologies.

Our proposed algorithm directly addresses this challenge, providing a systematic approach to uncovering achiral-to-chiral phase transitions driven by structural instabilities. It is designed to integrate easily into high-throughput workflows, enabling the rapid screening of large databases to identify a wide range of new candidate materials exhibiting chiral phase transitions.

We apply this methodology on the chiral phases of TeO2, Na2SeO9, Sr2As2O7, As2O5, Rb2Be2O3, and CaTe2O3. Demonstrating that some do not have a minimal supergroup that allows for an achiral phase; some can have a minimal supergroup, still, no unstable phonon mode exists in the achiral phase; and somewhere the minimal supergroup exists with a soft phonon mode connecting the identified achiral phase and the chiral phase through small continuous displacements. By applying our methodology, we have already identified new promising materials, demonstrating both the effectiveness of our approach and its potential to significantly expand the catalog of materials with chiral displacive transitions.

Keywords: Displacive chiral transitions, Soft chiral phonons, Chiral phonons, Enantimorphic groups

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Theory of generation of spin polarizations by chiral phonons

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Abstract: Phonons can have rotational motions in some materials [1,2]. Such phonons are called chiral phonons. For example, in systems with chiral structure such as tellurium, phonon modes possess angular momenta. We study novel phenomena associated with phonon angular momentum by using an analogy to electron spins.

We have theoretically shown that chiral phonons induce spin magnetization in electronic systems [3]. This phenomenon is caused by dynamic modulation of electronics states by chiral phonons, which induces a spin polarization. The formula of the time-averaged value of the spin magnetization is given in terms of the Berry curvature in the phonon coordinates [4], analogous to the orbital magnetization [5]. Furthermore, in ferromagnets and antiferromagnets, we found that chiral phonons induce changes in magnon excitations [6]. This shows that chiral phonons can serve as an effective magnetic field for electrons and magnons [3,6,7], and this scenario can be a microscopic mechanism for spin-rotation coupling. We also demonstrate the similar physics of the coupling between the surface acoustic wave and the magnetostatic waves.

Keywords: Chiral phonons, magnetization, spin, surface acoustic wave

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Chiral phonons

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Abstract: In recent years, a rapidly increasing number of studies has reported novel physical phenomena arising from lattice vibrations that carry angular momentum, leading to the emergence of the field of 'chiral phonons' [1]. In magnetic systems, the coupling between lattice vibrations and magnetic degrees of freedom has been identified as a key mechanism behind phonon chirality and the ensuing thermal Hall effects. However, recent observations of giant thermal Hall signals in a range of compounds suggest that additional mechanisms, such as impurity scattering and coupling to out-of-phase ionic motion, play a significant role. In this talk, I will present an overview of these sources of phonon chirality and discuss their implications for the interpretation of recent experimental findings [2,3,4].

Keywords: Thermal Hall effect, Phonon Hall Viscosity, Magnon-polarons.

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Role of Chiral Phonon in High-T_c Superconductivity

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Abstract: Breaking down the traditional perception on phonons which are achiral, the existence of a chiral phonon carrying angular momentum provides possible ways to couple electrons, photons, spins, magnons, and excitons, etc. We theoretically proposed an electron-chiral phonon interaction with a two-phonon process, in contrast to a conventional electron-phonon interaction, and a kind of effective Hubbard interaction through exchanging two chiral phonons is proposed. Taking a two-dimensional diatomic honeycomb lattice as an example, we found this repulsive Hubbard interaction mediated by chiral phonons induces unconventional and high-temperature superconductivity. Moreover, the numerical calculations show an inverse isotope effect which is consistent with experimental observations in high-T_c superconductors. Our finding on an electron-chiral phonon and the associated Cooper pair provides a path to understand the high-T_c superconductivity.

Keywords: Chiral phonon, high-T_c superconductivity, electron-phonon coupling, Hubbard model

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Geometric and nonlinear aspects of electron-phonon interactions

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Abstract: The interaction between electrons and phonons plays a pivotal role in shaping both the phononic and magnetic properties of materials. On one hand, time-reversal symmetry breaking in the electronic system gives rise to nonlocal effective magnetic fields acting on lattice dynamics, manifested as molecular Berry curvatures [1]. These effects lead to chiral optical phonons at the Brillouin zone center, topological phonon bands, and anomalous thermal Hall responses. We highlight the resulting nonreciprocal propagation of acoustic phonons in PT-symmetric antiferromagnets, which can be tuned by external electric fields and are captured through flexo-viscosity and torques in continuum theory [2]. On the other hand, chiral phonons themselves break time-reversal symmetry in the electronic sector, inducing magnetization in otherwise nonmagnetic systems. Of particular interest is the topological orbital contribution, characterized by a second Chern form of the electronic wavefunction in a hybrid parameter space spanned by lattice displacement and electronic momentum [3,4]. Viewed together, these reciprocal interactions form a feedback loop, introducing intrinsic nonlinearity. When driven far from equilibrium, such nonlinearities can give rise to dynamical instability like bifurcation with spontaneous symmetry breaking [5], opening new avenues for on-demand magnetic control and the realization of exotic nonequilibrium phases of matter.

Keywords: Berry curvature, Nonlinearity, Bifurcation, Adiabatic dynamics

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Chiral nanocrystals with optically active spins and phonons

