



# PHONONS 2025

Buenos Aires, Argentina

December 1<sup>st</sup> – 5<sup>th</sup> 2025

EBOOK

# Topics

- ◆ Thermal
- ◆ New Phonon
- ◆ Phonon Magnon
- ◆ XFEL Ultrafast
- ◆ SAW
- ◆ Optomechanics
- ◆ Quantum Nonlinear

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# Phonons Conference Series


The history of the Phonons Series (Conference on Phonon Scattering in Condensed Matter) has been long-standing since 1972. Over the past 50 years, it took place in the following venues:

 **Phonons 2023.** Paris, France.  
*Chaired by Daniel Lanzillotti Kimura*


 **Phonons 2018.** Nanjing, China.  
*Chaired by Lifa Zhang.*

 **Phonons 2015.** Nottingham, UK.  
*Chaired by Tony Kent.*


 **Phonons 2012.** Ann Arbor, USA.  
*Chaired by Kevin Pipe.*


 **Phonons 2010.** Taipei, Taiwan.  
*Chaired by Chi Kuang Sun.*


 **Phonons 2007.** Paris, France.  
*Chaired by Bernard Perrin.*


 **Phonons 2004.** St. Petersburg, Russia.  
*Chaired by Alexander A. Kaplyanskii.*


 **Phonons 2001.** Hanover, USA.  
*Chaired by Martin Wybourne.*


 **Phonons 1998.** Lancaster, England.  
*Chaired by John Wigmore*

 **Phonons 1995.** Sapporo, Japan.  
*Chaired by Tsuneyoshi Nakayama.*


 **Phonons 1992.** Ithaca, USA.  
*Chaired by R. O. Pohl.*


 **Phonons 1989.** Heidelberg, Germany.  
*Chaired by Siegfried Hunklinger, Wolfgang Ludwig, Georg Weiss*

 **Phonons 1986.** Urbana, USA.  
*Chaired by A. C. Anderson and J. P. Wolfe.*

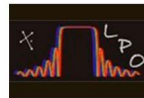
 **Phonons 1983.** Stuttgart, Germany.  
*Chaired by W. Eisenmenger.*

 **Phonons 1979.** Providence, USA.  
*Chaired by Humphrey J. Maris.*

 **Phonons 1975.** Nottingham, UK.  
*Chaired by L.J Challis, V. W. Rampton and A.F.G. Wyatt*

 **Phonons 1972.** St. Maxime and Paris, France.  
*Chaired by H. J. Albany..*

# Sponsors



# Program at a Glance

Plenaries
Posters
\* Virtual

Thermal
New Phonon
Phonon Magnon
XFEL Ultrafast
SAW
Ophomechanics
Quantum Nonlinear

	December 1 <b>MONDAY</b>		December 2 <b>TUESDAY</b>		December 3 <b>WEDNESDAY</b>		December 4 <b>THURSDAY</b>		December 5 <b>FRIDAY</b>
07:30-08:45	Registration		Registration						
08:45 - 9:00	Opening								
09:00-09:50	Cleland		Bargheer		Chu		Kimura		Kalashnikova
09:50-10:20	coffee break		coffee break		coffee break		coffee break		coffee break
10:20-10:50	Kirilyuk	Verhagen	Foglia	Palombo	Stiller	Xi	Zhang_*	Bruchhausen	Baumberg  Solomayor + Prize Ceremony + Farewell
10:50 - 11:00	Finardi	Carraro-Haddad	Trigo	Margueritat	Zhao	Matsuda	Pitanti	Garcia-Martin	
11:00 - 11:10	Granada	Schilder	Murphy-Armando	Romano	Adambukulam		Jansen	Aversa	
11:20 - 11:30		Wiederhecker			Wang		Szewczyk	Karzel	
11:30 - 11:40									
11:40 - 11:50									
11:50 - 12:00									
12:00-13:20	Lunch		Lunch		Lunch		Lunch		
13:20-13:50	Behnia	Santos	Boisen		Faugeras	Fomin	Reparaz	Kuznetsov	
13:50 - 14:10	Rurali	Aboelto			Merlin	Sathyan	Sharma	Benevides	
14:10 - 14:30	Stanley	Bhattacharjee	Cavalleri		Cucini	Liang,Sun	Chapuis	Guo	
14:30 - 14:50	Krysztofik	Diego			Kamba	Cardozo Oliveira	Martin	Bustamante	
14:50 - 15:10									
15:10 -15:40	Zardo	Foa Torres	Free time		Nomura	Alegre	Schmiegelow	Sharp	
15:40 - 16:00	Anufriev	El Sachat			Wu	Bailey	Martí	Bosak	
16:00 - 16:20	Koch	Singh			Termentzidis	Reynoso	Stroscio*	Raciti	
16:20 - 16:30						Silverman		Emtenani	
16:30 - 16:40	Barzaga	Graczykowski							
16:40 - 17:10	coffee break				coffee break		coffee break		
17:10 - 17:50	Safavi-Naeini				Scherbakov		Pimenta		
17:50 - 18:10									
18:10 - 19:30	Poster Session 1 Gathering & Drinks				Poster Session 2 Gathering & Drinks		Students activity IEEEE + OPTICA		
19:30-22:00			Conference Dinner: Patio Cervecero & Tango						

MONDAY - DECEMBER 1	
07:30 - 08:45	Registration
08:45 - 09:00	Opening
09:00 - 09:50	Plenary <b>Andrew Cleland</b> Itinerant phonons: Prospects for quantum computation and quantum sensing
09:50 - 10:20	Coffe Break
10:20 - 10:50	<i>Invited</i> <b>Andrei Kirilyuk</b> Shaken or stirred: ultrafast phononic switching of ferroic order
10:50 - 11:10	<b>Alice Margherita Finardi</b> Phonon dynamics across the Verwey transition by time-resolved Raman spectroscopy
11:10 - 11:30	<b>Mara Granada</b> Structural and nanoacoustic characterization of ferromagnetic Pt/Co superlattices
10:20 - 10:50	<i>Invited</i> <b>Ewold Verhagen</b> Thermodynamics and information processing in programmable optomechanical circuits
10:50 - 11:10	<b>Ignacio Carraro-Haddad</b> Coherent Control of Pseudospin Precession and Optomechanical Coupling in Polariton Time Crystals
11:10 - 11:30	<b>Nick Schilder</b> Photoelastic Coefficients of Thin-Film Silicon Nitride Determined via Optomechanically Induced Absorption
11:30 - 12:00	<i>Invited</i> <b>Gustavo Wiederhecker</b> Vectorial Brillouin Scattering in Anisotropic Materials: Lithium niobate and beyond
12:00 - 13:20	Lunch
13:20 - 13:50	<i>Invited</i> <b>Kamran Behnia</b> What generates a phonon thermal Hall effect?
13:50 - 14:10	<b>Riccardo Rurali</b> Optical Control of the Thermal Conductivity in ferroelectrics and charge density wave materials
14:10 - 14:30	<b>Christopher Stanley</b> Challenging Assumptions About Size Effects in Thermal Boundary Resistance
14:30 - 14:50	<b>Adam Kryzstofik</b> Acoustic phonons and thermal transport in stacked polydopamine nanomembranes

13:20 - 13:50	<i>Invited</i> <b>Paulo Santos</b> Electrically excited GHz helical acoustic modes on a chip
13:50 - 14:10	<b>Jouni Ahopelto</b> Integrable Electromechanical Broadband Phonon Source
14:10 - 14:30	<b>Paromita Bhattacharjee</b> Acoustoelectric effect in organic-inorganic semiconductor systems
14:30 - 14:50	<b>Michele Diego</b> Acoustic wave manipulation via disordered hyperuniform nanopillar architectures on lithium niobate
15:10 - 15:40	<i>Invited</i> <b>Ilaria Zardo</b> To Be Announced
15:40 - 16:00	<b>Roman Anufriev</b> Spectral and spatial limits of phonon coherence in two-dimensional phononic crystals
16:00 - 16:20	<b>Dominik M. Koch</b> Exploring Thermal Properties of Freestanding Thin Perovskite Oxide Membranes
16:20 - 16:40	<b>Geraudys Mora Barzaga</b> Tuning Phonon-Mediated Heat Transport in Systems with Defects
15:10 - 15:40	<i>Invited</i> <b>Luis E. F. Foa Torres</b> Surprises from electron-phonon interactions in two- dimensional materials
15:40 - 16:00	<b>Alexandros El Sachat</b> Geometric thermoelectricity - interplay of phonons and electrons in 2D materials
16:00 - 16:20	<b>Bhanu Jai Singh</b> Quantum transport modeling of phonons in 2D Transition metal dichalcogenides heterostructures: A Non-Equilibrium Green's Function (NEGF) approach
16:20 - 16:40	<b>Bartłomiej Graczykowski</b> Acoustic phonons and photoelastic coupling in van der Waals crystals
16:40 - 17:10	Coffe Break
17:10 - 17:50	Keynote <b>Amir Safavi-Naeini</b> Lithium Niobate Nanophononic Devices
17:50 - 19:30	Poster Session 1 & Gathering and drinks

TUESDAY - DECEMBER 2	
07:30 - 08:45	Registration
09:00 - 09:50	Plenary <b>Matias Bargheer</b> Picosecond ultrasonics with x-rays - applications to energy transport and magnetisation dynamics
09:50 - 10:20	Coffe Break
10:20 - 10:50	<i>Invited</i> <b>Laura Foglia</b> Nanoscale transient grating beyond thermoelasticity
10:50 - 11:20	<i>Invited</i> <b>Mariano Trigo</b> Polarization density waves in SrTiO <sub>3</sub>
11:20 - 11:40	<b>Felipe Murphy-Armando</b> Experimental and first-principles calculation of the time-dependent evolution of phonon and carrier populations after photoexcitation in GaAs observed by diffuse x-ray scattering at the PAL-XFEL
10:20 - 10:50	<i>Invited</i> <b>Francesca Palombo</b> BioBrillouin: state-of-the-art and perspectives
10:50 - 11:20	<i>Invited</i> <b>Jérémie Margueritat</b> Low-frequency Raman scattering as a tool for probing nanocrystals surface chemistry
11:20 - 11:50	<i>Invited</i> <b>Rosana Mariel Romano</b> Advancing in-situ analysis: Applications of flexible SERS substrates in food safety, forensics, and cultural heritage
11:40 - 13:20	Lunch
13:20 - 14:10	Plenary <b>Anja Bolsen</b> Therapeutic drug monitoring using centrifugal microfluidics and Surface Enhanced Raman Scattering
14:10 - 15:00	Plenary <b>Andrea Cavalleri</b> Nonlinear Phononics - Coherent Control over Materials Phases
	Free time

<b>WEDNESDAY - DECEMBER 3</b>	
09:00 - 09:50	Plenary <b>Yiwen Chu</b> Quantum technologies with bulk acoustic wave phonons
09:50 - 10:20	Coffe Break
10:20 - 10:50	<i>Invited</i> <b>Birgit Stiller</b> Quantum and classical optoacoustics for photonic neuromorphic computing and quantum signal processing
10:50 - 11:20	<i>Invited</i> <b>Jimin Zhao</b> Unveiling Novel Quantum States and Couplings by Coherent Phonons in Correlated Materials
11:20 - 11:40	<b>Chris Adambukulam</b> A coherent interface between colour centre spins and phonons
11:40 - 12:00	<b>Hailin Wang</b> Ultracoherent GHz Diamond Lamb Wave Spin-Mechanical Resonators for Quantum Spin-Mechanics
10:20 - 10:50	<i>Invited</i> <b>Xiang Xi</b> Ultralow-loss transport of topological phonons
10:50 - 11:20	<i>Invited</i> <b>Osamu Matsuda</b> Time-resolved two-dimensional imaging of Lamb-like acoustic modes in topological phononic crystals at sub-GHz frequencies
Lunch	
13:20 - 13:50	<i>Invited</i> <b>Clément Faugeras</b> Magnetic order in an air-stable frustrated van der Waals magnet
13:50 - 14:10	<b>Roberto Merlin</b> Magnetophononics: Breaking Time Reversal Symmetry with Non-Maxwellian Magnetic-esque Fields
14:10 - 14:30	<b>Riccardo Cucini</b> Coherent and Dissipative Coupling in a Magnetomechanical System
14:30 - 14:50	<b>Stanislav Kamba</b> Phonomagnetism in quantum paraelectrics
13:20 - 13:50	<i>Invited</i> <b>Vladimir M. Fomin</b> Manifestations of magneto-polaron effects in resonant Raman scattering in Transition Metal Dichalcogenides

13:50 - 14:10	<b>Sathyan Sandeep</b> Phonon transport and bandgap engineering in self-assembled nanosphere monolayers
14:10 - 14:30	<b>Liang Sun</b> ABACUS and Its Interfaces for Phonon Calculations: Bridging DFT, Machine Learning, and Lattice Dynamics
14:30 - 14:50	<b>Edson Rafael Cardozo de Oliveira</b> Environment-responsive mesoporous-based GHz acoustic resonators
15:10 - 15:40	<i>Invited</i> <b>Masahiro Nomura</b> Graphite Thermal Tesla Valve
15:40 - 16:00	<b>Kexin Wu</b> An experimental study of thermal rectification driven by heat hydrodynamic transport in diamond
16:00 - 16:20	<b>Konstantinos Termentzidis</b> Thermal rectification via nanostructuring in 1D and 2D materials
15:10 - 15:40	<i>Invited</i> <b>Thiago P. M. Alegre</b> Optomechanical Platforms for Photonics and Quantum Transduction
15:40 - 16:00	<b>James Bailey</b> THZ Quantum Cascade SASER
16:00 - 16:20	<b>Andrés A. Reynoso</b> Optomechanical lockings of double trap exciton-polariton spins
16:40 - 17:10	Coffe Break
17:10 - 17:50	Keynote <b>Alexey V. Scherbakov</b> Coherent control of magnons in phononic nanoresonators
17:50 - 19:30	Poster Session 2 & Gathering and drinks

THURSDAY - DECEMBER 4	
09:00 - 09:50	Plenary <b>Daniel Lanzillotti Kimura</b> Shaping Sound at the Nanoscale: Integrated Architectures for Coherent Phonon Confinement and Guiding
09:50 - 10:20	Coffe Break
10:20 - 10:50	<i>Invited</i> <b>Lifa Zhang*</b> Chiral phonons and emergent novel phenomena
10:50 - 11:10	<b>Alessandro Pitanti</b> Asymmetric negative refraction and GHz acoustic vortices
11:10 - 11:30	<b>Menno Jansen</b> Parametric control of dynamical backaction using multimode optomechanical interactions
11:40 - 12:00	<b>Daria Szewczyk</b> Boson Peak and Two-Level Systems in 1-Halo-Adamantane: Role of Phonon Dispersion and Vibrational States
10:20 - 10:50	<i>Invited</i> <b>Axel E. Bruchhausen</b> Resonant Ultrafast Spectroscopy of Acoustic Phonons in Semiconductor Superlattices
10:50 - 11:10	<i>Invited</i> <b>Antonio Garcia-Martin</b> Torsional mechanical modes in acousto-plasmonic antennas
11:10 - 11:30	<b>Martín Aversa</b> Breathing modes in free-standing and supported MoS <sub>2</sub> : acoustic and optical resonances from atomically thin to bulk-like structures
11:30 - 11:50	<b>Marek Karzel</b> Ultimate detection sensitivity of picosecond strain pulses exploiting polariton resonance
12:00 - 13:20	Lunch
13:20 - 13:50	<i>Invited</i> <b>Juan Sebastian Reparaz</b> High-Throughput Thermal Screening in the Quasi-Ballistic Thermal Transport Regime in Metal Oxides
13:50 - 14:10	<b>Deeksha Sharma</b> Probing thermal transport in supported graphene and few-layers graphene via Frequency-Domain Thermoreflectance
14:10 - 14:30	<b>P-Olivier Chapuis</b> Temperature and doping level effect on silicon thermal conductivity
14:30 - 14:50	<b>Evelyne Martin</b> Thermal conductivity of amorphous materials by first-principles molecular dynamics

13:20 - 13:50	<i>Invited</i> <b>Alexander Kuznetsov</b> Coherent polaromechanical control of exciton-polariton condensation in microcavities
13:50 - 14:10	<b>Rodrigo Benevides</b> Optomechanical coupling to surface acoustic waves
14:10 - 14:30	<b>Xiaofei Guo</b> Programmable Optomechanical Logic Circuits
14:30 - 14:50	<b>Carlos Bustamante</b> Rabi-driven vibrational excitations under electronic strong coupling in optical cavities
15:10 - 15:40	<i>Invited</i> <b>Christian Schmiegelow</b> Laser cooling of solids: an emerging technology with complex challenges
15:40 - 16:00	<b>Stefano Marti</b> Building blocks for boson sampling in a bulk acoustic wave resonator
16:00 - 16:30	<b>Michael Stroschio*</b> Proper Normalization of Phonon Modes for Rayleigh Waves
15:10 - 15:40	<i>Invited</i> <b>Ian D. Sharp</b> Illuminating ultrafast photocarrier-lattice coupling and dynamics in bismuth vanadate photoanodes
15:40 - 16:00	<b>Alexei Bosak</b> Elasticity of violet phosphorus and its siblings from inelastic x-ray scattering
16:00 - 16:20	<b>Grazia Raciti</b> From Bulk to Nanostructures: Understanding Carrier-Phonon Dynamics in Semiconductors
16:20 - 16:40	<b>Pouria Emtenani</b> Experimental Study of Thickness, Temperature, and Alloy Composition Dependence of Thermal Conductivity in ScN and Sc <sub>x</sub> Cr <sub>1-x</sub> N Thin Films Using Two-Color TDTR
16:40 - 17:10	Coffe Break
17:10 - 18:00	Plenary <b>Marcos Pimenta</b> Electron-phonon interactions in 2D materials studied by resonance Raman spectroscopy
18:00 - 19:30	Students activity IEEE + OPTICA

FRIDAY - DECEMBER 5	
09:00 - 09:50	Plenary <b>Alexandra Kalashnikova</b> Ultrafast opto-magnonics: from the center to the edge of the Brillouin zone
09:50 - 10:20	Coffe Break
10:20 - 11:10	Plenary <b>Jeremy Baumberg</b> Exploring extreme optomechanics of a handful of molecules inside individual plasmonic nanocavities
10:20 - 11:10	Plenary <b>Clivia Marfa Sotomayor Torres</b> Phonon propagation in a topological non-trivial phononic waveguide
	Prize Ceremony + Farewell

# Abstracts

Plenaries

## Plenary

Transient strain and lattice dynamics with EUV and X-rays.

# Picosecond ultrasonics with x-rays - applications to energy transport and magnetisation dynamics

Matias Bargheer<sup>1, 2</sup>

University of Potsdam, Institute of Physics and Astronomy  
HZB - Helmholtz-Zentrum für Materialien und Energie Berlin

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Picosecond ultrasonics with x-ray probe pulses (PUX) provide unique access to coherent longitudinal acoustic phonons (coherent strain wave packets) and heat transport at the nanoscale (flow of incoherent excitations)[1]. Bragg-peak shifts are especially useful experimental observables in nano-layered systems, where all layers can be simultaneously probed and identified by their Bragg angle. Contemporary laser-based sources of hard x-rays with femtosecond pulse duration have sufficient x-ray flux and stability to analyze the dynamics of films with single-digit nanometer thickness, and large-scale facilities even yield access to nanoparticle dynamics. This presentation will show that Ultrafast X-ray diffraction (UXRD) and extensions to Ultrafast Reciprocal Space Mapping (URSM) are broadly applicable to fundamental physics question and materials science.

We will highlight fascinating phenomena such as the counterintuitive localization of heat via dissipation [2] and heat transport at metallic interfaces dominated by phonons [3]. We shall discuss coupling of strain and heat to magnetization dynamics [4,5] and magnetic phase transitions [6]. Ultrathin metal superlattices are introduced as a metamaterial and means to transduce large amplitude terahertz strain waves via electronic pressure on metallic interfaces.[7]

## References

- [1] Mattern, A., von Reppert, S. P., Zeuschner, M., Herzog, J.-E., Pudell, J.-E., and Bargheer, M., *Concepts and use cases for picosecond ultrasonics with x-rays*, **Photoacoustics** 31, 100503 (2023).
- [2] Stete, S., Kesarwani, C., Ruhmlieb, F., Schulz, M., Bargheer, M., and Lange, H., *Inverted Temperature Gradients in Gold-Palladium Antenna-Reactor Nanoparticles*, **Nat. Commun.** 16, 8168 (2025).
- [3] Herzog, A., von Reppert, J.-E., Pudell, C., Henkel, M., Kronseder, C. H. Back, A., Maznev, and Bargheer, M., *Phonon-dominated energy transport in purely metallic heterostructures*, **Adv. Funct. Mater.** 32, 2206179 (2022).
- [4] Jarecki, M., Mattern, F.-C., Weber, J.-E., Pudell, X.-G. Wang, J.-C. Rojas-Sánchez, M. Hehn, A. von Reppert, and Bargheer, M., *Controlling effective field contributions to laser-induced magnetization precession by heterostructure design*, **Communications Physics** 7, 12 (2024).
- [5] Walz, F.-C., Weber, S.-P., Zeuschner, K., Dumesnil, A., von Reppert, M., and Bargheer, M., *Large strain contribution to the laser-driven magnetization response of magnetostrictive TbFe<sub>2</sub>*, **Appl. Phys. Lett.** 127, 052406 (2025).
- [6] Mattern, J., Jarecki, J., Arregi, J. A., Uhlř, V., Rössle, M., and Bargheer, M., *Speed limits of the laser-induced phase transition in FeRh*, **APL Materials** 12, 051124 (2024).
- [7] Bargheer, M., *et al.*, *Electron pressure drives THz phonons in metal-metal superlattices*, preprint DOI: 10.21203/rs.3.rs-6597328/v1 (2021).

## Plenary

Biophysics and biosensing. Raman scattering.  
CARS. SERS. Catalysis and energy

# Exploring extreme optomechanics of a handful of molecules inside individual plasmonic nanocavities

Jeremy Baumberg<sup>1</sup>

1. NanoPhotonics Centre, University of Cambridge

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The ability to routinely confine light to nanoscale volumes around molecules using plasmonic nanocavities opens up a wide landscape to explore optomechanical coupling. In this talk I will explore the capabilities and vision.

We have exploited a nanoparticle-on-mirror configuration to create thousands of identical nanocavities.[1] Embedding self-assembled monolayers of molecules in these nanocavities allows exploration of how they vibrationally couple (including at THz frequencies),[2,3] how they can be optomechanically-pumped,[4,5] how they can create new modes,[6] and how they can transport heat. We also explore the vibrational coupling of molecules with radical electrons, to access a new generation of qubits which can operate at room temperature.[7]

We also show applications ranging from photocatalysis to sensing. These have been enabled by a new discovery that we can completely clean out and reinsert molecules in nanogaps repeatedly, producing ideal SERS substrates which can be operated in flow with electrochemical control.[8] Monolayers of water on the gold nanogap facets can be tracked, allowing their orientation and hydrogen-bonding to be studied in situ, and sensitising for ultralow gas/vapour detection.

[1] JJ Baumberg et al, Nature Materials 18, 668 (2019); DOI: 10.1038/s41563-019-0290-y

[2] NS Muller et al, Nano Letters (2022); DOI: 10.1021/acs.nanolett.2c02806

[3] A Boehmke et al, Nature Comm (2024); DOI: 10.1038/s41467-024-50823-x

[4] L Jakob et al, Nature Comm 14, 3291 (2023); DOI 10.1038/s41467-023-38124-1

[5] L Jakob et al, ACS Nano (2025); DOI: 10.1021/acsnano.4c16535

[6] R Arul et al, PRL (2023); DOI: 10.1103/PhysRevLett.131.126902

[7] Y Bar-David et al, ACS Nano 19, 7650 (2025); DOI: 10.1021/acsnano.4c09661

[8] S Sibug-Torres et al, Nature Comm. (2024); DOI: 10.1038/s41467-024-46097-y

## Plenary

Biophysics and biosensing. Raman scattering. CARS. SERS. Catalysis and energy

# Therapeutic drug monitoring using centrifugal microfluidics and Surface Enhanced Raman Scattering

Anja Boisen<sup>1</sup>, Martyna Pytlarz<sup>1</sup>, Gohar Gohar Soufi<sup>1</sup>, Isidro Badillo-Ramírez<sup>1</sup>, Laura Seriola<sup>1</sup>, Roman Slipets<sup>1</sup>, Yaman Göksel<sup>1</sup>, Anders Perner<sup>2</sup>, Kjeld Schmiegelow<sup>3</sup>

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We have for the past ten years been developing and exploring solid SERS substrates based on gold or silver coated nanopillars. Recently, we have, with kind support from the Danish Bio Innovation Institute and the European Innovation Council, focused on developing a SERS based platform for therapeutic drug monitoring (TDM). Here, we detect e.g., anti-cancer drugs and antibiotics in patient blood samples, to monitor if the patient is receiving a correct dose within the therapeutic window. The vision is to be able to provide a tool for personalized treatment of critical diseases where correct dosing is essential and where a wrong dose can be lethal or cause severe side effects. We will share our recent findings and the prototype of a complete TDM device, with integrated sample pre-treatment using centrifugal microfluidics.

