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ABSTRACT

Magnetic Structures Database from Symmetry-aided High-Throughput Calculations

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ABSTRACT

Magnetic structures, which play a central role in determining their physical properties, are known for only very limited compounds. Traditional theoretical approaches to predicting magnetic structures predominantly rely on first-principles calculations. A key challenge of these methods is their requirement for initial magnetic configurations as inputs, which theoretically possess infinite possibilities. In this work, we introduce a strategy based on irreducible representation basis vectors that effectively narrows down the vast space of potential magnetic configurations to a finite set, typically comprising around 20 candidates per material. Despite this significant reduction, the compact input sets generated by our method already encompass the experimental magnetic structures for 253 out of 302 benchmark materials (83.8%) from the MAGNDATA database. These materials have propagation vectors q=0 and unit cells containing up to 40 atoms, all within the Landau framework. Subsequent first-principles calculations correctly identify the magnetic structure in 198 of these cases. We further apply our highly efficient method to 8,422 stoichiometric transition-metal compounds with fewer than 30 atoms per unit cell in the Inorganic Crystal Structure Database, and establish a magnetic structure database containing 2,906 magnetic materials. To demonstrate its utility, we use this database for the systematic exploration of magnetic topological phases and altermagnets, identifying 1,070 and 392 candidate materials, respectively.

KEYWORDS

Magnetic structure prediction, First-principles calculation, Magnetic materials database

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Theory of 2x2 pair density wave in Kagome materials

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ABSTRACT

Pair density wave (PDW) is a superconducting state with non-zero center-of-mass momentum Cooper pairing in the absence of external magnetic field. Recent experiments show signature of such an intriguing state. However, the properties of the PDW state are not yet fully explored, and theoretical models supporting such a state are rare. Here we firstly discuss the property of the possible PDW state in a single-orbital Kagome lattice that would be relevant in AV3Sb5 materials, at the level of self-consistent mean field theory. We find the PDW leads to highly anisotropic quasiparticle gap on the normal state Fermi surface, and the chiral PDW is topological with Chern number C = 2, supporting quantized thermal Hall conductance. Both predictions are consistent with recent experiments. Secondly, by state-of-art functional renormalization group, we show that a genuine PDW state as the primary order can be realized, out of competing orders, in a two-orbital Kagome lattice under fairly realistic material conditions: finite-sized Fermi pockets and moderate local Coulomb interactions, thanks to the correlation effects enriched by the sublattice and orbital polarization of the Bloch states. We propose this model can be realized in some p- or d-orbital Kagome materials, such as CsCr3Sb5, and may also be simulated by cold atoms.

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KEYWORDS

pair density wave, Kagome lattice, sublattice /orbital polarization, functional renormalization group

2D METAL DICHALCOGENIDES-BASED NANOELECTRONIC DEVICES FOR INTELLIGENT HUMAN-ROBOT INTERFACE, PHOTOEMISSION, AND BIOSENSING APPLICATIONS

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ABSTRACT

Chemical-vapor-deposition (CVD)-grown tin disulfide (**SnS_2**) nanosheets, exhibiting pronounced inverse piezoelectricity as measured by piezoresponse force microscopy, were integrated into a piezoelectric nanogenerator (PENG) device to demonstrate efficient energy harvesting and active sensing capabilities. This SnS_2 PENG device was utilized to explore the synchronous human-robot control of a smart sign language system, highlighting its significant potential for next-generation human-machine interfaces and enabling sensing technologies. **$ReSe_2$** nanosheets-fabricated light-emitting transistors ($ReSe_2$-LET) exhibit nearly symmetric ambipolar charge transport. By judiciously employing asymmetric Cr/Pt electrodes, with their work functions align respectively with the conduction- and valence-band edges of $ReSe_2$, a low turn-on voltage $ReSe_2$-LET was realized with the balanced number density and field-effect mobility of bipolar carriers (i.e., electrons and holes). At room temperature, the $ReSe_2$-LET emits near-infrared electroluminescence at 980 nm under a bias voltage of <1 V. This nanoscale $ReSe_2$-LET can be integrated with photonic crystal cavities to construct an electrically pumped nanolaser operating at 980 nm, offering potential for a wide range of on-chip optoelectronic applications, such as a light source for silicon photonics. By integrating upconverting nanoparticles (UCNP) into an SnS_2 nanosheets-fabricated field-effect transistor (SnS_2-FET) using target-specific aptamers (Apt) as a crosslinker, a phototransistor aptasensor (**UCNP/Apt/SnS_2-FET**) was constructed, in which photo-generated signals outperform the electric-field-induced counterpart and govern the sensor sensitivity. This phototransistor aptasensor enables detection of both charged and neutral biomarkers in high-ionic-strength media (e.g., serum) beyond the Debye screening length. The binding free energy and the length of a folded aptamer within the target-aptamer complex calculated by molecular dynamics simulation closely agree with UCNP/Apt/SnS_2-FET measurements, providing mechanistic insights into the complex formation. Compared with existing biosensing technologies, this innovative

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phototransistor aptasensor demonstrates superior performance metrics, including higher detection sensitivity, improved signal resolution, and a broader analyte concentration range, underlining its potential as a versatile biomedical platform for clinical diagnostics.

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KEYWORDS

SnS_2 nanosheets, Piezoelectric nanogenerator, $ReSe_2$ nanosheets, Light-emitting transistor, Phototransistor biosensor

Symmetry-conserving maximally projected Wannier function and its applications in strong physical response materials designment

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ABSTRACT

The symmetry conserving maximally projected Wannier functions (SCMPWF) approach has been implemented in the full potential-local orbital code, FPLO. SCMPWFs are obtained from the initial step of the maximally localized Wannier function algorithm, projecting a subset of wave functions onto a set of suitably chosen local trial functions with prescribed symmetry properties with subsequent orthonormalization. The particular nature of the local orbitals in FPLO makes them an ideal set of projectors since they are constructed to be a small basis adapted to the occupied sector and the lowest-lying unoccupied states. While in many cases projection onto the FPLO basis orbitals is sufficient, the option is there to choose particular local linear combinations as projectors, in order to treat cases of bond centered Wannier functions. This choice turns out to lead to very localized Wannier functions, which obey the space group symmetry of the crystal by construction. The SCMPWF approach has been successfully applied in quantum response calculations for realistic materials.

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Electronic structure and energy scales in superconducting $(La,Pr,Sm)_3Ni_2O_7$ films

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ABSTRACT

The discovery of superconductivity in Ruddlesden-Popper (RP) bilayer nickelate films under ambient pressure provides an unprecedented opportunity to directly investigate the electronic structure and energy scales of the superconducting state.

In this talk, we will present our recent results on $(La,Pr,Sm)_3Ni_2O_7$ thin films epitaxially grown on $SrLaAlO_4$ substrates. Angle-resolved photoemission spectroscopy (ARPES) measurements have been carried out on the superconducting films by developing an ultra-high vacuum cryogenic quenching and transfer technique. The electron energy bands with different orbitals have been revealed. In the superconducting state, a finite superconducting gap with pronounced coherence peak is observed along the Brillouin zone diagonal direction. Remarkably, the finite superconducting gap persists across the entire Brillouin zone of the underlying Fermi surfaces, revealing the absence of gap nodes. An abrupt band renormalization, manifested as a kink in the energy-momentum dispersion at ~70 meV below the Fermi level, indicates an electron-boson coupling in the system. The simultaneous observation of a nodeless superconducting gap and electron-boson coupling provides crucial insights into the pairing symmetry and gluing mechanism in high-T_C RP bilayer nickelates.

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Nodeless superconducting gap and electron-boson coupling in $(La,Pr,Sm)_3Ni_2O_7$ films, *arXiv:2502.17831*, Jianchang Shen et al.

KEYWORDS

Nickelate superconductors, Superconducting gap, Electron-boson coupling

Non-Hermitian quantum systems and non-unitary criticality

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ABSTRACT

The characterization of non-unitary conformal field theories (CFTs) via entanglement measures is often hindered by the appearance of negative central charges, which lack a clear interpretation in standard entanglement theory. We address this by formulating a generalized entanglement entropy that remains well-defined in the non-unitary regime. Through numerical and analytical validation—including applications to the PT-symmetric Su-Schrieffer-Heeger model and quantum-group-invariant XXZ chains—we show that this measure accurately captures the scaling of non-unitary CFTs [1,2]. We further apply this framework to investigate non-Hermitian critical phenomena. Our results reveal that local non-Hermitian perturbations can induce exceptional points that significantly alter the system's criticality, specifically shifting the central charge from c=1 to c=−2 [3]. Additionally, we present a novel PT-symmetric gapless SPT phase characterized by the presence of boundary modes that exhibit an unconventional degree of robustness, suggesting new directions for the study of topology in non-Hermitian critical systems [4].

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KEYWORDS

Conformal field theories, non-Hermitian quantum systems, exceptional points, symmetry enriched criticality, symmetry protected topological phases.

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Cascade of fractional quantum Hall states in 2D system

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ABSTRACT

The observation of the fractional quantum Hall (FQH) effect in 2D electron gases ushered in investigations of topological phases driven by strong electron correlations. Their remarkable features include fractionalized elementary excitations, gapless boundary states and non-trivial quantum entanglement patterns. Thanks to persistent efforts in the building of new platforms and making higher-quality samples, a diverse plethora of FQH states have been unveiled in experiments. We report a systematic study of ultrahigh-quality GaAs/AlGaAs quantum wells with mobility up to 3.7×10^7 $cm^2\ V^{-1}\ s^{-1}$ using quantum transport measurements in nuclear adiabatic demagnetization and dilution refrigerators down to 1 mK. In addition to many FQH states that have already been identified in previous work, new longitudinal resistance dips are observed at filling factors 17/33 and 15/31. The application of an in-plane magnetic field causes disparate variations of the FQH states. The theoretical foundation of these states is discussed in the framework of composite fermion theory. While most fractions can be explained as non-interacting composite fermions forming integer quantum Hall states, a few states correspond to FQH states of composite fermions that arise from residual interaction between them. We summarize the observed fractions in the range of $0 < \nu < 2$ and propose a pattern to account for their experimental appearance that provides an intuitive picture about the relative strengths of different FQH states.

REFERENCE STYLE

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KEYWORDS

pattern of fractional quantum Hall states, composite fermion theory, 2D system, nuclear adiabatic demagnetization

MULTIFERROIC C_{84} FULLERENCES ON Si(111): DEFECT-DRIVEN QUANTUM TRANSPORT AND RESISTIVE SWITCHING FOR NEXT-GENERATION MEMORY

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ABSTRACT

Fullerene molecules, particularly C_{84}, possess rich electronic structures and unique bonding flexibility; however, their multiferroic behavior and relevance to memory applications remain largely unexplored. In this work, we investigate the structural, electronic, and switching properties of few-layer C_{84} films deposited on Si(111)-7×7 substrates using thermal evaporation under ultra-high vacuum (UHV) conditions.

UHV scanning tunneling microscopy (STM) measurements reveal a bandgap of approximately 3.7 eV at the C_{84}/Si(111) interface. Multiferroic characteristics are identified through magnetic force microscopy (MFM) and piezoresponse force microscopy (PFM), where ferromagnetism originates from localized spin-exchange interactions, while ferroelectricity is associated with spin–orbit coupling and asymmetric charge distribution.

Complementary density functional theory (DFT) calculations using the VASP package indicate that external electric fields induce intermediate electronic states near the Fermi level, facilitating charge transport across defect-mediated pathways. Spectroscopic analyses, including Raman, X-ray photoelectron spectroscopy (XPS), and photoluminescence, further confirm the presence of sp^2/sp^3 hybridization, dangling bonds, and defect-related states that play a critical role in electronic conduction.

Device-level measurements of Au/C_{84}/Si(111) heterostructures demonstrate stable bipolar resistive switching behavior, as verified by conductive atomic force microscopy (C-AFM). The switching mechanism is governed by defect-assisted charge transport and electric-field-induced bond reconfiguration, particularly involving transitions between sp^2 and sp^3 bonding states.

These findings establish a direct link between multiferroicity, defect engineering, and quantum transport in fullerene-based systems, highlighting the potential of C_{84} as a novel active material for next-generation non-volatile memory devices, including ReRAM and FeRAM.

KEYWORDS

C_{84} Fullerenes, Multiferroicity, Resistive Switching, Quantum Transport

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QUASIPARTICLE EXCITATIONS IN FESE$_{0.45}$TE$_{0.55}$: A THERMAL TRANSPORT PERSPECTIVE ON SUPERCONDUCTING SYMMETRY

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ABSTRACT

In this talk I discuss the Fe based superconductors, with a personal perspective on the Fe chalcogenides. I'll provide a summary of our understandings of the materials thus far, and discuss our group's recent investigations into the superconducting and transport properties of FeSe$_{0.45}$Te$_{0.55}$ single crystals using magnetic susceptibility, electrical resistivity, Seebeck coefficient, and thermal conductivity measurements. I'll also discuss new directions and tuning knobs for the Fe based superconductors.

Magnetization and resistivity data confirm bulk superconductivity with a sharp transition near 14.5 K, marked by strong Meissner screening and zero resistance. The Seebeck coefficient exhibits a sign change near 107 K, indicating a crossover in dominant carrier type from holes to electrons, consistent with multiband conduction. An anomaly at 14.5 K aligns with the superconducting onset, while a dip near 30 K suggests enhanced scattering or band reconstruction. Thermal conductivity reveals corresponding anomalies at ~12.7 K and ~107 K, highlighting the interplay between carrier dynamics and heat transport. A finite residual linear term of 0.01346 W/mK^2 in κ/T as (T to 0) at zero field provides direct evidence for low-energy quasiparticles, ruling out a fully gapped s-wave state. The monotonic field dependence and near-quadratic scaling with (H^2) are consistent with vortex-induced quasiparticle transport and the Volovik effect, supporting a nodal or strongly anisotropic gap structure. These results, confirm the presence of unconventional superconductivity in FeSe$_{1-x}$Te$_x$ and establish it as a robust platform for exploring correlated electronic states and pairing mechanisms.

KEYWORDS

Fe chalcogenide, unconventional superconductivity

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Pre-asymptotics of Multiband Non-Hermitian Systems

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ABSTRACT

In this work, we develop a rigorous theory for fundamentally unconventional scaling in non-Hermitian systems. Non-Hermitian systems can exhibit the non-Hermitian skin effect (NHSE), where eigenstates accumulate near open boundaries. In the thermodynamic limit (TDL), this is described by non-Bloch band theory, which allows complex wave-vectors: the generalized Brillouin zone (GBZ) admits open-boundary standing-wave solutions, while the amoeba formalism is its higher-dimensional extension, giving a geometric representation of the GBZ. However, existing theories describe spectra only in the TDL and fail to capture finite-size effects, including pronounced pre-asymptotic regimes in multiband systems. Unlike in Hermitian systems, finite-size effects are not small corrections but among the most intriguing NHSE phenomena due to extreme boundary sensitivity. In such cases, the finite-size spectrum is not necessarily governed by a single standing-wave quantization condition, instead, multiple bulk modes can participate to fulfill the boundary conditions. A more general and universal framework that fully captures all eigenmodes and applies to both finite-size systems and the TDL is therefore required. Here we develop this rigorous, general framework for finite open-boundary multiband non-Hermitian lattices, giving a predictive description beyond existing thermodynamic-limit approaches. We uncover emergent scaling behaviors far more dramatic than usual finite-size scaling: new competitive mechanisms produce sharp crossover scales, different scaling laws at different system sizes, and clear deviations from standard thermodynamic-limit predictions at experimentally accessible sizes. The framework explains novel boundary-induced effects not fully understood by non-Bloch band theory, including size-dependent topological edge modes appearing only above the critical system size. Our framework is an extension and generalization of previous theories: it reproduces earlier results in their regime of validity, while capturing all eigenmodes and finite-size pre-asymptotic behavior. These results bridge asymptotic theory and real devices, guiding the interpretation of experiments and the engineering of boundary-sensitive behaviors in photonic, acoustic, mechanical, and related platforms.