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Abstract: Crystal lattices with broken inversion symmetry can induce chirality in spin configurations and phonon vibrations, opening new avenues for topological and quantum properties in light-matter interactions. These features have attracted significant attention for next-generation applications in optics, electronics, and energy. However, controlling chirality in long-range ordered metal oxides or metal chalcogenides is particularly challenging, especially when extended beyond atomic layers into the nanoscale regime. In this presentation, we will share our recent findings, focusing on how to realize crystallographically chiral nanocrystals and reveal their emergent chiral interactions with light through spin and phonon modes. First, we demonstrate a previously unknown two-dimensional (2D) iron oxyhydroxide that can host a low-dimensional quantum spin system, enabled by chiral hybridization between organic ligands and Fe–O octahedra. The material is synthesized as uniform nanoplatelets (~40 nm in thickness) and can be scaled up to 100 grams. The surface ligand incorporation process is universal across various ligand types and induces a transition from achiral to chiral crystallographic symmetry upon the intercalation of enantiomeric amino acids. This chiral transformation also significantly affects the quantum magnetic state. The resulting quantum spin state, capable of site-specific spin polarization, manifests not only in magnetic circular dichroism in the visible range but also in enhanced electrochemical catalytic activity. Second, we revealed that chiral phonon excitation can also lead to strong polarization of terahertz (THz) light. Our custom-built time-domain THz polarimetry system, equipped with multiple polarizer configurations, is capable of extracting the circular dichroism component of THz light induced by chiral phonons. Using the surface ligand penicillamine, we directed the chirality of mercury sulfide (α-HgS) nanoparticles to adopt specific handedness among the enantiomeric space group ($P3_121$ or $P3_221$). Despite the significant length-scale mismatch between the nanomaterials and the wavelength of THz light, the restructured HgS nanoparticle assemblies exhibited exceptionally strong optical rotation with a high asymmetry factor (g-factor), driven by strong interactions between chiral phonons referred to as collective chiral phonon modes. We believe these results provide a versatile strategy for exploring diverse families of chiral crystal lattices with novel quantum and topological functionalities.

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Phonon Thermal Hall Effect in Mott Insulators via Skew Scattering by the Scalar Spin Chirality

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Abstract: Thermal transport is a crucial probe for studying excitations in insulators. In Mott insulators, the primary candidates for heat carriers are spins and phonons; which of these candidates dominates the thermal conductivity is a persistent issue. Typically, phonons dominate the longitudinal thermal conductivity while the thermal Hall effect (THE) is primarily associated with spins, requiring time-reversal symmetry breaking. The coupling between phonons and spins usually depends on spin-orbit interactions and is relatively weak. Here, we propose a new mechanism for this coupling and the associated THE: the skew scattering of phonons via spin fluctuations by the scalar spin chirality. This coupling does not require spin-orbit interactions and is ubiquitous in Mott insulators, leading to a thermal Hall angle on the order of 10−3 to 10−2. Based on this mechanism, we investigate the THE in YMnO3 with a trimerized triangular lattice where the THE beyond spins was recognized, and we predict the THE in the kagome and square lattices.

Keywords: Thermal Hall Effect, Chiral Phonon, Scalar Spin Chirality

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Current-driven chiral vibrations

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Abstract: Vibrations of single molecule can couple indirectly through their mutual interaction with flowing electrical current, i.e., in a single-molecule junction setup. This effect is especially important for nearly degenerate vibrations. It can be understood through momentum/angular momentum transfer from electrons to the vibrations, in contrast to the Joule heat transfer. Using this effect, we have designed and realized a single molecular motor, akin to Archimedes screw, based helicene molecule. We will discuss the working mechanism of this Archimedes molecular motor.

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Selective observation of right- and left-handed chiral phonons in α-quartz by circularly polarized Raman spectroscopy

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Abstract: Recently, it has become clear that phonons, which are quanta of lattice vibrations, can have not only energy and momentum but also angular momentum [1-3]. In particular, phonons with angular momentum and nonzero momentum are called chiral phonons, corresponding to lattice vibrations with rotating atomic displacements and propagating in a crystal [4]. Chiral phonons have been observed in chiral crystals with helical structures, such as α-HgS [4], Te [5], and α-quartz [6]. Among these materials, interesting phenomena have been reported for the chiral phonons of α-quartz, such as the chiral phonon diode effect [7] and chirality-induced phonon angular momentum selectivity [8]. In relation to these phenomena, it is important to selectively observe the right- and left-handed chiral phonons in α-quartz. Therefore, we performed circularly polarized Raman spectroscopy on the right- and left-handed quartzes [9]. In this presentation, we will report the details of the circularly polarized Raman spectra obtained and the Raman selection rules for the chiral phonons in the right- and left-handed quartzes.

Keywords: Raman spectroscopy, Circularly polarized light, Chiral crystal, α-quartz, Chirality

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Chiral Phonons Investigated by Ultrafast X-Ray Scattering

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Abstract: Here I like to address chiral and circular phonon modes in real time using ultrashort X-ray pulses from a X-ray Free Electron Lasers. In the first example. I will show how we can tackle chirality by resonant X-ray diffraction on a chiral crystal of $CsCuCl_3$ using circularly polarized X-rays. With this we can address how X-rays can observe a chiral order parameter (chiral amplitude) and how we can modulate it in real time by above band gap and THz excitations. The second example concerns the quantification of atomic motions using a circular drive exemplified for the soft mode for $SrTiO_3$ and $EuTiO_3$, where we can directly observe and quantify the circular atomic motions in real time by ultrafast X-ray diffraction. I will also address how we try to directly detect the loss of time reversal symmetry using x-rays.

Keywords: ultrafast x-ray scattering, resonant drive, quantified atomic motions

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Theory of dichroic absorption, Faraday and Kerr rotation in non-collinear magnetic insulator with strong relativistic effects

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Abstract: In crystals with broken time reversal symmetry, non collinear magnetism and spin-orbit coupling the phonon degrees of freedom can host a finite angular momentum. Despite being of the same order of the electron spin, its detection is difficult. The main reason is that the dynamical effects generally induce small phonon splittings. Here in an effort to develop spectroscopic fingerprints of chiral phonons, we develop a first principles based theory of the dichroic absorption and of the Kerr and Faradays effects. We show that these spectroscopies probe phonon chirality and the dynamical phonon response. We evaluate the magnitude of the effects in time dependent density functional theory within the adiabatic local density approximation for the prototypical non- collinear relativistic magnet CrI3.