## Plenary

Time-resolved phononics. Ultrafast photoacoustics

# Nonlinear Phononics - Coherent Control over Materials Phases

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Coherent electromagnetic radiation at TeraHertz frequencies is increasingly used to drive materials. When tuned to collective resonances such as phonons and plasmons, TeraHertz light can create exotic transient states, reflecting functional properties that do not exist in equilibrium and which can be activated at ultrafast speeds. I will discuss instructive examples for the case of strongly driven lattices, as well as the development of new ultrafast methods to interrogate these states.

## Plenary

Quantum materials. Quantum phononics. Quantum acoustics

# Quantum technologies with bulk acoustic wave phonons

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Bulk acoustic wave (BAW) resonators are mechanical oscillators that confine sound waves in a solid-state material. Due to their use in a wide range of classical devices, they have been engineered to exhibit high quality factors, and their interactions with electromagnetic fields have been extensively studied. Recently, BAW resonators have also rapidly developed into a promising platform for new quantum devices. In this talk, I present our work on interfacing them with microwave frequency superconducting circuits and using such circuit quantum acoustodynamics systems for quantum control and measurement of phonons.

## Plenary

Quantum materials. Quantum phononics. Quantum acoustics

# Itinerant phonons: Prospects for quantum computation and quantum sensing

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My group has been developing individual itinerant phonons for possible applications to quantum computing and quantum sensing. Using superconducting qubits as deterministic sources and detectors of individual microwave-frequency phonons, we can create individual phonons in a mechanical resonator; generate quantum entangled states between phonons in two physically separate mechanical resonators; transmit quantum states between superconducting qubits via phonons, and generate quantum entanglement by sharing “half-phonons” between two superconducting qubits. By assembling a single-phonon interferometer, we have also demonstrated the acoustic version of the Hong-Ou-Mandel effect from quantum optics, which in turn has allowed us to demonstrate coherent one- and two-phonon classically-controlled phase gates. These point to the possible development of a phonon-based architecture for quantum computing, in which phonons, generated as “throw-away” qubits, can in principle allow scaling to very large numbers of qubits at no additional expense. I will also briefly describe our recent efforts to use this technology for quantum sensing.

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## Plenary

Phonon-magnon interaction. Coherent Phonon-Induced Magnetism. Spin and phonon dynamics

# Ultrafast opto-magnonics: from the center to the edge of the Brillouin zone

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Efficient generation, propagation, control, and detection of spin waves is essential for development of magnonic components for conventional and neuromorphic computing. Spin wave wavelengths can be as short as nanometers, while their frequencies reach Terahertz, and working with such waves is a challenging task in magnonics. Promising approach to this issue is to exploit femtomagnetic phenomena – ultrafast laser-induced changes of magnetic parameters in combination with strong localization of laser pulses.

In this talk, we first discuss generation of magnetostatic waves - spin waves near the centre of the Brillouin zone in anisotropic ferromagnetic films based on a laser-driven localized perturbation of magnetic anisotropy [1-3]. Based on experimental findings and micromagnetic simulations, we suggest a tunable source of magnetostatic wavepackets using a focused laser pulse and a spin texture in a magnonic waveguide [4]. Next, we demonstrate a novel regime of spin waves generation facilitated by magneto-elastic interaction. This regime can be understood as a magnon-Cherenkov effect with the laser-induced picosecond strain pulse serving as a localized moving source of the spin wave [5], and enables reaching spin waves beyond the magnetostatic regime [6].

Finally, we tackle a problem of reaching ultimate exchange waves – those at the edge of the Brillouin zone, that cannot be realized so far via the above mentioned approaches. We show how ultrafast perturbation of the exchange interaction drives coupled spin-wave pairs across the whole Brillouin zone – two-magnon modes, and outline an approach to selective excitation of two-magnon modes with different wavevectors [7-9].

The work was supported by RSF grant No. 23-12-00251.

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## Plenary

Optomechanics, Phononic and  
phoxonic crystals, Phonon laser

# Shaping Sound at the Nanoscale: Integrated Architectures for Coherent Phonon Confinement and Guiding

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Phonons in the GHz–THz range (wavelengths of 1–100 nm) offer a rich platform for exploring nanoscale wave phenomena and enabling new functionalities in nanoelectronics, photonics, sensing, and quantum technologies. Their strong interactions with other excitations in solids position them as key elements in the development of nanophononic devices and hybrid systems [1]. However, electrical generation of propagating acoustic waves remains limited to a few gigahertz due to transducer miniaturization constraints, while optical methods—though capable of reaching THz frequencies—have largely struggled to efficiently couple energy into traveling phonon modes.

This work is presented in two parts. First, we revisit phonon confinement using optophononic resonators based on AlAs/GaAs superlattices. These include planar Fabry-Pérot, topological, and adiabatic cavities, as well as 3D micropillars that co-confine near-infrared photons and hypersound at ~20 GHz within the same volume. This simultaneous confinement significantly enhances photon-phonon transduction in compact architectures.

Second, we demonstrate phonon guiding by etching these multilayers into waveguide geometries that support in-plane propagation of coherent acoustic waves. Using ultrafast transient-reflectivity pump-probe measurements, we generate and detect high-frequency phonons over remote regions, realizing a quasi-continuous acoustic source operating at room temperature. Interference measurements confirm mutual coherence between multiple spatially separated sources, demonstrating controllable, coherent transport.

Looking ahead, this platform is well-suited for programmable phononic control via spatial light modulation. By tailoring the number, location, and phase of optical excitation sites, it should be possible to synthesize arbitrary propagating acoustic waveforms. These results pave the way for reconfigurable nanophononic circuits and the integration of phononics with optomechanics, polaritonics, and quantum acoustics.

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## Plenary

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

# Electron-phonon interactions in 2D materials studied by resonance Raman spectroscopy

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In this lecture I will discuss the use of Raman spectroscopy to study phonons and electron-phonon interactions in 2D materials. I will start reviewing the Raman spectrum of graphene, showing that measurements performed by changing the energy of the incident photon provide information about the electronic structure and phonon dispersion of the material. I will then focus on the resonance Raman effect in twisted bilayer graphene (TBG), presenting experimental results performed in TBG samples with different twisting angles that allow the distinction between intralayer and interlayer electron-phonon (el-ph) interactions. I will then present results in 2D crystals of the transition metal dichalcogenide (TMD) family, starting with the semiconducting MoS<sub>2</sub> where we could observe symmetry dependent el-ph interactions and investigate the scattering of electrons by acoustic phonons between different valleys in the electronic structure. Finally, I will present angle-resolved polarized Raman measurements in triclinic ReSe<sub>2</sub> and show that the Raman tensor elements for the different phonons are given by complex numbers due to the resonance Raman effect.

## Plenary

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

# Phonon propagation in a topological non-trivial phononic waveguide

Clivia Marfa Sotomayor Torres<sup>1</sup>, O.R. Ranjbar-Neini<sup>1</sup>, G. Conte<sup>1</sup>, M. Balagopalan<sup>1</sup>, M.D. Kojam<sup>2</sup>, Y. Pennec<sup>2</sup>, B. Djafari-Rouhani<sup>2</sup>, O. Ylivaara<sup>3</sup>, S. Pourjamal<sup>3</sup>, T. Makkonen<sup>3</sup>, J. Ahopelto<sup>3</sup> and C.M. Sotomayor Torres<sup>1</sup>

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In the quest for a token of information which is fundamentally one using low power, we homed in phonons for interconnects.

In this context we report recent studies of topological non-trivial phononic interface waveguides in silicon at room temperature. The nanocrystalline silicon (nc-Si) structures are based on phononic band structure simulations. They were fabricated by electron beam lithography and dry etching in a suspended membrane. Theoretical work has been carried out considering also the modes of two valley Hall phononic crystals forming an interface waveguide.

The propagation is studied by launching a surface acoustic wave and measuring its amplitude along the waveguide by laser Doppler vibrometry.

Our preliminary observations indicate minimum losses. This work-in-progress confirms the role of critical dimension variability among others.

We discuss the significance of this finding in this frequency regime as a useful approach to transmit information at chip level and hypothesize about improvements as well as integration approaches.

# Abstracts

Keynotes

## Keynote

Phonon-magnon interaction. Coherent  
Phonon-Induced Magnetism. Spin and phonon dynamics

# Coherent control of magnons in phononic nanoresonators

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Ultrafast optical excitation of a metallic ferromagnetic nanostructure induces a simultaneous coherent response of the lattice and spin system; in other words, it generates coherent phonons and magnons. The range of generated wave vectors, determined by the structural design and the spatial profile of optical excitation, is between  $10^4$  and  $10^6$   $\text{cm}^{-1}$ . In this range, the characteristic frequencies for both types of excitations are  $\sim 10$ - $100$  GHz, and the phonon and magnon dispersions intersect. This allows us to enhance the role of the magnon-phonon interaction in the coherent response of the spin system to optical excitation. The key parameters, which are considered crucial for the contribution of the magnon-phonon interaction to coherent spin dynamics, are the coupling strength of the phonon and magnon eigenmodes of the nanostructure and their spectral overlap. The phases of the optically excited modes are usually not considered. The present work illustrates that this parameter can crucially determine the coherent spin dynamics and proposes a concept of hybrid coherent control of magnons in a phononic nanoresonator.

The talk will be based on a series of experiments with ferromagnetic (Fe,Ga) nanostructures that host spectrally narrow phonon and magnon modes [1,2]. The coherent response of the lattice and spin system to ultrafast optical excitation is measured in the time domain at room temperature using a pump-probe scheme with asynchronous optical sampling. We will review the main mechanisms contributing to the coherent magnon response, how these contributions depend on the nanostructure design and experimental conditions, and how to control the contribution of coherent acoustic phonons to the coherent spin dynamics. In the central part of the talk, we will consider the interference effect, when the quasi-harmonic phonon driving of a magnon mode interferes with its response to ultrafast optical excitation [2]. By manipulating the phase relation of these two contributions by an external magnetic field and achieving constructive or destructive interference, we can either significantly increase the spectral amplitude of the magnon mode or completely suppress it. The demonstrated approach enhances our ability to manipulate coherent spin dynamics at the nanoscale through magnon-phonon interactions.

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## Keynote

# Lithium Niobate Nanophononic Devices

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# Abstracts

## New Phonon

## Invited

Time-resolved phononics. Ultrafast photoacoustics

### New Phonon

# Resonant Ultrafast Spectroscopy of Acoustic Phonons in Semiconductor Superlattices

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We investigated the generation and detection of coherent acoustic phonons in GaAs/AlAs superlattices under resonant excitation of confined electronic states. Pump-probe experiments were performed on high-quality samples [1], varying the excitation photon energy around the interband transitions  $e1hh2$ ,  $e1lh1$ , and  $e2hh2$ . By tuning the excitation energy close to these transitions, strong resonance effects were observed in both phonon generation and photoelastic detection.

Experiments using picosecond pulses revealed well-resolved resonances with linewidths of 4-7 meV, allowing selective excitation of individual electronic states. Modeling of the pump-probe response, using a unified approach to describe the complex refractive index and the resonant photoelastic function based on a Brillouin-Raman electronic density model [2,3], successfully reproduced the experimental spectra. The extracted parameters describe the excitonic transitions and the optical coupling of the quantum wells within the superlattice, providing quantitative insight into the resonant generation of coherent acoustic phonons.

Power-dependent measurements revealed saturation effects in the  $-1$  CZ mode intensity when the excitation was resonant with the  $e1hh1$  transition, while the  $e2hh2$  resonance increased linearly up to the highest pump powers. A phenomenological population-dynamics model, based on rate equations for the confined electronic levels, explains these saturation effects as a consequence of state filling and carrier relaxation dynamics associated with the acoustic phonon generation process.

These results highlights the capability of resonant picosecond ultrafast spectroscopy to probe electron-phonon coupling in semiconductor superlattices, enabling the extraction of electronic, optical, and elastic parameters with sub-meV precision.

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## Invited

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

### New Phonon

# Surprises from electron-phonon interactions in two-dimensional materials

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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 effect. Our findings shed light on harnessing these unconventional states in quantum research.

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## Invited

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

### New Phonon

# Manifestations of magneto-polaron effects in resonant Raman scattering in Transition Metal Dichalcogenides

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The field of two-dimensional materials, particularly, Transition Metal Dichalcogenides (TMDs), has attracted increasing attention due to their unique properties that differ significantly from their bulk counterparts. These materials possess remarkable optical, electronic, magnetic, mechanical, and thermal characteristics, making them promising candidates for emerging technological applications [1]. There remain key issues regarding the dimensionality-governed properties of those materials, large-scale production, and their functionalization for sustainable applications. Recent investigations have highlighted the outstanding potential of TMDs in optoelectronics, photonics, and semiconductor technologies, underlying their prospective role in sustainable development, e. g., environmental applications and low-dissipation device architectures. First-order resonant Raman spectroscopy in an applied magnetic field is a unique method that allows for studying configurations of energy levels that facilitates development of applications of TMDs. We have discovered the behavior of the magneto-polaron (MP) resonances as a function of the phonon symmetry inherent in monolayer TMDs [2]. Many avoided-crossing points of energy branches assisted by an optical phonon in the MP spectrum, superposition of the electron and hole states in the emerging excitations, and their impact on optical transitions in various scattering configurations are specific for these two-dimensional structures [3]. The MP resonant scattering in a monolayer TMD is explored as a function of the laser intensity and the magnetic field. The MP resonant Raman intensity manifests three resonant splittings of double avoided-crossing levels. The three MP excitation branches occur by virtue of the coupling of electron and hole Landau levels to an out-of-plane  $A_1$  optical phonon mode. The energy gaps at the anticrossing points in the MP Raman spectrum are determined for various electron and hole deformation potential constants. The derived explicit expressions for the resonant MP Raman efficiency as a function of the magnetic field allow us to explore the relative contribution of the conduction and valence bands in TMDs to the formation of MP excitation branches [4]. The obtained results provide a background for on-demand engineering of the MP effects in the magneto-optical properties of TMDs.

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## Invited

Biophysics and biosensing. Raman scattering.  
CARS. SERS. Catalysis and energy

### New Phonon

# Low-frequency Raman scattering as a tool for probing nanocrystals surface chemistry

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Low-frequency Raman spectroscopy has emerged as a powerful technique for investigating the vibrational dynamics of inorganic nanoparticles. These nanostructures support confined acoustic modes whose frequencies are governed by their size, shape, and composition. As such, low-frequency Raman measurements enable rapid, non-destructive characterization of nanoparticles, whether embedded in solid matrices or dispersed making it a valuable tool in nanomaterials science.

Colloidal nanoparticles are particularly appealing for applications in nanophononics due to the precise control they offer over size, morphology, and composition. [1] In this context, surface ligands not only guide self-assembly but also influence the vibrational properties of the nanoparticles. This sensitivity of the acoustic vibration modes to surface modifications opens the door to using nanoparticles as sensitive "nanoresonators" probes for detecting and quantifying ligand adsorption.

In this work, we demonstrate how colloidal semiconductor nanoplatelets with precisely controlled thicknesses can serve as vibrational probes for monitoring surface chemistry via low-frequency Raman spectroscopy. We show that, beyond the simple "mass loading" effect of ligands, surface functionalization can induce notable structural modifications at the nanoscale, which are detectable through changes in vibrational spectra. [2] These findings are crucial for the accurate calibration of such nanoresonators when deployed as chemical or biological sensors.

In the second part, we examine the potential of nanoparticle-based vibrational probes for investigating chemical processes at interfaces. In particular, we present measurements related to the detection and monitoring of protein binding events, which suggest that low-frequency Raman scattering may be used as a label-free approach for probing biochemical interactions at the nanoscale.

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## Invited

Time-resolved phononics. Ultrafast photoacoustics

### New Phonon

# Time-resolved two-dimensional imaging of Lamb-like acoustic modes in topological phononic crystals at sub-GHz frequencies

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The concept of topological insulators for the electronic system has been extended to various aspects of physics including optical and acoustic waves. In acoustics, substantial improvements in waveguiding efficiency have been demonstrated in topological phononic crystals. The interface between two phononic crystal structures both based on a two-dimensional hexagonal structure but having different topological natures may have a topologically protected interface mode which allows a high efficiency wave propagation even at sharp corners.[1]

In this paper, we present the time-resolved two-dimensional imaging of Lamb-like acoustic waves propagating along the interface between two different types of valley Hall topological phononic crystals. Each phononic crystal consists of a two-dimensional hexagonal array of micron-scale voids formed on a self-supported GaAs thin slab of 1 micron thickness.[2] Each void has a three-fold rotational symmetry, but slightly (5 degrees) rotated clockwise or counter-clockwise so that the mirror symmetry which the original unrotated structure possesses is broken. These two rotated structures may have different topological natures and the interface between them may accommodate localized modes which serve for waveguiding. The acoustic waves in the frequency range 550-600 MHz are generated by an electric signal using an inter-digital transducer located adjacent to the phononic crystal structure. The acoustic field is optically monitored using periodic ultrashort light pulses and an optical interferometer with micron spatial resolution and picosecond temporal resolution.[3,4] We observe a high efficiency acoustic wave propagation along a Z-shaped folded waveguide.

This study proves that the topological effect is feasible for achieving high efficiency waveguiding in the sub-GHz frequency region, and that the time-resolved acoustic wave imaging is capable of clarifying the properties of topological acoustic devices.

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## Invited

Brillouin microscopy. Fiber sensors. Brillouin integrated photonics

### New Phonon

# BioBrillouin: state-of-the-art and perspectives

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Brillouin Micro-spectroscopy has gained significant interest in the past decade as part of the broader field of optical elastography, enabled by advancements in instrumentation, analysis, and use of correlative approaches. BM is an all-optical technique that maps the three-dimensional viscoelastic properties - i.e. stiffness and viscosity - of materials on a micro-scale using light scattered from sound waves (acoustic phonons). This allows for the investigation of live cells, tissues, and entire organisms with unprecedented detail, without requiring any physical contact, transducers, or external agents. Thus providing a new contrast mechanism in biomedical studies.

BM applications in biomechanics and mechanobiology have led to the discovery of novel features and mechanisms, highlighting the significance of mechanical properties measured with subcellular resolution in biological processes and disease diagnosis.

In my lecture, I will cover the fundamentals of BM and my team's work in laying the bases for the application of BM in biology and medicine. I will highlight the latest advancements, emphasising the BM's unique capabilities [1], perspectives [2], and progress towards unified instrument development [3].

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## Invited

Biophysics and biosensing. Raman scattering.  
CARS. SERS. Catalysis and energy

### New Phonon

# Advancing in-situ analysis: Applications of flexible SERS substrates in food safety, forensics, and cultural heritage

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Surface-Enhanced Raman Spectroscopy (SERS) has emerged as a powerful analytical tool renowned for its rapid, non-invasive, and highly sensitive detection capabilities. The technique's sensitivity is significantly augmented under electronic resonance conditions, leading to Surface-Enhanced Resonance Raman Spectroscopy (SERRS). A key innovation in this field is the development of flexible SERS substrates, which are ideally suited for in-situ analysis across diverse fields.

This presentation will showcase the latest advances in the fabrication and application of these flexible SERS substrates. Their principal advantage lies in a straightforward "stamping" sampling protocol, where the substrate is applied directly to the surface of interest. This method effectively eliminates potential sample interferences, preserves delicate samples from laser-induced damage, and enables the analysis of materials that cannot be transported to a laboratory.

Compelling case studies are presented that demonstrate the versatility of this approach in food safety, with the detection of agrochemical residues on fruit and vegetable peels achieving detection limits far below permitted thresholds (1,2); in forensic science, through the identification of cocaine on complex matrices such as banknotes (3); and in cultural heritage, via the minimally invasive study of priceless historical objects such as the first Argentine flags and artworks (4). Beyond the advantage of conforming to the sample's surface due to its flexibility, it has also been demonstrated that the substrates are capable of encapsulating and retaining the analyte, allowing to conserve the trapped molecules and its long-term SERS activity. The results underscore that these flexible SERS substrates represent a robust, versatile, and highly effective platform for rapid in-situ analysis, with profound implications for public health, forensic science, and the study of cultural heritage.

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## Invited

Phonon transport. Thermal transport. Thermal properties

### New Phonon

# Laser cooling of solids: an emerging technology with complex challenges.

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In this talk, we will explore the advances made over the past decade in the field of laser cooling of solid nanoparticles and present our ongoing experiment at the Laboratory of Trapped Ions and Cold Atoms. We will discuss the fundamental principles of laser cooling in solids, the current limitations of this technique and possible solutions, as well as the theoretical and experimental challenges that arise from both a physics and chemistry perspective. We will also examine the innovative ideas we are exploring in this field.

## Invited

Surface and bulk acoustic waves.

### New Phonon

# Proper Normalization of Phonon Modes for Rayleigh Waves

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Rayleigh waves are finding numerous modern applications including: universal quantum transducers (Schuetz et al., 2015), carrier mobility studies in diamond-based transistors (Singh, et al., 2020; Bonomo et al., 2020), and acoustic preparation of spin states (Whiteley et al., 2019), as examples. Moreover, there is substantial interest in using nanomechanical systems (Cleland, 2003) to drive EPR interactions in a context where phonon effects are important.

The classical theory of Rayleigh waves has been presented correctly for many years (Auld, 1973; Graff, 1991; Landau, 1986; Love, 1944), but there have been many unnecessary approximations and much confusion in the literature when normalizing Rayleigh waves. In part, this confusion stems from the different but equivalent Rayleigh expressions in the literature (Auld, 1973; Graff, 1991; Hassan and Nagy, 1998; Steg and Klemens, 1974). In a very insightful contribution, Hassan and Nagy (1998) have demonstrated the equivalence of the family of Rayleigh modes and how to convert between these modes. In the present contribution, Rayleigh wave phonons for the Auld-type, Graff-type, and Steg-Klemens-type are properly normalized (Strocio and Dutta, 2001) by including the necessary integral over the mode vertical profile such that the mechanical energy in the modes is equated with the energy of a phonon modes. A portion of the results to be presented may be found on Strocio and Dutta (2025).

The phonon mode normalizations to be presented have many contemporary applications. Research supported, in part, under AFOSR award FA9550-19-1-0282.

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## Invited

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

### New Phonon

# Ultralow-loss transport of topological phonons

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Topological insulators were originally discovered in condensed matter systems. Recently this concept has been transferred to bosonic systems such as photons and phonons, which has provided methods for constructing non-trivial states. In principle, topology protects propagation of phonon against backscattering, but not against loss, which has remained limited to the dB/cm-level for phonon waveguides, be they topological or not. On-chip phononic waveguides with propagation losses due to dissipation of  $\sim 3$  dB/km at room temperature is reported, which is orders of magnitude below any previous chip-scale devices. This is realized by the combination of advanced dissipation engineering, in particular the recently introduced method of soft-clamping, with the concept of a valley-Hall topological insulator for phonons. The low losses enable high-resolution ultrasound spectroscopy, and thus for the first time allow to accurately quantify backscattering protection in a topological phonon waveguide. We infer that phonons follow a sharp,  $120^\circ$ -bend with a 99.99%-probability instead of being scattered back, and less than one phonon in a million is lost. We also demonstrated that our phononic system has strong nonlinearities that allows large parametric gain. Our work will inspire new research directions on ultralow loss phononic waveguides, and provides a clean bosonic system for investigating topological protection and non-Hermitian topological physics.

## Contributed talk

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

### New Phonon

# Breathing modes in free-standing and supported MoS<sub>2</sub>: acoustic and optical resonances from atomically thin to bulk-like structures

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Two-dimensional transition metal dichalcogenides (TMDCs) are semiconducting materials with strong in-plane covalent bonding and weak inter-plane van der Waals forces, enabling isolation of monolayers via simple methods like mechanical exfoliation. Interest in TMDCs has surged due to their notable properties, including strong light–matter interactions at room temperature, making them promising for electronics, optoelectronics, and acousto-optics [1–2]. In the latter, TMDC flakes of varying thickness act as nanocavities generating high-frequency longitudinal acoustic phonons (~10 GHz to ~1 THz), outperforming other materials used in sensors, modulators, and filters [3]. However, a comprehensive understanding of its resonant behavior and dissipation mechanisms across a broad thickness range and under different boundary conditions remains lacking.