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KEYWORDS
Non-Hermitian skin effect, Pre-asymptotic scaling, Operator theory, Spectrum theory

BOSON DENSITY IN K_3C_{60} UNDER PRESSURE: INVERSION FROM $T_c(a)$ DATA WITHIN A BOSON-FERMION MODEL

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ABSTRACT
The microscopic pairing mechanism in the superconducting fulleride K_3C_{60} remains debated. The parity-doublet model by Friedberg, Lee, and Ren predicts a pseudoscalar boson band arising from electron pairs between the low-lying T_{1u} and T_{1g} levels, yet the boson density is not directly measurable. Here we show that hydrostatic pressure offers a clean, doping-independent tuning of the lattice parameter. Using the boson-fermion mixture model, we employ the relation between the logarithmic pressure derivative of the critical temperature $\frac{d \ln T_c}{d \ln a}$ and the boson density n_b. Inverting this relation with high-quality experimental $T_c(a)$ data obtained from a single K_3C_{60} sample that exhibits both zero resistance and the Meissner effect, we extract the ambient-pressure boson density and follow its evolution under compression. The obtained boson fraction is physically consistent and agrees with independent estimates from earlier literature. Upon lattice compression, the boson density decreases monotonically, directly explaining the experimentally observed suppression of superconductivity with pressure. The internal consistency of the inversion and the agreement with prior independent estimates provide strong support for the parity-doublet pairing mechanism. Our work demonstrates that the pressure response of T_c serves as an indirect probe of the boson density, offering a new quantitative perspective on the superconductivity of fullerides.

REFERENCE STYLE

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Parity doublets and the pairing mechanism in C_{60}, Phys. Rev. B, 46, 14150–14173, 1992, R. Friedberg, T.D. Lee, H.C. Ren.

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KEYWORDS
K_3C_{60} superconductor, Boson-fermion model, Pressure effect

Topological Magnon-Phonon Hybridization in 2D Antiferromagnets

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ABSTRACT

Topological magnons, regarded as a promising candidate for efficient and stable transport channel, have been studied in various magnetic materials. Their topological structure can be even richer when taking into consideration other dynamic degrees of freedom in the system. We show that nontrivial topology can emerge in the hybridized excitations of magnons and phonons in a collinear antiferromagnet due to magnetoelastic coupling. Our theory has a general applicability to two-dimensional magnets, which is demonstrated by developing a continuum theory as the long-wavelength approximation to the tight-binding model. Here, the associated topological transport can be highly tunable as magnons are thermal excitations sensitive to magnetic field. In particular, the thermal Hall effect can exhibit sign switchings as we change the direction or the strength of the applied magnetic field, which may be of practical interest in spincaloritronic applications. We provide experimentally relevant predictions for the van der Waals antiferromagnet MnPS3 and the bilayer FeCl2.

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KEYWORDS

Topological magnons, magnon-phonon coupling, spincaloritronics, thermal Hall effect, spin Nernst effect

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Stacking-orientation and Twist-angle Control on Integer and Fractional Chern Insulators in Moiré Rhombohedral Graphene

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ABSTRACT

Rhombohedral-stacked multilayer graphene (RMG) aligned with hexagonal boron nitride (hBN) has emerged as an excellent platform for investigating exotic quantum phenomena arising from the interplay between electron correlations and nontrivial topology. However, the microscopic mechanism governing the emergence of both the integer and fractional Chern insulator states in this system remains an open question. In this talk, we report a systematic transport study of RMG/hBN moiré superlattices with controlled alignment orientations and twist angles. We demonstrate that alignment orientation strongly modulates correlated phenomena in the moiré-proximal regime, while having negligible influence on the formation of integer and fractional Chern insulators in the moiré-distant regime. Instead, the moiré periodicity—tuned by the twist angle—serves as the key parameter controlling the stability of these correlated topological states in the moiré-distant regime. Furthermore, in the moiré-proximal regime of one specific alignment, we observe anomalous Hall effect and a variety of competing phases near $\nu = 1$, including integer Chern insulator states, extended Chern insulator states, and trivial insulators, whose stability is highly sensitive to both the applied displacement electric field and magnetic field. Our results underscore the critical role of stacking-alignment and twist-angle engineering in exploring novel quantum states based on rhombohedral-stacked multilayer graphene moiré systems.

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KEYWORDS

Rhombohedral Multilayer Graphene, Moiré Superlattices, Chern Insulators, Stacking alignment orientation, twist-angle engineering

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Superconducting pair density modulation and charge order in monolayer high-T_c iron-based superconductors

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ABSTRACT

The emergence of spatially modulated electronic states and symmetry-breaking phenomena in unconventional superconductors has opened new perspectives for understanding the mechanism of high-temperature (high-T_c) superconductivity. Experimentally, the pair density wave (PDW) state, in which the superconducting order parameter exhibits a spatial modulation due to finite-momentum Cooper pairing, has been observed in unconventional superconductors and is hypothesized to play a fundamental role in high-T_c superconductivity. Using molecular beam epitaxy and scanning tunneling microscopy (STM), we previously observed a PDW with a period of about 3.6a_{Fe} (where a_{Fe} is the distance between neighboring Fe atoms) at domain walls in monolayer $FeTe_{0.5}Se_{0.5}$ films grown on $SrTiO_3$ (STO) [1]. By further performing STM measurements with sub-unit-cell resolution on monolayer $FeTe_{1-x}Se_x$/STO (x ≈ 1 and 0.7), we observed the intra-unit-cell superconductivity pair density modulations (PDM) characterized by the superconducting gap size and the coherence peak sharpness. The local maxima and minima in the superconducting gap modulation are centered at the locations of the chalcogen atoms, revealing the breaking of the glide-mirror symmetry of the chalcogen atoms [2]. Moreover, by tuning the growth conditions, we detected a commensurate CDW order with a period of 4a_{Fe} in monolayer $FeTe_{0.3}Se_{0.7}$ film. Further analyses demonstrate that the observed CDW is a smectic order, which breaks both translation and C_4 rotational symmetry. Moreover, the nematicity of the CDW order is closely related to the superconducting state [3]. These results provide a new route for studying the complex intertwined orders and their interplay in high-T_c superconductors.

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KEYWORDS
high-T_c superconductors, iron-based superconductors, pair density modulation, charge order, nematicity

Consecutive Phase Transition in Twisted Double Bilayer WSe2 System

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ABSTRACT

Valley degrees of freedom provide a powerful route to realizing correlated electronic phases beyond the single-band paradigm, including the possibility of valley-selective Mott and charge-transfer insulating states. Such phases are generically difficult to stabilize, as screening by itinerant carriers strongly suppresses interaction-driven localization when multiple electronic degrees of freedom coexist within the same spatial region. Here we demonstrate that twisted double bilayer WSe2 enables controlled access to valley-selective correlated physics in a multiband moiré system without spatial separation of valleys. By applying a perpendicular displacement field, we continuously tune the relative alignment of flat bands derived from the Γ and K valleys and drive two consecutive phase transitions at half filling: from a Mott insulator to a charge-transfer insulator, followed by a transition into a metallic state. These transitions occur as the K-valley band is driven between, and eventually through, the Hubbard bands associated with the Γ -valley flat band. Concomitantly, additional correlated states emerge and propagate toward finite hole doping, defining sharp phase boundaries that separate regimes of single-valley and multivalley transport. In high

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magnetic fields, these boundaries are revealed by Landau level spectroscopy, consistent with a valley-selective correlated regime in which one valley remains interaction-gapped while the other remains itinerant. Upon hole doping near the charge-transfer insulator, we observe a pronounced hysteresis in the Hall response, indicating the emergence of ferromagnetic order stabilized by multiband correlations. Our results establish twisted double bilayer WSe2 as a tunable platform for realizing and controlling valley-selective Mott and charge-transfer physics in moiré materials.

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KEYWORDS
Correlated states, Charge transfer insulator, Mott insulator, Phase transition, Multiband system

Layer-dependent Band Gap and Edge states in 2D $PtSe_2$

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ABSTRACT

Platinum diselenide ($PtSe_2$) has garnered extensive attention due to its unique semiconductor-to-metal transition, which is driven by strong interlayer interactions. In its monolayer form, $PtSe_2$ exhibits a bandgap of approximately 2.0 eV. This bandgap systematically narrows to 1.1, 0.6, and 0.2 eV for two, three, and four layers, respectively, before transitioning into a metallic state at five layers and beyond.[1] While $PtSe_2$ is widely utilized in optoelectronic devices and demonstrates exceptional performance, previous studies—particularly theoretical investigations—have predominantly focused on its intrinsic or bulk properties, largely overlooking the influence of its edge electronic states. In this study, we systematically investigated the electronic properties of $PtSe_2$ thin film edges using molecular beam epitaxy (MBE) and scanning tunneling microscopy (STM). Our findings reveal that these edge states also exhibit a pronounced layer-dependent behavior. Specifically, while the edges of monolayer, bilayer, and trilayer films retain their semiconducting nature, their bandgaps are significantly reduced to approximately 1.0, 0.5, and 0.2 eV, respectively. Notably, from a thickness of four layers onward, the edge transitions into a metallic state.[2] This strong layer dependence of the edge electronic properties profoundly impacts the overall electrical characteristics of the thin films.[3] Our research provides crucial supplementary insights into the fundamental mechanisms governing $PtSe_2$-based devices.

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KEYWORDS

Platinum diselenide, Layer-dependent band gap, Edge states, Molecular beam epitaxy, Scanning tunneling microscopy

Ultrafast Carrier Relaxation in Graphite Probed via kz-Resolved Tr-ARPES

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ABSTRACT

Time- and angle-resolved photoemission spectroscopy (Tr-ARPES) provides direct access to the ultrafast relaxation of photoexcited carriers in quantum materials. In graphite, fluence- and energy-dependent measurements at the H point reveal how the electronic temperature, chemical potential, and nonthermal spectral weight evolve from strongly nonequilibrium to quasithermal states. At low pump fluence, the electronic system is well described by a Fermi–Dirac distribution, whereas at higher fluences nonthermal carriers with lifetimes of about 280 fs emerge, reflecting strong electron–electron scattering and coupling to optical phonons. High-energy carriers relax predominantly via ultrafast scattering, while low-energy carriers experience a pronounced phonon-window bottleneck, leading to decay times of up to several tens of picoseconds.

A photon-energy-tunable high-harmonic pulse laser source enables k_z-resolved Tr-ARPES measurements that compare carrier dynamics at the K and H points along the out-of-plane direction. The K point exhibits bi-exponential cooling with sub-picosecond and few-picosecond components, in sharp contrast to an extended hot-electron bottleneck of roughly 9 ps at the H point. Calculations of electron–phonon matrix elements and available scattering phase space show that this K–H asymmetry is governed primarily by k_z -dependent phase-space structure, rather than by large differences in coupling strength, establishing graphite as an intrinsic momentum-space heterostructure for ultrafast carrier relaxation.

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Robust quantum Hall phase by interfacial charge coupling

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ABSTRACT
Quantum Hall edge states often require extreme experimental conditions of very low temperature and very high magnetic fields. In this talk, we will introduce a van der Waal hybrid system in which an unusually robust quantum Hall phase is realized up to liquid nitrogen temperature at a magnetic field of only 0.35 T. Based on these observations, potential application in quantum Hall resistance standard with precisions exceeding 1E-8 above 50 K is demonstrated. We will also discuss AI-driven robotic system for high yield 2D heterostructure sample fabrications – potentially for scaled up production of van der Waals nanoelectronics.

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KEYWORDS
Quantum Hall, Charge transfer, AI-assisted 2D assemblies

Dynamic study on moire excitons in twisted WS2/WSe2 heterostructures

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ABSTRACT

Van der Waals (vdW) heterostructures provide a versatile platform for manipulating multiple electronic and excitonic degrees of freedom and for engineering artificial lattices. Their stacking flexibility enables the creation of tunable moiré superlattices that host a variety of emergent quantum states. Among these systems, moiré excitons in transition metal dichalcogenide (TMD) heterostructures have attracted particular interest due to the direct bandgap of monolayer TMDs and their rich internal degrees of freedom. In this talk, I will present our dynamical study of moiré excitons in twisted WSe_2/WS_2 superlattices. We observe that exciton relaxation dynamics vary significantly across different moiré filling states. I will also discuss measurement artifacts encountered in pump–probe spectroscopic studies of moiré superlattices.

KEYWORDS

2D semiconductor, moire superlattice, exciton, electron-exciton interactions

Unusual Magnetic Oscillations in Kondo Insulator and Kagome Mott Insulator

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ABSTRACT
Observations of Landau level quantization in narrow-gap correlated Kondo insulators raise intriguing questions about the origins [1, 2, 3]. However, two key questions remain: (1) Do the oscillations originate from the bulk material or a minority phase? (2) Do these phenomena exist in wide-gap insulators? To address the first question, we conducted heat capacity measurements in DC magnets with fields up to 41 T and resolved quantum oscillations in the Kondo insulator YbB_{12}. This observation provides strong evidence for the bulk origin of the quantum oscillations [4]. Furthermore, we applied ultrasensitive manometry and calorimetry to a wide-gap kagome Mott insulator, $YCu_3(OH)_{6.5}Br_{2.5}$. Our magnetometry results resolved both the 1/3-plateau and 1/9-plateau transitions. Surprisingly, the magnetometry also revealed strong oscillations in the magnetic torque [5]. Heat capacity measurements further indicate a dominant quadratic temperature dependence at the 1/9 plateau, suggesting a possible Dirac fermion nature for this 1/9 plateau state [6].

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KEYWORDS
Landau Level Quantization, Spin Liquid, Kondo Insulator

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BANDGAP MODULATIONS AND PROMOTED CARRIER SEPARATION IN CRYSTALLINE G-C_3N_4 THIN FILMS VIA CHEMICAL VAPOR DEPOSITION

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ABSTRACT

Graphite-like carbon nitride (g-C_3N_4) is a promising polymeric semiconductor due to its excellent stability and unique electronic properties. Our group has carried out first-principles studies that provide fundamental insights into its electronic structure and related carbon-nitride systems, guiding the rational design of high-performance CN-based materials.[1] In addition, its tunable bandgap and graphene-like layered structure offer opportunities for modification, and our group have developed strategies such as ionic-liquid gating to effectively regulate defect states and enhance photocatalytic performance.[2-4] However, most existing studies focus on g-C_3N_4 powders, while investigations on thin films remain limited. The fabrication of high-quality thin films remains challenging, which limits the potential optoelectronic and photocatalytic applications. Here, we report the growth of crystalline g-C_3N_4 films with thicknesses of approximately 100-200 nm on the indium tin oxide substrates by chemical vapor deposition. The optimized growth conditions for high-quality g-C_3N_4 films deposition have been obtained through combined optical characterizations and detailed electronic

structure analyses using x-ray spectroscopies. The as-grown g-C_3N_4 films exhibit a bandgap value of 3.05eV as well as an enhanced fluorescence lifetime of 12.43 ns. By adding thiourea to the melamine precursors, N vacancies have been formed in the main heptazine structure, achieving the modulation of the bandgap and the promoted carrier separation. This work provides guidelines for understanding the property-structure relationships during g-C_3N_4 film deposition. The deposition of high crystallinity g-C_3N_4 films therein further extends the applications in the fields of optoelectronic and photocatalytic devices.[5]

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KEYWORDS

g-C_3N_4 films, chemical vapor deposition, bandgap modulation, defect engineering, photocatalysis

Magnon Generation, Transport and Detection in Multiferroic Heterostructures

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Abstract:

Magnons, the quanta of spin waves, have emerged as promising information carriers for next-generation, ultra-low-power computing and data storage because they can transport angular momentum without moving electric charges, thereby minimizing energy losses from Joule heating. Multiferroic materials, which exhibit coupled magnetic and electric orders, provide a transformative platform for controlling magnons. Among them, $BiFeO_3$ stands out as the most studied room-temperature multiferroic material and has become a model system for extensive research.