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Keywords: Chiral phonons, Faraday and Kerr effect, first principles calculation,

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Chiral Mechanism in Ferroelectrics: Electric Dzyaloshinskii-Moriya Interaction

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Abstract: Noncollinear ferroelectricity is as intriguing as noncollinear magnetism, especially in small-scale phenomena and topological polar defects at room temperature[1, 2]. Questions surrounding intrinsic interactions responsible for chirality order parameters in materials have persisted until the discovery of the oxygen octahedral tilting-mediated electric Dzyaloshinskii-Moriya interaction (eDMI) [3] and the subsequent elucidation of its electronic origin [4]. Recent studies have documented various noncollinear polar solitons [1]. However, no ferroelectric system dominated by eDMI has been verified. This raises the question: Is there an overlooked type of ferroelectricity defined by the eDMI mechanism, or does eDMI contribute to chiral phonons?

In this talk, I will summarize the eDMI, focusing on the second type of electric Dzyaloshinskii-Moriya interaction, which elucidates the screw-like polar textures observed in a recent experiment [5]. Additionally, we will introduce screw-stacking 2D ferroelectric materials, a new type of stacking ferroelectric enabled by this eDMI. We find that (i) screw-stacking ferroelectrics presents a system where material chirality can be manipulated through the control of ferroelectric polarization and (ii) the screw-stacking strategy offers a promising avenue for engineering negative piezoelectric materials. Our research might reveal a new ferroelectric mechanism, enhancing the understanding of electric Dzyaloshinskii-Moriya interactions.

Keywords: Noncollinear Ferroelectrics, Dzyaloshinskii-Moriya Interaction

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From Acoustic Spin, Elastic Spin to Phonon Spin

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Abstract: Spin angular momentum is an inherent property of classical waves. It was believed that only circularly polarized transverse waves carry spin, while longitudinal waves lack spin structures. However, recent progress has challenged this understanding. Here, I'll share recent progress on acoustic spin, elastic spin, and phonon spin, along with spin related chiral phenomena.

1) SAM of elastic wave and acoustic wave Elastic waves, which refer to vibrations in elastic media, can be described by the displacement field $\boldsymbol{u}(\boldsymbol{r},t)= \boldsymbol{u}_0(\boldsymbol{r})e^{i(\boldsymbol{k}\cdot\boldsymbol{r}-\omega t)}$. The SAM density carried by elastic waves can be expressed as [1,2]: $\boldsymbol{S} = \rho\omega \ \mathrm{Im}[\boldsymbol{u}^* \times \boldsymbol{u}]/2$. $\boldsymbol{S}$ is also applicable to acoustics waves. Experimentally, we can utilize absorbers that absorb acoustic waves to actually measure the torque induced by SAM of acoustics and verify its existence [3].

2) Spin related chirality in acoustic meta waveguides The chiral phenomena associated with the spin of air acoustics can be harnessed as a tool for manipulating acoustic waves. For example, by disrupting the symmetry of an acoustic waveguide, we can establish a fixed chiral relationship among SAM, wave vector, and the waveguide's structure [4]. Leveraging this relationship, we can tailor specific propagation paths for acoustic waves, as demonstrated in Fig. 1a. Furthermore, by exploiting the chiral relation between spin, energy flow, and reactive power in surface waves [5], we can achieve selective excitation of acoustic waves [6], as shown in Figs 1b and 1c.

3) Hybrid Spin in elastic waves Electromagnetic waves belong to the category of transverse waves, since $\nabla\cdot \boldsymbol{E}=0$. Longitudinal waves, such as those found in air acoustics, exhibit a velocity field with zero vorticity $\nabla\times \boldsymbol{v}=0$. Elastic waves, however, stand apart from both of these types, display both divergence-free and cure-free parts. Their displacement field can be represented by $\boldsymbol{u} = \boldsymbol{u}_l + \boldsymbol{u}_t$, satisfying $\nabla\times \boldsymbol{u} = 0$ and $\nabla\cdot \boldsymbol{u} = 0$. The spin of elastic waves is expressed as $\boldsymbol{S} = \rho\omega \ \mathrm{Im}[\boldsymbol{u}^*\times \boldsymbol{u}]/2$ $= \rho\omega \ (\mathrm{Im}[\boldsymbol{u}_l^*\times \boldsymbol{u}_l] + \mathrm{Im}[\boldsymbol{u}_t^*\times \boldsymbol{u}_l] + \mathrm{Im}[\boldsymbol{u}_l^*\times \boldsymbol{u}_t] + \mathrm{Im}[\boldsymbol{u}_t^*\times \boldsymbol{u}_t])/2$, which possess the hybrid parts $\boldsymbol{u}_l^*\times \boldsymbol{u}_t$ and $\boldsymbol{u}_t^*\times \boldsymbol{u}_l$ [1,2,7]. Therefore, even within similar systems, the spin distribution of elastic waves may vary significantly, as shown in Fig. 2. This uniqueness endows controlling elastic waves are unparalleled in other systems.

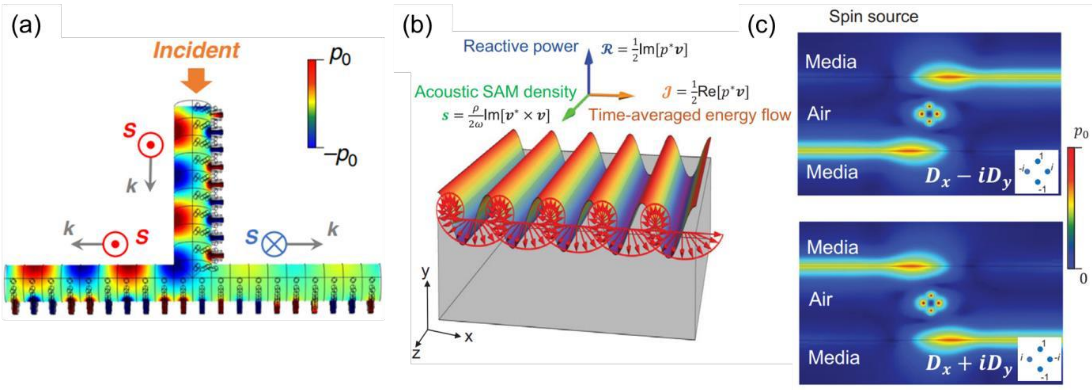

Figure 1. (a) A metasurface waveguide for sound carrying non-zero acoustic spin with tight spin-momentum coupling can be achieved by imposing an effective soft boundary. Assuming that the direction vector from the soft boundary to the hard boundary is denoted as $\boldsymbol{n}$, we can obtain the right-handed chirality as $\boldsymbol{s}\cdot(\boldsymbol{n}\times\boldsymbol{k})>0$. The acoustic wave will selectively propagate along one side due to the SAM match when facing multiple channels. (b) The evanescent wave can be supported on the interface between conducting (air in the acoustic case) and insulating media (gray block). We can obtain the right-handed chirality as $\boldsymbol{s}\cdot(\boldsymbol{\mathcal{J}}\times\boldsymbol{\mathcal{R}})>0$. (c) Selective excitation according to the spin-related symmetry.