We present ultrafast pump–probe measurements of breathing modes in ~300 MoS<sub>2</sub> flakes, from <10 to ~1000 layers, under three substrate conditions: free-standing, and supported on dense or mesoporous silica (~100 nm thick). Measured frequencies span 4–300 GHz. Quality factors (Q) generally follow expected trends based on acoustic decoherence— anharmonicities and Lamb waves at low frequencies, scattering at high frequencies. However, we observe distinct resonances at specific thicknesses. Notably, resonant enhancement of oscillation amplitude and Q occurs under two conditions: (i) when the MoS<sub>2</sub> mode aligns with an acoustic cavity mode in the mesoporous film, and (ii) when optical and acoustic resonances coincide in MoS<sub>2</sub>. In peak cases, Q improves by an order of magnitude over off-resonance values.

We also detect higher harmonics in flakes with fundamental frequencies below 20 GHz, sometimes matching or exceeding the fundamental in amplitude, with parity consistent with expected boundary conditions. Furthermore, we directly observe surface waves propagating radially from the optically pumped region, attributed to Lamb-type waves in unsupported structures [4].

Our findings show that coupling between MoS<sub>2</sub> vibrational modes and substrate resonances—both acoustic and optical—enables enhanced, tunable mechanical behavior. This reveals complex dynamics in both free-standing and supported TMDCs and suggests potential for hybrid phononic–photonic devices.

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## Contributed talk

Time-resolved phononics. Ultrafast photoacoustics

### New Phonon

# Environment-responsive mesoporous-based GHz acoustic resonators

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Acoustic phonons, the quanta of lattice vibration, in the gigahertz range, are an asset for potential technological breakthroughs. [1] Novel approaches for tunable nanophononic resonators responsive to environmental conditions add extra control and functionality for these devices. Mesoporous materials for example, with nanoscale size pore diameters, are responsive to ambient humidity. It has been shown that multilayered resonators based on mesoporous SiO<sub>2</sub> and TiO<sub>2</sub> support acoustic modes in the 5-100 GHz range. [2,3] Design strategies, using periodic stacks of oxide materials, have also been proposed to enhance the acoustic confinement. [4] The pores of these materials can undergo liquid and vapor infiltration, modifying the material's effective optical and elastic properties. Liquid infiltration within the pores at the nanoscale has a nonlinear response with the ambient relative humidity, characterized by a sudden pore-filling increase at a threshold humidity, along with a hysteresis between adsorption and desorption sweeps, and is strongly dependent on the pore size distribution of the material. [5] Here, we compare two open-cavity acoustic resonators of SiO<sub>2</sub> MTFs with different pore diameters and different film thicknesses. The resonators are composed of a nickel acousto-optical transducer deposited on a glass substrate, and the MTF on top. We characterize the resonators by transient reflectivity experiments with a pump-probe scheme for coherent acoustic phonon generation and detection. We demonstrate that these resonators are responsive to humidity variations. In addition, our findings show that the acoustic modes confined in the MTF are independent of the pore size distribution, but mainly depend on the material properties and layer thickness. These results pave the way towards next-generation tunable and responsive nanophononic devices.

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## Contributed talk

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

### New Phonon

# Geometric thermoelectricity - interplay of phonons and electrons in 2D materials

Alexandros El Sachat<sup>1</sup>, Stuart Finch<sup>2</sup>, Stefania Skorda<sup>1</sup>, Charalambos Evangelis<sup>2</sup>, Sergio Gonzalez<sup>5</sup>, Peng Xiao<sup>3</sup>, Emigdio Chávez-Ángel<sup>4</sup>, Oleg Kolosov<sup>2</sup>

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Geometric Thermoelectricity (GTE) in van-der Waals (vdW) materials is a recently discovered phenomenon of significant modification of Seebeck thermoelectric (TE) coefficient in the nanoscale sized "constrictions" of uniform graphene layers [1]. The GTE is not linked with local doping or material change, signifying a radical deviation from conventional classic thermoelectric phenomena requiring a junction of two dissimilar materials (like a typical "thermocouple" or TE "junctions") with the underlying mechanism being the energy-dependent modification of electron mean-free path in the constriction [1]. GTE opens a new paradigm for creating TE devices solely by varying the geometry of two-dimensional van der Waals (vdW) material, drastically simplifying the design of TE devices. This work addresses key questions whether it is possible to use GTE to modify large areas of vdW materials, rather than a single constriction, what is the ultimate performance of such devices, and what are the details of heat, electron transport and TE conversion mechanisms in GTE phenomenon. To answer these, we use scanning thermal and scanning thermal gate microscopies (SThM and STGM) with heated nanoscale tip in contact with the probed device to measure a local thermal transport in the device and a thermovoltage generated by the device in response to the local raise of the temperature measuring local gradients of Seebeck coefficient [1]. We also used focused ion beam (FIB) to create different patterns of holes of varying pitch, number and diameter in the layer of vdW material – SnSe<sub>2</sub>. First, we investigated the dependence of local Seebeck coefficient on the diameter of the features and the distance from them. We found that while thermal transport varies on distances of a few tens of nanometres, the modification of Seebeck coefficient expands on much larger distance with the characteristic Seebeck exponential "decay length" evaluated by comparison of experiment and FEA modelling being on the order of 1  $\mu\text{m}$ . By selecting appropriate density and diameter of the nanofabricated patterns, it was possible to create large areas of Seebeck coefficient modification.

## Contributed talk

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

### New Phonon

# Torsional mechanical modes in acousto-plasmonic antennas

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Metallic nanoantennas have been studied as efficient coherent phonon generators and detectors, harnessing their characteristic optical absorption and polarization dependence of the optical modes [1-2]. The ability to control the excitation of phononic modes depends on the properties of the multiple optical resonances of the system. Lately, it has been made possible to optimally excite and detect phonon modes via plasmon resonances at the same optical frequency using chiral nanostructures and circularly polarized light [3]. However, torsional modes remain elusive in nanophononic studies. We have pursued two different approaches, one consisting in a twisted single nanostructure (toroidal propeller) [4] the second being composed of two coupled bars [5]. The twisting of the phononic mode is provided by the peculiar geometry of the nano-nanoantenna, either intrinsic in the case of the toroidal propeller or as a result of the interaction of the bars through the substrate.

In this work, we will present a complete theoretical analysis of the phononic and plasmonic modes, as well as their surface deformation field profiles in the two-coupled-bars system.

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## Contributed talk

Surface and bulk acoustic waves.

### New Phonon

# Acoustic phonons and photoelastic coupling in van der Waals crystals

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Recent advancements in the synthesis of single-crystal van der Waals (vdW) materials and supported 2D layers have led to the widespread availability of high-quality, large-area commercial samples. These developments have opened new avenues for exploring a range of physical properties—structural, electronic, optical, magnetic, thermal, and vibrational—that are highly sensitive to parameters such as thickness, strain, and layer stacking. However, the same level of control has not yet been achieved in tailoring their elastic behavior, highlighting a critical knowledge gap. A central question arises: Are current experimental methods sufficient to provide reliable and comprehensive insights into the mechanical properties of vdW systems, ranging from bulk crystals to individual atomic layers and complex nanoscale architectures?

In this work, we explore the anisotropic acoustic and elastic behavior of over 20 vdW single crystals using angle-resolved Brillouin light scattering (BLS). This technique, dating back over a century, remains one of the most effective non-invasive tools for probing phonons in the long-wavelength regime. Spontaneous BLS measures the frequency shift of monochromatic light scattered by thermally excited hypersonic (GHz) acoustic waves. The observed shifts are directly linked to the velocity and wavevector of these phonons, providing a window into the material's elastic properties.

Among the suite of methods for assessing elastic anisotropy, non-contact techniques such as BLS are particularly advantageous when dealing with ultra-thin or delicate samples. We demonstrate the suitability of BLS for micrometer-scale vdW materials and introduce two experimental protocols—customized for transparent and opaque crystals—paired with data analysis strategies aligned with their optical characteristics. These findings provide a robust experimental foundation for probing complete elastic as well as photo-elastic and dielectric tensors, advancing our understanding of vdW materials, and addressing long-standing experimental gaps in this field.

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## Contributed talk

Time-resolved phononics. Ultrafast photoacoustics

### New Phonon

# Ultimate detection sensitivity of picosecond strain pulses exploiting polariton resonance

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In a conventional ultrafast acoustic experiment, coherent acoustic phonons are generated in the form of a picosecond strain pulse and detected by monitoring strain-induced changes in the optical properties of the studied medium. This experimental scheme has been used over the years to investigate a wide range of phenomena and seems to have little room for significant enhancement. Nevertheless, in our study, we demonstrate how to achieve ultimate detection sensitivity within this scheme, employing a layer with a narrow polariton resonance as a phonon detector that allows detection of strain pulses with amplitudes well below lattice thermal fluctuations [1].

The key element of the performed experiment is the periodic structure grown on a GaAs substrate and consisting of 30 GaAs quantum wells (QWs) of 17.5-nm thickness separated by 8-nm (Ga,Al)As barriers. Each QW hosts a narrow exciton resonance centred at  $\hbar\omega_X = 1.5307$  eV. Photons with the energy  $\hbar\omega \approx \hbar\omega_X$  and excitons in the QWs form a coupled state referred to as an exciton-polariton, and the entire structure can be treated as an effective medium with a narrow optical resonance at  $\hbar\omega = 1.5307$  eV and strong permittivity dispersion within the resonance spectral width. The strain-induced shift of  $\hbar\omega_X$  through the deformation potential mechanism results in significant changes of the refractive index and, thus, modulation of reflectivity.

In the validating experiment performed in a conventional pump-probe scheme, the 150-fs pump laser pulses excited a 100-nm-thick Al film on the backside of the GaAs substrate. Ultrafast thermal expansion of the film generated a strain pulse, which travelled through the substrate toward the polaritonic layer, where it was monitored employing the probe pulses tuned to the spectral position of the polariton resonance. We measured the transient reflectivity, which possesses periodic oscillations due to the dynamical interference of the probe pulse reflected at the structure's front surface and the propagating strain pulse. This signal, often referred to as time-domain Brillouin scattering, remained well detectable at the pump fluences down to 10 nJ/cm<sup>2</sup> and the corresponding strain pulse amplitude of 10<sup>-9</sup>. The increase of the Al film temperature at this fluence was just 0.1 K, resulting in its thermal expansion of 100 attometres, which is 4 orders of magnitude less than atomic thermal motion at T = 10 K. We have also proved the large dynamical range of the polaritonic detection and examined how the transient reflectivity signal depends on the probe pulse fluence and its spectral detuning from the polariton resonance [2].

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## Contributed talk

Surface and bulk acoustic waves.

### New Phonon

# Building blocks for boson sampling in a bulk acoustic wave resonator

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Gaussian boson sampling (GBS) is a computational process that can show quantum advantage under conservative assumptions [1]. This is because the output distribution of a network, consisting of squeezing and beamsplitter operations, can be mapped to a classically intractable operation on a matrix. Notable applications of GBS include the sampling of molecular spectra and the search of maximum cliques in graphs. Experimental realizations of GBS have been carried out both in photonics platforms [2] and cQED systems [3]. However, the former are limited by non-tunable squeezing strengths and challenging Fock state preparation. In the latter case, each bosonic mode is hosted by a bulky microwave cavity, which hinders the scaling beyond a few modes.

In contrast, high-overtone bulk acoustic resonators (HBARs) host a large density of long-lived phonon modes that can be well controlled in a circuit quantum acoustodynamics (cQAD) device. I will present our work on implementing the building blocks of GBS based on bilinear interactions between HBAR modes coupled to a transmon qubit. In particular, we show how beamsplitter and squeezing operations can be realized by driving the ancilla qubit bichromatically. Using this parametric driving, we achieve up to 3dB of squeezing below the zero-point fluctuations and beamsplitter rates exceeding 20 kHz [4,5], allowing for gate times that are significantly shorter than the phonon coherence times of several hundred microseconds. Together with displacements and measurements of the Fock basis, these complete the universal continuous-variable gate set required for GBS. We show preliminary results on concatenating such gates as a step toward scalable GBS in cQAD.

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## Contributed talk

Surface and bulk acoustic waves.

### New Phonon

# Phonon transport and bandgap engineering in self-assembled nanosphere monolayers

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Phononic crystals—elastic counterparts of photonic crystals—offer prospects for controlling the propagation of elastic energy, with potential applications in tunable filters, thermal management, and acousto-optic devices<sup>1,2</sup>. By modulating phonon transport, these structures enable dynamic control over thermal conductivity. Colloidal self-assembly provides a cost-effective method to fabricate phononic crystals with tailored properties<sup>3,4</sup>. In this work, we present a time-resolved study of hypersonic phononic properties in two-dimensional colloidal crystals formed by self-assembled polystyrene (PS) nanospheres on a silicon substrate. We demonstrate that the hypersonic phononic bandgap can be tuned by modifying the interparticle interactions. Ultrafast pump-probe transient reflectivity techniques were used to investigate phononic modes across different frequency ranges<sup>5</sup>. The experimental results reveal strong phonon insulating behavior, supported by finite element method simulations. We also identify an avoided crossing, indicative of strong coupling between the contact resonance of the nanospheres and surface acoustic waves. These findings highlight the potential of self-assembled colloidal crystals as tunable hypersonic phononic insulators, advancing their prospects for next-generation phononic and thermal control devices.

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## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### New Phonon

# Quantum transport modeling of phonons in 2D Transition metal dichalcogenides heterostructures: A Non-Equilibrium Green's Function (NEGF) approach

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Nanoscale miniaturization and AI-driven hyperscale data centers are creating unprecedented thermal management challenges due to self-heating and energy-intensive cooling. Current solutions are unsustainable, with data center power use projected to double by 2026, reaching levels comparable to national electricity consumption. Urgent innovation in thermal technologies is essential. In that context, **transition metal dichalcogenides** (TMDs) are strong candidates for next-generation nanoelectronics. However, high integration densities will still cause chip self-heating. Fortunately, the van der Waals (vdW) bonds between layers and covalent bonds within layers give these heterostructures very versatile behavior. It is, for instance, possible to use electrostatic gating to dynamically modulate the thermal properties of stacked TMDs. Moreover, the superlattices made of lateral heterojunctions of those 2D materials also provide an opportunity to tune thermal properties using the wave nature of phonons.

In this work, we investigate how thermal transport behaves in distinct configuration of 2D TMD-based structures: vertically stacked **vdW** heterostructures and **lateral superlattices**. Materials such as MoS<sub>2</sub>, WS<sub>2</sub>, MoSe<sub>2</sub>, and WSe<sub>2</sub> combine strong in-plane covalent bonding with tunable interlayer interactions, offering a versatile platform for thermal engineering. In vertically stacked structures, the nature and strength of interlayer vdW coupling significantly influence phonon transmission and scattering at the interfaces. In contrast, lateral superlattices—formed by alternating strips of different TMDs—act as periodic phonon barriers that modulate heat flow through interference effects, leveraging the wave nature of phonons.

We analyzed the transport mechanisms using the NEGF formalism, which allows to accurately model how phonons behave and carry heat at the nanometer scale. To do this, we first calculate the second order interatomic force constants using density functional theory (DFT). These force constants are then used to build the dynamical matrices and surface Green's functions needed for NEGF simulations. In addition, we also investigate how applying mechanical strain modifies the thermal response, as strain is a powerful tuning parameter: it changes bond lengths, phonon group velocities, and interface coupling, offering a way to actively control heat flow.

By comparing these systems, we aim to clarify how geometry, interface design, external strain influence phonon transport. We will provide a comprehensible control heat transfer in TMD-based heterostructures, with optimal thermal properties.

## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### New Phonon

# ABACUS and Its Interfaces for Phonon Calculations: Bridging DFT, Machine Learning, and Lattice Dynamics

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ABACUS (Atomic-orbital Based Ab-initio Computation at UStc) is an open-source density functional theory (DFT) software that supports both plane-wave and numerical atomic orbital bases, offering comprehensive capabilities including LDA, GGA, meta-GGA, hybrid functionals, and advanced features like DFT+U and van der Waals corrections. The platform provides robust infrastructure for integrating machine learning methods such as DeePKS and DP-GEN into materials simulations. For phonon calculations, ABACUS features seamless interfaces with key computational tools: (1) ASE (Atomic Simulation Environment) through its ase-abacus calculator for streamlined simulation workflows; (2) Phonopy for efficient calculation of phonon band structures, density of states, and thermal properties; (3) ShengBTE for processing force constants to determine lattice thermal conductivity via Boltzmann transport equation solutions; and (4) DeePMD-kit, which combines with ABACUS to enable large-scale phonon calculations using deep learning potentials, overcoming traditional DFT computational limitations while maintaining accuracy for phonon dispersion and thermal property simulations in complex materials. This integrated approach positions ABACUS as a versatile platform bridging ab initio DFT, machine learning, and lattice dynamics for next-generation materials modeling.

# Abstracts

## Optomechanics

**Invited**

Optomechanics, Phononic and phoxonic crystals, Phonon laser

**Optomechanics**

# Optomechanical Platforms for Photonics and Quantum Transduction

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Integrated optomechanical systems provide a powerful platform for quantum-coherent sensing and transduction between optical and microwave domains. This functionality relies on a shared mechanical mode—often coupled to a piezoelectric layer—that mediates the exchange of information between photons and phonons. A central challenge in such hybrid systems remains residual heating, which continues to limit their quantum performance. In this talk, we present recent advances addressing this issue through the development of two-dimensional optomechanical crystals featuring enhanced thermal anchoring and gigahertz mechanical modes compatible with superconducting qubits. Two distinct geometries will be discussed as representative examples. We also introduce a dissipation-based coupling scheme operating in the sideband-resolved regime, achieving record-high mechanical frequencies and coupling rates. Together, these results advance the prospects of robust quantum transducers and long-lived optomechanical memories, paving the way toward hybrid photonic interfaces and optomechanical quantum repeater nodes for future quantum networks.

Optomechanics

# Coherent polaromechanical control of exciton-polariton condensation in microcavities

Alexander Kuznetsov<sup>1</sup>, Ignacio Carraro-Haddad<sup>2,3</sup>, Gonzalo Usaj<sup>2,3</sup>, Klaus Biermann<sup>1</sup>, Alejandro Fainstein<sup>2,3</sup>, Paulo Santos<sup>1</sup>

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Engineered coupling between optical, electronic and vibrational degrees of freedom in semiconductor structures opens a pathway to manipulate light-matter interactions at the nanoscale. On the one hand, excitons can couple strongly to resonant photons, resulting in light-matter exciton-polariton quasiparticles. On the other hand, lattice phonons can couple efficiently to excitons via the deformation potential mechanism. Moreover, interactions between phonons, excitons and photons can be enhanced in semiconductor microcavities (MCs). This enables a novel field of polaromechanics<sup>1</sup>, which studies interactions between non-equilibrium exciton-polariton Bose-Einstein-like condensates (BECs)<sup>2</sup> and GHz phonons in hybrid phonon-photon MCs<sup>3</sup>. Polaromechanical MCs are a powerful platform to study phonon lasing<sup>4</sup>, phonoritons<sup>5</sup>, locking<sup>6</sup> and time crystals<sup>7</sup>.

In this talk, we will address one of the challenges related to the tunable coherent population transfer in quantum systems on the timescale comparable to their microscopic coherence in the context of polariton BECs. Specifically, we demonstrate very precise and tunable control of the gain and loss, and therefore the population distribution within confined multimode polariton BEC system using an acoustic Floquet modulation. We use an (Al,Ga)As patterned MC that hosts spatially confined multimode polariton BEC<sup>8</sup> and show that the BEC population can be selectively transferred between confined levels by modulating the excitonic BEC component by the strain of a piezoelectrically excited GHz bulk acoustic wave<sup>9,10</sup>. For large-enough acoustic amplitudes, the bare exciton energy is periodically swept through all of the confined photonic levels, which leads to the periodic passage through multiple avoided crossings. As our experiments and the accompanying theory show, an interplay between the bosonic stimulation and the adiabatic Landau-Zener-like population transfer leads, for large enough modulation amplitudes, to the ground state BEC and the emission of coherent sub-50 ps pulses in the time domain and frequency combs in the spectral domain<sup>11</sup>. The demonstrated results are relevant for tunable ultrafast pulsed laser-like emission for novel information technologies.

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## Plenary

Optomechanics, Phononic and phoxonic crystals, Phonon laser

### Optomechanics

# Thermodynamics and information processing in programmable optomechanical circuits

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We study mechanical fluctuations and transport in resonator networks that are fully induced and controlled through radiation pressure drives. The optical spring effect in a multimode nano-optomechanical cavity allows the programming of arbitrary quadratic bosonic Hamiltonians for mechanical resonator networks, as well as Duffing-like nonlinearities. We use this to create networks with varying symmetry, topology, and functionality. In particular, we study how broken time-reversal symmetry, i.e., synthetic magnet fields in mechanical circuits, impacts the refrigeration performance of a network. Enhanced cooling efficiency is associated with persistent heat currents arising from the induced chirality. Moreover, we construct nonlinear mechanical networks that function as minimal information processing systems, to enable fundamental investigations of computing performance near the thermal limit. We demonstrate programmable logic gates in a single nanomechanical resonator, where different logic operations can be dynamically selected by adjusting laser parameters. Additionally, by coupling multiple mechanical modes within one resonator structure, we achieve cascable logic gates, paving the way to programmable optomechanical computing networks.

## Plenary

Optomechanics, Phononic and phoxonic crystals,  
Phonon laser, Phonon laser, Phononic and phoxonic crystals

### Optomechanics

# Vectorial Brillouin Scattering in Anisotropic Materials: Lithium niobate and beyond

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Stimulated Brillouin Scattering (SBS) enables strong light–sound interactions for applications in narrow-linewidth lasers, signal processing, and quantum transduction. While silicon platforms offer limited SBS performance, anisotropic materials like Lithium Niobate (LNO) and Lithium Tantalate (LT) unlock new opportunities through enhanced photoelastic coupling and crystallographic control. In this talk I'll review our recent progress in these materials: (1) strong cross-polarized backward SBS in LNOI waveguides, where TE and TM modes interact via shear surface acoustic waves. The observed gain exceeds  $80 \text{ m}^{-1}\text{W}^{-1}$  and arises from a nontrivial photoelastic tensor component, enabling polarization-sensitive Brillouin devices; (2) our progress investigating SBS in LTOI. These results mark a shift toward vectorial Brillouin photonics, where polarization and crystal orientation serve as design parameters. LNOI and LTOI together offer a flexible materials platform for scalable, tunable, and multifunctional SBS-enabled photonic systems.

## Contributed talk

Optomechanics, Phononic and phoxonic crystals, Phonon laser

### Optomechanics

# THZ Quantum Cascade SASER

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A high gain quantum cascade terahertz (THz) sound-laser (SASER) device was designed and fabricated using principles inspired by THz optical quantum cascade lasers. In this acoustic device, phonons are generated by driving current pulses through the highly ordered superlattice structure. The superlattice structure is designed to utilise inversely populated intersubband electron transitions to achieve high acoustic phonon generation efficiency. High performance was achieved by systematically scaling a 1.2 THz superlattice structure to 700 GHz. The high-intensity phonons were confirmed using superconducting bolometers on-axis, i.e. directly opposite the SASER device, and off-axis (0.5 mm away from the SASER device). The detected phonon intensity on-axis was observed to increase with applied current above a threshold at a faster rate than the increase of power dissipated in the device, while the intensity measured off-axis decreased. This observed collimation of the phonon emission provides strong evidence for stimulated phonon emission.

## Contributed talk

Optomechanics, Phononic and phoxonic crystals, Phonon laser

### Optomechanics

# Optomechanical coupling to surface acoustic waves

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Electrically driven surface acoustic wave (SAW) devices are used in a wide range of applications, including delay lines, RF filters, and sensors, with their functionalities recently expanding into the quantum regime [1]. In parallel, cavity optomechanics has developed into a mature field, allowing, for instance, the amplification and cooling of mechanical excitations, the observation of non-classical features of phononic modes, and even the quantum teleportation of optical states to mechanical oscillators [2-3]. In this work, we numerically investigate the interconnection of these two fields, building upon previous experiments demonstrating optomechanical coupling to surface acoustic waves [4-5]. We analyze the interplay between moving boundary and photoelastic contributions to the coupling, examine the influence of different material platforms, and propose an experimental implementation aimed at advancing the optomechanical readout of SAWs through the increase of the light-enhanced optomechanical coupling. Finally, we discuss broader perspectives of this approach, particularly in the context of quantum acoustics and microwave-optical quantum transducers.