In this talk, I will discuss the generation, transport and detection of magnons in multiferroic heterostructures, highlighting their potentials in next generation spintronic devices.

Title: Scalable Transition Metal Dichalcogenide Memtransistor Arrays with Schottky-Barrier Control for Energy-Efficient Artificial Neural Networks

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Memtransistors that integrate memristor and transistor functionalities are promising candidates for scalable, energy-efficient neuromorphic computing. However, achieving high performance in memtransistor arrays—particularly in terms of resistive switching ratio, uniformity, and scalability—remains a significant challenge for practical deployment in artificial neural networks. Here, we present scalable memtransistor arrays based on transition metal dichalcogenides (TMDCs), where the Schottky barrier is precisely controlled by modulating vacancy distribution and migration behavior. This approach enables a substantial improvement in the resistive switching ratio, reaching 10^5 through gate modulation. The device-to-device variation is maintained below 6.8%, and the power consumption is as low as 1 pJ per operation. These devices demonstrate high performance in artificial neural network applications, achieving greater than 98% accuracy in image recognition tasks. Furthermore, the devices exhibit remarkable scalability, with a cell size as small as 4.65 F^2, and can be further miniaturized by adjusting the channel size without affecting the switching performance. This work highlights the potential of TMDC-based memtransistor arrays for energy-efficient, high-performance artificial neural networks, offering a scalable solution for next-generation neuromorphic computing hardware.

Memristive device based on a-In2Se3/MoS2 heterostructure for in-memory computing

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ABSTRACT

Advancements in semiconductor technology, once guided by Moore's Law and Dennard Scaling, now face challenges such as the "memory wall" arising from unequal processor and memory performance improvements. Memristors, theorized in 1971 and realized in 2008, offer solutions for nonvolatile storage and in-memory computing[1]. Conventional types like resistive random-access memory and phase-change memory suffer from stochastic switching, limited endurance, and modest on/off ratios, restricting neuromorphic applications[2]. Ferroelectric memristors, leveraging polarization reversal, enable deterministic operation, fast switching (<10 ns), high endurance (>10^{10} cycles), and superior on/off ratios (10^2–10^3). Their intrinsic rectifying behavior also helps suppress sneak currents in crossbar arrays. Compared to bulk or thin-film ferroelectrics, which degrade at nanometer scales due to depolarization fields, oxygen defects, and size effects, two-dimensional ferroelectrics retain polarization down to monolayers and feature dangling-bond-free surfaces, ensuring clean interfaces and seamless 2D integration with other materials.

This study investigates MoS_2/α-In_2Se_3 heterostructure memristors achieved high switching ratio (~10–10^3), high rectification ratio (~10^3), and durability. Electrical measurements show thickness-dependent rectifying ratio peaking at 10^3. Synaptic behaviors including short-term potentiation (STP) and long-term plasticity (LTP/LTD) are also demonstrated. Hardware-aware simulations on the MNIST dataset achieve ~97% recognition accuracy, comparable to software benchmarks, by compensating non-idealities through optimized activation functions and training schemes. Future work will focus on hardware CNN implementations and all-ferroelectric reservoir computing to overcome von Neumann bottlenecks in energy-efficient AI systems.

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KEYWORDS
Memristor, Two-dimensional material, In-memory computing, Ferroelectric material, Von Neumann bottlenecks.

ACKNOWLEDGEMENTS

This research is supported by Singapore National Research Foundation Investigatorship under Grant No NRF-NRFI08-2022-0009 and SUSTech-NUS Joint Research Program.

Evidence for time-reversal symmetry breaking and electronic glassiness in superconducting (La, Pr, Sm)$_3$Ni$_2$O$_7$ films

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ABSTRACT

The discovery of Ruddlesden-Popper (R-P) nickelate superconductors under high pressure heralds a new chapter of high-transition temperature (high-T_c) superconductivity. Recently, ambient-pressure superconductivity is achieved in R-P bilayer nickelate thin films through epitaxial compressive strain, offering an exceptional platform to investigate the potential symmetry-breaking orders intertwined

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with high-T_c superconductivity. Here, through electrical transport study, we report an unconventional superconducting phase characterized by time-reversal symmetry (TRS) breaking and electronic glassiness in bilayer nickelate (La, Pr, Sm)$_3$Ni$_2$O$_7$ films. Rather than being inherited from the normal-state ordering, this symmetry-broken phase emerges within the superconducting transition regime, and extends to zero-resistance ground state. Three defining characteristics are observed: 1. Magnetoresistance hysteresis, direct evidence of TRS breaking, whose magnetic field-dependence is fundamentally distinct from trapped vortices or long-range-ordered magnetism. Successive oxygen reductions simultaneously weaken both the zero-resistance superconductivity and hysteresis, revealing their intimate correlation. 2. Magnetic field history-dependence and zero-field non-reciprocity in the current-voltage responses, further substantiating the intrinsic and spontaneous TRS breaking. 3. Logarithmically slow resistance relaxations upon the removal of magnetic field, hallmarks of the glassy dynamics. Collectively, our findings uncover an unprecedented superconducting phase in the nickelate superconductors, providing phenomenological and conceptual insights into high-T_c superconductivity with intertwined symmetry breakings.

REFERENCE STYLE

Time-reversal symmetry breaking superconductivity with electronic glass in nickelate (La, Pr, Sm)$_3$Ni$_2$O$_7$ films, *arXix*: 2508. 16412 (2025), H. Ji, Z. Xie, Y. Chen, G. Zhou, L. Pan, H. Wang, H. Huang, J. Ge, Y. Liu, G.-M. Zhang, Z. Wang, Q.-K. Xue, Z. Chen, J. Wang.

KEYWORDS

Nickelate superconductors, time-reversal symmetry breaking, glassy phase, unconventional superconductivity

Poor Man's Majorana modes (PMMs) in quantum-dot–superconductor hybrid systems provide a minimal and tunable platform for exploring Majorana physics. Recently, many experimental signatures potentially associated with PMMs have been reported, which has stimulated extensive theoretical studies. Here we develop a microscopic description that treats the quantum-dot and superconducting quasiparticle degrees of freedom on an equal footing, instead of integrating out the superconductor. We focus on the finite-length effect of the superconducting segment and show that it strongly modifies both local and nonlocal couplings induced between the quantum dots. As a result, the number of PMMs depends sensitively on the superconductor length and oscillates between zero and two in finite-length devices. We further show that strictly end-localized PMMs do not exist for finite superconducting length; only nearly localized modes can appear in the strong-magnetic-field regime. In the long-superconductor limit, the corresponding dressed PMM result is naturally recovered. These results provide a unified microscopic description of PMMs in realistic devices and clarify the crucial roles of finite-size effects and superconducting dressing in their emergence and observability.

From Validation to Control: Ferroelectric Switching in 3R-MoS_2 and Carrier extraction modulation

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ABSTRACT

Rhombohedral (3R) MoS_2 is emerging as a strategically attractive 2D ferroelectric platform because its polarization originates from intrinsic 3R stacking symmetry, while remaining chemically inert and thermally stable—features that favor scalable device integration and reproducible switching. Motivated by the advantages of in-plane polarization (lower barriers/voltages and better planar CMOS compatibility), we establish experimental evidence of in-plane ferroelectric (IP-FE) switching in few-layer 3R-MoS_2 by first validating the 3R phase and broken-symmetry signatures using AFM/Raman/SHG, then demonstrating IP-related electrical hysteresis and reliability using scan protocols, electrode geometry optimization (linear vs ring), and retention/endurance tests. To link switching to crystallographic directionality, multi-direction segmented ring electrodes and PFM amplitude/phase hysteresis ($\approx 180^\circ$ phase switching) are used to support direction-correlated polarization switching. Finally, we address a key bottleneck—Coulomb screening by free carriers that narrows the memory window and limits field-driven control —by integrating a top-gate stack to tune channel carrier density via carrier extraction, yielding a larger, cleaner hysteresis/memory window and improved polarization stability, with back-gate measurements confirming controllable extraction and reset capability. Overall, this work demonstrates a clear progression from validation to control of in-plane ferroelectricity in 3R-MoS_2, establishing it as a strong candidate for future memory and synaptic devices.

REFERENCE STYLE

Sliding ferroelectric memories and synapses based on rhombohedral-stacked bilayer MoS_2, *Nat Commun,* 15, 10921, 2024, Xiuzhen Li, Biao Qin, Yaxian Wang, Yue Xi.

KEYWORDS

3R-MoS_2, in-plane ferroelectricity, carrier extraction, Coulomb screening, neuromorphic devices.

Energy-momentum causality of interacting Weyl quasiparticles

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ABSTRACT

Causality—the principle that physical influence from one event to another cannot propagate faster than the speed of light—is traditionally encoded in the spacetime light cone. However, for quasiparticles in crystalline systems, characteristic velocities are not universal in the absence of Lorentz invariance, leaving the causal structure governing quasiparticle interactions fundamentally unclear. Here, in an acoustic Weyl crystal, we experimentally establish that causality for relativistic Weyl quasiparticles emerges as a geometric constraint in energy–momentum space, where quasiparticle dispersion cones play the role of effective light cones. We show that two quasiparticles can interact to open a bulk bandgap only when they lie within each other's energy–momentum cones, whereas interaction is forbidden when neither lies within the other's cone. This constraint extends to the gap opening of surface Fermi arc states, establishing a causal bulk–boundary correspondence. Beyond this reciprocal regime, we identify a quantum horizon in which causal accessibility becomes intrinsically non-reciprocal: one quasiparticle lies within the energy–momentum cone of another, whereas the converse does not hold, thereby providing direct experimental access to intrinsically non-reciprocal causality, a phenomenon absent in relativistic systems. Our study establishes a tabletop platform for probing causal connections in analogue wave

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systems, revealing causality itself as an emergent and tunable property beyond the spacetime paradigm.

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KEYWORDS

Causality, Weyl quasiparticles, acoustic crystals, charge density waves

Designing "more is different" functional nanomaterials *via* "bottom-up" approach

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ABSTRACT

Discovering new materials, exploring their unique properties and potentials in various applications are of paramount importance to condensed matter physics and materials science. Based on the concept of "bottom-up", we constructed a few stable low-dimensional nanomaterials using boron metal clusters of inverse sandwich structures as blocks, among which, Ir_2B_8 carries a magnetic anisotropy energy of 93.43 meV, the K_2B_9 exhibits superconductivity contributed by the van Hove Singularity near the Fermi surface in the electronic dispersion of the hidden kagome lattice, and the TiB_2-II presents CO-sensing property. Furethermore, the novel inverse sandwich configuration was extended to graphene by positioning two metal atoms symmetrically at the two sides of carbon vacancy, such structures hold high promise as electrocatalysts towards CO_2 reduction reactions. Additionally, two monolayers of 1T-TiX_2 (X=S, Se, and Te) were stacked together, and coexistence of charge-density-wave state and ferroelectricity was found by interlayer sliding. Using the "bottom-up" approach, with the aid of first-principles and machine learning technique, our investigations achieve new nanomaterials with multi-functionality of "more is different". .

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KEYWORDS

Bottom-up, First-principles, Machine learning, Low-dimensional functional nanomaterials

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High-Pressure Artificial Synthesis of Hexagonal Diamond

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ABSTRACT

High pressure, as an extreme condition, facilitates atomic rearrangement to synthesize novel materials like hexagonal diamond—a rare meteoritic carbon phase with hexagonal structure and exceptional hardness surpassing cubic diamond. Despite its discovery decades ago, hexagonal diamond's independent existence remained contentious due to its higher formation energy barrier compared to cubic diamond, which dominates conventional high-pressure synthesis. Here, we present two innovative strategies for synthesizing near-pure hexagonal diamond: First, through in situ diamond anvil cell experiments, we identified a new pathway where graphite transforms into hexagonal diamond via "post-graphite phase" upon heating, applicable to both single-crystal and nanoscale graphite precursors. By integrating a self-developed large-volume press with thermally heterogeneous assemblies, we exploited temperature gradients under pressure to achieve the first bulk synthesis of high-quality hexagonal diamond. Second, a novel (6-8-2) high-pressure assembly incorporating uniaxial force enabled the conversion of highly oriented pyrolytic graphite into pure-phase, millimeter-sized hexagonal diamond under milder conditions (lower pressure/temperature). The synthesized hexagonal diamond exhibits a hardness exceeding natural cubic diamond by >40% and remarkable thermal stability. These breakthroughs establish effective routes for hexagonal diamond fabrication, expanding the family of superhard materials and offering alternatives to overcome cubic diamond's application limitations. Furthermore, this work provides critical insights into the origins of meteoritic diamonds and geological processes involving extreme conditions.

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KEYWORDS
High pressure, Hexagonal diamond, Cubic diamond, Superhard materials, Graphite

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Magnon Structure around Skyrmions

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ABSTRACT
Magnon eigenstates around isolated skyrmions develop complex localization patterns through coherent interference of degenerate eigenstates. We study this effect numerically in frustrated and chiral magnets, and identify two distinct classes: magnon superlattices and multifractal magnons. The former are crystal-like structures found in frustrated magnets, where an underlying 'Mexican-hat' type dispersion encodes a characteristic magnon length scale closely matching the skyrmion size. The latter are self-similar magnon structures emerging in the large-lattice limit of both platforms. We demonstrate that these patterns can be dynamically generated and sustained through AC field activation of the localized skyrmion modes with which the extended magnons hybridize. Our findings constitute a novel mechanism by which complex and observable structures dynamically emerge in magnetic systems.

REFERENCE STYLE
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A. Hullahalli, C. Panagopoulos, and C. Psaroudaki, Multifractal Magnons around Magnetic Skyrmions (2026), manuscript in preparation.

KEYWORDS
Condensed matter physics, magnonics, magnetic skyrmions

Substituted Bi induced localized defect state in $CrTe_3$

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ABSTRACT

Two-dimensional (2D) ferromagnets have attracted significant attention owing to their potential applications in spintronics, magnonics, and spin-orbitronics. Among them, ultrathin $CrTe_3$ has been theoretically predicted to be a van der Waals antiferromagnetic semiconductor with intrinsic intralayer antiferromagnetic ordering. However, the regulation of its electronic properties remains insufficiently explored. In this work, few layer $CrTe_3$ films were fabricated on HOPG by molecular beam epitaxy, followed by Bi deposition and thermal annealing. Scanning tunneling microscopy (STM) revealed distinct bright dot-like features on the $CrTe_3$ surface after annealing. By combining STM with density functional theory calculations, the type-I bright dots were identified as Bi atoms substituting Te atoms in the topmost Te layer. Scanning tunneling spectroscopy further revealed bandgap narrowing and a pronounced peak near the Fermi level in the vicinity of the substituted Bi sites, indicating the emergence of a localized defect state. These findings demonstrate that Bi substitution can effectively modulate the local electronic structure of $CrTe_3$, offering a potential route for tuning its antiferromagnetic properties and designing functional 2D magnetic materials.