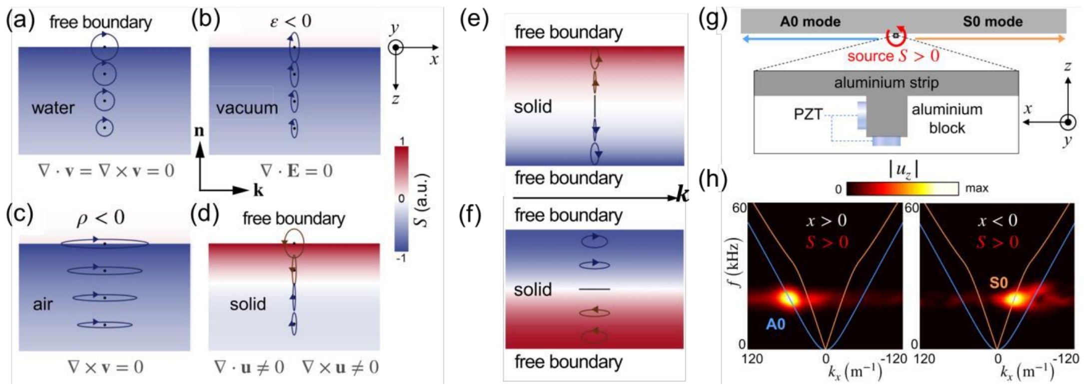

Figure 2. Anomalous spin-momentum locking in elastic waves. Transverse spin density in surface water (a), electromagnetic (plasmon-polariton) (b), acoustic (c), and elastic Rayleigh (d) waves. The spin-normal-momentum triad is right-handed in (a), (b) and (c) as $\boldsymbol{s}\cdot(\boldsymbol{n}\times\boldsymbol{k})>0$ and left-handed near the surface for Rayleigh waves as $\boldsymbol{s}\cdot(\boldsymbol{n}\times\boldsymbol{k})<0$. In Lamb wave, the A0 mode (e) has a reversed spin sign with S0 mode (f). As such, a spin source will induce the spin-induced directional excitation of the Lamb modes, as shown in (g) and (h).

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Magnetic Control of Chiral Phonons and Chiral Light-Matter Coupling

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Abstract: Chiral phonons arise in crystals with broken mirror symmetries. In a magnetic field, the circular motion of lattice ions in a chiral phonon leads to a finite magnetic moment, even when the host material is purely nonmagnetic. To explore such hitherto unobserved phenomena, we studied Pb1-xSnxTe, which is a narrow-bandgap semiconductor that exhibits a topological phase transition as a function of Sn composition, x – from a trivial insulator ($x < 0.32$) to a topological crystalline insulator ($x > 0.32$). This material system possesses soft optical phonons (in the terahertz frequency range) and exhibits ferroelectric instabilities. First, I will describe our observations of novel magnetic phenomena associated with chiral phonons in PbTe [1]: magnetic circular dichroism, a Zeeman splitting, and a diamagnetic shift. Second, I will show the observation of two orders of magnitude larger values of phonon magnetic moment for films in the topological crystalline insulator phase than those in topologically trivial films [2]. These results strongly hint at the interplay between the magnetic properties of chiral phonons and the topology of the electronic band structure. Lastly, I will discuss our results on coupling PbTe phonons with quantum vacuum fluctuations in a small mode-volume terahertz cavity [3] and a chiral cavity with time-reversal symmetry breaking [4].

Keywords: PbTe, PbSnTe, phonomagnetism, chiral phonons, chiral cavity

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Phonon Edelstein effect in chiral metals

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Abstract: We propose a mechanism of current-induced phonon angular momentum, which we call phonon Edelstein effect. We investigate this effect in three-dimensional chiral metals with spin-orbit coupling and chiral phonons, and obtain an analytical expression of phonon angular momentum induced by the current. We also discuss the physical interpretation of this effect and give an estimation of its magnitude.

Keywords: Edelstein effect, chiral metals, phonon angular momentum

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Adiabatic theory of phonon-magnon dynamics in magnetic materials: Emergence of chiral phonons, band structure calculations, and topological properties

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Abstract: Phonons and magnons are bosonic quasiparticles associated with atomic vibrations and spin excitations, respectively. Their calculations typically involve diagonalizing the dynamical matrix and solving the Landau-Lifshitz equation. However, the study of their interactions remains at an early stage. In our recent work [1,2], we developed an adiabatic-theory-based formalism that incorporates both nuclear Berry curvature and phonon-magnon coupling, allowing phonons and magnons to be treated on equal footing. This framework reveals an additional force proportional to the atomic velocity, which gives rise to circularly polarized chiral phonons in CrI_3, even at the Brillouin zone center.

While our earlier studies focused on zone-center modes, we have recently extended the framework to finite momenta using both a finite-difference method and a newly developed density functional perturbation theory formalism [3]. In this talk, we will present phonon-magnon band structures for both bulk and monolayer CrI_3, revealing numerous anti-crossing features known as magnon polarons. We also identify over one hundred Weyl points in the phonon-magnon band structures, arising from broken time-reversal symmetry. Finally, we will demonstrate the computation of Chern numbers and band Berry curvatures, confirming the nontrivial topology of both magnons and magnon polarons in CrI_3. These Berry curvatures are directly connected to thermal transport phenomena, including the thermal Hall effect and the spin Nernst effect.