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## Contributed talk

Light, neutron and x-ray inelastic scattering; Lattice Dynamics;  
Phonons in glasses and disordered materials; Electron-phonon interactions

### Optomechanics

# Rabi-driven vibrational excitations under electronic strong coupling in optical cavities

Carlos Bustamante<sup>1</sup>, Franco Bonafé<sup>1</sup>, Michael Ruggenthaler<sup>1</sup>, Maxim Sukharev<sup>2</sup>, Abraham Nitzan<sup>3</sup>, Angel Rubio<sup>1</sup>

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The strong coupling between light and matter within optical cavities has opened a new path to modify material properties and chemical reactions. Particularly important for chemical effects are the cases of photonic modes of the cavity resonating with molecular vibrations or electronic transitions, leading to vibrational strong coupling (VSC) and electronic strong coupling (ESC), respectively, where hybrid states of light and matter called polaritons arise. On the other hand, it has been known for decades that the impulsive Raman mechanism can launch molecular vibrations or coherent phonons with A1 symmetry due to a sudden displacement of the equilibrium coordinate upon optical excitation. However, so far, these processes have not been studied in optical cavities with collective effects.

Here, using our recent implementation, which combines numerical propagation of Maxwell's equations with quantum mechanical simulations of molecules, we have observed the launching of optically-inactive vibrational modes in molecules under ESC inside optical cavities, when driven by an external pulse. The amplitude of the oscillations depends on the energy separation between the two new polaritonic states (Rabi splitting), reaching a maximum when the Rabi splitting matches the molecular vibrational frequency. We explain this mechanism by a periodically driven oscillator that can resonate with the cavity, depending on the number of molecules and mirror conditions. Our results suggest possible spectroscopic ways to detect this novel mechanism with applications in the new field of polaritonic chemistry.

## Contributed talk

Optomechanics, Phononic and phoxonic crystals

### Optomechanics

# Coherent Control of Pseudospin Precession and Optomechanical Coupling in Polariton Time Crystals

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Ga(Al)As semiconductor microcavities provide a versatile platform to study strong light-matter interactions and their coupling to confined GHz-frequency acoustic phonons. In these systems, exciton-polaritons—hybrid quasiparticles resulting from the strong coupling between excitons and cavity photons—combine pronounced nonlinearities with efficient coupling to bulk acoustic waves (BAWs) confined within the microcavity. Under non-resonant continuous-wave excitation, polaritons can undergo Bose-Einstein condensation above a threshold pump power, forming spin-polarized condensates with a well-defined pseudospin arising from the interplay between light polarization and exciton spin. We recently demonstrated that, in the presence of a trapping potential, the condensate pseudospin can spontaneously enter a regime of self-sustained precession, breaking continuous time-translation symmetry—thus forming a continuous time crystal (CTC) [1]. This self-induced dynamic can resonantly drive the mechanical modes of the system, generating coherent vibrations that feed back into the condensate and lead to frequency locking of the CTC [1, 2, 3].

Here we show that introducing a resonant optical drive enables coherent control over the polariton modes and their pseudospin precession via frequency pulling and injection locking. This allows for precise tuning of the condensate's energy and phase, and even full suppression of the precessional dynamic. Furthermore, when the resonant laser is red- or blue-detuned from the polariton modes by an amount equal to the phonon frequency, mechanical vibrations can be externally driven and controlled. This interaction leads to the emergence of complex nonlinear trajectories in polarization space (on the Poincaré sphere), including period doubling with respect to the phonon frequency, as also captured by our theoretical model. These mechanisms open new avenues for manipulating time-crystalline phases, tailoring inter-site coupling in polariton lattices, and implementing novel schemes for non-reciprocal or topological transport.

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## Contributed talk

Optomechanics, Phononic and phoxonic crystals, Phonon laser

### Optomechanics

# Programmable Optomechanical Logic Circuits

Xiaofei Guo<sup>1</sup>, Jonne Drost<sup>1</sup>, Jesse Slim<sup>1,2</sup>, Fons van der Laan<sup>1</sup>, Marc Serra Garcia<sup>1</sup>, Ewold Verhagen<sup>1</sup>

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We explore the use of light-induced mechanical nonlinearities to create basic information processing functionalities in optomechanical systems. Due to its high level of control and precise measurement capabilities, this platform could allow studying the fundamentals of computing performance near the thermal limit. Computation in the mechanical domain has also gained interest recently for its potential use in extreme environments. However, it is challenging to make mechanical logic gates cascadable for complex operations, and even more so to make them actively reconfigurable beyond a single function.

We realize programmable logic gates in nanomechanical resonators by using lasers to control mechanical nonlinearity through optical cavity dynamics. We demonstrate that a single nanobeam can achieve different types of logic gates through adjusting the laser drives. Additionally, we achieved adjustable cascading logic circuits using multiple mechanical modes of the same structure. Our findings pave the way for realizing complex and adjustable mechanical circuits without requiring large and complex structures, offering a promising route towards miniaturized and efficient mechanical logic devices.

## Contributed talk

Optomechanics, Phononic and phoxonic crystals, Phonon laser

### Optomechanics

# Optomechanical lockings of double trap exciton-polariton spins

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Inspired by experimental results, we present a model of two coupled, non-resonantly driven exciton-polariton spins located at two neighboring traps in presence of optomechanical interactions. Our framework considers a comprehensive set of interactions, including polariton-polariton, phonon-mediated inter-trap and intra-trap couplings as well as dissipative, reservoir-mediated effects. By analyzing the system dynamics, we identify complex spin and phonons states. The results help us to interpret experimental spectral observations of phonon related inter-trap and intra-trap lockings.

## Contributed talk

Optomechanics, Phononic and phoxonic crystals, Phonon laser

### Optomechanics

# Photoelastic Coefficients of Thin-Film Silicon Nitride Determined via Optomechanically Induced Absorption

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Silicon nitride (SiN<sub>x</sub>) is a promising material for photonic integrated circuits due to its higher power-handling capability compared to silicon, owing to the absence of two-photon absorption in the telecom regime. This makes SiN<sub>x</sub> particularly suitable for nonlinear processes like optomechanics. The interactions between photons and phonons enable for instance cooling, quantum information storage, and RF-to-optical transduction.

To design SiN<sub>x</sub>-based optomechanical devices with GHz-level mechanical modes, knowledge of the full photoelastic tensor is essential. For amorphous SiN<sub>x</sub>, the tensor is uniquely characterized by  $p_{11}$  and  $p_{12}$ . So far, Gyger *et al.* have measured  $|p_{12}|=0.047$  [1]. In this work, we determine both  $p_{11}$  and  $p_{12}$  by using a silicon nitride microgear cavity [2], enabling independent interaction of TE-like and TM-like whispering gallery modes with a 1.82 GHz mechanical breathing mode at the microgear's edge. The device was fabricated by Ligentec, a Swiss silicon nitride foundry. We used buffered HF to under-etch the device that was embedded in silica. Optical quality factors of  $10^5$  were measured through optical transmission spectroscopy.

We use optomechanically induced absorption (OMIA) to determine the vacuum optomechanical coupling rate  $g_0$ . Comparing the experimental data together with numerical results, with the previously obtained results from Gyger *et al.* [1], we find the values of  $p_{11}$  and  $p_{12}$ , which have opposite signs, indicating that the photoelasticity of SiN<sub>x</sub> is closer to silicon than to silica, yet stronger. We anticipate that this work will serve as a crucial milestone in advancing SiN<sub>x</sub> optomechanics.

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# Abstracts

## Phonon Magnon

## Invited

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

### Phonon Magnon

# Magnetic order in an air-stable frustrated van der Waals magnet

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Van der Waals magnets appeared in 2017 [1] in the form of monolayers and since then, are stimulating a lot of experimental and theoretical efforts to understand and describe their properties to finally integrate them into spintronic or magnonic devices [2].

In this talk, I will describe the properties of an orthorhombic frustrated van der Waals magnet, CrOCl, that shows a wide variety of B field-induced magnetic phases characterized by magnetic cells much larger than the crystallographic cell. Together with a strong magneto-elastic coupling, this leads to pronounced zone folding effects in the phonon spectrum that provide a unique possibility to describe the B-field induced phases using Raman scattering techniques. I will describe the cascade of magnetic phases that bulk CrOCl exhibits when it is subjected to an external magnetic field, before the spin saturation at  $B=30\text{T}$  [3].

Finally, taking advantage of the weak van der Waals interlayer interaction, we can thin down these materials and I will describe from the view point of magneto-Raman scattering spectroscopy, the properties of thin layers of CrOCl, down to the monolayer limit.

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[2] J.F. Sierra et al., Nat. Nanotechnol.16, 856 (2021)

[3] A. Pawbake et al., ACS Nano 19, 23693, (2025)

## Invited

Phonon-magnon interaction. Coherent Phonon-Induced Magnetism. Spin and phonon dynamics

### Phonon Magnon

# Shaken or stirred: ultrafast phononic switching of ferroic order

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Vibrations of the crystal lattice have a significant impact on the orbital dynamics of the electrons, and through it, on spins. Recently, ultrafast optical techniques have provided new insights into the coherent coupling of individual phonon and spin modes [1]. Ultrafast excitation of phonons resulting in drastic repopulation of phononic system was even shown to be able to modify the fundamental magnetic interactions [2]. And last but not least, very recently time-resolved X-ray scattering and electron diffraction experiments demonstrated the angular momentum transfer from magnetization to the phonon system, on a femtosecond time scale, dubbed ultrafast Einstein-de-Haas effect [3,4]. It should therefore be possible to realize the opposite process, by changing the lattice and thus controlling the magnetization, on the same time scale - in femtoseconds! 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 [5]. 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. The helicity-dependence of the switching implies that the lattice vibrations excited in the substrate deliver a directional field that pushes the magnetization towards a switched or non-switched state. The nature of such field is however completely unknown at present.

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 [6], confirming the mechanism. The mechanism appears to be very universal, as observed in variety of systems [7]. The dynamics of the domain formation was shown to proceed via a strongly inhomogeneous magnetic state resulting in a self-organization of magnon-polarons [8] and formation of magneto-elastic solitons.

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## Contributed talk

Phonon-magnon interaction. Coherent Phonon-Induced Magnetism. Spin and phonon dynamics

### Phonon Magnon

# Coherent and Dissipative Coupling in a Magnetomechanical System

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Hybrid elastic and spin waves hold promises for energy-efficient and versatile generation and detection of magnetic signals, with potentially long coherence times. Systems based on the coupling between elastic and magnetic degrees of freedom can boost transduction and sensing capabilities, down to the single-quantum detection and manipulation, or allow novel computation, simulation and storage platforms. In particular, magneto-elastic coupling allows for efficient magnon-phonon hybridization in the few gigahertz and inverse micron range, resulting in so-called magnon-phonon polarons.

The main channel of coupling in hybridized system is the so-called coherent coupling, highlighted by a gap (avoided crossing) in the dispersion relation. Recently, a different coupling mechanism was observed, stemming from correlation in the dissipation of the parent modes into a common incoherent bath: this further channel was dubbed dissipative coupling.

Here we report the experimental observation of magnon-phonon hybridization in a 1D magnonic-phononic crystal via time-resolved Magneto-Optical Kerr Effect (tr-MOKE), Brillouin Light Scattering, and micromagnetic simulations, namely the building of a Von Neumann-Wigner hybridization gap in a quasiparticle-quasiparticle system in the solid state. We obtain experimental evidence of the mixture of coherent and dissipative coupling, a condition we dub here mixed coupling. A Hamiltonian model for the hybridized modes corroborates our findings.

Such quantitative information will be crucial for identifying the experimental parameters that continuously tune the coupling in a magneto-mechanical system, transitioning from purely coherent to purely dissipative coupling. Our results suggest magnonic-phononic crystals as ideal platforms to investigate magnon-phonon mixed coupling, and hint to the possibility of novel magnonic-phononic devices.

Moreover, we propose the observed frequency-damping mismatch as an experimental identifier for such mixed coupling: this is not limited to magnon-phonon coupling, rather can be a useful discriminator also for other hybridizing platforms [1].

[1] P. Carrara et al, Phys. Rev. Lett., 132, 216701 (2024)

## Contributed talk

Light, neutron and x-ray inelastic scattering; Lattice Dynamics;  
Phonons in glasses and disordered materials; Electron-phonon interactions

### Phonon Magnon

# Phonon dynamics across the Verwey transition by time-resolved Raman spectroscopy

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Understanding the interplay between lattice dynamics and phase transitions in strongly correlated oxides remains a central challenge in condensed matter physics. Even magnetite ( $\text{Fe}_3\text{O}_4$ ), despite being studied for decades, continues to be the focus of active research due to its puzzling Verwey transition, a metal-insulator transition accompanied by a complex structural distortion and charge/orbital ordering [1]. In this framework, the use of ultrafast techniques allowed for novel approaches to the detection of transient states associated to the phase transitions, in particular highlighting the importance of the coupling of nonthermal electronic perturbations with symmetry-specific phonons in driving or stabilizing the Verwey transition [2,3].

Here, we present the results of a time-resolved spontaneous Raman spectroscopy (TRRS) study on  $\text{Fe}_3\text{O}_4$ , aimed at probing the mode-resolved phonon dynamics following impulsive 633 nm excitation. Measuring both the antiStokes and Stokes sides of the Raman spectrum of a magnetite sample poised below the Verwey transition temperature, we were able to simultaneously monitor the evolution of the crystal symmetry and the transient phonon population subsequent to the laser pump pulse, in the picosecond timescale. The comparison of these distinct dynamics can point out the role of specific phonons in accompanying or driving the phase transition.

The observed spectral changes, consistent with previously reported signatures of the Verwey transition [4], reveal the disruptive effect of the pump pulse on the low-temperature charge/orbital ordered phase and the photoinduced transition to the high-symmetry state. The antiStokes spectra show the prompt enhancement of the phonon population induced by the optical pumping and reveal distinct behavior of two Raman-active optical phonons. The  $A_{1g}$  mode exhibits "hot phonon" characteristics, indicating a strong coupling with the photoexcited electrons, while the  $E_g$  mode behaves as a "colder", less coupled, phonon. This points to the presence of mode-selective relaxation pathways, with energy transfer from excited carriers preferentially directed to lattice vibrations of specific energy or symmetry.

Overall, our findings provide new insights into phonon-specific energy flow and phase evolution in magnetite and underscore the capability of TRRS to unravel ultrafast lattice dynamics, making it a valuable tool to explore the physics of phase transitions in complex oxides and strongly correlated materials.

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## Contributed talk

Time-resolved phononics. Ultrafast photoacoustics

### Phonon Magnon

# Structural and nanoacoustic characterization of ferromagnetic Pt/Co superlattices

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Superlattices presenting a modulation of the elastic properties appear as a main tool to reach the THz regime in nanoacoustic devices. The exploration of alternative materials with multifunctional properties remains a fertile domain of research. In this work, we have investigated the structural, magnetic, and acoustic properties of Pt/Co-based ferromagnetic superlattices with varying cobalt thicknesses.

The Pt/Co superlattices were deposited by magnetron sputtering on Si substrates. X-ray reflectometry and scanning transmission electron microscopy (STEM) imaging confirmed the periodic structure of the Pt/Co layers with sub-5 nm-thick period thickness. STEM with local compositional analysis revealed that the samples present a modulation in composition instead of sharp interfaces, due to the effect of roughness and atomic interdiffusion. The polycrystalline nature of the superlattices is evidenced by X ray diffraction and TEM. These superlattices exhibit out-of-plane magnetization hysteresis, with a perpendicular magnetic anisotropy strongly dependent on the Co layer thickness.

We employed a pump-probe setup to study the coherent acoustic phonon dynamics in the metallic superlattices. Picosecond acoustic experiments demonstrated the generation and detection of short-lived ultrahigh-frequency acoustic phonons close to 900 GHz, along with up to 7 acoustic echoes at frequencies below 300 GHz. Simulations based on transfer matrix method and finite element method were performed to characterize the acoustic modes and their dynamics, further supporting our experimental results. The lower frequency peaks correspond to acoustic modes related to the total thickness of the sample, which acts as an acoustic resonator with a fundamental frequency of approximately 40 GHz. The high frequency peaks are linked to the superlattice modes at the Brillouin zone center with displacement profiles commensurate with the period of the superlattice. The cobalt thickness dependence of phonon modes highlights the ability of these structures for phonon engineering at the nanoscale, compatible with the stringent nanophononic requirements. Significant acoustic absorption in Pt/Co superlattices remains challenging for extending oscillation cycles of the acoustic response.

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## Contributed talk

Phonon-magnon interaction. Coherent Phonon-Induced Magnetism. Spin and phonon dynamics

### Phonon Magnon

# Phonomagnetism in quantum paraelectrics

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Juraschek et al.[1,2] theoretically showed that resonant pumping of double- or triple-degenerate phonons using circularly polarized THz radiation can induce circular motion of ions, which in turn can generate a magnetic moment measurable via the magneto-optical Faraday effect. This phenomenon can, in theory, occur even in non-magnetic materials such as the quantum paraelectrics SrTiO<sub>3</sub> and KTaO<sub>3</sub>. Based on the assumption that the time-dependent polarization  $\mathbf{P}$  associated with the circular motion of polar phonons generates a magnetization  $\mathbf{M} \propto \mathbf{P} \times \partial_t \mathbf{P}$ , the concept was termed *dynamical multiferroicity*.<sup>1</sup>

Transient THz-field-induced magnetization in SrTiO<sub>3</sub> was recently observed by Basini et al. [3], who pumped the soft mode at room temperature using circularly polarized THz radiation. However, the detected magnetization was surprisingly four orders of magnitude higher than predicted by theory.<sup>2</sup> Several theoretical explanations have been proposed for this unexpectedly strong effect, but these require further experimental validation.

We decided to study the THz-field-induced Faraday effect (TFE) in KTaO<sub>3</sub>. Compared to SrTiO<sub>3</sub>, KTaO<sub>3</sub> has the advantage of remaining cubic at all temperatures, enabling low-temperature measurements where soft mode damping is significantly reduced compared to room temperature. In this regime, the effective charge of the soft phonon is large, allowing efficient coupling with the THz field. This leads to greater phonon amplitudes and higher values of the phonon magnetic moment.

For our measurements, we used intense circularly polarized pulses at 0.7 THz, generated by an accelerator-based source with an undulator at the TELBE beamline of the Helmholtz-Zentrum Dresden-Rossendorf. The transient magnetic moment on the picosecond timescale was measured via the magneto-optic Faraday effect using a probe wavelength of 800 nm. For comparison with Ref. 3, we also performed measurements at room temperature using a 3 THz pump beam generated by an optically nonlinear crystal on a tabletop spectrometer.

We found that the TFE signal is always mixed with the electro-optic THz-field-induced Kerr effect (TKE) signal, which we also measured directly using a linearly polarized THz pump beam. This allowed us to quantitatively compare the TKE contribution to the overall signal containing the TFE response. Our measurements convincingly demonstrate the magnetic moment of a circularly polarized soft phonon in KTaO<sub>3</sub>.

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## Contributed talk

Phonon-magnon interaction. Coherent Phonon-Induced Magnetism. Spin and phonon dynamics

### Phonon Magnon

# Magnetophononics: Breaking Time Reversal Symmetry with Non-Maxwellian Magnetic-esque Fields

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Optical rectification of circularly polarized light generates a static magnetization through the inverse Faraday effect. Recent ultrafast experiments have unveiled a substantial, orders-of-magnitude gap between the measured, associated magnetic fields and theoretical predictions. In this talk, we show that the discrepancy arises due to a missing factor on the order of  $\alpha^{(-2)} \sim 2 \times 10^4$ , where  $\alpha$  is the fine structure constant.

We demonstrate that circular polarization generally creates large non-Maxwellian fields that disrupt time-reversal symmetry, effectively mimicking authentic magnetic fields within the material while eluding detection externally. These unconventional fields, reaching effective magnitudes as high as 100 T, lead to phenomena akin to Faraday rotation and robustly interact with magnons in magnetically ordered materials. The connection between the non-Maxwellian fields and the Autler-Townes and AC Stark effects of atomic physics will be discussed.

These considerations are particularly relevant to the direct, resonant excitation of polar phonons. Contrary to common perception, the origin of phonon-induced magnetic activity does not stem from the motion of ions themselves; instead, it arises from the effect their motion exerts on the electron subsystem via the electron-phonon interaction. Because the light-induced non-reciprocal fields depend on the square of the phonon displacements, the chirality the photons transfer to the ions plays no role in magnetophononics.

# Abstracts

Quantum nonlinear

**Invited**

Quantum materials. Quantum phononics. Quantum acoustics

**Quantum Nonlinear**

# Quantum and classical optoacoustics for photonic neuromorphic computing and quantum signal processing

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Photonics has the potential to advance modern quantum technologies and high-speed applications such as communications and the processing of large amounts of data. However, to replace or improve the well-established systems with photonic solutions, there is still a way to go. A new promising approach to manipulate light all-optically is to use the link of optical waves with acoustic vibrations. Our research experimentally investigates how traveling sound waves can be used to process states of light in the classical and quantum regime.

Via the nonlinear effect of stimulated Brillouin scattering (SBS), acoustic waves can be created all-optically by counter-propagating optical signals. With help of acoustic waves, we implement several building blocks for photonic machine learning, such as an optoacoustic recurrent operator, optical memory and a photonic activation function for all-optical neural networks. We experimentally demonstrate a temporary storage for light information and show how to extend the performance in terms of bandwidth and storage time. SBS is also a versatile tool for processing polarization states and orbital angular momentum (OAM), where we demonstrate a non-reciprocal device for OAM modes, a vortex laser and frequency conversion of OAM information. In order to enter the regime of quantum signal processing, cooling of traveling acoustic phonons is an essential precondition and we show experimental results of optomechanical cooling by 220K starting from room temperature. As a milestone towards quantum interactions of photons and traveling phonons, we present the first experimental realization of cavity-free strong coupling between groups of photons and phonons in a continuous optoacoustic system. This work can path the way to optical-fiber-based and chip-integrated quantum optoacoustic control for application to photon-phonon entanglement and quantum memory.

## Invited

Quantum materials. Quantum phononics. Quantum acoustics

### Quantum Nonlinear

# Unveiling Novel Quantum States and Couplings by Coherent Phonons in Correlated Materials

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The generation and detection of coherent phonons constitute a fundamental research focus in ultrafast condensed matter physics [1]. Their ubiquitous presence in quantum materials enables the characterization of microscopic properties and the discovery of novel quantum states. In this talk, I will present our recent ultrafast pump-probe spectroscopy studies of the charge-density-wave (CDW) material 1T-TaS<sub>2</sub>. We directly detect its amplitude mode (AM) and coherent phonon modes, identifying a novel quantum state at low temperature [2]. Furthermore, we review our group's recent work utilizing coherent phonon detection via ultrafast spectroscopy to probe emergent phenomena across diverse condensed matter systems, including topological materials [3,4,5], superconductors [6,7], correlated materials [8] and 2D materials [9].

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## Contributed talk

Quantum materials. Quantum phononics. Quantum acoustics

### Quantum Nonlinear

# A coherent interface between colour centre spins and phonons

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The spins of colour centres are some of the most coherent systems available for quantum information processing. However, short-range entanglement generation from one centre to another or to a different quantum system is incredibly challenging. Nonetheless, doing so would have significant applications in quantum computing. This includes the colour centre serving as a quantum memory to a comparatively short-lived superconducting qubit, that is capable of robust qubit operations. This could be achieved by mutually coupling a colour centre and superconducting qubit to the same acoustic mode that serves as an intermediary. Here, we present a device consisting of a single silicon-vacancy (SiV) colour centre in diamond that is coupled to the phononic mode of a high-overtone bulk acoustic wave resonator (HBAR) and provide preliminary experimental and theoretical results. This hybrid device would enable the SiV to couple a variety of other quantum systems, including the proposed superconducting qubits. More broadly, our device would pave the way forward to using the techniques of cavity quantum acousto-dynamics to interface colour centres, and to explore the hitherto understudied interactions of spins and phonons at the level of single quanta.