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KEYWORDS

2D materials, chromium telluride, defect state, scanning tunneling microscopy/spectroscopy

Deterministic Manipulation of Structural Variants in Freestanding Antiferroelectric Membranes

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ABSTRACT

Antiferroelectric materials, characterized by antiparallel dipole moments that cancel net polarization and exhibit distinct phase-transition behavior, hold strong potential for applications in actuators, sensors, and high-power capacitors. However, achieving deterministic control of structural variants in perovskite antiferroelectrics remains a major challenge. In this talk, we introduce electron-beam irradiation and optical illumination as complementary approaches for reversibly switching structural variants in freestanding $PbZrO_3$ membranes, enabling spatially selective and energy-tunable manipulation at room temperature. Using in-situ TEM, we directly visualize electron-beam–driven structural transitions, supported by phase-field simulations that reveal localized electric fields from beam–membrane interactions. Optical illumination provides an additional degree of control, stabilizing or dynamically modifying domain configurations through light–matter coupling. Our findings reveal a synergy between screening charges and optical stimuli that enables deterministic structural transformations in freestanding membranes. This precise control of domain states offers key insights into antiferroelectric phase transitions and provides an effective route for tuning functional responses in complex oxide systems.

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KEYWORDS

Freestanding membrane, complex oxide, antiferroelectric, epitaxy, thin film

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HIGH-THROUGHPUT COMPUTATIONAL SCREENING OF TWO-DIMENSIONAL MONOLAYER MATERIALS FOR EXCITONIC BOSE-EINSTEIN CONDENSATION.

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ABSTRACT

Excitons or electron-hole pairs bound by long range Coulomb interactions, exhibit exceptionally high binding strengths in 2D materials due to reduced electrostatic screening. These bosonic particles can undergo quasi-condensation marked by the Berezinskii–Kosterlitz–Thouless (BKT) transition to a coherent "condensate" phase, exhibiting superfluidity below the condensation temperature Tc. Their enhanced interaction strengths are suitable for achieving larger Tc values, making them potential candidates for achieving superfluidity at room temperature. Momentum-direct excitons are better suited for achieving the sharply-peaked zero momentum distribution and phase coherence of the condensate. The low radiative lifetime of the excitons can still act as a bottleneck for achieving condensation. In this study, we perform high-throughput search of the 2Dmatpedia and the Materials project database to screen for 2D materials which can host, optically generated, momentum-direct, long-lived excitons. For the selected 2D materials, we perform state-of-the-art GW-BSE calculations including spin-orbit coupling interactions, to obtain the excitonic size and lifetimes. Using a dilute boson gas model, we identify 2D materials with low-energy excitons which can achieve the superfluid transition at temperatures close to room temperature.

KEYWORDS

Exciton condensation, superfluidity, GW-BSE, high-throughput material screening, room-temperature condensation.

Universality of the Holographic Principle in Induced Horizons: Quantum Causal Penetration and Topological Corrections

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ABSTRACT
The holographic area law is fundamentally linked to the nature of spacetime. In this talk, we demonstrate the universality of the holographic principle by inducing causal horizons in simple strongly correlated many-body systems. Using DMRG simulations of the Antiferromagnetic Heisenberg model, we show that an area law emerges as a dynamical consequence of local interaction enhancement.
We report the discovery of "Quantum Causal Penetration": a phenomenon where global topological constraints (spin parity) force persistent long-range entanglement across these induced horizons. While even-sized subsystems exhibit strict area laws and causal isolation, odd-sized systems manifest a robust ln2 topological correction and residual mutual information ($I \approx 2$). These findings provide direct micro-numerical evidence for topological black hole entropy and support the "ER=EPR" conjecture. Our results suggest that spacetime geometry acts as a robust quantum error-correcting code, where global logical protocols can override local causal barriers.

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Universality of the Holographic Principle in Induced Horizons: Quantum Causal Penetration and Topological Corrections, *To be submitted*, X. Ming, Q.-y.~Cai.

KEYWORDS
Holographic Principle, Area Law Entropy, Quantum Causal Penetration

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Ordered and tunable Majorana-zero-mode lattice in iron-based superconductors

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ABSTRACT

Majorana zero-modes (MZMs) are spatially-localized zero-energy fractional quasiparticles with non-Abelian braiding statistics. They are believed to hold great promise for topological quantum computing. By using low-temperature and strong-magnetic-field scanning tunneling microscopy/spectroscopy, a breakthrough of Majorana zero mode has been firstly achieved in a single material platform of high-T_c iron-based superconductor, $FeTe_{0.55}Se_{0.45}$. The mechanism of two distinct classes of vortices presented in this system was revealed, which directly tied with the presence or absence of zero-bias peak. We further found the Majorana conductance plateau in vortices. Both the extrinsic instrumental convoluted broadening and the intrinsic quasiparticle poisoning can reduce the conductance plateau value, and when extrinsic instrumental broadening is removed by deconvolution, the plateau nearly reaches a $2e^2/h$ quantized value. Moreover, we confirmed the existence of MZMs in the vortex cores of $CaKFe_4As_4$ and LiFeAs. Based on these works mentioned above, most recently, we have successfully achieved the large-scale, highly-ordered and tunable MZM lattice in strained LiFeAs. Notably, more than 90% of the vortices are topological and possess the characteristics of isolated MZMs at the vortex center, forming ordered MZM lattice with the density and the geometry tunable by external magnetic field. With decreasing the spacing of neighboring vortices, the MZMs start to couple with each other. This kind of materials combine the advantages of a simple material, high- T_c, large ratio of Δ/E_F and etc. Our results show a great potential of MZMs in the application of topological quantum computations in the future.

ABSTRACT TOPIC

Topological Matter

KEYWORDS

Majorana zero modes, Topological superconductivity, Iron-based superconductors

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FROM TRIMERS TO CHAINS: GROWTH AND DEFECT DYNAMICS IN ANISOTROPIC TELLURIUM FILMS

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ABSTRACT

Thin films of tellurium (Te) are fundamentally built from one-dimensional (1D) helical atomic chains, and it exhibits semiconducting properties that are tunable with dimensionality. The repeating structural motif within these chains is a triangular arrangement of three Te atoms, referred to as a trimer, which contributes to the overall helical geometry. Using scanning tunneling microscopy (STM), we investigated the layer-dependent changes in electronic structure of these trimer units. In monolayer and bilayer Te grown on Au(100), we observed defects characterized by multiples of trimer vacancy clusters. In contrast, for thicker films, such isolated trimer-vacancies are replaced by 1D chains of missing row atoms or 1D edge dislocations. The propensities to form such vacancies and edge dislocations contribute to *p*-type semiconducting characteristics. These defects are segregated at the surface and ALD deposition of amorphous Al_2O_3 on the surface was found to induce surface transfer doping that converted the *p*-type to *n*-type characteristics.

KEYWORDS

tellurium, scanning tunneling microscopy, trimer vacancy clusters, edge dislocations, n-type transition

Anomalous Narrow-band Correlation in a Natural Superconducting Heterostructure

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ABSTRACT

A new frontier in condensed matter physics is to stack atomically thin layered-materials with different properties and create intriguing phenomena which do not exist in any of the constituent layers. Transition metal dichalcogenide 4Hb-TaS_2, with an alternating stacking of a spin liquid candidate 1T-TaS_2 and a superconductor 1H-TaS_2, is a natural heterostructure for such a purpose. Recently, rare phenomena are indeed observed, including chiral superconductivity, two-component nematic superconductivity, topological surface superconductivity and enigmatic magnetic memory. A widely proposed starting point to understand such a mysterious heterostructure requires strong electronic correlation, presumably provided by 1T-TaS_2 layers with a narrow flat band near the Fermi level (E_F). Here, by using angle-resolved photoemission spectroscopy, we reveal the theoretically expected flat band near E_F in the energy-momentum space. However, this flat band only exists on the 1T-TaS_2 terminated surface layer with broken translational symmetry, but not on the 1T-TaS_2 layers buried in the bulk. These results directly challenge the foundation of the current theoretical paradigm. On the 1T-TaS_2 terminated surface layer, we further reveal a pseudogap and an anomalous doping effect. These phenomena and the dichotomy between surface and bulk layers also shed new light on the unusual coexistence of distinct electronic orders in this mysterious heterostructure.

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KEYWORDS

Electronic structure, Charge density waves, Flat bands, Angle-resolved photoemission spectroscopy

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SUBSTRATE-DEPENDENT PHOTOLUMINESCENCE MODULATION IN PEROVSKITE/MONOLAYER WS_2 HETEROSTRUCTURES

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ABSTRACT
We report a substrate-dependent reversal of photoluminescence in mixed-dimensional perovskite/monolayer WS_2 heterostructures. In our structure, a ML-WS_2 flake partially overlaps with a halide perovskite region, enabling direct comparison between the heterostructure and adjacent bare-WS_2 regions within the same flake. Under 532nm laser excitation, the WS_2 in heterostructure on Si exhibits markedly enhanced emission relative to bare WS_2 on the same substrate, whereas the opposite trend is observed on SiO_2, where the WS_2 in heterostructure becomes quenched.
This contrasting behavior cannot be explained by the perovskite/WS_2 interface alone. Instead, it indicates that the substrate plays a decisive role in setting the electronic boundary conditions of the heterostructure. Kelvin probe force microscopy reveals a significant surface potential difference between bare WS_2 on the silicon substrate and WS_2 on the perovskite/silicon substrate, suggesting that the perovskite/silicon stack significantly reconstructs the local electrostatic environment of the WS_2. Therefore, we attribute the enhanced emission on the Si substrate to substrate-assisted charge redistribution, which shifts the exciton equilibrium in WS_2 towards a more luminescent state; while on the SiO_2 substrate, interface quenching channels of perovskite dominate. Our results show that the optical response of perovskite/TMDC heterostructures is governed not only by the immediate van der Waals interface, but also by the substrate. These findings establish bottom-interface control as a strategy for engineering excitonic emission and interfacial charge states in mixed-dimensional optoelectronic heterostructures.

KEYWORDS
Halide perovskite, Heterostructures, Charge redistribution, Substrate-mediated photoluminescence

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Electronic structures across superconductor-insulator transition in Ruddlesden-Popper bilayer nickelate films

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ABSTRACT

High-transition-temperature (T_C) superconductivity is recently discovered in Ruddlesden-Popper (RP) nickelate films with extraordinarily strong oxidation. While investigating phase diagrams is essential for uncovering the superconducting mechanism, the oxygen-tuned superconductor-insulator transition (SIT) in RP nickelates differs fundamentally from that in cuprates or iron-based systems. Here, we unveil the evolution of electronic structure in RP bilayer nickelate thin films across the SIT, combining angle-resolved photoemission spectroscopy (ARPES) and X-ray absorption spectroscopy (XAS) for both occupied and unoccupied states. In the

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superconducting state, a coherent quasiparticle band near Fermi level (E_F) coexists with an incoherent waterfall feature at high energy, paralleling that in cuprates. Approaching the insulating state with oxygen deficiency, the spectral weight of the occupied coherent quasiparticle band is gradually suppressed, accompanied by pronounced density of states redistribution and orbital reconfiguration in unoccupied states. These results reveal the electronic origin of the SIT in the phase diagram, which transcends carrier doping effects and oxygen vacancy states. Our findings point to a decisive role of oxygen in shaping the essential electronic landscape of RP bilayer nickelates, offering crucial insights into the superconducting mechanism.

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KEYWORDS
Nickelate thin films, Superconductor-insulator transition, Oxygen stoichiometry, Electronic structure, ARPES

TROTTER SCARS: TROTTER ERROR SUPPRESSION IN QUANTUM SIMULATION

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ABSTRACT
Recent studies have shown that Trotter errors are highly initial-state dependent and that standard upper bounds often substantially overestimate them. However, the mechanism underlying anomalously small Trotter errors and a systematic route to identifying error-resilient states remain unclear. Using interaction-picture perturbation theory, we derive an analytical expression for the leading-order Trotter error in the eigenbasis of the Hamiltonian. Our analysis shows that initial states supported on spectrally commensurate energy ladders exhibit strongly suppressed error growth together with persistent Loschmidt revivals. We refer to such states as *Trotter scars*. To identify such states in practice, we further introduce a general variational framework for finding error-minimizing initial states for a given Hamiltonian. Applying this framework to several spin models, we find optimized states whose spectral support and dynamical behavior agree with the perturbative prediction. Our results reveal the spectral origin of Trotter-error resilience and provide a practical strategy for discovering error-resilient states in digital quantum simulation.

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KEYWORDS
Digital quantum simulation, Trotter error, Quantum many-body scars, Loschmidt echo, Variational optimization

Nodeless superconducting gap and electron-boson coupling in $(La,Pr,Sm)_3Ni_2O_7$ films

Jianchang Shen[1†], Guangdi Zhou[2†], Yu Miao[1,3†], Peng Li[2,4†], Zhipeng Ou[1,3,5†], Yaqi Chen[2], Zechao Wang[2], Runqing Luan[1,3,5], Hongxu Sun[1,3,5], Zikun Feng[1,3,5], Xinru Yong[1,3,5], Yueying Li[2], Lizhi Xu[2], Wei Lv[2], Zihao Nie[2], Heng Wang[2,4], Haoliang Huang[2,4], Yu-Jie Sun[2,4], Qi-Kun Xue[2,4,6]*, Junfeng He[1,3,5]*, Zhuoyu Chen[2,4]*

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ABSTRACT [*major heading style: Bold 12 pt, UPPERCASE*]
The discovery of superconductivity in Ruddlesden-Popper (RP) bilayer nickelate films under ambient pressure provides an opportunity to directly investigate electronic energy scales of the superconducting state and the pairing mechanism. We report angle-resolved photoemission spectroscopy measurements of superconducting $(La,Pr,Sm)_3Ni_2O_7$ thin films by developing an ultra-high vacuum cryogenic sample quenching and transfer technique. A superconducting gap of ~18 meV with coherence peaks is observed along the Brillouin zone diagonal. The finite gap persists across the entire Brillouin zone, revealing the absence of gap nodes. A kink is observed in the energy-momentum dispersion at ~70 meV below Fermi level, indicating an electron-boson coupling. The simultaneous observation of a nodeless superconducting gap and electron-boson coupling provides insight into the pairing symmetry and gluing mechanism in RP bilayer nickelates.

REFERENCE STYLE

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KEYWORDS
Nickelates, Superconducting gap, Electron-boson coupling

Redefining the Limits of Thermal Transport: Extreme Materials and Emergent Phonon Physics

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ABSTRACT

What ultimately limits heat conduction in solids — and can those limits be engineered, controlled, or even surpassed? Thermal transport lies at the foundation of modern technologies ranging from microelectronics, quantum systems, and AI hardware to thermoelectrics and energy platforms operating under extreme conditions. Yet many conventional assumptions regarding thermal conductivity and phonon transport are now being fundamentally challenged by emerging materials and nonequilibrium transport phenomena. This talk will present our recent advances that redefine the boundaries of thermal transport through the discovery of extreme thermal materials and engineered phonon physics across diffusive, tunneling, and wave-like regimes.

I will first discuss the development of ultrahigh-thermal-conductivity boron arsenide (BAs), where unconventional lattice dynamics and strongly suppressed phonon scattering enabled record thermal conductivity among semiconductors. More recently, we discovered θ-phase tantalum nitride (θ-TaN), a metallic material exhibiting thermal conductivity approaching three times that of copper, enabled by exceptionally weak electron-phonon interactions and reduced anharmonicity. Beyond extreme thermal conductivity, I will discuss phonon transport beyond classical diffusion, including phonon tunneling across ultrathin interfaces and electrically controlled nonequilibrium thermal transport. Finally, I will explore emerging opportunities in low-dimensional and twisted materials, including twisted graphene systems, where moiré engineering and coherence effects may enable wave-like phonon propagation and new quantum transport regimes.