Keywords: Phonon-magnon interaction, topological magnons and magnon polarons, Weyl points, Berry curvatures

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Single Weyl Point and Nodal Chain in Topological Phononic Materials

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Abstract: Topological semimetal materials feature nontrivial band crossings which permit the existence of novel physical properties and the potential applications in high-performance electronic devices, magnetic storage, etc. The concept of topology has been extended from electronic systems to bosonic systems, such as topological phonons. Compared with topological electrons, topological phonons can be excited at all frequencies in the terahertz range, which makes topological phononic material a rich platform for the study of bosonic quasiparticles. In this presentation, I will briefly introduce the single Weyl point and nodal chain in topological phonon systems, as well as topological phononic material design based on first-principles calculations.

Keywords: Topological phononic materials, Weyl semimetals, First-principles calculations

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Introduction of inelastic neutron scattering technology and possible direct measurement of full chiral phonon dispersion

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Abstract: Experimental detection of chiral phonons - vibrational modes with angular momentum and handedness - is pivotal for advancing quantum technologies, spintronics, and thermal control, as they mediate phenomena like the phonon Hall effect and spin-phonon coupling [1]. Current methods include circularly polarized Raman spectroscopy (Raman), transient infrared (IR), resonant inelastic X-ray scattering (RIXS), and so on [2-5]. The first two techniques are based on light scattering and can only measure the center of the Brillouin zone or a specific momentum point; while the latter technique has a very limited energy resolution. Inelastic neutron scattering (INS) is a matter-wave based spectroscopic technique that can map complete phonon dispersion spectrum in a large energy and momentum space with high energy and momentum resolution. It may provide another way to experimentally verify or characterize chiral phonon. This talk will introduce the basic principle of INS in the measurement of conventional phonons. Then, a possible strategy to detect chiral phonon with INS will be discussed.

Keywords: Chiral phonon, Neutron scattering, Phonon dispersion, Zeeman splitting, magnetic response

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The topology and chirality of phonons

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Abstract: In solids, lattice vibrations—phonons at the terahertz scale—play a crucial role in thermal conductivity, transport properties, and phenomena like structural phase transitions and conventional superconductivity. However, their zero spin and electrical neutrality make phonons difficult to manipulate in physical processes. Recently, introducing *topological* and *chiral* degrees of freedom into the phonon spectrum has provided a new "control handle" for phonons, offering fresh insights into their influence on heat conduction, superconductivity, and other fundamental phenomena.
In the first half, I will discuss classifications and diagnostic methods for topological phonons, along with material predictions and experimental validations 1—including FeSi (the first topological phonon material) and BaPtGe (hosting Weyl phonons with the highest Chern numbers). The second half will cover chiral phonons: their definition, distinctions from topological phonons, and experimental detection 2. Examples include chiral phonons in systems with nonsymmorphic symmetries (e.g., α-HgS and Te), spin-phonon-induced chiral phonons in $Co_3Sn_2S_2$, and the interplay between Weyl and chiral phonons.

Keywords: Topological phonons, Weyl phonons, chiral phonons, symmetry-constrained phonons

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Towards Carrier-Controlled Phonon Chirality and Polar Order in Topological Epitaxial Films

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Abstract: Chiral phonons have recently attracted intense research interest because, unlike conventional phonons, they carry angular momentum and respond to magnetic fields [1]. Phonon magnetic moments, observed through the phonon Zeeman effect, have been measured at values reaching several Bohr magnetons. While several mechanisms can generate a finite phonon magnetic moment, recent theoretical studies indicate that electronic contributions are essential for predicting the larger values observed experimentally. In this context, experimental results have demonstrated that electronic contributions to the phonon magnetic moment enable an interplay between phonon chirality and electronic topology [2]. However, evidence of how free carrier density influences phonon magnetic properties remains lacking. Here, I will present my group's efforts to address this subject using $Pb_{1-x}Sn_xTe$ as a model system. Two lines of investigation with unpublished results will be discussed: (i) the interaction between carrier cyclotron resonance and chiral phonons in PbTe films, and (ii) the carrier-dependent control of the polar phase in the topological crystalline insulator $Pb_{0.5}Sn_{0.5}Te$. In the first case, we show that film thickness serves as a tool to tune carrier concentration. In the latter, bismuth doping was employed to control the film’s metallicity and enhance the critical temperature of polar order. This work was supported by the São Paulo Research Foundation (FAPESP), Grants Nos. 2021/12470-8 and 2023/04245-0.

Keywords: polar metals, topological insulators, terahertz time-domain spectroscopy, cyclotron resonance, chiral phonons

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Magnetic switching of phonon angular momentum in a ferrimagnet insulator

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Abstract: Circularly polarized phonons offer a new route for mediating angular momentum in solids. However, controlling phonon angular momentum without altering the material's structure or composition remains challenging. Here, we demonstrate the non-volatile switching of angular momentum-carrying phonons by leveraging intrinsic ferrimagnetism in an insulator. We find a pair of chiral phonons with giant energy splitting reaching 20 % of the phonon frequency, due to spontaneously broken time-reversal symmetry. With a moderate magnetic field, the phonon angular momentum of the two chiral phonon branches can be switched along with the magnetization. Notably, near the critical temperature, the effective phonon magnetic moment is enhanced, reaching 2.62 Bohr magneton, exceeding the moment of a magnon. A microscopic model based on phonon-magnon coupling accounts for the observations. Furthermore, we identify two types of phononic domains with opposite phonon Zeeman splitting and propose the existence of topologically protected phononic edge modes at domain boundaries. These results demonstrate effective manipulation of chiral phonons with magnetism, and pave the way for engineering chiral phononic domains on the micrometer scale.