## Contributed talk

Quantum materials. Quantum phononics. Quantum acoustics

### Quantum Nonlinear

# Ultracoherent GHz Diamond Lamb Wave Spin-Mechanical Resonators for Quantum Spin-Mechanics

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Diamond Lamb wave resonators (LWRs) protected by a phononic band gap can enable a new technology platform for controlling interactions between spin qubits and single phonons and for using phonons to mediate coherent coupling between distant spin qubits. A LWR has the simple geometry of a thin elastic plate with free boundaries. The mechanical clamping or tethering loss of the compression modes in a LWR can be eliminated by shielding the mechanical modes with a phononic band gap. In this regime, mechanical damping is primarily due to intrinsic materials loss. Here, we report the fabrication and experimental demonstration of diamond LWRs that feature a GHz fundamental compression mode with a linewidth less than 100 Hz at a temperature near 7 K, corresponding to a Q-factor exceeding 10 million [1]. The ultrasmall linewidth achieved is one order of magnitude smaller than that of the state-of-the-art silicon GHz nanomechanical resonators obtained at similar or even lower temperatures, indicating ultrasmall intrinsic mechanical loss of diamond.

The nearly ideal protection provided by the phononic band gap also makes it difficult to excite and detect the compressional mechanical modes in a LWR. To overcome this difficulty, we have developed an all-optical approach, exciting compression modes with the temporally modulated optical gradient force of a sharply focused laser beam and probing the induced vibrations via strain coupling to a silicon vacancy (SiV) center. A resonant optical gradient force can effectively drive the fundamental compression mode, leading to strong phonon sidebands in the optical excitation spectrum of the SiV center. Vibrations as small as picometer are detected through sideband optical interferometry as well as sideband optical transitions.

The ultracoherent GHz nanomechanical resonator and its coupling to long-lived spin qubits in diamond should enable us to reach the quantum regime in spin-mechanics, opening a new path to developing spin-based quantum computers.

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# Abstracts

## SAW

Invited

Surface and bulk acoustic waves.

SAW

# Electrically excited GHz helical acoustic modes on a chip

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Helical acoustic fields open the way for several advanced functionalities including particle manipulation, the generation of optical beams with orbital angular momentum (OAM), polarization control of magnetic excitations as well as the exploitation of non-reciprocal and topological phenomena [1]. Helical acoustic fields have so far only been electrically excited at relatively low (i.e., sub-GHz) frequencies, which considerably limits their application scope.

In this contribution, we introduce a novel concept for the electrical excitation of laterally confined GHz helical acoustic modes in the form of surface acoustic (SAW) or Lamb bulk acoustic waves (plate modes, LBAW) on a chip [2,3]. The lateral confinement relies on the strong dependence of the frequency spectrum of the Lamb acoustic modes on the thickness of the propagating medium. As a result, waves generated by a piezoelectric resonator in a thicker (or thinner) region of the substrate remain confined via reflections at the lateral boundaries with thinner (thicker) substrate regions. If the generation area is disk-shaped, the lateral reflections form drum-like modes, which are like the low-frequency (sub-GHz) modes of a thin membrane but now oscillating at GHz frequencies. We experimentally confirm the lateral confinement by radio-frequency spectroscopy as well as by mapping of the surface displacements of the surface using scanning optical interferometry with a high spatial resolution of one mm.

Helical drum modes with tunable helicity are generated by an array of sector-shaped piezoelectric transducers powered with appropriate radio-frequency phases. Design of these structures require careful consideration of the acoustic anisotropy of the substrate. Interferometric maps of the acoustic fields show that the OAM of the acoustic field can be transferred to an optical beam, thus providing a way to produce light with OAM modulated at GHz frequencies. Our finite-element and analytical models confirm that the confined Lamb modes with tunable helicity arise from the intrinsic elastic response of the structured sample and provide useful insights into the acousto-elastic coupling, thus guiding adaptation to other material systems.

The helical SAW and LBAW drum modes demonstrated here provide a flexible platform for acousto-optical chiral functionalities in the GHz frequency range. Applications for spin chiral control as well as for the efficient generation of optical beams with OAM will be discussed.

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## Contributed talk

Surface and bulk acoustic waves.

### SAW

# Integrable Electromechanical Broadband Phonon Source

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In electromechanical excitation of mechanical or optoelectromechanical nanostructures, surface acoustic waves (SAW) are typically used [1,2]. The challenges are the relatively low coupling efficiency [3] and the, typically, large surface area of the interdigitated transducer (IDT). Here we demonstrate a new concept of a nanoscale and high efficiency electromechanical transducer for phonon generation. Instead of using IDTs, we use small freestanding bulk acoustic wave (BAW) transducers integrated directly into nanostructures. This configuration provides an efficient and broadband source in the GHz range with a small footprint. FEM simulations show that the efficiency of coupling of mechanical power to a nano beam can easily exceed 50 %. The main loss mechanism is the anchor loss from the freestanding transducer to substrate via the supporting beams. This leakage loss can be eliminated by making the supporting beams 1-dimensional phononic crystals and then the coupling efficiency can reach 90 %. In addition, the simulations show that a transducer optimized for operation at 4 GHz can act as an efficient source from 10 MHz to 10 GHz. The first test devices were fabricated using standard MEMS fabrication processes. The layer thicknesses of the transducer were optimized for operation at 4 GHz. The transducers have shapes from concave to straight triangles to convex horn shapes and the size ranging from a few to fifteen  $\mu\text{m}^2$ . To estimate the coupling efficiency, the transducers are integrated to 220 nm thick and 800-2800 nm wide straight nanocrystalline Si nanobeams and characterised by laser Doppler vibrometry (LDV). The vibrometry measurement provides vertical displacement magnitudes, and the ratio of the magnitudes between different locations can be used to estimate the coupling. The magnitude ratio does not give the true coupling efficiency because of interference effects. Consequently, detailed 3-dimensional FEM simulations based on the LDV data are required to quantify the energy fluxes inside the device and to define the true coupling efficiency. The upper frequency limit of the vibrometer is 2.6 GHz. The amplitude magnitudes on the transducer and the nanobeam were measured from 2.0 GHz to 2.4 GHz, showing normalised magnitude ratios of several tens of percent and indicating relatively high phonon generation efficiency. In this talk we will describe in detail the concept, fabrication and experimental vibrometry results.

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## Contributed talk

Surface and bulk acoustic waves.

### SAW

# Acoustoelectric effect in organic-inorganic semiconductor systems

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Often referred to as “nanoscale earthquakes”, surface acoustic waves (SAWs) are elastic waves which propagate on the surface of a solid at the speed of sound. A voltage signal applied to comb-like metal electrodes, termed as interdigital transducer, generates SAW on a piezoelectric substrate. The applications of SAWs are wide spanning from electronics, optics, microfluidics, medical diagnostics or mobile communication and even quantum technologies [1]. While interacting with a semiconductor, the strain and piezoelectric fields of SAW modulate the semiconductor band structure. Strain-induced field imposes an acoustoelectric (AE) drag on the charges in the direction of SAW propagation, and when paired with an optically-active semiconductor, excitons can be ionized by piezoelectric field into separate electrons and holes, captured and transported by the SAW towards an output spot [2]. Utilizing these effects, first-of-a-kind organic polymer, poly(3-hexylthiophene) (P3HT) and poly[2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylvinylene] (MEH-PPV) based charge transport devices [3-4] and excitonic transistor [5] have been demonstrated, opening up the integration of acoustic charge transport with emerging low cost and solution processable semiconductor systems.

Here, we present the first study of the SAW-induced charge transport in hybrid organic-inorganic semiconductor system. This system comprises P3HT and halide perovskite ( $\text{CsPbBr}_3$  and  $\text{CsPb}(\text{I}_x\text{Br}_{1-x})_3$ ) nanowires (NWs). We observe a pronounced AE effect driven by the SAW. The AE current can be efficiently gated by optical excitation using a focused green laser. Initially, we show that in reference samples with only halide perovskite NWs the total AE current nearly vanishes due to comparable mobilities for electrons and holes in these materials [6]. In strong contrast, in devices with hybrid layers, a weak AE effect is observed for  $\text{CsPb}(\text{I}_x\text{Br}_{1-x})_3$  NWs and a hole dominated AE transport for  $\text{CsPbBr}_3$  NWs. These observations can be explained by the band alignment at the interface between LUMO between the P3HT and the perovskite. While for  $\text{CsPb}(\text{I}_x\text{Br}_{1-x})_3$ -P3HT ambipolar electron and hole transport occurs in the perovskite, for  $\text{CsPbBr}_3$ -P3HT, electrons are transferred to the low electron mobility in P3HT, inhibiting electron-mediated AE transport.

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## Contributed talk

Surface and bulk acoustic waves.

### SAW

# Acoustic wave manipulation via disordered hyperuniform nanopillar architectures on lithium niobate

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The role of disorder in phononic structures is a fundamental question with implications for the design of future phononic nanodevices. Phononic crystals, composed of ordered and periodic arrays of engineered scatterers, have proven effective for nanoscale acoustic wave control [1]. However, these systems are typically designed to operate within a narrow frequency window, and fabrication imperfections can further degrade their performance. An open question in these systems is to what extent their order can be perturbed while preserving their mechanical properties [2]. This is both a fundamental question and one with practical implications, as disordered structures can exhibit greater robustness to imperfections and fabrication errors. In this context, hyperuniformity emerges as a distinctive regime that bridges order and disorder, combining characteristics of both random and periodic structures [3].

Here, we report the experimental realization of a hyperuniform phononic structure consisting of gold nanopillars on a piezoelectric lithium niobate layer, enabling the control over the propagation of surface acoustic waves. The structure induces broadband acoustic attenuation, including bandgap-like regions of strong wave suppression. Furthermore, by selectively removing pillars, we design waveguides that support high-transmission modes within these effective bandgaps.

This work provides a framework for designing advanced phononic nanodevices based on hyperuniform patterns, offering new functionalities and design flexibility.

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# Abstracts

## Thermal

## Invited

Phonon transport. Thermal transport. Thermal properties

### Thermal

# What generates a phonon thermal Hall effect?

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Heat travels in solids thanks to phonons. In clean non-magnetic crystalline insulators, thermal conductivity is governed by Umklapp phonon-phonon collisions and phonons become ballistic at cryogenic temperatures. The thermal conductivity peaks at an intermediate temperature where most phonon-phonon collisions cannot produce entropy. Recently, a phonon thermal Hall signal has been observed in numerous insulators. In all cases, the thermal Hall angle is maximum at this peak temperature, and its maximum amplitude does not exceed an intriguing upper bound independent of the phonon mean-free-path. I will argue that a plausible explanation of this experimental observation is to be found beyond the adiabatic and the harmonic approximations. Combined with anharmonicity, the breakdown of the Born-Oppenheimer approximation in a magnetic field can offer a geometric phase to acoustic phonons. The expected bound to thermal Hall angle is close to what is seen experimentally in black P, Ge and Si.

## Invited

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Graphite Thermal Tesla Valve

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We report directional heat conduction in isotopically purified graphite using Tesla valve architectures. Through phonon hydrodynamic transport, we achieved asymmetric thermal conductivity with 15% difference between opposing directions at 45 K. This directional heat transfer occurred exclusively within 25-60 K, where phonons exhibit collective fluid-like behavior. Our work represents the first application of Tesla valve principles to thermal transport in crystalline solids.

Modern electronics require advanced thermal management for optimal performance. This study adapts Tesla valve concepts from fluid mechanics to phonon heat transport in graphitic materials.

We used isotopically enriched graphite with <sup>13</sup>C content reduced from 1.1% to 0.02% to fabricate solid-state Tesla valve structures. This material exhibits strong phonon hydrodynamic behavior, enabling Poiseuille-type phonon flow [1]. Isotopic purification minimizes phonon-isotope scattering, creating favorable conditions for collective transport. Tesla valve devices were constructed as 90 nm thick, 4.5 μm wide suspended structures to ensure heat conduction exclusively through graphite. Thermal conductivity measurements used microsecond time-domain thermoreflectance (μ-TDTR) from 10-300 K.

Directional effects reached 15% asymmetry within 25-60 K, peaking at 45 K where forward thermal conductivity exceeded reverse by 15.4%. This occurred only where phonons demonstrate fluid-like behavior. Below 20 K (ballistic regime), thermal conductivity was identical in both directions. Above 60 K, Umklapp scattering disrupted hydrodynamic flow, eliminating rectification.

The mechanism involves collective phonon behavior in the hydrodynamic regime. Forward-flowing phonons pass primarily through the main channel with minimal resistance, while reverse flow diverts through bent channels before converging, creating thermal impedance. This asymmetric transport mirrors conventional Tesla valve fluid dynamics.

Control experiments with silicon Tesla valves showed no rectification, confirming that phonon hydrodynamics, that are strong in graphite but weak in silicon, are essential for thermal diode functionality. This work establishes solid-state thermal rectification through phonon hydrodynamics in graphite[2]. Unlike conventional methods requiring temperature gradients or heterojunctions, our approach achieves rectification through geometry alone, promising advances in electronic thermal management.

### References

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## Invited

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Possibilities for Thermal Control Opened by Phonon Hydrodynamics

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The rectification of fluid flow using Tesla valves has been a cornerstone technology in microfluidics since Nikola Tesla's invention in 1920. Inspired by this fluid dynamics principle, we demonstrate the first realization of thermal rectification in solid-state materials through hydrodynamic phonon transport in graphite Tesla valves.

Thermal rectification—the preferential heat conduction in one direction over another—has long been pursued for thermal management applications. While previous approaches relied on temperature-dependent material properties or complex heterostructures, our work introduces a fundamentally new paradigm based on collective phonon behavior analogous to viscous fluid flow.

We fabricated micrometer-scale Tesla valve structures in 90-nm-thick isotopically enriched graphite crystals (99.98% <sup>12</sup>C, 0.02% <sup>13</sup>C) using electron beam lithography and suspension techniques. The Tesla valve geometry consists of a main channel (26 μm length, 4.5 μm width) with an asymmetric bent channel designed to create directional flow resistance. Using microsecond time-domain thermoreflectance (μ-TDTR) measurements, we characterized thermal conductivity in both forward and reverse heat flow directions across temperatures from 10-300 K.

The key breakthrough lies in exploiting phonon hydrodynamics—a regime where phonons exhibit collective motion similar to viscous fluids through momentum-conserving normal scattering. At low temperatures (~10 K), ballistic phonon transport shows negligible directional dependence ( $\kappa_f \approx \kappa_r \approx 4.2 \text{ W m}^{-1} \text{ K}^{-1}$ ). However, within the hydrodynamic temperature window (25-60 K), we observed remarkable thermal rectification with a peak diodicity  $D = \kappa_f/\kappa_r = 1.152$  at 45 K, corresponding to 15.2% higher thermal conductivity in the forward direction. Our experiments confirmed that hydrodynamic phonon behavior is essential for thermal rectification. The rectification effect disappears above 60 K as increased Umklapp scattering breaks phonon momentum conservation, transitioning to diffusive transport.

Our findings represent a paradigm shift from traditional thermal rectification approaches that require external stimuli or heterogeneous interfaces. Instead, we demonstrate thermal control through intrinsic material physics—the collective hydrodynamic motion of phonons in carefully designed geometric structures. This work opens new avenues for thermal management in microscale electronic devices, potentially enabling solid-state thermal diodes, switches, and logic elements.

## Invited

Phonon transport. Thermal transport. Thermal properties

### Thermal

# High-Throughput Thermal Screening in the Quasi-Ballistic Thermal Transport Regime in Metal Oxides

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In this presentation, we introduce an innovative experimental methodology designed to systematically examine the contributions of phonons with varying mean free paths (MFPs) to the thermal conductivity in metal oxide thin films, including:  $\text{-Ga}_2\text{O}_3$ ,  $\text{-Ga}_2\text{O}_3$ ,  $\text{Cr}_2\text{O}_3$ , and  $\text{ZnO}$ . Our approach specifically targets the quasi-ballistic regime (Knudsen number  $\text{Kn} \gg 1$ ), characterized by phonon MFPs that exceed the film thickness ( $d$ ), and is distinguished by its ability to deliver high-resolution data on the thickness dependence of thermal conductivity in terms of phonon MFPs. To accomplish this, we fabricated gradient samples with continuously decreasing thicknesses reaching sub-10 nm scales (as low as 3 nm), thereby enabling unprecedented spatial resolution and direct access to quasi-ballistic transport phenomena.

Our findings indicate that the suppression of phonons with reduced thickness is not uniform but is significantly influenced by the thermal boundary conductance at the film-substrate interface, as demonstrated in the case of a  $\text{Ge}/\text{GaAs}$  thermal interface. Notably, minimal interface conductance substantially diminishes the suppression of phonons with longer mean free paths (MFPs), highlighting the critical role of interfaces in governing quasi-ballistic thermal transport. Complementary in-plane transient thermal grating (TTG) experiments conducted at the FERMI synchrotron facility corroborate our observations, showing consistency with established harmonic suppression functions typical of TTG experiments. In contrast, frequency-domain thermoreflectance measurements reveal that suppression functions significantly deviate from steady-state assumptions and closely align with forms observed in TTG studies. We discuss the selection of a specific suppression function tailored to our experimental geometry and boundary conditions, emphasizing its complexity and sensitivity to experimental parameters. This comprehensive analysis elucidates the interplay among phonon mean free paths, interface thermal conductance, and various transport regimes, providing valuable insights critical for nanoscale thermal management strategies.

We further illustrate the versatility and robustness of our methodology by applying it to a range of technologically significant and diverse oxide materials. In each instance, we directly derive the phonon accumulation function as a function of maximum phonon mean free paths (MFPs), thereby yielding an intrinsic material property that is independent of specific excitation conditions and boundary constraints. Our approach offers a straightforward yet powerful technique for conducting detailed analyses of phonon MFP spectra at length scales below 10 nm, thereby significantly enhancing our understanding of nanoscale heat transport mechanisms.

## Invited

Phonons in 2D materials. Topological phonons. Non linear phononics.  
Chiral phononics. Nanophononics

### Thermal

# Chiral phonons and emergent novel phenomena

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Phonons were traditionally considered as linearly polarized. Recently we predicted that phonons can be chiral and have angular momentum both in magnetic and nonmagnetic systems. The nondegenerate chiral phonons are also predicted and easily tuned in graphene/hexagonal Boron Nitride heterostructures. The chiral phonons were observed in monolayer tungsten diselenide, where the phonon chirality is confirmed by the infrared circular dichroism arising from pseudoangular momentum conservation. Our further experiments showed that through the emission of a chiral phonon the momentum-dark intervalley exciton is brightened and chiral phonons can have entanglement with photons. Recently, we predicted that the chiral phonons can propagate along high-symmetry axis of 3D materials, and can show a diode effect in chiral systems, and can induce high-temperature superconductivity. We also observed a chiral-phonon-activated spin-Seebeck effect in chiral materials very recently.

## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Spectral and spatial limits of phonon coherence in two-dimensional phononic crystals

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Phononic crystals are artificial periodic structures engineered to manipulate mechanical vibrations, sound, and heat through phonon interference. However, the spatial and spectral limits at which phonons still sense the periodicity and experience interference remain unclear, as does the nature of their transition into an incoherent state.

In this work, we use Brillouin-Mandelstam light scattering (BMLS) and Raman spectroscopy to experimentally probe phonon dispersion relations in two-dimensional silicon phononic crystals. We measured the dispersion relations of six phononic crystals with periods ranging from 150 to 4000 nm, with 0.7 diameter-to-period ratio. Our findings reveal distinct interference regimes: at nanoscale dimensions, phonons exhibit in-plane interference consistent with elasticity theory up to at least 35 GHz. However, at larger scales and higher frequencies, phonons transition into an out-of-plane interference regime dominated by the out-of-plane phonon confinement, with the dispersion relation similar to that of plain membrane. This transition occurs approximately at the phonon wavelength twice shorter than the period of phononic crystals. Beyond these regimes, interference ceases altogether and phonon transport transitions into incoherent regime, as evidenced by the Raman spectroscopy data.

These results challenge the prevailing assumption that phonon transport transitions directly from a coherent to an incoherent state at a critical frequency or size. Instead, we identify an intermediate out-of-plane interference regime that persists up to much higher frequencies. This refined understanding of phonon transport establishes a framework for the applications of phononic crystals in quantum computing, sensing, and microelectronics.

Acknowledgments:

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## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Temperature and doping level effect on silicon thermal conductivity

P-Olivier Chapuis<sup>1</sup>, Carlos Acosta<sup>1</sup>, Mélanie Brouillard<sup>2</sup>, Raja Sen<sup>3,4</sup>, Jelena Sjakste<sup>3</sup>, Lorenzo Paulatto<sup>6</sup>, Jérôme Saint-Martin<sup>4</sup>, Nathalie Vast<sup>3</sup>, Nicolas Horny<sup>5</sup>, Séverine Gomès<sup>1</sup>, P-Olivier Chapuis<sup>1</sup>

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We examine the temperature dependence of silicon (Si) thermal conductivity as a function of doping level across a range of p- and n-type concentrations varying from  $10^{14} \text{ cm}^{-3}$  to  $10^{19} \text{ cm}^{-3}$ . Interestingly, there is still a debate on the reason why thermal conductivity decays at high doping: usual analytical work tends to suggest that the reason is impurity scattering of phonons while more-recent ab-initio work demonstrates that electron scattering of phonons [1] could surpass impurity scattering. Most high-doping experimental data were obtained at room temperature, so analysing the temperature dependence of this effect could help in settling the discussion. We have systematically characterized planar Si substrates, covered with a 200 nm-thick silicon dioxide layer, by using the  $3\omega$  method [2] over temperatures ranging from 80 K to 303 K. Thermal conductivity of the Si samples is determined by comparing experimental results with a semi-analytical model [3]. The obtained lattice thermal conductivity values are compared to analytical models based on the Boltzmann transport equation and other published experimental results, with an emphasis on recent DFT data. In particular, we provide an expression of the critical doping at which thermal conductivity starts to reduce, as a function of temperature. These results help understanding how to resolve the controversy related to the key mechanism of the high-temperature thermal-conductivity decay.

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## Contributed talk

Optomechanics, Phononic and phoxonic crystals, Phonon laser

### Thermal

# Parametric control of dynamical backaction using multimode optomechanical interactions

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Optomechanical systems hold great promise for applications in quantum information transduction and routing. To get the system in the required mechanical ground state using optomechanical cooling, the optical linewidth needs to be smaller than the mechanical frequency (the so-called resolved sideband condition), which avoids the detrimental heating by quantum backaction that gives rise to the Doppler limit in sideband-unresolved cavities.

However, by parametrically coupling a low frequency mechanical mode to an auxiliary high frequency mechanical mode, the low frequency mode can be efficiently cooled, even when the optical linewidth is larger than its frequency [1].

We realize an optomechanical device possessing mechanical modes in both the MHz and GHz range, coupled to the same NIR optical mode. We theoretically and experimentally demonstrate linewidth broadening due to the induced interaction, indicating potential for cooling beyond the Doppler limit. Moreover, we show that this interaction can be used to reverse the effect of dynamical backaction, leading to amplification instead of cooling. We find a sharp transition between both regimes indicating great responsivity to the control tone.

This shows that parametric control in multimode optomechanical systems can dramatically alter the dynamics, suggesting potential for improved control of resonators and their couplings.

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## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Exploring Thermal Properties of Freestanding Thin Perovskite Oxide Membranes

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Functional oxides attract significant attention due to their wide range of properties including superconductivity, ferroelectricity, ferromagnetism, and multiferroicity. This plethora of properties arises from the strong interactions between charge, orbital, spin, and structural properties, leading to a wide range of functionalities. Among functional oxides, perovskites stand out as one of the most versatile thanks to their integrability as thin-films with silicon-based electronic devices, making them suitable for applications ranging from memory transistors and memory devices to optical circuits, from sensors to transducers [1]. In addition to the intrinsic properties of the bulk crystals, the possibility of nanostructuring them in a thin-film fashion makes them perfect candidates for integration into electronics and it opens a further degree of freedom to control some of their properties [2]. However, the thermal behavior of this family of materials, specifically as thin-films, has not been fully investigated yet.

In this work, the thermal properties of suspended oxide perovskite membranes with varying thicknesses are studied. Specifically, suspended SrTiO<sub>3</sub> films, with thickness between 30 and 100 nm, that were epitaxially grown onto a sacrificial layer of Sr<sub>3</sub>Al<sub>2</sub>O<sub>6</sub> using the pulsed laser deposition technique [3]. First, the films were transferred to a substrate with patterned holes to suspend them and to study the evolution of the phonon modes by Raman spectroscopy as a function of temperature (between 20 K and 300 K), as phonons are the fingerprint of the phase transition (from a cubic to a tetragonal). Secondly, a study of the dependence of the thermal conductivity on temperature (also from 20 K to 300 K) was conducted using a combination of the thermal bridge method [4] and the three probe technique [5], using a scanning laser as a heat source to correct for contact resistance. Finally, the experimental results were corroborated by second-principles density-functional theory calculations.