Together, these advances establish a broader framework for controlling heat flow through lattice dynamics, interfaces, disorder, and dimensionality, opening new directions for condensed-matter physics, electronics thermal management, energy conversion, and future quantum and energy technologies.

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KEYWORDS
Thermal transport, Phonon engineering, Extreme materials, Quantum heat transport, Twisted graphene

Two-dimensional transition metal dichalcogenides (TMDs) like 2H-$TaSe_2$ have attracted considerable interest due to the intricate interplay between charge density wave (CDW) order and superconductivity (SC). While hydrostatic pressure studies on 2H-$TaSe_2$ have reported CDW suppression and SC emergence up to ~12.5 GPa, the non-hydrostatic pressure effect remains largely unexplored. Here, we systematically investigate the evolution of CDW and SC in single-crystal 2H-$TaSe_2$ under non-hydrostatic compression up to 30 GPa using in-situ X-ray diffraction (XRD) and Raman spectroscopy. Our results reveal a previously unreported phenomenon: beyond a critical pressure, the crystalline order is gradually destroyed, and the sample undergoes a quenchable amorphous transition. Remarkably, this amorphous phase exhibits robust superconductivity, as evidenced by the disappearance of CDW-related signatures and the emergence of a superconducting ground state. To the best of our knowledge, this is the first observation of quenchable amorphous superconductivity in a two-dimensional TMD material under high pressure. Our findings open a new pathway for designing amorphous superconductors and understanding the unconventional relationship between structural disorder and superconductivity in low-dimensional systems.

Poor Man’s Majorana Modes in Quantum Dot–Superconductor Hybrid Systems: Finite-Length Effects and Superconducting Dressing

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ABSTRACT

Poor Man’s Majorana modes (PMMs) in quantum-dot–superconductor hybrid systems provide a minimal and tunable platform for exploring Majorana physics. Recently, many experimental signatures potentially associated with PMMs have been reported, which has stimulated extensive theoretical studies. Here we develop a microscopic description that treats the quantum-dot and superconducting quasiparticle degrees of freedom on an equal footing, instead of integrating out the superconductor. We focus on the finite-length effect of the superconducting segment and show that it strongly modifies both local and nonlocal couplings induced between the quantum dots[2]. As a result, the number of PMMs depends sensitively on the superconductor length and oscillates between zero and two in finite-length devices. We further show that strictly end-localized PMMs do not exist for finite superconducting length; only nearly localized modes can appear in the strong-magnetic-field regime. In the long-superconductor limit[1], the corresponding dressed PMM result is naturally recovered. These results provide a unified microscopic description of PMMs in realistic devices and clarify the crucial roles of finite-size effects and superconducting dressing in their emergence and observability.

REFERENCE STYLE

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KEYWORDS

Poor Man’s Majorana, finite-length effects, superconducting dressing, quantum dots, hybrid superconductors

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Autferroicity: physics & materials

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ABSTRACT

Primary ferroicities like ferroelectricity and ferromagnetism are essential physical properties of matter. Multiferroics, with coexisting multiple ferroic orders in a single phase, provide a convenient route to magnetoelectricity. Even so, the general trade off between magnetism and polarity remains inevitable, which prevents practicable magnetoelectric cross-control in the multiferroic framework. In this talk, I will introduce an alternative strategy, i.e., the so-called autferroicity (originally named alterferroicity), to circumvent the magnetoelectric exclusiveness, which exhibits multiple but noncoexisting ferroic orders. The natural exclusion between magnetism and polarity, as an insurmountable weakness of multiferroicity, becomes a distinct advantage in autferroicity, making it an inborn rich ore for intrinsic strong magnetoelectricity. The general design rules for autferroic materials rely on the competition between the instabilities of phononic and electronic structures in covalent systems. Based on primary density functional theory calculations, Ti-based trichalcogenides are predicted to be autferroic candidates, which exhibit unique seesaw-type magnetoelectricity. Furthermore, the autferroicity and multiferroicity, can be uniformed within the framework of Laudau theory.

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KEYWORDS

Autferroicity, seesaw-type magnetoelectricity, dual instabilities, ferroic phase separation, Laudau theory

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Phonon Transport in Low-Dimensional Systems

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ABSTRACT

Nanoscale heat conduction has attracted substantial recent interests due to both the technological importance of thermal management in nanoelectronic devices and the scientific merits of novel transport physics. In this talk, I will present the recent theoretical advances in my group on the phonon transport in low-dimensional systems from the following three aspects. First, I shall discuss the novel phonon transport mechanisms, including phonon hydrodynamics, and coherent heat conduction theory. Then, I will discuss the interfacial heat transfer mechanisms in 2D heterogeneous systems, such as the twist angle effect in solid-solid interfaces and surface microstructure modifications in solid-liquid interfaces. In particular, I will demonstrate the power of atomic level simulations in probing the novel interfacial phenomena different from the bulk case. Finally, potential applications of phononic metamaterials will also be demonstrated. Our work paves the theoretical foundation for studying phonon transport in low-dimensional materials.

KEYWORDS

Phonon transport mechanism, low-dimensional materials, heat conduction, interfacial thermal resistance

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Emergent Caloric Materials

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ABSTRACT

Refrigeration technology serves as a fundamental pillar of modern human civilization. The refrigeration materials field currently confronts two critical challenges: developing low-carbon, high-efficiency room-temperature refrigeration materials and advancing helium-free ultra-low temperature refrigeration solutions. Addressing the first challenge, we have demonstrated a colossal barocaloric effect in plastic crystals driven by pressure-induced orientational order-to-disorder transitions [1]. More recently, we extended classical caloric effects to solution systems, proposing a dissolution barocaloric effect in aqueous NH_4SCN solutions that originates from pressure-induced precipitation [2]. A comprehensive overview of novel materials and proof-of-principle refrigerators will be presented in detail. For the second challenge, we have developed ferromagnetic magnetocaloric materials: $LiHoF_4$ for 4 K refrigeration applications and NH_4GdF_4 for sub-Kelvin temperature ranges. Both materials demonstrate performance significantly surpassing the benchmark $Gd_3Ga_5O_{12}$ [3]. These discoveries establish promising pathways toward sustainable refrigeration technologies that simultaneously address environmental imperatives and resource scarcity constraints, while advancing the fundamental understanding of caloric effects across diverse material systems and operational temperature ranges.

REFERENCE STYLE

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KEYWORDS

Caloric effect, Disorder, Phase transition, High pressure

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Resonance Suppression Principle for Prethermalization beyond Periodic Driving

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ABSTRACT

A closed quantum many-body system subjected to time-dependent external driving generally undergoes unbounded energy absorption. However, the intermediate non-equilibrium dynamics leading to thermalization is poorly understood, especially for strongly non-periodically driven systems. While periodically driven systems are known to display exponentially slow heating with respect to drive frequency, called Floquet Prethermalization, a variety of non-periodic drives have been found to produce widely different heating rate scalings, with no clear unifying framework. In this work, I explain how a simple frequency domain `resonance-suppression principle' unifies scaling laws, by distinguishing two complementary spectral properties: (i) Suppressed single-photon processes, quantified by the degree of suppression of the drive's Fourier Transform near the origin and (ii) Suppressed multi-photon processes, requiring exceptional arithmetic spectral structure to prevent resonances in the non-linear regime. Remarkably, by a Fer Expansion analysis, if property (ii) is satisfied, heating rates are solely determined by property (i), greatly simplifying the theory of prethermalization and revealing structure not apparent in conventional Magnus Expansion approaches. To illustrate the principle's applications, I (I) Classify existing drives into one of three `Prethermal Universality Classes' to resolve inconsistencies in previous literature, and (II) Provide new examples of `Factorial Drives', which are well-behaved and non-periodic in the time-domain, yet possess a factorial spectrum arithmetic structure enabling prethermalization. This work reframes the search for nonperiodic prethermal phases in programmable quantum simulators as a problem of spectral arithmetic design. In this sense, arithmetic plays a role analogous to organizing principles such as symmetry and topology in many-body physics: arithmetic isolates structural constraints that enable far-from-equilibrium stability classes across disparate microscopic realizations.

REFERENCE STYLE

Resonance Suppression Principle for Prethermalization beyond Periodic Driving, *in preparation. (will arXiv before talk)*

KEYWORDS

Many-body Dynamics, Non-equilibrium Physics, Quantum Ergodicity-breaking, Quantum Technologies, Programmable Quantum Simulators

TOWARD COMPLETING THE PHASE DIAGRAM OF HIGH-Tc CUPRATE SUPERCONDUCTORS

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ABSTRACT

Despite four decades of research on high-Tc cuprate superconductors, a complete understanding of their physics remains elusive. In particular, the establishment of the global phase diagram has been hindered by the observation of various orders. In this talk, I am going to show you that a quantum critical point (QCP) that is buried under the superconducting dome is potentially responsible for the observed various orders. The existence of this QCP is confirmed by the scaling analysis on the dynamical charge-charge correlation obtained by using the high-resolution resonant inelastic X-ray scattering [1]. In particular, it shows that the QCP appears to be in the universality class characterized by the O(4) symmetry. Furthermore, by using the renormalized mean-field theory, we solved the phase diagram of density waves for the t-J model. It indicates that the O(4) critical point results from the vanishing of the order parameter composed by the charge density wave (CDW) and pair density wave (PDW). Furthermore, the CDW order $n(\mathbf{Q})$ and PDW order $\Delta(\mathbf{Q})$ generally prevail in the phase diagram with $\mathbf{Q}$ being either $(\pm\pi/2,0)$, $(0,\pm\pi/2)$, $(\pm\pi/4,0)$, or $(0,\pm\pi/4)$. Our results provide a complete phase diagram for high-Tc cuprate superconductors.

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KEYWORDS

cuprate superconductors, phase diagram, quantum critical point, charge density wave, pair density wave

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Superfluid density wave as one kind of orbital-FFLO states

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ABSTRACT

A sufficiently strong parallel magnetic field between two weakly coupled superconducting ultrathin films produces staggered supercurrent loops and a superfluid density wave, yielding an inhomogeneous Fulde-Ferrell Larkin-Ovchinnikov (FFLO) state characterized by Josephson vortex-antivortex pairs. Conversely, a weak parallel magnetic field produces a uniform Fulde-Ferrell (FF) state. The transition between these states falls into the universality class of 2D commensurate-incommensurate transitions.

REFERENCE STYLE

KEYWORDS

Superconductivity

PHYSICS-GUIDED AND INTERPRETABLE MACHINE LEARNING FOR MATERIALS PROPERTY PREDICTION

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ABSTRACT

Machine learning has become increasingly influential in materials design. Yet a persistent challenge remains: predictive models often lack interpretability, and their outputs are difficult to connect to underlying physical mechanisms. An important question, therefore, is whether data-driven approaches can maintain high predictive accuracy while remaining grounded in physical insight.

In this talk, I will present two case studies spanning different physical scales—from microscopic electronic structure to macroscopic mechanical response.

First, in two-dimensional perovskites, we start from the physics of local symmetry breaking and spin-orbit coupling. By identifying a small set of structurally meaningful distortion descriptors, we establish a direct mapping between crystal distortions and frontier band spin splitting using a neural network model. The approach requires only a limited number of low-cost first-principles samples, yet remains effective for complex hybrid systems.

Second, for inorganic mechanical properties, we begin from basic physical quantities such as atomic volume, electronic filling, and structural compactness. By combining physics-informed feature engineering with symbolic regression, we construct interpretable models and extract explicit analytical expressions. These compact formulas provide experimental researchers with a simple and fast predictive tool, enabling rapid estimation without relying on complicated calculations.

Through these two examples, we argue that, at the present stage, machine learning does not replace physical theory. Rather, when guided by physical mechanisms, it serves as a tool for identifying low-dimensional and physically meaningful descriptors, thereby accelerating materials property prediction and design.

ABSTRACT TOPIC: Condensed Matter & Materials Physics

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KEYWORDS
Machine learning, Materials property prediction, First-principles, Electronic structure, Mechanical properties

Title of the paper

Symmetry-protected control of Liouvillian topological phases via Hamiltonian band topology

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ABSTRACT

We establish a symmetry-protected correspondence between band topology of coherent Hamiltonians and Liouvillian spectral winding of open quantum systems with quadratic dissipations. This allows the Hamiltonian topology to act as a knob for controlling Liouvillian topology and corresponding non-equilibrium dynamics, rather than being passively manipulated by system-environment exchanges. In particular, by exactly solving the Liouvillian spectrum in a class of one-dimensional dissipative lattices, we find that the Hamiltonian band topology constrains the Liouvillian spectral winding and determines the Liouvillian skin effect, provided the Hamiltonian and quantum jump operators respect the same chiral symmetry. We further demonstrate that lattice parity controls the associated bulk-boundary correspondence and the coherence properties of the steady state. Our results unveil a symmetry-enforced topological control of spectral and spatial organization in open quantum systems, providing a unified perspective on topology in Hamiltonian and dissipative dynamics.

REFERENCE STYLE

Symmetry-protected control of Liouvillian topological phases via Hamiltonian band topology, *arXiv:2602.22323*, 2026, S. Long， Hong-Sen Yin, Chao Yang, Sen Mu, Jia-Wei Zhang, and Linhu Li

KEYWORDS

Topological phases, bulk-boundary correspondence, open quantum systems, Liouvillian skin effect

Indication of time-reversal symmetry breaking superconductivity in Kagome CsV_3Sb_5

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ABSTRACT

The interplay among frustrated lattice geometry, non-trivial band topology and correlation yields rich quantum states of matter in Kagome systems. A series of recent members in this family, AV_3Sb_5 (A = K, Rb or Cs), exhibits a cascade of symmetry-breaking transitions, involving the chiral charge ordering, electronic nematicity, pair density wave and superconductivity. The nature of the superconducting (SC) order is still under debate. Here we report an indication of time-reversal symmetry-breaking (TRSB) SC domains in intrinsic CsV_3Sb_5 flakes. The magnetic field-free SC diode effect is observed with polarity modulated by thermal histories, suggesting dynamic SC order domains in a spontaneous TRSB background. Strikingly, the critical current exhibits double-slit SC interference patterns when subjected to an external magnetic field. The characteristics of patterns are modulated by thermal cycling. These phenomena are proposed as a consequence of periodically modulated supercurrents flowing along certain domain boundaries constrained by fluxoid quantization. Recently, thermally modulated d.c. and a.c. Josephson effects are observed in intrinsic CsV_3Sb_5 flakes, strongly suggesting the presence of dynamic SC domains with weak links at domain boundaries. All these observations fall into the framework of chiral SC domain network, offering new insights into the SC nature of Kagome systems [1-3].

REFERENCE STYLE

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KEYWORDS

Kagome superconductors, Superconducting diode effect, Superconducting interference effect, Time-reversal symmetry breaking

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Cooper-pair density modulation state in an iron-based superconductor

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ABSTRACT

Superconducting (SC) states that break space-group symmetries of the underlying crystal can exhibit nontrivial spatial modulation of the order parameter. Previously, such states were intimately associated with the breaking of translational symmetry, resulting in the density-wave orders, with wavelengths spanning several unit cells. However, a related basic concept has long been overlooked: when only intra-unit-cell symmetries of the space group are broken, the SC states can show a distinct type of nontrivial modulation preserving long-range lattice translation. Here we refer to this new concept as the pair density modulation (PDM) and report the first observation of a PDM state in exfoliated thin flakes of the iron-based superconductor $FeTe_{0.55}Se_{0.45}$. Using scanning tunnelling microscopy (STM), we discover robust SC gap modulation with the wavelength corresponding to the lattice periodicity and the amplitude exceeding 30% of the gap average. Notably, we find that the observed modulation originates from the large difference in SC gaps on the two nominally equivalent iron sublattices. The experimental findings, backed up by model calculations, suggest that, in contrast to the density-wave orders, the PDM state is driven by the interplay of sublattice symmetry breaking and a peculiar nematic distortion specific to the thin flakes. Our results establish new frontiers for exploring the intertwined orders in strong-correlated electronic systems and open a new chapter for iron-based superconductors.