Keywords: Phonon angular momentum, phonon-magnon coupling, chiral phonon domain

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Angular momentum of electrons and phonons

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Abstract: Understanding of process such as Einstein--de Haas requires a theory of periodic solids with (I) a well-defined electron angular momentum, (II) a well-defined phonon angular momentum, (III) rotationally invariant Hamiltonian, and (IV) appropriate coupling between electrons and phonons. Presently, it is unclear how to deal with these four requirements in a way that would enable one to compute from first principles the transition rates for the Einstein--de Haas effect in a periodic solid. On the other hand, first-principles electron-phonon calculations for transfer of energy -- instead of angular momentum -- between electrons and phonons are rather routine these days. In this talk, I will first provide a symmetry-based classification of atomic vibrations with well-defined crystal momentum and phonon angular momentum [1]. In some materials, phonons acquire angular momentum via forces induced by relative displacements of atoms out of their equilibrium positions. For other materials, phonon angular momentum arises from the forces induced by relative velocities of atoms. These effects are dominant terms for all physical properties where ionic motion breaks time-reversal symmetry [2]. In the second part of the talk, I will show that there are algebraically localized eigenstates of electrons in a perfectly periodic solid with a well-defined crystal angular momentum. [3] I will discuss possible generalization of this concept to phonons.

Keywords: angular momentum, electrons, phonons, first-principles, Einstein--de Haas.

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Inelastic Neutron Scattering for Direct Detection of Chiral Phonons

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Abstract: Chiral phonons [1] have attracted significant attention due to their potential applications in spintronics, superconductivity, and advanced materials, but their detection has predominantly relied on indirect photon-involved processes [2-4]. Here, we propose inelastic neutron scattering (INS) as a direct and versatile approach for chiral phonon detection. Leveraging INS sensitivity to phonon eigenmodes, we clearly distinguish linear, elliptical, and chiral phonons and determine phonon handedness through angular-resolved measurements. We demonstrate predict INS signatures differentiating chiral from linear phonons in the prototypical chiral material tellurium (Te). Additionally, we showcase the unique capability of INS to directly probe phonon magnetic moments and effective magnetic fields induced by chiral phonons, as exemplified by significant phonon splitting in CeF_3. Our results establish INS as a robust experimental technique for comprehensively investigating various properties of chiral phonons.

Keywords: Chiral Phonon, Direct Detection, Inelastic Neutron Scattering

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Control of spin transition and resonance by chiral phonons

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Abstract: Chiral phonons possessed angular momentum are tightly associated with phonon modes that exhibit circular vibrations of lattice. When considering chiral phonons in organic chiral materials, the interactions between phonon angular momentum and spin angular momentum exhibit rich diversity. In this work, organic chiral enantiomers are prepared with different magnitudes of chiral asymmetry factor. Using a circularly polarized Raman setup, the chiral phonons can be observed. As the asymmetry factor decreases, the chiral phonons will gradually disappear. The coupling between the angular momentum of chiral phonons and electron spins becomes more pronounced with larger asymmetry factor. Furthermore, electrons will present a broader array of pathways to enhance recombination, satisfied with the conservation of angular momentum. Also, the electron spin resonance signals of chiral samples demonstrate differential responses to left- and right-handed circularly polarized light with identical intensity. Overall, the chiral phonons with non-zero angular momentum in the chiral systems will be strongly coupled with electron spins to effectively modulate spin transition and spin resonance, thereby enhancing the potential application of chiral phonons in opto-phononic-spintronic devices.

Keywords: Chiral phonon angular momentum; Electron spin; Angular momentum coupling

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Utilizing topological invariants for encoding and manipulating chiral phonon devices

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Abstract: As a fundamental degree of freedom, phonon chirality is expected to promote the development of quantum information technology just like electron spin. Currently, central to this area is the realization of efficient transmission and control of chiral information. In this work, we propose an approach by integrating topological theory, leveraging topologically invariant Chern numbers, to encode hexagonal lattice systems. Our investigation reveals the presence of topologically protected chiral interface states within the shared band gaps of both trivial and non-trivial system units. By precisely modulating the magnetic field distribution within the encoding system, we can effectively manipulate the topological pathways. Building upon this framework, we design and implement a chiral phonon three-port device. Through dynamic calculations, we demonstrate the transmission process of chiral information, showcasing the chiral phonon switching effect and logical OR operation. Our findings not only establish a fundamental mechanism for the manipulation and control of phonon chiral information but also provide a promising direction for research in harnessing chirality degrees of freedom in practical applications.

Keywords: chiral phonon, topological edge state, phonon device

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Linear and Nonlinear Spin-Lattice Dynamics in 2D Antiferromagnetic Insulators

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Abstract: The response of quantum materials to external perturbations is largely governed by collective excitations, which dictate many correlated phenomena. Both linear and nonlinear dynamics of these collective modes offer rich insights into the underlying interactions between different quantum degrees of freedom and provide pathways for manipulating quantum phases. Two-dimensional (2D) honeycomb lattice spin systems, with their diverse magnetic orders, present an ideal setting for studying the coupling between (chiral) magnons and phonons, across both linear and nonlinear regimes. In this presentation, we report the observation of the linear magnon-phonon hybridization and magnon-induced chiral phonons in 2D zigzag antiferromagnets. Using coherent two-dimensional terahertz spectroscopy, we further unveil the nonequilibrium and nonlinear dynamics of both magnons and phonons, shedding light on their intricate interactions in 2D antiferromagnetic materials.

Keywords: 2D antiferromagnet, magnon polaron, terahertz 2D spectroscopy.

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Infrared and Raman driven ultrafast spin dynamics through axial phonons

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Abstract: Axial phonons with large effective magnetic moments due to coupling with spin-orbit polarization can induce large effective magnetic fields on the electrons. Following our experimental demonstration of such a phenomenon in CeF_3 with coherent infrared-active phonons excited by resonant circularly polarized terahertz pulses, I will show our recent results of time-resolved phonon and spin dynamics in a few different settings, including Raman-active phonons in bulk CeF_3, two-dimensional (2D) monolayers, CeF_3-2D heterostructures, and antiferromagnetic oxides. We found that the axial lifetime can span two orders of magnitudes for phonon modes with different decoherence mechanisms. The induced spin effects, if any, may also drastically differ in magnitude and dynamics from what would be expected from the simple spin-phonon hybridization model. Our results point out more unknown territories calling for theoretical and experimental investigations in the field of chiral phonon-spin coupling and the dynamic structural-property relationship in quantum materials.