This combination of Raman spectroscopy and electro-thermal measurements allows to relate the thermal properties with the phase-changes of the studied thin-films, highlighting the impact of structural phase transitions on their thermal behavior. Understanding these effects is key to optimize the integration of functional oxide thin films in novel advanced electronic devices.

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## Contributed talk

Surface and bulk acoustic waves.

### Thermal

# Acoustic phonons and thermal transport in stacked polydopamine nanomembranes

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Polycatecholamines and polyamides have received significant attention in recent years due to their wide-ranging applications in coating technologies, composite materials, sensing, and biomedicine (1,2). Among them, polydopamine (PDA), inspired by the adhesive properties of mussels, exhibits exceptional adhesion to nearly any surface.

In this study, we investigate the elastic and thermal properties of PDA using micro-Brillouin light scattering spectroscopy ( $\mu$ BLS) and frequency-domain thermorefectance (FDTR). PDA layers, approximately 20 nm thick, were synthesized via cyclic voltammetry electropolymerization and subsequently stacked to form thicker freestanding membranes.  $\mu$ BLS spectroscopy, performed in backscattering geometry with a high-contrast tandem-type Fabry–Pérot interferometer, enabled the analysis of flexural (antisymmetric Lamb, A0 mode) waves and the determination of the Young modulus. The results indicate that the stacking process does not deteriorate the elastic properties, suggesting that the multilayer structure behaves as a single, mechanically homogeneous film.

Similarly, FDTR measurements provided both in-plane and cross-plane thermal conductivity values, revealing isotropic thermal transport independent of the total layer thickness. This further supports the conclusion that stacked layers function as a single thermally uniform medium.

Additionally, we demonstrate that the analysis of phononic dispersion relations and FDTR data can be significantly enhanced through the use of neural networks. By employing multilayer perceptrons and Kolmogorov–Arnold networks as universal approximators, we streamline the modeling process—eliminating the need for complex programming and enabling fast, straightforward, and user-friendly data analysis.

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## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Thermal conductivity of amorphous materials by first-principles molecular dynamics

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Thermal conductivity of amorphous and glassy materials has received significantly less attention than in crystals. Furthermore, the mechanisms underlying thermal conduction in disordered materials are considerably less well understood. With regard to the field of nanomaterials, a decline in thermal conductivity in thin films for the case of amorphous silicon can be attributable to two factors. Firstly, the limited resolution of thermal measurements (50 nm) and, secondly, the challenges associated with measuring small thermal conductivities that are characteristic of amorphous materials. However, it can be conjectured that disorder could potentially cause size effects that manifest themselves at smaller thicknesses. In order to achieve a more precise understanding of these phenomena, first-principles molecular dynamics (FPMD) can be employed. This approach provides a quantitative atomic-scale description of materials properties, including anharmonicity effects a significant impacting thermal conduction. In this presentation, the methodology for obtaining the thermal conductivity of disordered materials described by FPMD using thermal transients (via the approach-to-equilibrium AEMD method) for a range of amorphous materials will be detailed. The physical origins of the size dependence of thermal conductivity for different materials will be discussed by highlighting the quantitative agreement with experimental data for bulk sizes. The observed changes in thermal conductivity, measured over short lengths, can be explained by invoking current theories of thermal transport in disordered materials. Finally, the impact of these effects on applications based on amorphous materials, such as phase-change devices, will be considered.

## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Tuning Phonon-Mediated Heat Transport in Systems with Defects

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Phonon transport in nanostructured materials is critical for thermal management in a wide range of technologies. While defects are typically associated with reduced thermal conductivity, their influence can be more nuanced depending on how they interact with lattice vibrations and mechanical properties. We use classical molecular dynamics simulations to investigate how dislocations, plasticity, and nanostructuring affect phonon-mediated heat transport in a variety of systems.

Our recent study on dislocations challenges the traditional view that they reduce thermal conductivity. Although dislocations act as scattering centers, they also relax stress and increase the contact radius at interfaces between nanoparticles, which can compensate or even outweigh their scattering effect, leading to an overall conductivity increase [1]. Similarly, when examining thermal transport between nanoparticles under compression, we show that plastic deformation modifies the local atomic structure and enhances contact, increasing the interfacial lattice conductivity [2].

In high-entropy alloys, electronic heat conduction is strongly reduced and it is similar to lattice conductivity. Thermal processing can lead to precipitation and chemical short-range order (SRO). Matrix-precipitate interfaces could decrease phonon mean-free paths, but we find that percolation of ordered phases enhances phonon propagation and increases thermal conductivity [3]. Therefore, different synthesis structures might allow conductivity tuning.

Thermal conductivity of amorphous carbon nanostructures can be understood in terms of phonon transport with short mean free paths. Surprisingly, systems with porosity display higher conductivity than systems without porosity, due to stiffening of the carbon network that leads to higher sound velocity [4].

New results for samples with defects, including irradiation defects in Fe, W, and Bi nanowires, related to recent experiments, will also be discussed.

Together, these findings highlight the complex role of disorder, morphology, and defects in phonon transport, offering new insights and design principles for materials with tunable thermal properties at the nanoscale.

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## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Optical Control of the Thermal Conductivity in ferroelectrics and charge density wave materials

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An effective strategy for the dynamical tuning of  $k$  in solids would be critical for developing novel phononic devices able to perform logic operations with phonons, as well as for solid-state refrigeration, energy harvesting, and thermoelectrics. A promising approach consists in taking advantage of field-induced phase transitions, using electric or magnetic fields to manipulate the crystal lattice of polar and magnetic materials, respectively. Such *electrophononic* and *magnetophononic* effects can provide fast and dynamical manipulation of the heat carriers, thus yielding à la carte thermal properties for on-demand applications. On the other hand, the possibility of manipulating  $k$  with light has received very little attention. Light-driven control of the thermal conductivity could bypass some of the issues posed by the schemes described above (e.g., application of large driving fields) as well as simplify the design of logic devices (i.e., lack of electrical contacts).

Here we discuss this scenario in the archetypal ferroelectrics BaTiO<sub>3</sub> and KNbO<sub>3</sub>, where by means of first-principles calculations, we show that photoinduced charge injection can trigger a ferro-to-paraelectric phase transition, yielding a (potentially ultrafast) reversible change in thermal transport properties [1,2]. Our results reveal a substantial reduction in lattice thermal conductivity, especially at low photoexcited charge densities, as the material undergoes a polar-to-nonpolar transformation. This reduction is primarily due to the suppression of low-frequency phonon modes, which limits heat flow as a result of enhanced phonon-phonon scattering.

We will also discuss the case of TiSe<sub>2</sub>, a van der Waals 2D material where a photoinduced phase transition can restore a more symmetric crystal phase [3], similar to what we report with ferroelectric oxides. In particular, photoexcited charges or electron/hole doping suppress the charge density wave (CDW, a periodical modulation of the electron density), which is the ground state below ~200 K. Such a CDW melting is accompanied by a sizable reduction in the thermal conductivity, a variation that also in this case almost entirely originates from the changes in the phonon-phonon scattering processes.

These findings underscore a step forward in tunable thermal conductivity, offering new prospects for efficient thermal management in phonon logic, advanced electronics and energy-harvesting applications.

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## Contributed talk

Phonons in 2D materials. Topological phonons. Non linear phononics.  
Chiral phononics. Nanophononics

### Thermal

# Probing thermal transport in supported graphene and few-layers graphene via Frequency-Domain Thermoreflectance

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Heat dissipation in electronic devices has become the bottleneck to further improve their speed operation and performance. Graphene has attracted significant interest to overcome this challenge and advance next-generation devices because of its exceptional mechanical, electrical and thermal properties. In particular, the extraordinary high thermal conductivity of graphene, in the range of 2000–4000 W.m<sup>-1</sup>.K<sup>-1</sup>, makes this material ideal to boost heat dissipation in energy-efficient devices [1,2].

While theoretical studies have suggested that graphene's thermal conductivity depends on the number of layers, experimental validation remains limited [1,3]. Previous research has reported thermal measurements for suspended multilayer graphene [3], however, the geometry of suspended graphene differs significantly from that of supported graphene, which is more relevant for the architecture required in electronic devices. In fact, the thermal properties of supported graphene can vary considerably from those of suspended graphene. Even though some pump-probe measurements have already been performed on supported exfoliated graphene [4], the exfoliation process yields small sample sizes, that can cause challenges in the measurements. Not only this, the small sample size can also hinder broader applicability of graphene in emerging technologies. In this work, we investigate the thermal transport properties of large-area, chemical vapor deposition (CVD)-grown graphene and few-layers graphene on quartz substrates using frequency-domain thermoreflectance (FDTR). This in-house, non-contact pump-probe technique enables the assessment of layer-dependent thermal behavior in supported graphene. While FDTR is primarily used for studying bulk materials and thick layers, its application to ultra-thin layered materials like graphene introduces challenges in both measurement and thermal modeling. We overcome this limitation and show clear variations in the thermal signal among different graphene layers. Our findings contribute to a deeper understanding of thermal transport in 2D materials and support their integration into practical thermal management applications.

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## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Challenging Assumptions About Size Effects in Thermal Boundary Resistance

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Despite decades of research, the nature of size effects and phonon confinement in thermal boundary resistance (Kapitza resistance) remains poorly understood. While size-dependent thermal transport is well documented in homogeneous crystalline systems, the assumption that identical size-dependent phenomena occur in these fundamentally different systems lacks strong support. In fact, what evidence does exist often turns out to be either simulation artifacts or misleading interpretations arising from inadequate model assumptions. First-principles simulations of interface systems only a few nanometers long yield Kapitza resistance values that match those obtained from semi-infinite (Greens Function) simulations and agree well with experimental data. This suggests that interfacial size effects, while likely real, manifest in fundamentally different ways from their homogeneous, crystalline counterparts. To our knowledge, these interfacial-specific size effects have not been systematically investigated. This work presents a focused study of size-dependent interfacial phonon behavior, with implications for understanding heat transport in nanotechnology and in next-generation semiconductor devices.

## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Boson Peak and Two-Level Systems in 1-Halo-Adamantane: Role of Phonon Dispersion and Vibrational States

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Simple rigid molecules, of 1-Cl-, 1-Br-, and 1-I-adamantane, exhibit remarkable polymorphism. These compounds undergo phase transitions between a high-temperature orientationally disordered state and a low-temperature ordered phase (P21/c, Z=4). In this ordered state, the molecules exhibit rotational dynamics around the C3 molecular axis, which aligns with the C-X bond (X = Cl, Br, I)—a phenomenon confirmed by <sup>13</sup>C NMR spin-lattice relaxation measurements.

Through heat capacity experiments conducted in the temperature range of 100 mK to 25 K, we identify a Boson peak (BP)-like anomaly in the low-temperature ordered phase of both materials. This anomaly originates from strong interactions between propagating (acoustic) phonons and low-energy quasi-localized (optical) phonons, as described through phonon dispersion relations and vibrational density of states obtained via first-principles calculations based on density functional theory.

Moreover, our experimental results reveal a linear temperature dependence, commonly associated with quantum tunneling between nearly equivalent yet distinct system configurations—referred to as two-level systems (TLS). For chosen materials, using the same first-principles simulation approach, we analyze the intermolecular potential governing molecular rotation along the three-fold axis within the crystal lattice. Interestingly, this potential exhibits three equivalent energy minima, directly contradicting the conventional TLS model, which is often employed to explain the "universal" anomaly observed in glasses and is considered a deviation from Debye's theory of classical crystalline solids.

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## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Thermal rectification via nanostructuring in 1D and 2D materials

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The control of the energy carriers flow direction is fundamental for many applications. While the first step toward this control was achieved for electrons 100 years ago, the rectification of phonons is still under debate. Thermal diodes would be new device paradigms for efficient thermal management in modern nanotechnology, citing electronics, energy conversion, and cooling among others. Such devices could regulate heat flow, mitigate overheating, and optimize energy usage in nanoscale systems. Thermal rectification traditionally has been demonstrated mainly using bulk materials, with new trends toward using 1D or 2D low-dimensional materials. It arises from the asymmetric flow of phonons when changing the direction of the thermal bias. Although there is so far no greater consensus in the literature concerning the exact generic mechanism of thermal rectification, it has been proven that there are at least two necessary conditions: asymmetry along the heat-flux direction and non-linearity of the thermal properties with respect to the temperature bias  $\Delta T$ . The different strategies used to achieve thermal rectification are either joining two materials with different thermal properties separated by an interface perpendicular to the heat flux, or tailoring the thermal properties through appropriate geometries at the nanoscale.

Here, we will show thermal rectification for two distinct configurations: tapered crystalline-core/amorphous-shell nanowires and partially perforated graphene. Concerning the first group, the interface parallel to the heat flux, with a variable thickness of the amorphous shell along the growth direction, is a new strategy. It induces a position-dependent phononic dynamics in the crystalline core of the nanowire due to the variation of the amorphous shell thickness, resulting in variable axial and radial phonon propagation and confinement. The estimated rectification is of the order of 5% (90% when selecting the cross-section on the hottest thermostat), with a better heat flow from the smaller cross-section to the larger one; thicker shells increase phonon scattering [Phys. Rev. B 103, 014202 (2021)].

For the second configuration, the partially perforated graphene, we show the influence of geometric parameters on the thermal conductivity and the thermal rectification ratio, revealing a maximum thermal rectification of ~20%. The analysis considers key geometric factors such as the length of the pristine region and pore size, shape, alignment, and orientation. It is found that heat preferentially flows from the perforated graphene to the pristine region, indicating that the principal rectification mechanism is the difference in the temperature dependence of  $\kappa(T)$  for the pristine and the porous graphene [arXiv:2504.16013]

## Contributed talk

Phonon transport. Thermal transport. Thermal properties

### Thermal

# Probing phonon transport in diamond nanostructures with NV-based thermometry

Kexin Wu<sup>1</sup>, Valentin Goblot<sup>1,3</sup>, Enrico Di Lucente<sup>4</sup>, Claudio Jaramillo<sup>1</sup>, Nicola Marzari<sup>4</sup>, Michele Simoncelli<sup>5</sup>, Christophe Galland<sup>1,3</sup>

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Heat transport in microstructures and low-dimensional materials exhibits novel physics that transcends the traditional Fourier law. Different non-Fourier heat conduction regimes emerge depending on the relative magnitudes of phonon mean free paths resulting from various scattering events and the material's characteristic dimensions. The hydrodynamic regime, where heat behaves like a viscous fluid, exists between diffusive and ballistic transport under stringent conditions. Although previously thought to be limited to temperatures below 50 K, hydrodynamic heat transport has been observed in graphite up to 200 K [1]. Notably, theoretical predictions suggest that this behavior could extend to room temperature in diamond, which possesses ultralong phonon mean free paths that favor momentum-conserving scattering as the dominant transport mechanism [2].

By utilizing negatively charged nitrogen-vacancy (NV) centers as precise nanoscale temperature sensors, I will show how we can study heat transport in diamond microstructures with unprecedented spatial and thermal resolution, in a non-invasive manner [3]. Suspended diamond nano-microstructures with arbitrary geometries, ranging in size from 50 nm to tens of microns, were created to function as customizable heat transport channels. Heat is generated through laser-absorbing metal patches placed at the apex of these structures. At the same time, a second laser beam probes the temperature gradient via optically detected magnetic resonance (ODMR) with diffraction-limited resolution [3].

We also present ongoing work aimed at specifically investigating the heat rectification effect driven by hydrodynamic phonon transport in paired nozzle and diffuser geometries. We report measurements of the temperature profiles and rectification factors of structures with varying parameters to experimentally examine diamond thermal rectification devices within the hydrodynamic phonon transport regime.

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# Abstracts

XFEL, ultrafast

## Invited

Transient strain and lattice dynamics with EUV and X-rays.

XFEL, ultrafast

# Nanoscale transient grating beyond thermoelasticity

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Collective dynamics of matter, which determine its optical, thermal and magnetic properties, often exhibit strong dependence on the length scale. Experimental tools for probing such dynamics in the sub-100 nm length-scales and on the relevant timescales (i.e. picosecond and sub-ps) mainly rely on the combination of ultrafast lasers and ad-hoc nanostructuring of the sample.

In this talk I will present an alternative approach, developed at the FERMI free electron laser (FEL), where the sensitivity to the sub-100 nm length-scale is obtained exploiting extreme ultraviolet transient gratings (EUV TGs) <sup>1</sup>. First, I will briefly address the applications of EUV TG to the investigation of the thermoelastic properties of materials on a previously inaccessible wavelength range <sup>2,3</sup>. Then, I will discuss the potential of EUV TGs in other contexts, beyond its original goal. Building upon the first demonstration of magnetization TGs <sup>4</sup>, I will discuss the newest demonstrations of transient magnetization dynamics at the nanoscale <sup>5-7</sup>. To conclude, I will review further approaches exploiting the nanoscale periodically structured photoexcitation besides TG spectroscopy <sup>8</sup>

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## Invited

Transient strain and lattice dynamics with EUV and X-rays.

XFEL, ultrafast

# Illuminating ultrafast photocarrier-lattice coupling and dynamics in bismuth vanadate photoanodes

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Electron-lattice coupling significantly influences the functional properties of many transition metal oxide (TMO) photoelectrodes, resulting in the formation of polarons that govern carrier mobilities, recombination rates, and interfacial energetics. Bismuth vanadate ( $\text{BiVO}_4$ ), a best-in-class TMO photoanode for solar water splitting, is believed to host small electron polarons. However, the mechanisms by which electronic localization couples to structural degrees of freedom under illumination remain poorly understood. In this work, we combine femtosecond optical pump/X-ray probe methods to directly track the photoinduced evolution of photocarriers and the  $\text{BiVO}_4$  lattice across multiple length and time scales. Time-resolved X-ray absorption spectroscopy (tr-XAS) reveals sub-picosecond electron localization within individual  $\text{VO}_4$  tetrahedra, consistent with the formation of small electron polarons that introduce significant majority carrier transport barriers. In contrast, time-resolved X-ray diffraction (tr-XRD) shows a delayed non-thermal lattice response that develops over several picoseconds. Rietveld refinement of the tr-XRD data indicates a persistent lattice contraction that is accompanied by a reduction of the monoclinic distortion throughout the complete film thickness. The resulting photoexcited structure is distinct from both the monoclinic ground state and the high-temperature tetragonal phase, representing a hidden state that only emerges under optical excitation. Analysis of the electronic structure reveals that this long-range structural change is driven by photoexcited hole-lattice interactions rather than electron polaron formation. Together, these results provide a unified picture of  $\text{BiVO}_4$  under illumination, with both electron- and hole-lattice coupling shaping the excited state landscape. The coexistence of localized electron polarons with a hole-driven structural reorganization has direct implications on transport and recombination pathways, as well as photocatalytic function. The identification of this hidden state highlights the importance of non-equilibrium structural responses in oxide semiconductors and may offer new opportunities for designing materials that harness such transient phases to achieve enhanced performance.

## Invited

Quantum materials. Quantum phononics. Quantum acoustics

XFEL, ultrafast

# Polarization density waves in SrTiO<sub>3</sub>

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Ultrafast optical excitation can drive materials into novel states that cannot be achieved under equilibrium conditions. Strong terahertz (THz) pulses have been shown to induce transient ferroelectricity in the quantum paraelectric SrTiO<sub>3</sub> (1-2), opening possibilities for ultrafast, reversible structural control. This behavior differs markedly from equilibrium observations, which suggest an incipient phase characterized by spatially modulated polarization at low temperatures (3–6), underscoring the necessity for microscopic structural characterization of the nonequilibrium ferroelectric state. In this presentation, I will discuss our investigation of quantum paraelectric SrTiO<sub>3</sub> using THz excitation combined with diffuse x-ray scattering, a technique that allows us to probe collective excitations of the lattice (phonons) with wavelengths of nanometers. We present a new methodology for probing inversion symmetry breaking, which uncovers hybrid polar-acoustic modes exhibiting pronounced softening at characteristic wavelengths of tens of nanometers. These findings point to a structural instability in SrTiO<sub>3</sub> featuring spatially-modulated polarization that differs from uniform ferroelectricity (5,6). Our observations (7) underscore the critical role of momentum-resolved measurements of fluctuations and offer fresh understanding of the microscopic nature of quantum paraelectric materials.

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## Contributed talk

Light, neutron and x-ray inelastic scattering; Lattice Dynamics;  
Phonons in glasses and disordered materials; Electron-phonon interactions

XFEL, ultrafast

# Elasticity of violet phosphorus and its siblings from inelastic x-ray scattering

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Violet phosphorus, or Hittorf's phosphorus, was first obtained in 1865 by both sublimation and lead flux growth [1], its structure was revealed in 1969[2]. The interest to the violet phosphorus has recently returned as to the parent of 2D violet phosphorene, promising for advanced optoelectronic. Presently, the information on the elasticity and, more generally, lattice dynamics, is scarce.

Our first step was to establish the robust constraints on the elasticity of violet phosphorus and derived materials (i.e. phosphorene), in a way we explored previously for graphite [3] and BN [4]. As crystalline quality of commercially available crystals was clearly compromising for the inelastic x-ray scattering experiment, we have attempted to grow high quality crystals of violet phosphorus in-house. The result serendipitously brought something beyond the expectations.

Using the inelastic x-ray scattering (IXS) at ID28 beamline of ESRF, we were indeed able to determine the main components on the elastic tensor of violet phosphorus from the phonon dispersion. It is worth noting that thus obtained elastic moduli approach the intrinsic values, as the IXS signal is essentially collected from the domains of coherent scattering.

But – the extensive screening of violet phosphorus crystals, collected from the synthesis following the described protocol [5], at the diffraction/diffuse scattering station of the same beamline ID28, revealed crystals with unusual monoclinic angles and lattice dimensions. Within the same batch two new polymorphs of phosphorus were found beyond the “normal” violet phosphorus - and structures solved. All three polymorphs use the same unique building block, assembled in different ways.

Strong anisotropy and the domination of “intralayer” elastic moduli allow us to evaluate the components of elastic tensor for new polymorphs/polytypes. Simultaneously they serve as robust constraints for the intrinsic elasticity of phosphorenes, providing reference values for the modelling.

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## Contributed talk

Phonon transport. Thermal transport. Thermal properties

XFEL, ultrafast

# Experimental Study of Thickness, Temperature, and Alloy Composition Dependence of Thermal Conductivity in ScN and $\text{Sc}_x\text{Cr}_{1-x}\text{N}$ Thin Films Using Two-Color TDTR

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Scandium nitride (ScN), a transition-metal nitride with a rocksalt structure, has recently attracted attention as a promising material for thermoelectric applications due to its combination of high electrical conductivity and the potential to reduce thermal conductivity (TC) in nanostructured forms<sup>1,2,3</sup>. Controlling thermal transport in ScN is critical for improving its thermoelectric performance, as bulk and pure ScN exhibit intrinsically high TC, which limits the thermoelectric properties and overall efficiency. Thin-film configurations, however, enable suppression of phonon transport through enhanced boundary scattering<sup>5</sup>. Furthermore, thin-film alloys such as  $\text{Sc}_x\text{Cr}_{1-x}\text{N}$  ( $0 < x < 1$ ) can exhibit further reductions in TC due to enhanced phonon scattering from alloy-induced mass and strain disorder and can be considered as an additional approach to modify thermal transport properties<sup>6</sup>. In this study, we investigated the thickness, temperature, and alloy composition dependence of the TC of ScN and  $\text{Sc}_x\text{Cr}_{1-x}\text{N}$  thin films. The ScN samples had nominal thicknesses of 85 nm, 200 nm, and 500 nm, and were grown on  $\text{Al}_2\text{O}_3$  (0001) substrates using plasma-assisted molecular beam epitaxy (PAMBE)<sup>1</sup>. TC was measured using a home-built two-color time-domain thermoreflectance (TDTR) setup. At room temperature, a clear thickness dependence was observed, with the 500 nm film exhibiting 24.6 W/mK, the 200 nm film 15.8 W/mK, and the 85 nm film 12.3 W/mK. Temperature-dependent measurements indicated an Umklapp peak in TC at approximately 150 K for the 500 nm film (34.7 W/mK) and 200 K for the 200 nm film (23.1 W/mK). This upward shift in peak temperature with decreasing thickness reflects the dominance of phonon-boundary scattering, as the phonon mean free path (MFP) approaches the film thickness. Further reducing the temperature results in a decrease in TC due to the diminished phonon population, which limits the number of effective heat carriers. Additionally, we measured a series of eight  $\text{Sc}_x\text{Cr}_{1-x}\text{N}$  alloy thin films with a thickness of approximately 80 nm and compositions ranging from pure CrN to pure ScN. The results showed a minimum in TC at around 45% Cr and 55% Sc, which was notably lower than the values measured for both pure CrN and pure ScN thin films. This minimum is consistent with maximum phonon scattering caused by alloy disorder, where mass and strain field fluctuations disrupt phonon propagation most effectively at intermediate compositions<sup>7</sup>.