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KEYWORDS

Strong-correlated superconductor, Intertwined order, Gap modulation, Scanning tunneling spectroscopy, Two-dimensional heterostructure.

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Nonreciprocal superconducting critical currents with normal state field trainability in kagome superconductor CsV_3Sb_5

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ABSTRACT

Determining time-reversal symmetry (TRS) and chirality in the superconducting state and its relation to the symmetry and topology in the normal state are important issues in modern condensed matter physics. Here, we report the observation of nonreciprocal superconducting critical currents (I_c) at zero applied magnetic field: I_c exhibits different values in opposite directions, in both flakes and micro-bridges of the kagome superconductor CsV_3Sb_5 [1]. Such spontaneous nonreciprocity requires TRS and inversion symmetry breakings. We find that the direction of asymmetry changes randomly in repeated sample heating to 300 K and cooling into the zero-resistance state, consistent with the expected behavior arising from spontaneous TRS breaking. Crucially, on applying a perpendicular magnetic field at 300 K, above the charge density wave (CDW) transition at T_{CDW} in this compound and removing it to zero above the superconducting onset critical temperature (T_c), the direction of the I_c asymmetry consistently flips on changing the direction of the field. This magnetic field training ascertains that the CDW state above the superconducting transition temperature may also break the Z_2 TRS and has a macroscopic directionality which can be changed by a uniform training field. The symmetry breaking continues into the superconducting state and gives rise to the nonreciprocal superconducting critical currents. These results indicate the loop-current CDW normal state with topological features in CsV_3Sb_5. Our observations provide direct evidence for the TRS breaking in kagome superconductor CsV_3Sb_5, and offer new insights into the mechanism of TRS breaking in kagome superconductors.

1. Nonreciprocal superconducting critical currents with normal state field trainability in kagome superconductor CsV_3Sb_5, arXiv:2506.04601, 2025, Jun Ge#, Xiaoqi Liu#, Pinyuan Wang, Haowen Pang, Qiangwei Yin, Hechang Lei, Ziqiang Wang, Jian Wang*.

KEYWORDS

kagome superconductors, time-reversal symmetry breaking, nonreciprocal superconducting critical currents, magnetic field training

Topological pair density wave

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ABSTRACT

The pair density wave (PDW) is an unconventional superconducting state exhibiting periodic pairing modulations due to pairing with finite momentum Q. In two dimensions, multiple Q components of the PDW can have a non-trivial relative phase, breaking time-reversal symmetry and resulting in a topological electronic structure. In this talk, I will discuss the progress on exploring such topological PDWs (TPDWs) and their potential realization in kagome superconductors. I first introduce the concept of a TPDW starting from the Fulde-Ferrell-Larkin-Ovchinnikov state and examine the challenges toward its realization. I then discuss a possible TPDW in the kagome lattice, which intertwines with chiral superconductivity and loop currents, thus connecting to models describing the quantum anomalous Hall effect. Furthermore, I will discuss the experimental signatures of TPDW in AV_3Sb_5 (A=Cs, Rb, K) superconductors and highlight related quantum effects, including switchable chiral pairing modulations, Bogoliubov Fermi states, the superconducting diode effect, and the anomalous thermal Hall effect. Finally, I project the future research opportunities of this correlated topological quantum phase and discuss its broad implications for finite-momentum pairing, topological matter, and chiral superconductivity.

KEYWORDS

Kagome superconductivity, Pair density wave, topological matter

Non-reciprocal control of the speed of light

Can-Ming Hu

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ABSTRACT

Cavity Magnonics is an emerging field studying the light-matter interactions involving cavity photons and magnons [1]. Via the quantum physics of spin-photon entanglement on the one hand, and classical electrodynamic coupling on the other, this field connects some of the most exciting modern physics, such as quantum information and quantum optics, with one of the oldest science on the earth, the magnetism.

In this talk, I will focus on the nonreciprocal physics of cavity magnonics, which has enabled unidirectional microwave transmission [2] and non-reciprocal control of the speed of light [3].

REFERENCE

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[2] Nonreciprocity and Unidirectional Invisibility in Cavity Magnonics, *Phys. Rev. Lett.*, **123**, 127202, 2019, Yi-Pu Wang, J.W. Rao, Y. Yang, Peng-Chao Xu, Y.S. Gui, B.M. Yao, J. Q. You, and C.-M. Hu.
[3] Nonreciprocal Control of the Speed of Light Using Cavity Magnonics, *Phys. Rev. Lett.*, **134**, 196904, 2025, Jiguang Yao, Chenyang Lu, X.L. Fan, D.S. Xue, Greg E. Bridges, C.-M. Hu.

KEYWORDS

Light-matter interaction, Cavity magnon, Slow light, Fast light, Nonreciprocity

Error-resilient Reversal of Quantum Chaotic Dynamics Enabled by Scramblons

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ABSTRACT

Drawing inspiration from gravity and solvable SYK-type models, recent developments in the study of information scrambling have identified the scramblon, a novel collective excitation in quantum many-body systems with all-to-all connectivity, as the fundamental carrier of scrambling dynamics. In this talk, I will present our recent collaboration with the experimental group at USTC, demonstrating the validity of scramblon theory in a solid-state NMR system. Crucially, this enables us to isolate and mitigate errors in the OTOC caused by imperfections in the backward evolution, which uncovers the anticipated exponential behavior of quantum many-body chaos and extracts the quantum Lyapunov exponent in a many-body experimental system for the first time. I will also present our further theoretical proposal for distinguishing coherent and incoherent errors using multi-round time-reversed dynamics.

REFERENCE STYLE

[1]. Error-Resilient Reversal of Quantum Chaotic Dynamics Enabled by Scramblons, *PHYSICAL REVIEW LETTERS*, 136, 060403 (2026), Y.-C. Li, T.-G. Zhou, S. Zhang, Z. Wu, L. Zhao, H. Yin, X. An, H. Zhai, P. Zhang, Xinhua Peng, and Jiangfeng Du.
[2]. Distinguishing Coherent and Incoherent Errors in Multi-Round Time-Reversed Dynamics via Scramblons, *arXiv*:2601.04856, Z. Liu and P. Zhang.

KEYWORDS

Information scrambling, Quantum chaos, NMR systems

From Correlation Irreversibility to Constraints on Eigenstate Thermalization

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ABSTRACT
In this talk, I will present a new operational perspective on eigenstate thermalization based on the irreversibility of correlations in closed quantum systems. Starting from our earlier result that unknown correlations cannot be universally erased by bounded closed-system control, I will show how this idea leads to nontrivial constraints on ETH violation. The key mechanism is that a local ETH anomaly induces a branch structure, while chaotic non-broadcasting prevents the corresponding environment records from becoming perfectly distinguishable. This nonorthogonality generates a finite correlation-reduction potential, but implementing it within a genuinely record-free closed protocol incurs unavoidable transfer and record-erasure costs. The resulting tension suggests that ETH can be understood not only as a statistical property of many-body eigenstates, but also as an operational consistency condition tied to the impossibility of systematically removing correlations in isolated quantum matter.

REFERENCE STYLE
Bridging quantum mechanics and thermodynamics: Irreversible correlations as the arrow of time, *Ann. Phys.* 485, 170318, 2026, X. Ming, Q.-y.~Cai.

KEYWORDS
Arrow of Time, Correlation Irreversibility, ETH

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DIVERSE MOIRÉ EXCITONIC PHYSICS IN 2D VAN DER WAALS SUPERLATTICES

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ABSTRACT
Moiré superlattices, created by combining low-dimensional materials with small lattice mismatches or different orientations, offer a powerful platform for exploring fascinating physical phenomena. Recent advances in optical spectroscopies have revealed rich experimental signatures of novel moiré exciton states in 2D superlattices; however, the microscopic nature of these states and strategies for their effective manipulation remain to be fully explored. In this talk, I will introduce our recent discoveries in 2D moiré-induced exciton physics based on newly-developed time-dependent interacting Green's function approach and the Bethe-Salpeter Equation method. First, I will demonstrate that moiré excitonic effects can greatly enhance nonlinear optical responses, leading to the striking formation of light-induced nonlinear photocurrent vortex crystals—2D arrays of moiré-scale current vortices and associated magnetic fields. This provides a promising all-optical control route to manipulate such exotic photoexcited moiré quantum matter. Second, I will show that the moiré potential can be continuously and efficiently tuned via pressure engineering, driving exciton physics from the weak- to the strong-moiré regime. In this process, we identify a previously underexplored moiré exciton state arising from the interplay between intrinsic excitonic Coulomb attraction and external moiré confinement. It establishes a pioneering paradigm of moiré excitonic wavefunction engineering, enabling the on-demand creation of tailored excitonic species in moiré superlattices. Our results highlight the rich photophysics of 2D moiré superlattices and open new opportunities for applications in moiré-based optoelectronics and photovoltaics.

KEYWORDS
2D materials, Moiré superlattices, Excitons, First-principles calculations

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Optical Spectroscopy of Quantum Materials Under Extreme Conditions

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ABSTRACT

Many emergent phenomena in quantum materials appear only when the delicate balance between electronic, magnetic, and lattice interactions is tuned away from ambient conditions. Pressure provides a particularly powerful way to continuously reshape this balance by directly modifying interatomic distances and coupling strengths without introducing chemical disorder. Accessing spectroscopic information in this regime, however, is experimentally demanding, especially when optical probes must operate simultaneously at high pressure and low temperature. In this talk, I will discuss how complementary optical spectroscopy techniques can be implemented under such extreme conditions to investigate quantum materials. Using examples including strongly spin–orbit–coupled Mott insulators and Weyl semimetals, I will show how optical measurements reveal the evolution of collective electronic, lattice, and magnetic excitations as interaction parameters are tuned. More broadly, the experimental approaches developed in these studies provide versatile tools that can be extended beyond quantum materials to a wide range of systems in materials science, including emerging nanoscale and functional materials.

KEYWORDS

Quantum materials, Optical spectroscopy, High-pressure, Strongly correlated electron systems

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$CsCr_3Sb_5$: a correlated kagome metal with flat band and pressure-induced superconductivity

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ABSTRACT

Kagome materials have recently attracted tremendous research interest in condensed matter physics, primarily due to their geometric frustration, electronic topology, and/or electron correlations. This talk will focus on a recently discovered kagome material, $CsCr_3Sb_5$, which is isostructural to the well-studied CsV_3Sb_5. Unlike the vanadium-based analogue, this chromium-based compound exhibits frustrated magnetism and significant electron correlations, which are likely associated with the kagome flat band near the Fermi level. Remarkably, upon applying pressure, superconductivity up to 6.4 K emerges in the vicinity of a density-wave quantum critical point, in a manner similar to the emergence of unconventional superconductivity in heavy-fermion and iron-based superconductors. The title material thus provides an opportunity to investigate the interplay between flat bands, magnetic frustration, electron correlations, and the emergent superconductivity within a correlated kagome system.

REFERENCE

Superconductivity under pressure in a chromium-based kagome metal, *Nature*, 632, 1032-1037, 2024, Yi Liu, Zi-Yi Liu, Jin-Ke Bao, Peng-Tao Yang, Liang-Wen Ji, Si-Qi Wu, Qin-Xin Shen, Jun Luo, Jie Yang, Ji-Yong Liu, Chen-Chao Xu, Wu-Zhang Yang, Wan-Li Chai, Jia-Yi Lu, Chang-Chao Liu, Bo-Sen Wang, Hao Jiang, Qian Tao, Zhi Ren, Xiao-Feng Xu, Chao Cao, Zhu-An Xu, Rui Zhou*, Jin-Guang Cheng*, **Guang-Han Cao***.

KEYWORDS

Kagome metal, Electron correlations, Flat band, Superconductivity, Density wave

* Corresponding author email: ghcao@zju.edu.cn; in collaboration with Jin-Guang Cheng' and Rui Zhou's groups of IOP, CAS, China.

PURE NEMATIC TRANSITION INSIDE THE SUPERCONDUCTING DOME OF AN IRON-CHALCOGENIDE SUPERCONDUCTOR

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ABSTRACT
Identifying the sole effect of a nematic quantum critical point (QCP) on the emergence of superconducting dome without interference of spin fluctuations is crucial for deciphering high transition temperature (T_c) superconductivity. By employing scanning SQUID microscopy on composition-spread $Fe_ySe_{1-x}Te_x$ films, we systematically investigate the superfluid density (ρ_s) across the pure nematic transition. The gap anisotropy, extracted from the temperature dependence of ρ_s, obeys a power-law dependence on $|x - x_c|$ near the critical doping x_c, evidencing nematic quantum criticality under the superconducting dome. The low-temperature ρ_s scales linearly with T_c for $x < x_c$, whereas the gap amplitude, maximized at x_c, determines T_c for $x > x_c$. These results establish a pure nematic QCP, separating two superconducting orders with distinct pairing boosted by nematic quantum fluctuations.

KEYWORDS
Iron-based superconductors; Nematicity; quantum critical point, Scanning SQUID microscopy

High-temperature field-free superconducting diode effect in high-T_c cuprates

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ABSTRACT

The superconducting diode effect (SDE) is defined by the difference in the magnitude of critical currents applied in opposite directions. It has been observed in various superconducting systems and attracted high research interests. However, the operating temperature of the SDE is typically low and/or the sample structure is rather complex. For the potential applications in non-dissipative electronics, efficient superconducting diodes working in zero magnetic field with high operating temperatures and a simple configuration are highly desired. Here, we report the observation of a SDE under zero magnetic field with operating temperatures up to 72 K and efficiency as high as 22% at 53 K in high-transition-temperature (high-T_c) cuprate superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ (BSCCO) flake devices. The rectification effect persists beyond two hundred sweeping cycles, confirming the stability of the superconducting diode. Our results offer promising developments for potential applications in non-dissipative electronics, and provide insights into the mechanism of field-free SDE and symmetry breakings in high-T_c superconductors.

REFERENCE

High-temperature field-free superconducting diode effect in high-T_c cuprates, *Nature Communications*, 16, 531, 2025, S. Qi, J. Ge, C. Ji, Y. Ai, G. Ma, Z. Wang, Z. Cui, Y. Liu, Z. Wang, and J. Wang.

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KEYWORDS
Superconducting diode effect, zero magnetic field, cuprates, non-dissipative electronics, symmetry breaking

Nonlinear valley Hall effect and its nonlocal transport signal

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ABSTRACT
Nonlinear transport effects have been a focus of recent research. Here, I will discuss the nonlinear version of valley Hall effect (VHE) and how it can be measured in the nonlocal transport setup. In contrast to the well-known reciprocity between direct and inverse VHEs in linear responses, the nonlinear inverse VHE needed to generate nonlocal voltage is not reciprocal to the nonlinear VHE it probes, but rather has distinct symmetry characters and physical origins. This fundamental distinction gives rise to unprecedented scaling behaviors in the measured signals, providing essential experimental hallmarks of nonlinear valley responses. Recently, our theory has been confirmed in an experiment on a graphene superlattice system.

REFERENCE STYLE

Nonlocal transport from nonlinear valley responses, *Physical Review B*, 112, L121404 (2025), J. Cao, H. Wang, S. Lai, C. Xiao, and S. A. Yang.

Observation of giant nonlinear valley Hall effect, *Nature Physics* (to be published), P. He, M. Zhang, J. Cao, J. Li, H. Liu, J. Zhai, R. Wang, C. Xiao, S. A. Yang, and J. Shen.