Keywords: Axial phonons, ultrafast spintronics, heterostructure, circularly polarized terahertz, optical centrifuge

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Nonreciprocal Phonons in PT -Symmetric Antiferromagnets

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Abstract: Phonon nonreciprocity, indicating different transport properties along opposite directions, has been observed in experiments under a magnetic field. We show that nonreciprocal acoustic phonons can also exist without a magnetic field or net magnetization. We identify crucial contributions in phenomenological elastic theory. In PT symmetric antiferromagnets, we find two terms, dubbed flexo viscosity and flexo torque, that induce phonon nonreciprocity. The microscopic origin of these terms is attributed to the derivatives of molecular Berry curvature, manifested as emergent nonlocal magnetic fields on phonons. The symmetry breaking that originated from spin order is transferred to the phonon system through spin-orbit coupling, where the orbital degree of freedom affects the lattice dynamics directly. By electrically breaking inversion symmetry and modifying the spin-orbit coupling, we find extra contributions and show that both the phonon nonreciprocity and helicity can be controlled and enhanced. Importantly, the phonon nonreciprocity is an odd function of the Ne´el vector, serving as an indicator of the order parameter.

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POSTERS

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Raman Optical Activity in 2D Chiral Hybrid Perovskites: Observation and Analysis

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Abstract: We report Raman optical activity in chiral two-dimensional hybrid organic-inorganic perovskites (2D-HOIP), specifically $(MBA)_2PbI_4$, using circularly polarized Raman spectroscopy (CP-RS). Indirect evidence of chiral phonons [1] was observed through Raman optical activity in both co- and cross-circular polarization configurations, with dissymmetry reversing between R- and S-enantiomers. First-principles calculations were employed to compute phonon dispersion and angular momentum, and symmetry analysis confirmed that only chiral phonons contribute to the dissymmetry. Notably, finite phonon angular momentum emerges away from the Γ-point, mainly contributed by vertically aligned iodine atoms in the PbI_4 framework. Our work establishes chiral 2D-HOIPs as a promising platform for phonon angular momentum transport and phononic spintronic applications

Keywords: Two-dimensional chiral hybrid organic-inorganic perovskites, Circularly polarized Raman spectroscopy, Phonon angular momentum

References:

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Unambiguous determination of crystal orientation in black phosphorus by angle-resolved polarized Raman spectroscopy

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Abstract: Angle-resolved polarized Raman spectroscopy (ARPRS) is widely used to determine the crystal orientations of anisotropic layered materials (ALMs), which is an essential step to study all of their anisotropic properties. However, the understanding of the ARPRS response of black phosphorous (BP) as a most widely studied ALM is still unsatisfactory. Here, we clarify two key controversies about the physical origin of the intricate ARPRS response and the determination of crystal orientations in BP. Through systematic ARPRS measurements, we show that the degree of anisotropy of the response evolves gradually and periodically with the BP thickness, eventually leading to the intricate response. Meanwhile, we find that using the Raman peak intensity ratio of the two Ag phonon modes, the crystal orientations of BP can be unambiguously distinguished via a concise inequality. Comprehensive analysis and first-principles calculations reveal that the external anisotropic interference effect and the intrinsic electron-phonon coupling are responsible for the observations.

Keywords: Angle-resolved polarized Raman; phonon anisotropy; BP; crystal orientation; interference

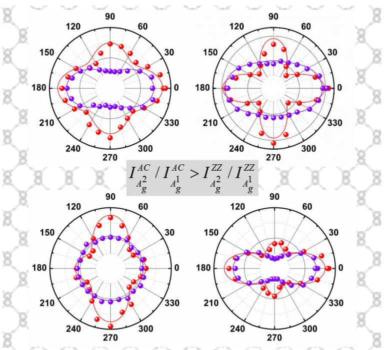

Figure 1. Intricate angle-resolved polarized Raman spectroscopy response and crystal orientation determination of black phosphorus.

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Magnetic order induced chiral phonons in a ferromagnetic Weyl semimetal

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Abstract: 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.

Keywords: Chiral phonon; Magnetic order; Weyl semimetal; Spontaneous energy splitting

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Monitoring the Unusual Deformation and Fracture in Nanoindented Gallium Telluride Multilayers Via Micro-Raman Spectroscopy

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Abstract: Angle-resolved Recent great advances in fabrication of two-dimensional (2D) materials enable considerable interests in 2D materials beyond graphene, including those of low in-plane symmetry whose material properties varying along different in-plane crystal orientations, such as black phosphorus (BP), rhenium disulfide (ReS2) and gallium telluride (GaTe), with diverse optical and electrical properties shown which strongly depend on their crystal and band structures. Their mechanical properties have also attracted more interests since the extremely high intrinsic in-plane Young’s modulus (~1 TPa) and strength (~130 GPa) of graphene was characterized using AFM based nanoindentation. In particular. low symmetry monoclinic phase layered GaTe has attracted much attention recently, not only due to its extremely high photoresponsivity (2×1016 A/W) for high performance phototransistors also because of its strong in-plane structural anisotropy. Despite its incomparable advantages in optoelectronic properties, however, notable electrical-mechanical coupling is likely to be resulted in which may change the electronic structure of GaTe during straining process for nanoflexible device application, thus requiring to know their individual mechanical abilities including anisotropy, which is still lacking in GaTe.