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## Contributed talk

Transient strain and lattice dynamics with EUV and X-rays.

XFEL, ultrafast

# Experimental and first-principles calculation of the time-dependent evolution of phonon and carrier populations after photoexcitation in GaAs observed by diffuse x-ray scattering at the PAL-XFEL

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We determine experimentally and using first-principles theory the evolution of phonons and the relaxation of photo-excited carriers on picosecond timescales across the Brillouin zone of GaAs by electron–phonon scattering. We simulate the time-evolution of phonon populations, based on first-principles band structure and electron–phonon matrix elements, and compare them to data from time-resolved x-ray diffuse scattering experiments, performed at the Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL-XFEL) facility, following photo-excitation by a 50 fs near-infrared optical pulse. We show that the intensity of the non-thermal x-ray diffuse scattering signal, which is observed to grow substantially at the L-point of the Brillouin zone over several ps, is due to phonons generated by scattering of carriers between the X and L valleys.

Besides phonon generation, we observe regions of strong phonon absorption due to the cooling of the electron plasma and strong electron-polar-phonon interaction.

# Abstracts

Posters

**Poster No.1**

Withdrawn

## Poster No.2

Biophysics and biosensing. Raman scattering.  
CARS. SERS. Catalysis and energy

# Metasurface Design Meets Phonon Engineering for Enhanced Light Manipulation and Energy Conversion

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This work explores how phonon-assisted processes and nanoscale design converge to boost optoelectronic performance, using electron-beam lithography (EBL) to fabricate two types of advanced metasurfaces.

In the first study, BiVO<sub>4</sub> metasurfaces are tailored to enhance infrared absorption near 980 nm. Charge transport in BiVO<sub>4</sub> is typically hindered by defect trapping and polaron formation. By nanostructuring the material and introducing targeted IR illumination, specific phonon modes are excited, enabling trapped electrons to return to the conduction band. Pump-push photocurrent experiments suggest improved charge separation and extraction under combined visible and IR light-revealing a phonon-assisted mechanism that could enhance carrier mobility in metal oxide photoelectrodes.

The second study investigates alternating arrays of gold and silicon nanostructures designed to generate and guide surface acoustic waves (SAWs). Ultrafast laser pulses induce rapid thermal expansion, launching coherent acoustic phonons. Pump-probe measurements and simulations are used to study the interaction between phonon modes generated by both plasmonic (Au) and dielectric (Si) elements. The interplay and mixing of these modes are actively explored to understand how array geometry influences wave interference and focusing, with the goal of enabling tunable acoustic energy landscapes at the nanoscale.

Together, these studies demonstrate the capabilities enabled by nanometer-precision metasurface design to harness phonon-assisted effects for improved light manipulation and charge transport. The results point toward new design strategies for advancing solar energy and optoelectronic devices, with ongoing research focused on refining phonon control at the nanoscale.

# Home-built VIPA-based Brillouin spectrometer for probing acoustic modes in self-assembled polystyrene nanoparticle opals

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We present a home-built Brillouin spectrometer based on a Virtually Imaged Phased Array (VIPA), designed for the investigation of acoustic vibrational modes of nanoparticles. This system enables rapid Brillouin spectral mapping, with acquisition times on the order of one second per point. Brillouin light scattering (BLS) is a powerful technique for probing acoustic vibrational modes in phononic crystals composed of submicron polystyrene (PS) particles, typically above 100 nm in diameter. In this work, we demonstrate the capabilities of our VIPA-based spectrometer by focusing on PS nanoparticle opals in the 20–100 nm size range. Particular attention is given to a low-frequency mode that arises from interparticle mechanical coupling that emerges from a mechanical interaction-induced feature absent in isolated nanoparticles. This mode follows an inverse dependence on particle diameter ( $\omega \propto 1/d$ ) and becomes indistinguishable in larger particles ( $d > 200$  nm), where intrinsic Lamb modes dominate the spectrum. Using the VIPA spectrometer, we perform fast hyperspectral mapping to uncover spatial heterogeneities linked to variations in particle packing, strain, and size dispersion. The presence of interparticle coupling leads to red- or blue-shifts of Lamb modes depending on the local mechanical environment, making the vibrational spectrum sensitive to both intrinsic nanoparticle properties and collective interactions. These results establish VIPA-based Brillouin spectroscopy as a promising technique for the comprehensive mechanical characterization of nanostructured materials. Potential implementations and further improvements will be discussed.

## Depth-resolved Brillouin microscopy of swift heavy ion irradiated ceramics

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Ceramics subjected to swift heavy ion (SHI) irradiation experience diverse types and extents of structural damage across different microscale depths, governed by the interplay between electronic (Se) and nuclear (Sn) energy loss mechanisms. As a result, establishing structure–property correlations within these spatially inhomogeneous damage zones is essential for advancing radiation-tolerant ceramic materials. In this study, Brillouin light scattering microscopy is employed for depth-profiling of longitudinal and shear GHz phonons. The elastic, photoelastic and stress responses within both the Se-dominated (Se >> Sn) and Sn-influenced (Sn > Se) regions of magnesium aluminate spinel ( $\text{MgAl}_2\text{O}_4$ ) irradiated with 710 MeV  $\text{Bi}^+$  SHIs at doses ranging from  $6 \times 10^{10}$  to  $6 \times 10^{12}$  ions/cm<sup>2</sup>.

While surface elastic and photo-elastic properties are suppressed with increasing fluence, a notable recovery is observed with rising probed subsurface depths, attributed to enhanced recrystallization facilitated by the tapering morphology of SHI-induced nanoscale-thick tracks. Interestingly, the greater the irradiation dosage at the surface leads to more rapid restoration of elastic and photoelastic performance at deeper depths, including near the ion end-of-range where point defect densities peak.

At the highest fluence ( $6 \times 10^{12}$  ions/cm<sup>2</sup>), spinel transforms into a nano-composite of closely spaced nano-crystalline "pillars" (~15 nm wide) separated by amorphous boundaries due to track overlap. This structure, present in both stressed and unstressed states, supports new confined GHz acoustic modes due to acoustic impedance mismatches. The amorphous phase, characterized by higher P12 and lower density, contrasts with the denser crystalline phase, consistent with LAADF-STEM and Brillouin depth profiling. Beyond the ion range, strain diminishes under compression, as evidenced by a 57.9 GHz Brillouin peak enhancement. Stress propagation into unirradiated regions alters elastic and photoelastic properties, as well as Raman, photoluminescence and refractive index signals.

These results challenge traditional understandings of SHI damage buildup and offer new insights into designing ceramics with tunable subsurface mechanical and opto-mechanical resilience. Such tuning is enabled by the fluence- and depth-dependent evolution of ion track morphology and point defect landscapes under extreme radiation environments, as revealed by Brillouin microscopy.

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# Backward Stimulated Brillouin Scattering in Lithium Tantalate Waveguides

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Stimulated Brillouin Scattering (SBS) is a third-order nonlinear effect involving the optically induced excitation of acoustic waves [1]. Several new materials have been proposed to harness SBS on-chip and enable strong SBS within integrated photonic devices. Recently, lithium tantalate (LiTaO<sub>3</sub>, or LT) has emerged as a promising platform for photonic applications due to its mechanical anisotropy, which enables effects such as piezoelectricity and pyroelectricity, along with low-cost scalable manufacturing and a high optical damage threshold [2]. In this work, we report the first measurement of backward SBS in a lithium tantalate on insulator (LTOI) integrated waveguide. Additionally, numerical simulations are presented to support the experimental data.

Our sample follows the "flower-shape" design from [3]. Measurements were taken on an X-cut lithium tantalate ridge waveguide with a width of 600 nm, a thickness of 600 nm, and a length of 5 mm. The waveguide was designed to confine only the fundamental transverse electric (TE) and transverse magnetic (TM) optical modes. A pump-and-probe scheme [3] was used to measure the Brillouin spectrum for co- and cross-polarized backward SBS at  $\theta_x = 60^\circ$ . We observed two Brillouin peaks between 7 GHz and 8 GHz for the co-polarized configuration. Based on finite element method (FEM) simulations performed using COMSOL Multiphysics for both optical and mechanical modes, we identified similar peaks in a simplified waveguide model, mechanically clamped at the lower LT-SiO<sub>2</sub> interface and oriented at  $62^\circ$ . Despite its simplification, this model still provides valuable insight into the actual mechanical modes supported by the full structure. In conclusion, we experimentally observed backward SBS in an LTOI ridge waveguide. This finding offers new insights into SBS behavior in anisotropic platforms.

## Funding

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**Poster No.6**

Light, neutron and x-ray inelastic scattering; Lattice Dynamics;  
Phonons in glasses and disordered materials; Electron-phonon interactions

## Enhancement of Raman Spectra in III-V Semiconductors Mediated by Proton Irradiation-Induced Defects

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Defects in crystalline materials can modify both their vibrational and electronic properties. In this work, these effects are studied through Raman and photoluminescence spectroscopies. The study focuses on high-electron-mobility III-V semiconductors with defects induced by proton irradiation. The samples were epitaxially grown in a MOVPE reactor at TU Berlin (Germany) and subsequently irradiated at the Tandem accelerator of CAB-CNEA (Bariloche, Argentina).

In this type of sample, defects are expected to deteriorate crystal quality, which in turn should reduce electron mobility and degrade the phonon spectrum. However, spectroscopic studies revealed an improvement in the features of the Raman peaks associated with LO phonons: their intensity increases and their width narrows in the more defective regions, contrary to expectations. Photoluminescence results, on the other hand, behave as expected: irradiated regions show a decrease in overall intensity, new peaks, and a flattened spectrum.

This work discusses the origin of the defect-dependent Raman intensity of LO phonons. For this purpose, studies were conducted on Raman scattering selection rules using polarizers, on the effective cross-section by varying the incident beam power, and on the resonance response by tuning the incident wavelength.

## Adjoint method-based model for optomechanics

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Topological optimization aims to find a material distribution (typically solid) that optimizes a given response. For example, in structural mechanics, the objective is to determine the density distribution of a beam to support a given load [1]. At the same time, one may also aim to use the least amount of material to reduce manufacturing costs. In nanophotonics, there are several examples of devices designed to control and modify the propagation and properties of light, such as mode converters [2], wavelength demultiplexers [3], and nonlinear port switchers [4]. In these cases, the minimum feature sizes are often subwavelength scale [5], that is, smaller than the operating wavelength. Topological optimization typically employs gradient descent algorithms to optimize an objective function, which represents the device's intended functionality. Concurrently, the adjoint problem must be solved, enabling the computation of the sensitivity or dependence of the objective function with respect to the design variables [6]. This method has attracted significant interest in both mechanics and photonics due to its strong algorithmic performance and its ability to discover devices with non-intuitive geometries. In this work, we aim to present a new model for designing optomechanical cavities, initially focused on enhancing the optomechanical coupling rate in the dispersive regime because of its significant implications for microwave signal conversion, quantum information processing [7] and others.

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# Self-Sustained Phonon Generation and Robust Power Extraction in a Nonlinear Optomechanical System

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We propose an autonomous monoparametric optomechanical mechanism that exploits nonlinearities to convert a constant energy current into a nonconservative mechanical force. This force self-sustains the generation of phonons whose frequency is much lower—by several orders of magnitude—than that of the photonic degrees of freedom. We identify conditions under which the maximum mechanical power extracted becomes invariant and uncover a new form of self-induced robustness, where power production remains stable in the presence of imperfections and external noise in the drive.

## Polariton Cascade Phonon Laser

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**Phonon lasers, known as "sasers," leverage stimulated emission of sound** and have traditionally been an academic curiosity, unlike photon lasers. However, their importance is growing due to their potential for **on-chip information processing at ultra-high frequencies and in the quantum realm** within integrated photonic and optomechanical devices.

Inspired by unipolar and quantum cascade lasers (QCLs), a **quantum cascade phonon laser (QCPL)** has been proposed and implemented. This QCPL operates by **optically inducing a condensate of exciton-photon quasiparticles, called polaritons**, in a microstructured semiconductor device. These polaritons **descend a ladder of carefully engineered energy levels**. A key distinction from QCLs is that the QCPL uses **bosonic polaritons**, enabling **double stimulation**. This polariton cascade is accompanied by the **efficient stimulated emission of phonons** at frequencies of approximately **20, 60, and 100 GHz**, which are designed for strong on-chip interaction with the polaritons.

The engineering of polaritonic energy levels is achieved by **microstructuring the spacer layer of an (Al,Ga)As microcavity into a "wedged stripe" with varying lateral thickness**. This configuration creates an effective potential, resulting in polariton states that are nearly equidistant in energy, with separations matching the fundamental confined vibrational mode (~20 GHz) and its overtones. Coulomb interactions and dissipation contribute to the **asynchronous locking of energy levels to optomechanical resonance** when phonon self-oscillation is induced.

Experimental evidence for this multimode phonon lasing in the 10–100 GHz range includes: **Inter-level locking** (orbital and pseudo-spin) at confined phonon cavity frequencies, such as ~20 GHz, ~60 GHz, and ~100 GHz. **The emergence of equidistant sidebands** in the polariton emission spectrum, indicating mechanical modulation and period-doubling behavior.

This concept paves the way for the **design of high-frequency integrated optomechanical devices**, including non-reciprocal photon transport and multi-wavelength Brillouin lasers. The significant vibrational amplitudes achievable suggest great potential for **nonlinear phononics**. While the current GaAs-based system requires low-temperature operation ( $T < 100$  K) due to small exciton binding energies, alternative molecular systems could potentially operate at room temperature. The principle of bosonic cascade phonon lasing also has implications for **ultrafast temporal modulation of photonic lattices**, the design of synthetic magnetic fields, non-reciprocal transport, and dynamical gauge-field simulators.

# Self-consistent Optomechanical Locking Theory of Coupled Bose-Einstein Condensed Polaritons with Dissipation

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Motivated by experimental studies [1], we propose a theoretical study of the synchronization in coupled Bose-Einstein condensed polaritons considering a dynamic interaction of two polaritonic modes with a dynamic phonon mode of 20 GHz. The considered hopping between the polaritons involves a linear or quadratic coupling to the phonon mode. Our model shows that nonlinear polariton-polariton and polariton-reservoir interactions are important to extend the synchronization regions characterized by integer and fractional locking to the phonon frequency taking the form of a ladder known in dynamical systems as the “Devil’s Ladder” [2]. Going beyond the situation in which the phonon population is assumed, we look for cases in which the phonon can oscillate due to the interplay with the polaritons. This involves self consistently solving the dynamics of the coupled polaritons and the phonon. Also an energy balance is introduced to identify the zones of self sustained phonon population. Stochastic calculations also demonstrate that phonon cooling effects can also be realized.

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## Memory effects in pulsed optomechanical systems

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La memoria, entendida como no-localidad del tiempo, es una propiedad fundamental de cualquier sistema físico, ya sea clásico o cuántico, y tiene aplicaciones importantes en una amplia variedad de tecnologías. En el contexto de las tecnologías cuánticas, los sistemas con memoria se pueden utilizar en información cuántica, comunicación y detección. Aquí, demostramos que los sistemas optomecánicos de cavidad impulsados por un láser pulsado puede funcionar como elementos de memoria cuántica programables. Al diseñar los pulsos adiabáticos y no adiabáticos, particularmente los impulsos gaussianos y sinusoidales, inducimos y controlamos diversos fenómenos de memoria como la histéresis dinámica, las transiciones fonónicas cuantificadas y las distintas respuestas de almacenamiento de energía. Dentro de un enfoque de campo medio, derivamos los criterios analíticos y numéricos bajo los cuales los observables fotónicos y fonónicos manifiestan los efectos de memoria en regímenes fuertemente impulsados. Los efectos de memoria se cuantifican a través de un factor de forma geométrica adimensional, que proporciona una métrica versátil para caracterizar la eficiencia de la memoria. Nuestro protocolo es fácilmente compatible con las plataformas optomecánicas actuales, destacando las nuevas posibilidades de funcionalidades avanzadas de memoria en tecnologías cuánticas.

# Superfluid phonon experiments that are out of this world

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The Gravity Laboratory at the University of Nottingham uses analog experiments to study cosmological events at laboratory scales. This includes studying quantum vortices generated in superfluid helium to simulate gravity and black holes. Phonon excitations and surface waves generate these vortices, which are then studied and applied to cosmological scale models. Measuring the properties of these features in superfluid helium is experimentally challenging due to ultra-low temperature requirements, optical access, low optical contrast and structures occurring between mm and nm scales. A concise overview of equipment, experiments, tools and techniques are presented to demonstrate how phonon activity can be used to simulate physics on the cosmological scale. This includes ultra-low cryogenics, Fourier transform profilometry

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# Phonon dynamics in novel materials and hybrid structures

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Nanometer-thick multilayer structures, characterized by contrasts in elastic properties, present promising avenues for engineering and manipulating acoustic phonons at the nanoscale. Semiconductor nano-acoustic cavities, particularly those based on Distributed Bragg Reflectors (DBRs), have demonstrated unique capabilities in simultaneously confining light and acoustic phonons. This dual confinement enhances phononic fields, making these structures attractive for ultra-high-frequency applications and as platforms for simulating solid-state systems[1].

In this study, we further explore hybrid nanostructures that are potentially tunable and responsive to changes in elastic properties induced by external stimuli such as temperature, humidity, and electric fields. Building upon our theoretical simulations [2,3], our experimental investigation focuses on the dynamics of acoustic phonons in the frequency range of 5–500 GHz, using near-infrared pump-probe ultrafast transient reflectivity techniques. The materials studied include mesoporous thin-films, YBCO/STO multilayers, GaAs/AIAs DBRs, and other responsive materials such as vanadium oxide.

Our experimental findings pave the way for developing nanoacoustic sensing technologies and reconfigurable optoacoustic nanodevices.

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# Ultrafast carrier and phonon dynamics in ZnO nanostructures probed by femtosecond spectroscopy

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Zinc oxide (ZnO) nanostructures are promising platforms for applications in optoelectronics, photocatalysis, and nanoscale transducers, owing to their wide direct bandgap (3.37 eV), high exciton binding energy (60 meV), and large exciton–phonon coupling [1]. In this work, we investigate both ensembles and individual ZnO microrods and nanowires -typically ~10 μm in length and ~2 μm in diameter for microrods, and ~2 μm in length and ~100 nm in diameter for nanowires-, to elucidate their relaxation dynamics following femtosecond excitation near or above the bandgap. Microrods were obtained via a simple hydrothermal method, while nanowires were grown via vapor transport deposition. Structural and morphological characterization was performed using X-ray diffraction (XRD) and scanning electron microscopy (SEM). The optical response was probed using steady-state photoluminescence (PL) with a 325 nm He–Cd laser, and ultrafast transient absorption spectroscopy with 325 nm and 400 nm pump pulses and broadband or 800 nm probe.

Preliminary time-resolved measurements on ZnO microrods reveal complete electronic relaxation within the first ~300 ps, consistent with rapid recombination dynamics. Data analysis is ongoing to identify additional relaxation pathways, including phonon-mediated channels.

We aim to resolve coherent acoustic phonons in these nanostructures, expected to appear as oscillatory modulations in the transient signal due to strain-induced refractive index changes. We are conducting pump–probe experiments on ZnO nanowires resting directly on substrates, where mechanical coupling to the underlying material may lead to enhanced acoustic damping. Unlike suspended nanowires, which have been extensively studied in the context of GHz mechanical vibrations, substrate-supported systems remain less explored in terms of their vibrational dynamics. Our ongoing efforts aim to compare different configurations—supported vs. suspended nanowires—on various substrates, in order to elucidate the interplay between electronic losses and phonon coherence. These comparisons are expected to provide insight into substrate-induced dissipation and guide the integration of nanowire-based systems in realistic optoelectronic and phononic devices. We also plan to extend these studies to SnS and SnS<sub>2</sub> nanostructures—semiconductors with strong anisotropy and potentially distinct phonon dynamics, broadening the scope of time-resolved phononics with relevance for future optoelectronic and phononic devices.

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# Resonant effects for efficient generation of high-frequency phonons

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High-frequency phonons have gained attention in the fields of quantum technology and nanophononics. Their small wavelengths make them compatible with quantum nano-devices and their frequencies can surpass modern computation speeds. This potential makes phonons useful for qubits, quantum memories, hybrid systems, and elements in quantum computing networks. The project focuses on using a novel experimental method based on the optical open cavity to excite and detect coherent phonons in nanostructures from the II-VI group of semiconductors. The project involves growth of the samples with an acoustic cavity enclosed in Distributed Bragg Reflectors (DBR), which support the cavity acoustic mode. By placing the sample inside the open optical cavity and adjusting its length, we can sweep the energy of the excitation photon, allowing comprehensive studies on the influence of photon energy on phonon generation efficiency [1,2]. Additionally, one can achieve resonant excitation in time domain, by implementing a high repetition rate laser [3] that matches a frequency of the mode supported in the acoustic cavity. This experimental scheme allows us to enhance the efficiency of phonon excitation by exploiting four resonances for coherent phonon generation: acoustic cavity resonance, optical cavity resonance, excitonic resonance, and in-phase (temporal) resonant excitation. As a result of the project, we expect to provide a comprehensive study on the efficiency of the high-frequency coherent phonon generation in the II-VI semiconductor nanostructures obtained by pump-probe experimental technique exploiting optical open cavity. Initial results include manufacturing and assembling an open optical cavity based on titanium mechanical parts and attocube positioners. Stable light source and active stabilization realized with Red Pitaya controller allowed us to control the cavity so it is continuously supporting particular optical mode. Various samples of Al and Ni thin films were deposited on Tungsten and Silicon substrates and investigated at the pump-probe set-up where we have obtained phonon echo signal. In this work we present the concept of enhancing efficiency of coherent phonon generation along initial results and simulations.

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# Tuning Mechanical Dissipation in Plasmonic Nanoresonators via Substrate Porosity

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Plasmonic nanoantennas, typically made of noble metals, have emerged as promising platforms for integrating optical and mechanical functionalities at the nanoscale, as they can sustain GHz mechanical vibrations upon ultrafast optical excitation [1]. However, their mechanical quality factor (Q) is typically limited by intrinsic losses and thermal effects, as well as by acoustic energy leakage into the substrate. Here, we demonstrate that inserting a mesoporous film between the nanoantenna and the substrate offers a scalable route to engineering high- $f^*Q$  nanoresonators, paving the way for tunable and low-loss nanomechanical systems relevant to sensing and nanophotonics.

We investigate gold nanorods (GNRs) fabricated by e-beam lithography on mesoporous silica films with controlled porosity (0%, ~20%, ~40%) synthesized via a sol-gel process. Their mechanical response is characterized using two-color ultrafast pump-probe spectroscopy. A consistent enhancement of Q, up to 25%, is observed for GNRs on porous substrates compared to non-porous ones, indicating that mesoporous films act as effective acoustic insulators. This effect is further supported by time-domain FEM simulations, which reveal longer phonon lifetimes with increasing porosity, achieved without the need for full suspension or complex nanofabrication.

Interestingly, we also reveal that both  $f$  and  $Q$  are tunable via environmental humidity due to water adsorption in the pores, which modifies the local density and acoustic impedance. This results in a consistent downshift of the resonance frequency with increasing humidity. While low-porosity substrates show reduced  $Q$  at high humidity (consistent with enhanced damping), high-porosity substrates display a slight  $Q$  improvement, likely due to the passivation of surface scattering centers by infiltrated water.

These results demonstrate that mesoporous substrates can act as passive acoustic barriers, enhancing the mechanical coherence of plasmonic resonators. The resulting  $f^*Q$  values, although still below the decoherence threshold ( $\sim 6 \times 10^{12}$  Hz) at room temperature [2], indicate promising progress toward integrated quantum optomechanical systems based on plasmonic elements.

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# Phonon-Assisted Stochastic Resonance in Nonlinear Thermal Radiation Devices

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Thermal radiation management poses fundamental and technological challenges. On the fundamental side, it touches on limits such as Kirchhoff's law of emissivity–absorptivity equivalence and Planck's bound on thermal emission. On the applied side, it underpins technologies ranging from daytime passive radiative cooling and enhanced solar cell performance to energy harvesting and thermal camouflage. In this work, we explore how the interplay between nonlinearities and a phononic driving can be harnessed to control the flow of thermal radiation. Using a Langevin framework, we show that a phonon field modulating a nonlinear system in contact with a thermal radiation reservoir can induce **stochastic resonance**, manifesting as noise-assisted, periodic transitions between metastable states. This mechanism offers a new pathway for dynamic control of thermal emissivity in nonlinear photonic systems.