KEYWORDS
Nonlinear responses, valley Hall effect, nonlocal transport, valleytronics

Cascade of Field-induced Spin Liquids in a Bilayer Triangular-lattice Antiferromagnet

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Frustrated magnets offer a route to exotic states like classical spin liquids (CSLs), where macroscopic ground-state degeneracy prevents long-range order. While CSLs are typically studied at zero field, we report the discovery of a cascade of high-field spin-liquid states in the spin-1/2 bilayer triangular-lattice antiferromagnet $Rb_2Co_2(SeO_3)_3$.

Using high-field magnetization, specific heat, and ^{85}Rb NMR spectroscopy up to 26 T, we investigated the material's phase diagram. Our magnetization measurements reveal distinct plateaus at 1/3, 1/2, 2/3, and 5/6 of the saturation magnetization. NMR lineshapes confirm a conventional up-up-down (UUD) order only in the 1/3-plateau phase. Crucially, the 2/3- and 5/6-plateau phases show no evidence of long-range magnetic order. This disorder, combined with a significant field-dependent reduction in magnetic entropy extracted from specific heat, provides key evidence for spin-liquid ground states in these high-field plateaus.

The behavior is explained by a generalized ice rule, where an applied field dilutes a sea of antiferromagnetic Ising dimers. This enforces a local "one-up-one-down" constraint on the remaining dimers, creating macroscopic degeneracy and residual entropy. The 2/3-plateau forms a CSL, while the 5/6-plateau, with its additional inter-bilayer dimer fluctuations, is a candidate for a quantum spin liquid (QSL) exhibiting gapless excitations. Our results establish a new high-field route to engineer spin liquids, demonstrating that the competition between field and frustration in a simple bilayer system can stabilize a rich variety of both classical and potentially quantum disordered states.

Title of the paper

Universal properties and half-filled fractional quantum Hall States in single and multilayer Graphene

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ABSTRACT

Universal chiral Luttinger liquid behavior is predicted for fractional quantum Hall (FQH) edge states, but remains unobserved in semiconductor 2DEGs, mainly due to ubiquitous edge reconstruction. Graphene avoids this via a unique confinement mechanism, enabling observation of the predicted universal behavior. Moreover, the FQHE at half-filling, grants access to non-Abelian topological phases. Here, we report a cascade of such states in mixed-stacked pentalayer graphene, a novel system with intertwined quadratic and cubic band dispersions. At half fillings, continuous quantum phase transitions between these FQH states, magnetic Bloch states and composite Fermi liquids are detected via external field tuning. Numerical results revealing six-fold ground-state degeneracy and chiral graviton spectral analysis confirm these as non-Abelian Moore-Read states, positioning mixed-stacked multilayer graphene as a versatile platform for tunable correlated topological phase studies.

REFERENCE STYLE

Realizing Universal Edge Properties in Graphene Fractional Quantum Hall Liquids, *Phys. Rev. Lett.*107, 236806, 2011, Zi-Xiang Hu, R. N. Bhatt, Xin Wan, Kun Yang,

Model Wavefunctions for the Collective Modes and the Magneto-roton Theory of the Fractional Quantum Hall Effect, *Phys. Rev. Lett.* 108, 256807, 2012, Bo Yang, Zi-Xiang Hu, Z. Papic, and F. D. M. Haldane

Cascade of Even-Denominator Fractional Quantum Hall States in Mixed-Stacked Multilayer Graphene , *arXiv:2507.20695,* Nat. Comm. under view, 2025, Yating Sha, Kai Liu, Chenxin Jiang, Dan Ye, Shuhan Liu, Zhongxun Guo, Jingjing Gao, Ming Tian, Neng Wan, Kenji Watanabe, Takashi Taniguchi, Bingbing Tong, Guangtong Liu, Li Lu, Yuanbo Zhang, Zhiwen Shi, Zi-Xiang Hu, Guorui Chen

KEYWORDS

fractional quantum Hall, graphene, topological state, non-Abelian, strongly correlated system.

Thin-film nickelate superconductivity and electronic structures

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ABSTRACT

This talk discusses the indispensable role of thin-film engineering in exploring nickelate superconductivity. We first examine infinite-layer nickelate films, utilizing an Operando Monitored Reduction (OMR) technique for precise Ni 3*d* occupancy modulation over ultrawide ranges. This enables the mapping of detailed superconductor-insulator phase diagrams and the discovery of field re-entrant superconductivity in Eu-doped samples. Furthermore, we introduce Gigantic-oxidative Atomic-layer-by-layer Epitaxy (GAE) to synthesize Ruddlesden-Popper (RP) bilayer and superstructure nickelates. We report achieving ambient-pressure superconductivity in monolayer-bilayer and bilayer-trilayer superstructures, together with an enhanced onset T_c reaching 63 K in the bilayers. With cryogenic ultrahigh vacuum (UHV) sample transfer, ARPES data reveals an underlying d_{z^2}-related band crossing the Fermi level in the superconducting structures, with a superconducting gap consistent with s-wave symmetry in the bilayers. These findings establish the thin-film platform with atomic-layer engineering as a powerful "quantum laboratory" for driving nickelate research.

KEYWORDS

Nickelate superconductors, thin film, ARPES

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Three-dimensional collective amplitude mode dynamics in charge-density-wave materials

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ABSTRACT

Low-dimensional materials are promising for ultrafast electronics due to their unique charge-density-wave (CDW) states. In one-dimensional (1D) systems, Fermi surface nesting induces Kohn anomalies and collective amplitude modes. However, the mechanisms governing three-dimensional (3D) CDW phase transitions and collective dynamics remain a subject of debate. Among telluride materials, CuTe is notable for its structural simplicity. Using orientation-resolved pump-probe spectroscopy, we investigated the temperature-dependent evolution of ultrafast collective-amplitude-mode dynamics in (001) CuTe single crystals. At 335 K, a 1D CDW with 1*c* periodicity forms along the *a*-axis. As temperature decreases, *c*-axis contraction induces quantum fluctuations that drive a dimensional transition from 1D to 3D CDW, accompanied by the emergence of *ab*-plane order. Below 220 K, the 3D CDW stabilizes with 2*c* periodicity and an anti-phase configuration along the *c*-axis, reaching a fully developed state through interlayer phase locking of the in-plane CDW. Additionally, Tb_2Te_5 single crystals were successfully grown via tellurium evaporation in boomerang-shaped quartz-glass ampoules. The magnetic measurements reveal two antiferromagnetic orders at $T_{N1} = 9.0$ K and $T_{N2} = 6.8$ K. Transient reflectivity change spectra exhibit a rapid rise and ultrafast demagnetization driven by photoexcited carriers. The subsequent relaxation involves a fast (~ps) decay via electron-phonon coupling and a slower (~100 ps) process associated with magnetic order recovery, highlighting the intricate coupling between the magnetic and electronic subsystems in Tb_2Te_5.

REFERENCE STYLE

Three-dimensional ultrafast charge-density-wave dynamics in CuTe, *Nature Communications*, 15, 2386, 2024, N. N. Quyen, C. W. Luo, et al.
Comparative study of terbium tellurides Tb_2Te_5 and $TbTe_3$, *Phys. Rev. B*, 112, 094434, 2025, I. Shamova, C. W. Luo, et al.

KEYWORDS

Charge density wave, Collective amplitude mode, Ultrafast dynamics

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RESOLVING QUANTUM CRITICALITY IN THE HONEYCOMB HUBBARD MODEL

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ABSTRACT

The semimetal-to-Mott-insulator transition in the honeycomb Hubbard model, belonging to the Gross-Neveu-Heisenberg (GNH) universality class, is a paradigmatic quantum phase transition with direct relevance to graphene and related two-dimensional materials. Despite decades of effort, consensus on its critical exponents has remained elusive due to severe finite-size effects. We address this long-standing controversy by performing projector determinant quantum Monte Carlo (PQMC) simulations on honeycomb lattices of unprecedented size, reaching 10,368 sites. This is enabled by a novel submatrix-T update algorithm that achieves over 24x speedup through optimized cache utilization. Through a systematic sliding-window finite-size scaling analysis, we reveal qualitatively distinct convergence patterns for different critical exponents: the fermion anomalous dimension converges rapidly, the correlation length exponent oscillates stably, and the boson anomalous dimension exhibits persistent monotonic drift requiring linear extrapolation. Our final estimates are the critical coupling $U_c = 3.664(5)$, correlation length exponent $\nu = 1.11(9)$, boson anomalous dimension $\eta_\phi = 0.79(2)$, and fermion anomalous dimension $\eta_\psi = 0.1888(40)$. Parallel simulations of the spinless t-V model in the Gross-Neveu-Ising universality class validate our methodology, yielding results consistent with conformal bootstrap predictions. Our work demonstrates that previous discrepancies among honeycomb Hubbard results stem primarily from insufficient system sizes and establishes a systematic workflow for resolving fermionic quantum critical phenomena.

REFERENCES

Resolving Quantum Criticality in the Honeycomb Hubbard Model, *arXiv*, 2602.03656, 2026, F.-H. Wang, F. Sun, C. He, X.Y. Xu.

KEYWORDS

Quantum criticality, Hubbard model, Quantum Monte Carlo, Gross-Neveu universality, Finite-size scaling

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FRACTONIC SUPERFLUIDS: FROM GENERALIZED HOHENBERG-MERMIN-WAGNER THEOREMS TO VORTEX FRACTIONALIZATION

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ABSTRACT

In this talk, I will introduce fractonic "superfluids" (coined first in arXiv:1911.02876), which is a type of exotic symmetry-breaking phases where charge-symmetry-breaking is constrained by the presence of higher moment conservation, e.g., dipole moments. The latter originally arises from the field of fracton physics where mobility restriction is considered a vital step towards robust quantum memory. I will unfold a trilogy of the theory of fractonic superfluids by focusing on effective field theory, generalized Mermin-Wagner theorems. I will introduce the construction of generalized Bose-Hubbard model on a lattice which realizes fractonic superfluids at weak Hubbard U regime. I will also present the construction of generalized vortices and the associated Kosterlitz-Thouless transitions by theoretical study and numerical simulation, which realizes the notion of vortex fractionalization: tradional vortices are fractionalized into more fundamental ones that are responsible for topological transitons.

REFERENCE

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Fractonic superfluids. III. Hybridizing higher moments, *Physical Review Research*, 7, 033118, 2025, H.-X. Wang, S. A. Chen, P. Ye

KEYWORDS

Superfluids, Symmetry breaking, Higher moment conservation, Mermin-Wagner theorem, Kosterlitz-Thouless transitions

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P.S. :

Below is the invitation letter of the 10th OCPA meeting canceled due to the covid-19. I am glad to see the reopening of this wonderful meeting. It will be defintely great and my honor if my talk can be selected and rearranged to this Singapore meeting. Thank you!

全球华人物理和天文学会

International Organization of Chinese Physicists and Astronomers

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January 21, 2020

Dear Professor Peng Ye

The International Organization of Chinese Physicists and Astronomers (OCPA) would like to cordially invite you to give an invited talk at the 10th OCPA meeting on June 28 ~ July 1, 2020 at National Chung Hsing University in Taichung, Taiwan. More information about the meeting can be found at http://ocpaweb.org/home/ocpa10-meeting/.

Your invited talk (20 mins) will be arranged. As an invited speaker, your registration and banquet fees will be waived.

Please contact us by email, Mon-Shu Ho msho@dragon.nchu.edu.tw or Mr. Andy Liu adliu@nchu.edu.tw , or by phone at +886-4-22840427 ext. 519 or 407 if you have any question. We look forward to meeting you in Taiwan.

Sincerely,

D. Zhong   Cheng Chin   Mon-Shu Ho

Dongping Zhong Chair of OCPA	Cheng Chin Vice-Chair of OCPA	Mon-shu Ho Chair, OCPA10 Local Committee

Orbital topology induced orbital Hall effect in two-dimensional insulators

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ABSTRACT

The exploration of ground-state topology in quantum materials has led to the discovery of a variety of exotic topological phases with unconventional Hall responses. In two-dimensional systems, Chern insulators exhibit the quantum anomalous Hall effect, while spin Chern insulators underlie the quantum spin Hall effect. Extending beyond charge and spin, recent advances in orbitronics have revealed a transverse response of orbital angular momentum—known as the orbital Hall effect.

In this talk, I will introduce a comprehensive framework for understanding orbital Chern insulators (OCIs)—topological phases characterized by a nontrivial orbital degree of freedom. We not only establish the theoretical foundations of OCIs but also identify two-dimensional phosphorene as a promising material platform for their realization. Our findings open new avenues for orbital topology in materials science and could pave the way for novel topological phases and orbitronics-based applications.

REFERENCE STYLE

Orbital topology induced orbital Hall effect in two-dimensional insulators, *Reports on Progress in Physics,* 89, 018001, 2026, Yueh-Ting Yao, Chia-Hung Chu, Arun Bansil, Hsin Lin, Tay-Rong Chang.

KEYWORDS

Topological materials, Orbital Hall effect, First-principles calculations, Two-dimensional materials.

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Unveiling Intrinsic Multiferroicity and Atomic-Scale Ion Dynamics in 2D Transition Metal Phosphorus Chalcogenides

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ABSTRACT

Two-dimensional (2D) transition metal phosphorus chalcogenides have emerged as a premier platform for exploring van der Waals multiferroicity and ion-based electronics. However, intrinsic properties and microscopic mechanisms in these materials often remain controversial due to sample quality and characterization limitations. This study provides a comprehensive synthesis of the intrinsic electric properties, atomic-scale dynamics, and magnetodielectric (MD) coupling in high-quality $CuInP_2S_6$ (CIPS) and $CuCrP_2S_6$ (CCPS) single crystals.

Using the chemical vapour transport (CVT) method, we synthesized high-purity single crystals to establish a benchmark for their intrinsic characteristics. For CIPS, we performed atomic-level direct imaging via aberration-corrected scanning transmission electron microscopy (AC-STEM) to trace Cu(I) migration. We identified multiple Cu(I) occupation sites—lattice, vacancy, interstitial, and interlayer—which lead to metastable $Cu_xInP_2S_6$ (x=2-4) local structures and a characteristic 1/6 ***b***-axis layer sliding to release lattice stress. Furthermore, we resolved the disputed dielectric nature of CIPS, identifying a first-order phase transition at ~330 K with no evidence of intrinsic dipole glass behavior.

Extending this framework to CCPS, we demonstrated robust and broad-range MD coupling from 2 K to 350 K. An external magnetic field reconfigures Cr spins, which raises the activation energy for Cu^+ hopping via spin-phonon coupling, thereby suppressing dielectric polarizability. The MD coefficient reaches up to -18% and remains stable above room temperature. These findings establish a unified understanding of how spin-lattice-ion interactions govern the multiferroic performance of layered materials, offering critical insights for designing next-generation, low-power spintronic and memory devices.

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Atomic-level direct imaging for Cu(I) multiple occupations and migration in 2D ferroelectric $CuInP_2S_6$, *Nature Communications*, 15, 10152, 2024, C. Guo, J. Zhu, X. Liang, C. Wen, J. Xie, C. Gu, W. Hu.
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KEYWORDS
Ferroelectric, Magnetodielectric coupling, Multiferroic, $CuCrP_2S_6$, Spin-phonon coupling

ACKNOWLEDGMENTS
This research is supported by Singapore National Research Foundation Investigatorship under Grant No NRF-NRFI08-2022-0009 and SUSTech-NUS Joint Research Program.