In this work, the mechanical properties of both substrates supported and suspended high-quality GaTe multilayers are experimentally characterized and compared for the first time using Berkovich-indenter based nanoindentation, combined with SEM, AFM and micro-Raman stress investigation. Concurrence of multiple pop-ins accompanied with load-drops events are observed, and the role of interlayer sliding as well as the mechanism of layers-by-layers deformation and co-fracture are investigated, which can be sensitively monitored by micro-Raman spectra. These results have provided first-hand mechanical performance and related theoretical mechanism on GaTe multilayers for their potential applications in nanoflexible and strain-modulation optoelectronics.[1,2]

Keywords: Micro-Raman; deformation and fracture; GaTe; nanoindentation

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Probing chiral phonons with ultrafast electron diffraction

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Abstract: Following the conception of chiral phonons, a variety of experimental techniques, including ultrafast infrared spectroscopy, circularly polarised Raman spectroscopy, and resonant inelastic X-ray scattering, have provided substantial evidence for their observation. As a lattice vibration mode that exclusively exists in systems with broken crystal symmetry, chiral phonons can also be probed by ultrafast electron diffraction (UED) technology, which has demonstrated unique advantages in lattice dynamics research. The interaction of ultra-short electron pulses with the crystal lattice enables the accurate measurement of real-time atomic displacement and vibration data, as well as the capture of transient fluctuations in lattice vibrations. In comparison to the aforementioned experimental methods, UED technology offers superior clarity in revealing the dynamic characteristics of chiral phonons. The present report will concentrate on the signatures of chiral phonons in UED by means of an analysis of phonon diffuse scattering and the experimental phenomena of coherent chiral phonon excitation, as documented in prior studies. This analysis explores the potential of UED technology to provide new perspectives and approaches for the detection of chiral phonons.

Keywords: Chiral Phonons, Ultrafast Electron Diffraction (UED), Structural Dynamics

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Magnetic fields induced by chiral phonons: A spherical charge model study

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Abstract: Chiral phonons can induce effective magnetic fields in crystals with nonzero effective charge. While recent studies have employed the point charge model to analyze these phonon-induced magnetic fields, this approach neglects the spatial distribution of charge in real materials, leading to limitations in describing near-field behavior and magnetic field superposition effects. In this work, we develop a theoretical framework for the effective magnetic field of chiral phonons based on the spherical charge model, derived from the Biot-Savart law. By comparing our results with those of the point charge model, we demonstrate the critical influence of charge distribution spatial extension on chiral phonon magnetic fields. Our spherical charge model shows significantly better agreement with physical reality at the atomic scale, offering a more robust theoretical foundation for experimental observations and device designs utilizing chiral phonon magnetic fields.

Keywords: Chiral phonons, Magnetic field, Spherical charge model

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Abnormal phonon angular momentum due to off-diagonal elements in the density matrix induced by a temperature gradient

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Abstract: Significant magnetic moment[1] signals have been experimentally detected in materials subjected to a temperature gradient[2], which are hypothesized to be linked to the phonon angular momentum[3] (PAM) induced by the temperature gradient. However, current theoretical frameworks have been found inadequate for fully explaining these experimental observations. In this work, we re-examine the principle of PAM generated by temperature gradients and develop corresponding computational methodologies based on Kubo's formula, incorporating both interband and intraband transitions. Through first-principles calculations, we theoretically investigate the PAM generated in bulk wurtzite AlN and 2D JMD materials MoSSe under temperature gradient conditions. Our results indicate that both interband and intraband contributions are critical in determining the PAM, suggesting that quantum transitions between distinct phonon branches, driven by the temperature gradient, significantly influence local atomic rotations.

Keywords: temperature gradient, Kubo formula, interband transition

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Symmetry-Driven Phonon Polarization in α-Graphyne: Unveiling the Interplay between Hybridization and Chirality

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Abstract: Chirality is crucial in many fields and has promising applications in phonon systems. Unlike graphene, graphyne includes extra sp-hybridized atoms, giving it unique physical properties. In this study, we employ first-principles calculations to investigate the effects of time and spatial reversal symmetry on phonon polarization in α-graphyne. Phonon polarization analysis reveals extrema at both high and non-high symmetry points, challenging the view that they occur only at high symmetry points. At the Γ point, phonon polarization depends on frequency and carbon hybridization: sp-hybridized atoms dominate below 25 THz and above 60 THz, while sp^2-hybridized atoms contribute significantly between 25–60 THz, becoming comparable to sp atoms as the magnetic field increases. Additionally, We examine how breaking spatial inversion symmetry (with time-reversal symmetry preserved) alters phonon polarization, especially at high frequencies. Our results offer insights into tuning vibrational properties of carbon-based materials via magnetic fields.

Keywords: phonon polarization; chiral phonons; the first-principles calculations

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Large Magneto-Thermal Conductivity from Phonon-Magnon Coupling in a vdW Antiferromagnet

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Abstract: Phonons and magnons constitute two fundamental neutral excitations governing lattice vibrations and spin waves, respectively. In magnetic systems, the interactions between these quasiparticles emerge when their energies are comparable or degrees of freedom become interdependent. Such magnetoelastic coupling exerts significant influence on thermal transport phenomena in insulating magnets, particularly owing to the negligible electronic contribution to heat conduction. This interplay provides a promising mechanism for magnetic field modulation of phononic thermal conductivity, with potential applications in thermoelectric energy conversion and thermal management technologies. Systematic investigation of magneto-thermal transport in insulators exhibiting strong phonon-magnon coupling is therefore crucial for elucidating the underlying quantum phenomena.

The van der Waals-layered antiferromagnet $FePX_3$ (X=S, Se) exhibits a two-dimensional Ising-type zigzag magnetic ordering. Raman spectroscopy reveals magnetic field-induced phonon-magnon hybridization with critical field onset near 15T [1]. Notably, in $FePSe_3$, chirality-selective hybridization between chiral phonons and magnons has been experimentally observed under circularly polarized excitation, suggesting angular momentum transfer mechanisms between vibrational and spin subsystems [2]. Nevertheless, the thermal transport manifestations of these hybridization remain unexplored.

This presentation details our systematic investigations of the thermal conductivity (κ) and magnetization in $FePS_3$ under varying magnetic fields and temperatures. The temperature evolution of κ deviates from conventional phonon-dominated behavior in magnetic insulators, consistent with theoretical predictions of phonon scattering via critical spin fluctuations [3]. Remarkably, field-dependent measurements reveal a 300% enhancement in thermal conductivity at intermediate temperatures under 12T, providing experimental evidence for chirality-selective phonon-magnon hybridization.

Keywords: Magnetothermal conductivity; Phonon-magnon coupling; vdW Antiferromagnet;

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