# Exceptional Point Formation Driven by Phonons in Nonlinear Non-Hermitian Polariton Systems

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Exceptional point (EP) degeneracies are non-Hermitian spectral singularities where multiple eigenvalues and their corresponding eigenvectors coalesce. This collapse of the eigenbasis has profound implications for the system's response and enables a range of striking phenomena, such as unidirectional invisibility, hypersensitive sensing, loss-induced transparency, and EP lasers. A key ingredient behind many of these effects is the enhancement of wave-matter interactions near an EP. EPs typically emerge from symmetries in the non-Hermitian Hamiltonian, most notably parity-time (PT) symmetry. When this symmetry is broken, the system shifts away from the EP regime. In this work, we use analytical and numerical methods to show that phonons can dynamically restore an effective PT symmetry, leading to the formation of an EP in nonlinear non-Hermitian polariton systems. This mechanism unveils a new route for engineering and controlling exceptional point physics through vibrational modes.

# Phonon and electron Monte Carlo simulator for microscale devices

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In this poster, we will present a free and open-source Monte Carlo simulator FreePATHS for multi-processed simulations of phonon and electron transport in complex three-dimensional geometries. Using FreePATHS, we simulate various micro-systems, such as nanowires, membranes, and phononic crystals, and demonstrate various nanoscale effects. For instance, we show the ballistic thermal phonon transport occurs at the nanoscale and impacts the heat conduction in nanowires and nanowire networks. We also demonstrate how pores in silicon membrane affect both phonon and electron transport and thus shape the performance of a thermoelectric device. This project offers a free and reliable tool for nanoscale simulations of thermal electric properties in semiconductor devices.

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## Local thermometry for non-equilibrium vibrational states of an ion chain

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The accurate simulation of vibrational energy transport and quantum thermodynamics with trapped ions requires good methods for the estimation of temperatures. One valuable tool with this purpose is based on the fit of dark resonances in the fluorescence spectrum; however, the reliability of this technique remains uncertain. In this work, we evaluate several simplified dynamical equations for simulating the spectrum of a trapped ion undergoing thermal motion, highlighting the strengths and limitations of each method. Additionally, we analyze the applicability of this approach to measure local temperatures in a chain of trapped ions. Our study includes a detailed experimental proposal for measuring non-equilibrium profiles of the effective temperatures in this system, supported by numerical simulations of the dynamics and the measurement process.

## Phonon-electron nonequilibrium close to a Ti/Si boundary

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Metal-semiconductor interfaces are ubiquitous in many types of devices, especially in electronics where Schottky contacts are widespread. In this work we investigate both the phonon and electron transport at an interface between a metal, titanium, and a semiconductor, silicon, by means of the Boltzmann transport equation solved with the discrete ordinate method. The Boltzmann equation is solved in energy intensity for each of the phonon and electron baths, with an average mean free path for each bath [1].

We first apply a temperature difference and then add on top a voltage bias. The aim is to analyse the nonequilibrium of electrons and phonons close to the interface. While it has already been studied with the two-temperature model, the local nonequilibrium of each of the energy carriers due to the presence of the boundary could not be systematically included. Here we therefore analyse the interplay between this 'ballistic' nonequilibrium and the nonequilibrium between the electron and phonon baths. The electron-phonon coupling length acts as a third mean free path in addition to the electron (few to tens of nanometers) and phonon average (~200 nm) mean free paths. When the materials on both sides of the interface are thin films, the electron-phonon coupling can be suppressed and the temperature field becomes complex. Finally, we study the case of a limited contact zone of extension smaller than the mean free paths, associated with ballistic dissipation.

This work sheds light on the thermal boundary resistance at semiconductor-metal interface and thermoelectric coefficients when the thickness of the layers is decreased to the nanometric size.

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# Cryogenic Spectroscopy of Lanthanide-Doped Nanoparticles

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Lanthanide-doped nanoparticles exhibit exceptional optical properties that enable their use in a variety of applications, including spectroscopy and laser cooling. Cryogenic spectroscopy of these nanoparticles allows for the investigation of their behavior under extreme conditions and the assessment of their suitability for optical refrigeration. In this work, we present the measurement of emission spectra of monocrystalline lanthanide-doped nanoparticles, with the aim of optimizing their spectral characterization in cryogenic environments. Specifically, we analyzed samples doped with Yb and with ErYb. Moreover, the emission spectra obtained at various known temperatures serve as a necessary tool for performing spectroscopic thermometry on these particles and for evaluating their potential for laser-based cooling. The experimental setup, based on a cryostat, was specifically developed and implemented for these measurements, and its construction and commissioning were also a key part of this study.

# Electrical Feedback Cooling of the Motion of Levitated Rare-Earth-Doped Nanoparticles for Implementation in Laser Cooling Protocols

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In recent years, various systems for trapping and cooling the center of mass of levitated nanoparticles have been explored. This is of interest not only for the study of fundamental physics in quantum systems but also due to the potential for developing contact-free cooling methods for condensed matter systems.

In this work, we present the progress made in trapping and cooling  $\text{Yb}^{3+}:\text{NaYF}_4$  nanoparticles with diameters between 100 and 200 nm using an electric feedback method, as well as subsequent fluorescence experiments that allow us to measure the internal temperature of the nanoparticles and test laser cooling protocols for the internal degrees of freedom of the crystal.

These cooling protocols exploit the coupling between the electronic transitions of  $\text{Yb}^{3+}$  dopants and the phonon modes of the host crystal. A tunable laser, aligned to the anti-Stokes region of the spectrum, is utilized to drive transitions that produce a net extraction of thermal energy from the crystal.

These experiments are part of a broader theoretical investigation conducted by our research group into anti-Stokes cooling protocols, which aim to surpass the current cooling limits established for these systems, as well as to explore alternative systems for overcoming such limits.

# Influence of flexural phonons and agglomeration on the heat capacity of carbon nanotubes

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Multi-walled carbon nanotubes (MWCNTs) are promising nanomaterials for nanoelectronics due to their exceptional electrical, thermal, and mechanical properties. Heat capacity is a key parameter influencing thermal energy storage and the rate of temperature change during heat dissipation. In this study, we investigate the low-temperature specific heat of MWCNTs subjected to different grinding treatments [1]. Two modified MWCNT samples—milled and oxidized/milled—with an average outer diameter of 9.4 nm were analyzed. Grinding reduces the size of MWCNT agglomerates, resulting in an increase in heat capacity. The oxidized/milled MWCNTs were prepared via a two-step process: primary oxidation of pristine MWCNT powder followed by mechanical grinding. Oxidation effectively diminishes agglomeration, further enhancing the total heat capacity of the system. At low temperatures, the heat capacity expands in odd powers of temperature, revealing three main contributions: a defect-disorder term ( $C_1T$ ), a Debye term ( $C_3T^3$ ), and a dispersive term ( $C_5T^5$ ). The negative value of the  $C_5$  parameter indicates flexural phonon dispersion.

Notably, an anomalous disappearance of the characteristic "hump" in the  $C/T^3$  vs.  $T$  plot was observed, which is attributed to the combined effects of flexural phonon dispersion and disorder related to MWCNT agglomeration.

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# Wigner formalism for modelling heat transport in thin films

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To develop new component concepts, like thermal sensors based on 2D effects [1], which can be realized on a basis of nanowires or superlattice structures, an appropriate understanding of the heat transport is essential. Thus, that the material parameters of those multi-layer components are very temperature-dependent, the heat transport has a strong influence onto the electronic and photonic functions of the device. In order to achieve an efficient device in terms of the temperature and energy management, the component needs to be designed in such a way, that the heat dissipation is low and fast [2].

Typically, a Boltzmann methodology is used to model such transport mechanisms [3]. But since this method often approximate the phonon dispersion through a power series focusing on a linear approximation, it results in an inaccurate description of the dispersion, especially at the edges of the first Brillouin zone. An inclusion of higher orders of the power series with regard to the dispersion relation could lead to a more precise approximation of the phonon transport. In particular regarding the diffusive heat transport, in this case the phonon-phonon scattering with occasionally occurring Umklapp-processes at the edges of the Brillouin zone can be described adequately.

In order to set up a heat transport model, firstly, a phonon Hamiltonian is introduced considering inversion symmetry with which a von Neumann type equation can be constructed in real space. The orders of the power series used to approximate the phonon dispersion is represented by the derivation order of the real space coordinates of the spatially dependent Hamiltonian. Utilizing a transformation onto center of mass coordinates and after the application of the Wigner-transform a Wigner type formalism in the phase space results. Through the inclusion of phonon-phonon scattering, a model for the diffusive heat transport can be realized.

This Wigner formalism leads to an intuitive approach and description of the ballistic and diffusive heat transport. Different approximation orders with respect to phonon dispersion are investigated and evaluated. A comparison is made with conventional Boltzmann approaches.

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# Modelling heat transport in thin films

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Through the increasing complexity and the development of nanoscale devices a better understanding of the heat transport is important. This purpose evokes investigations of new component concepts like thermal sensors based on 2D effects [1], as the heat transport has a significant impact on the electronic and optical properties of these devices. Furthermore, quantization effects induced by 2D effects, particularly occurring in thin layer structures, need to be taken into account and to be investigated through an appropriate modeling of the heat transport [2]. Along with these measures undertaken, it is possible to design energy efficient components [3] by realizing a reduced heat flow and a fast heat dissipation.

This heat transport mainly consists out of the ballistic and the diffusive transport [4]. While the diffusive transport describes the heat flow through interactions between phonons, like the phonon-phonon scattering, the ballistic transport neglects these effects and contains the interaction free transport through a device. Dependent on the mean free path length of the phonons one of the transport mechanisms is dominant. Especially, in devices with thin films, the ballistic transport is of great significance.

Therefore, modelling the ballistic heat transport is necessary from the perspective of circuit design. Such a model can be achieved by introducing a Hamiltonian for phonons, with which a Liouville von Neumann type equation can be set up. Applying the Wigner-Weyl transform, a Wigner formalism for phonons results. Through this formalism the heat transport through nanoscale devices can be modelled by the use of quasi probability distribution functions in the phase space. Thereby quantum mechanical effects, occurring at interfaces between two different materials can be taken into account. The diffusive heat transport, e.g., through scattering terms like the phonon-phonon scattering, can be integrated straightforward on this basis.

Wigner based algorithms to model the heat transport are developed and will be demonstrated to enable an energy efficient design of nanoscale devices including 2D components under the perspective of circuit design.

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# Role of atomic surface reconstruction in phonon tunneling through nanoscale vacuum gaps: Effects on Thermal Conductance.

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The transfer of thermal energy at the nanoscale is critical for understanding and designing advanced technologies. Ultra-thin membranes separated by nanometre-scale gaps, subjected to temperature gradients, present a unique platform to explore novel energy transfer mechanisms. In this work we examine the interaction energy between two reconstructed silicon nanomembranes using a density-functional-based tight-binding (DFTB) approach, focusing on its impact on thermal conductance across a nanogap. By coupling the DFTB method with a harmonic atomistic model, we calculate the vibrational modes (phonons) and the equilibration times, which are directly related to the thermal conductance. Our findings show that surface reconstruction and the relative alignment of facing dimer structures significantly influence the phononic contribution to thermal conductance. Although the harmonic model simplifies the interactions of the real system, our results agree well with previous studies, demonstrating that this model captures key aspects of phonon-mediated heat transfer. Overall, our approach provides a computationally efficient method for understanding phononic heat transfer across nanogaps, with implications for designing nanoscale thermal management systems.

# Exploring the Mechanisms of Laser-Induced Reshaping of Gold Nanorods (GNRs) under nanosecond High-Power Pulsed Irradiation

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Plasmonic nanoparticles (NPs) exhibit localized surface plasmon resonance (LSPR), arising from collective excitation of conduction electrons upon interaction with light. The LSPR peak wavelength is tunable via particle size, shape, material and dielectric environment<sup>1, 2</sup>.

LSPR excitation enhances and confines the electromagnetic field near the NP surface due to coherent electron oscillation<sup>3</sup>. This drives energy dissipation through inelastic electron–electron collisions (10–100 fs), followed by electron–phonon coupling (100 fs–1 ps), causing lattice heating, and phonon–phonon coupling (1 ps–1 ns), which transfers heat to the environment<sup>4</sup>.

These processes can lead to morphological changes. Gold nanorods (GNRs), for instance, may reshape into spherical forms upon pulsed laser irradiation<sup>5</sup>. Since these transformations are absorption-driven, their efficiency depends on the absorption cross-section ( $\sigma_{\text{abs}}$ ), which varies with shape, size, and dielectric context<sup>6-7</sup> as well as on the heat transfer processes and the power of the irradiation source.

GNRs exhibit two plasmon modes, with their spectral positions determined by the aspect ratio (AR). Here, we have performed a selective enrichment of GNR with a specific AR corresponding to the peak position of the experimental longitudinal LSPR mode, via laser irradiation at wavelengths slightly larger and shorter than the experimental LSPR peak. Spectral and thermal responses were analyzed via computational simulations. Morphological changes were studied using ANSYS Lumerical (FDTD), and thermal effects modeled in COMSOL Multiphysics (Heat Transfer in Solids – Time-Dependent). Post-irradiation, a marked decrease in FWHM of the longitudinal LSPR band was observed. Simulations indicated that this spectral narrowing results from selective reshaping of resonant GNRs, enriching populations with constrained AR. COMSOL temperature profiles pointed to localized melting as the dominant mechanism—over surface diffusion or bulk melting—affecting only resonant NPs.

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## Vibrational dynamics in ultracold ion systems

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Our research proposal focuses on the vibrational dynamics of small trapped ion crystals, combining theoretical modeling and experimental implementation at the Cold Ions and Atoms Laboratory (LIAF). Initial efforts target the characterization of vibrational states in individual ions under the Gaussian approximation, including coherent and squeezed states. These techniques will be extended to small ion chains to study entanglement dynamics in systems coupled to engineered baths via laser beams.

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# Stokes Thermometry in Single Lanthanide-Doped Nanoparticles

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Lanthanide-doped nanoparticles exhibit unique optical properties, making them highly relevant for advanced applications such as thermometry, biological sensing, and solid-state laser cooling. In particular, research has shown that for single doped nanoparticles these optical properties are influenced by many factors such as size and dopant concentration.

In this work, we present the experimental implementation of an optical system for Stokes thermometry on single nanoparticles deposited on a substrate. This system allows for the study of the relationship between the emission spectrum and the temperature of the nanoparticles, contributing to a deeper understanding of their thermal and optical properties. The experimental setup focuses a beam on the sample using a microscopy system, and collects the light scattered by single lanthanide-doped nanoparticles.

We will present the results obtained from the experimental implementation of the described system, including emission spectra of single nanoparticles, from which we derive the thermal behaviour of the nanoparticles.

# All-optical generation and detection of GHz surface acoustic waves for magnetoelastic control in YIG thin films

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The interaction between elastic waves and magnetization dynamics in magnetic thin films offers a powerful route to enabling ultrafast, low-power spintronic devices. In this work, we investigate the all-optical generation of surface acoustic waves (SAWs) in the GHz range using plasmonic nanoantennas, aiming to achieve resonant magnetoelastic coupling in ultrathin magnetic systems. This approach enables us to probe and potentially drive spin waves via strain, leveraging nanoscale magnetoelastic effects.

Plasmonic nanoantennas excited by femtosecond laser pulses act as localized mechanical nanoresonators, launching SAWs across the substrate. This technique enables directional propagation and spectral tunability of hypersonic surface waves without requiring interdigital transducers or piezoelectric materials, providing a new level of integration for nanoscale devices. Previous pump-probe experiments, have demonstrated the optical generation and far-field detection of GHz SAWs using single nanoantennas patterned on dielectric substrates [1–3].

Here, we extend this platform to probe magnetoelastic interactions in  $Y_3Fe_5O_{12}$  (YIG) thin films grown by pulsed laser deposition (PLD) on  $Gd_3Ga_5O_{12}$  (GGG) substrates. YIG is a ferrimagnetic insulator widely used in magnonics due to its low magnetic damping and GHz-range precession frequencies. We characterized the magnetic properties of the 50 nm-thick YIG films by magnetometry, recording magnetization curves with the field applied both in-plane and out-of-plane to the film.

Gold nanoantenna arrays ( $80 \times 80 \mu\text{m}^2$ ) were fabricated on the YIG surface via electron beam lithography. The antennas (primarily rods and rectangles) were designed with typical dimensions of  $\sim 130$  nm (length), 90 nm (width), and 35 nm (height) to ensure plasmonic resonance near 800 nm, matching the probe laser wavelength. The array pitch was varied between 1.5  $\mu\text{m}$  and 10  $\mu\text{m}$  to study SAW propagation.

Pump-probe differential reflectivity measurements on individual nanoantennas revealed localized oscillations between 9 and 15 GHz, with damping times of around 600 ps and amplitudes on the order of  $\Delta R/R \sim 10^{-5}$ . Finite element simulations showed excellent agreement with the observed coherent acoustic dynamics. Additionally, time-resolved Faraday and Kerr rotation were used to monitor magnetization precession under variable optical and mechanical excitation, enabling the investigation of magnetoelastic coupling on femtosecond to nanosecond timescales.

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**Poster No.32**

Phonons in 2D materials. Topological phonons.  
Non linear phononics. Chiral phononics. Nanophononics

**Poster**

# Phonon Quantum Valley Hall Effect in Graphane's Grain Boundaries

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The Quantum Valley Hall Effect (QVHE) is a topological phenomenon that can emerge in electronic or phononic bands of hexagonal materials. Typically, this effect requires a material to possess both an energy gap in its phonon or electron dispersion and a specific type of line defect in real space

In this work, we show that the phonon spectrum of graphane (fully hydrogenated graphene) can host topologically protected states along grain boundaries if they reverse the sublattices ( the hydrogenation pattern is swapped). These states are a manifestation of the QVHE. However, unlike any other version of the QVHE, there is no need to open a global band gap in the spectrum. This finding can be generalized to other systems, whether electrons or phonons, broadening the range of materials that could exhibit such topological phenomena.

Our calculations are based on tight-binding-like Hamiltonian models and supported by density functional calculations.

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# Vibrational and Electronic Properties of Lead Iodide Crystals

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Lead iodide ( $\text{PbI}_2$ ) is a semiconductor material that has attracted considerable attention from the scientific community due to its interesting physical properties, with applications in high-sensitivity photodetectors and X-ray and gamma-ray detectors [1], [2].  $\text{PbI}_2$  consists of a layer of lead atoms sandwiched between two layers of iodine atoms, which interact through weak van der Waals forces. In this work, we study the vibrational and electronic properties of  $\text{PbI}_2$  crystals and 2D flakes through Raman spectroscopy and the resonant Raman effect. The samples were synthesized via solution evaporation methods. Raman spectra were obtained using a wide range of laser excitation energies. A resonant Raman effect was observed at 2.33 eV at room temperature. Photoluminescence (PL) and UV-VIS spectra were acquired to investigate this resonant behaviour, which was associated with a defect level caused by lead vacancies in the  $\text{PbI}_2$  crystal. We also investigated the vibrational properties of  $\text{PbI}_2$  2D flakes as a function of their thickness. Atomic Force Microscopy (AFM) was used to determine the thickness of the flakes, and the Raman spectra were analyzed as a function of the number of layers. A strong dependence of the  $E_g$  and  $A_{1g}$  Raman modes was observed as the material goes from its bulk form to the few-layer limit. Additionally, the PL spectra showed a blueshift in the emission peak as the number of layers decreased, in agreement with both theoretical and experimental studies reported in the literature [3], [4].

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## Mirror mirror on the wall, who has the fairest phonons of them all?

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Vortices and surface waves generated in superfluids are used for laboratory-scale analog gravity experiments. Specifically, phonon excitations in supercooled helium generate quantum vortices that are equivalent to the gravitational geometry from a spinning black hole. Non-contact optical methods of these vortices and surface waves are required to measure their unique properties. However, experimental challenges arise from the low optical contrast of liquid helium and micron to nano scale feature sizes of the vortices and surface waves. A modified experimental method is being explored, which was inspired the ancient technology of Chinese magic mirrors. These ancient mirrors were prepared with localised stresses which deform their surface on the nano-scale. It is not possible to see these imperfections directly, due to their nano-scale size. However, these predefined imperfections reveal their hidden structure when observing diverging light reflected at relatively large distances. We demonstrate using a similar approach for measuring phonon/vortex activity in thin films of superfluid helium.

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# Surface acoustic wave tomography on halide perovskite nanowires

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Often known as “nanoscale earthquakes”, surface acoustic waves (SAWs) are widely used in electronics, optics, microfluidics and biological fields, applied in medical diagnostics to mobile communication and quantum computing [1]. Typically SAWs are generated on a piezoelectric substrate by applying a sinusoidal voltage signal to comb-like metal electrodes, called as interdigital transducers (IDTs), following which strain is produced in the substrate via inverse-piezoelectric effect, leading to internal stress and propagation of SAW. Commonly, symmetric IDTs produce a single frequency SAW propagating perpendicular to the aperture of the IDT. For so-called tapered IDTs (TIDTs) the periodicity is tuned along the aperture of the transducers. This variation increases the bandwidth and encodes the spatial coordinate along the aperture in the frequency of the SAW. This position-frequency encoding can be employed for position sensing of mass loading or local variation of the conductivity of a material [2, 3]. As a result, SAWs can uniquely probe the presence of a material completely contact-free, detecting on the change in its transmission coefficient,  $\Delta S_{21}$ .

Here, we present SAW tomography of the photophysical properties of two different types of halide perovskite ( $\text{CsPbBr}_3$  and  $\text{CsPb}(\text{I}_x\text{Br}_{1-x})_3$ ) nanowires (NWs). These NWs are drop-casted along the propagation path of delay lines formed by TIDTs. We begin by demonstrating position-dependent SAW-NW interaction by measuring the photoluminescence (PL) for different frequencies of the TIDT passband. In these experiments, we observe the expected quenching of PL of halide NWs in presence of SAW [4] exclusively at positions where SAW is propagating for the selected frequency. Next, we move on to photoconductivity tomography and measure the change of conductivity upon photogeneration via  $\Delta S_{21}$ . Using a blue laser, both the NWs absorb radiation and the corresponding  $\Delta S_{21}$  with respect to frequency along the aperture width of TIDT maps areas covered by the NWs. These tomograms agree well with the optical microscope images and the change of  $\Delta S_{21}$  due to mass loading by the NWs. Finally, when using a defocused red laser, only  $\text{CsPb}(\text{I}_x\text{Br}_{1-x})_3$  NWs absorb and the corresponding  $\Delta S_{21}$  probes exclusively the change of photoconductivity in these NWs. Our approach can be extended to fully-fledged spectrally resolved tomography on different materials harnessing wavelength-dependent light absorption and using a spectrally filtered white-light source.

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## Microwave optomechanics with a carbon nanotube nano-electromechanical resonator

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Carbon nanotube (CNT) nanomechanical resonators have been used as ultrasensitive force, mass, and charge sensors [1]. In addition, the nanoscale nature of CNTs makes them excellent for studying and exploiting quantum phenomena in nanomechanics. When suspended on source and drain leads and gated, a CNT nano-electromechanical resonator can at low temperature also be operated as a quantum dot. The motion of the nanotube is then strongly coupled to single electron tunneling processes, allowing extreme tunability of the nano-electromechanical parameters including resonance frequency, nonlinearity, and dissipation.

Using this configuration, we have realized optomechanical coupling of a single wall CNT nanomechanical resonator to a microwave cavity and quantified it through optomechanically induced transparency (OMIT) measurements [2,3]. The nonlinearity of Coulomb blockade in the CNT significantly enhances the coupling strength, reaching a single-photon optomechanical coupling of  $g_0 \sim 100$  Hz [2,3]; also back-action of the CNT on the microwave cavity has been demonstrated.

Ongoing work is directed towards strong coupling, motion read-out, and ground state cooling of the nanomechanical resonator. Updated chip design and fabrication techniques have led to larger geometric coupling capacitances as well as a significantly higher microwave cavity quality factor. The coherent optomechanical limit brings the possibility of building a mechanical “quantum switchboard” where quantum information could be transferred between the subsystems; suspended CNTs have been proposed as long-lived nano-electromechanical qubits [4]. Mechanical quantum computation platforms remain a topic of great interest [5], and a strongly coupled optomechanical system will be essential for the realization of a full CNT based quantum computation platform.

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