Deep Neural Network in Integrated Photonic Architecture

The growing computational demands of classical neural networks have intensified the search for energy-efficient and powerful computational alternatives. Quantum neural networks (QNNs) implemented on integrated photonic platforms present a compelling reason, offering enhanced computational power with inherent programmability and scalability of integrated architecture. Here, we briefly sketch some of our work in this area.

Revealing Atomic-Scale Spin Textures in Low-Dimensional Honeycomb/Magnetic Heterostructures

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ABSTRACT:

Introducing magnetism to two-dimensional topological insulators is a central issue in the pursuit of magnetic topological materials in low dimensionality. By means of low-temperature growth at 80 K, we succeeded in fabricating a monolayer stanene on Co/Cu(111) and resolving ferromagnetic spin contrast by field-dependent spin-polarized scanning tunneling microscopy (SP-STM) [1, 2]. Increases of both remanence to saturation magnetization ratio (M_r/M_s) and coercive field (H_c) due to an enhanced perpendicular magnetic anisotropy (PMA) are further identified by out-of-plane magneto-optical Kerr effect (MOKE). In addition to ultraflat stanene fully relaxed on bilayer Co/Cu(111) from density functional theory (DFT), characteristic topological properties including an in-plane s-p band inversion and a spin–orbit coupling (SOC) induced gap about 0.25 eV at the Γ point have also been verified in the Sn-projected band structure. On the other hand, we have also successfully fabricated the bismuthene covered Mn monolayer on Ag(111) by evaporating Mn atoms onto (p x √3)-Bi/Ag(111) at room temperature. By using SP-STM, we have resolved the magnetic triple-q (3Q) state. In combination with density-functional theory (DFT) calculations, the $3Q^3$-like spin texture is the magnetic ground state for the bismuthene covered Mn monolayer/Ag(111). Interestingly, the uniaxial magnetic anisotropy of $3Q^3$ state triggered by the bismuthene on top of Mn monolayer/Ag(111) has been revealed, which is consistent with the switching of $3Q^3$-up and $3Q^3$-down domains observed by SP-STM measurements with external magnetic fields.

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KEYWORDS

Stanene, Bismuthene, Ferromagnetic Co Nanoislands, Antiferromagnetic Mn Nanostructures, Spin-polarized STM, Density Functional Theory

Step-Edge-Guided Epitaxy of Polarized Multilayer h-BN Revealed by Angle-resolved Photoemission Spectroscopy (ARPES)

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ABSTRACT

Two-dimensional (2D) ferroelectrics that retain spontaneous polarization at atomic thicknesses are promising for next-generation nanoelectronics and nonvolatile information technologies beyond Moore's law. However, most van der Waals materials, including hexagonal boron nitride (h-BN), naturally favor centrosymmetric stacking configurations and therefore lack intrinsic ferroelectricity. Although symmetry breaking through artificial stacking has been demonstrated, achieving scalable and controllable growth of polarized multilayer structures remains a key challenge. In this work, multilayer h-BN films with controlled thickness were synthesized using nitrogen plasma–assisted molecular beam epitaxy (PA-MBE) on lattice-matched graphene grown on commercial 4H-SiC(0001) substrates with a 4° miscut. Under nitrogen-rich conditions, enhanced boron surface diffusion enables high-quality h-BN growth at relatively low temperatures. Microscopy and Raman spectroscopy reveal continuous, crystalline h-BN layers covering graphene terraces and extending across step edges. Preferential nucleation at graphene step edges promotes aligned island growth and seamless merging, resulting in uniform layer-by-layer epitaxial films. Angle-resolved photoemission spectroscopy (ARPES) measurements reveal clear layer-dependent band dispersions for mono-, bi-, and trilayer h-BN. The observed electronic structures agree well with layer- and stacking-dependent GW calculations, confirming polarized AB stacking for bilayer and ABA stacking for trilayer h-BN while excluding non-polar configurations. The spatial uniformity of the band structures further indicates homogeneous, millimeter-scale epitaxial growth. Density functional theory calculations and scanning transmission electron microscopy reveal that graphene step edges significantly lower the interfacial formation energy, acting as favorable nucleation sites that drive step-guided conformal epitaxy and mono-oriented polarized stacking. Ferroelectric behavior was confirmed by piezo-response force microscopy, showing clear polarization switching, butterfly-shaped amplitude loops, and coercive voltages of ~±1.5 V. Stable surface potential contrast and robust domain writing demonstrate nonvolatile polarization control. These results establish epitaxial multilayer h-BN as a scalable 2D ferroelectric platform and highlig step-edge–induced symmetry breaking as a viable route for engineering polarized van der Waals heterostructures.

REFERENCE STYLE

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KEYWORDS

Ferroelectricity, ARPES, hexagonal boron nitride, van der Waals heterostructures

Hydrodynamic Transport Induced High-Temperature MagnetoResistance in a Strongly Correlated 2D system

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ABSTRACT

Magnetoresistance in metals and semiconductors are usually only significant only at temperatures lower than the Fermi temperature of the electronic system and weakens as temperature increases. We report an unusual magnetoresistance that strengthens with the temperature in a strongly correlated two-dimensional (2D) hole system in GaAs/AlGaAs quantum wells with low densities (2D hole density p= 1.98-0.99× 10^{10}/cm^2 where r_s, the ratio between Coulomb energy and Fermi energy, is as large as 20-30. We show that, while the system exhibits a negative parabolic magnetoresistance at low temperatures (<~ 0.4 K) characteristic of an interacting Fermi liquid, a positive magnetoresistance emerges unexpectedly at higher temperatures, and grows with increasing temperature even in the regime $k_BT > E_F$, the Fermi energy. This unusual positive magnetoresistance at high temperatures can be attributed to the viscous transport of 2D hole fluid in the hydrodynamic regime where holes scatter frequently with each other. These findings give insight into the collective transport of strongly interacting carriers in the r_s>> 1 regime and open up new routes towards magnetoresistance at high temperatures.

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KEYWORDS

Strongly correlated electrons, 2D electrons, metal insulator transition, Wigner crystal, hydrodynamics

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Self-powered photomemristor array for in-sensor computing

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ABSTRACT

In-sensor computing has been proposed to mitigate the latency and energy consumption caused by inevitable data transfer among spatial-separated sensors, memory, and processors, yet the hardware implementation of all-in-one unit remains a challenge. In particular, optoelectronic multiply-accumulate computation further demands controllable photoresponse, weight tunability, and scalable array architectures. This work demonstrates self-powered in-sensor computing enabled by a photomemristor crossbar array based on molecular ferroelectrics (MFs). Blade-coated MF films exhibit highly oriented in-plane axis, large remanent polarization, and low operating voltage, while maintaining compatibility with III-V semiconductor wafers. The III-V semiconductors provide efficient photocarrier generation and substantial tunability for photoresponsivity. The in-plane polarization further induces a depolarization field in the interface, resulting in a lateral gradient p/n-type doping profile along the channel. Differ from conventional p-n junctions, the observed p/n-type doping electrostatically modulate the channel and form a lateral distribution. As a result, the photomemristor achieves self-powered, nonvolatile, and continuously tunable photoresponse with bidirectional photocurrents, ultimately enabling configurable synaptic weights for optoelectronic neural networks. The device shows stable operation with negligible degradation over 10^3 s retention and 2000 switching cycles. Notably, a maximum responsivity of 1 A W^{-1} and a fast rise time of 0.5 μs are achieved. Furthermore, a 10×10 crossbar array with a yield of 97% is demonstrated, enabling multiply-accumulate operations between light intensity and photoresponse. This molecular ferroelectric-based photomemristor is further shown to be compatible with a wide range of material platforms, including silicon, TMDs, and organic semiconductors. The proposed architecture holds potential for event-driven edge vision and in-sensor computing systems.

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This research is supported by Singapore National Research Foundation Investigatorship under Grant No NRF-NRFI08-2022-0009 and SUSTech-NUS Joint Research Program.

In-plane ferroelectric-reconfigured interface towards dual-modal intelligent vision, *Next Nanotechnol.*, 5, 100052, 2024, Y. Cai, *et al*.

KEYWORDS
Photomemristor, in-sensor computing, molecular ferroelectrics, crossbar array

Topological magnons with scalar spin chiralities in a centrosymmetric magnetic vortex lattice

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ABSTRACT
Two-dimensional magnetic materials with mixed spins serve as fertile platforms for exploring nontrivial magnetic states and collective excitations. Here we investigate a centrosymmetric honeycomb A_3B superlattice consisting of two different elements A and B with mixed spins, arranged in a hexagon-within-hexagon pattern. We first identify that such a lattice harbors radially-distributed Dzyaloshinskii-Moriya interaction, which in turn stabilizes noncollinear magnetic ground states featuring periodic arrays of hexagonal vortices. Based on linear spin-wave theory, we further demonstrate that the system harbors elementary collective excitations in the form of topological magnons with quantized Chern numbers, enabling dissipationless spin and heat transport via chiral edge states. Notably, the magnon dynamics is characterized by scalar spin chiralities, revealing circularly polarized precessions of the vortices with counterclockwise and clockwise chirality. These findings help to enrich physics of binary spins systems with prospective applications in spintronics and magnonics.

REFERENCE STYLE
Topological Magnons with Scalar Spin Chiralities in a Centrosymmetric Magnetic Vortex Lattice, *to be submitted*, J.Y. Bu, S.H. Zhang, Z.Y. Zhang.

KEYWORDS
Topological magnon, Chirality, Magnetic vortex

Local Measurements for Preparing and Certifying Complex Quantum Many-Body States

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ABSTRACT
Creating and probing complex many-body quantum systems often seems to require both deep circuits and extensive measurements. In this talk, I will present a different perspective: local measurements can serve as powerful resources for both the preparation and certification of complex quantum states. I will first show how local measurements can enhance variational circuits, enabling the preparation of highly entangled states while keeping the quantum circuit shallow. I will then show that measurements can concentrate a system's global quantum complexity into small subsystems. This reveals a fundamental principle: quantum complexity is incompressible, and measurement cannot circumvent the cost defined by a quantum circuit's volume. Building on this insight, I will introduce a unified framework based on "localizable quantumness" that certifies global properties—such as entanglement, magic, and fidelity—from local measurements alone. This provides a scalable and practical path for verifying the operation of large-scale quantum devices.

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KEYWORDS
Quantum computing, local measurements, quantum complexity, state certification, variational circuits, many-body systems

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TWO-DECADES OF GRAPHENE: PERSPECTIVE INDUSTRIAL SCALE APPLICATIONS

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ABSTRACT

Graphene is an extraordinary material, boasting unparalleled mechanical strength, ballistic conductivity, and superior thermal and corrosion resistance. Despite these properties, it has yet to achieve widespread industrial adoption since its discovery over two decades ago.

In this talk, we will explore the shifting landscape of graphene's industrial prospects. we will demonstrate how graphene composites significantly enhance the strength, thermal conductivity, and manufacturability of polymers—making them ideal for high-growth sectors like robotics, EVs, and 3D printing[1-3]. In the construction industry, graphene-enhanced concrete offers a dual advantage: a 30% reduction in CO_2 emission and a 150% increase in structural lifespan, all while remaining commercially viable[4]. Furthermore, I will discuss graphene's role in high-performance coatings—improving UV resistance, anti-bacterial properties, anti-corrosion and hydrophobicity for both marine and terrestrial use[5]. Finally we will present our results on graphene films for robust EMI shielding in communication technologies.

Ultimately, after 20 years of research, graphene powder and liquid solutions are finally reaching a tipping point for large-scale, real-world applications.

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KEYWORDS

Graphene, 3D printing, graphene-enhanced polymer, graphene-enhanced cement, coating.

Revealing Hidden Atomic Order in Functional Materials with Multislice Electron Ptychography

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ABSTRACT

Resolving local structural order and disorder at the atomic scale is essential for understanding the functionalities of a wide range of materials, including batteries, catalysts, and superconductors. While electron microscopy is one of the most powerful tools for structural characterization, many critical structural motifs remain hidden in the background—particularly those involving light elements such as oxygen, lithium, and hydrogen, which are notoriously difficult to detect using conventional approaches. In this talk, I will introduce multislice electron ptychography (MEP), a new imaging technique that overcomes these long-standing limitations. By inverting multiple scattering of the electron wave as it propagates through a specimen, MEP enables quantitative reconstruction of the three-dimensional electrostatic potential at atomic resolution. This capability allows us to identify nearly every element in the periodic table—including hydrogen—with unprecedented precision. I will demonstrate how MEP reveals subtle structural features that were previously inaccessible, including hidden ordering of oxygen point defects in complex nickelate superconductors and atomic-scale variations in hydrogen concentration in metal hydrides. Furthermore, I will present our recent advances in extending MEP to cryogenic conditions, enabling the visualization of atomic-scale structural orders such as the polarization textures in relaxor ferroelectrics at liquid nitrogen temperature.

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KEYWORDS
Structural characterization, superconductivity, point defects, ferroelectrics

Many-body phases in multilayer graphene: from half-integer quantum Hall effects to magnetism

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ABSTRACT

Thin graphite flakes behave as two-dimensional conductors in sufficiently high magnetic fields, with quantum Hall states extended throughout the bulk of the flake for low doping, and confined to the surfaces for large doping. I will discuss our observation of half-integer fractional quantum Hall states at large total filling factors. These single-component states likely stem from Pfaffian wavefunctions derived from those in graphene bilayers, which are predicted to host nonabelian quasiparticles. The facile integration of graphite with top and back surface gates makes this an excellent system to explore device geometries capable of manipulating such quasiparticles. Moreover, bilayer graphene (BLG) hosts a variety of tunable quantum many-body phases driven by strong electron-electron interactions. While these phases have been studied in bulk systems[1], experiments probing them in quantum-confined structures remain limited. Here, we investigate magnetism in gate-defined bilayer graphene quantum dots, where both the charge density and perpendicular displacement field are gate tunable. Using a relatively large dot to achieve high-density resolution and reduced quantum level spacing, we access regimes where magnetically-ordered phases emerge. Magneto-transport measurements reveal distinct Coulomb peak evolutions with magnetic field, providing evidence of a variety of valley and spin magnetic orders emerging over a large range of added electrons. These results demonstrate bilayer graphene quantum dots as a promising platform for exploring and tuning interaction-driven phases in two-dimensional materials.

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KEYWORDS

Rhombohedral graphene, fractional quantum Hall effect, quantum dots

ANGULAR MOMENTUM-DRIVEN CONTROL OF OPTICAL AND ELECTRICAL RESPONSES IN MONOLAYER MOS2

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ABSTRACT

Light carrying angular momentum, including spin angular momentum (SAM) from circular polarization and orbital angular momentum (OAM) from optical vortex beams, provides versatile degrees of freedom for controlling light-matter interactions. In two-dimensional transition metal dichalcogenides such as monolayer MoS_2, strong coupling between spin and valley degrees of freedom enables selective optical excitation, making these materials promising platforms for spin- and valley-based optoelectronics. However, the combined influence of SAM and OAM on carrier dynamics and optoelectronic responses remains insufficiently understood.

In this study, we investigate the interaction between structured light carrying both SAM and OAM and monolayer MoS_2. By employing polarization-resolved optical spectroscopy together with photocurrent measurements, we systematically examine how angular momentum of light influences valley-selective excitation, charge transport, and carrier recombination processes. Our approach enables direct comparison between different angular momentum configurations and their impact on optical and electrical responses.

We observe that the presence of OAM introduces additional modulation of the photoresponse beyond conventional circular polarization effects, indicating enhanced control over angular momentum transfer pathways. The interplay between SAM and OAM leads to tunable photocurrent behavior and modified optical emission characteristics, revealing a new degree of freedom in manipulating spin- and valley-related phenomena.

These results demonstrate that structured light provides an effective strategy for engineering coupled spin-orbital dynamics in two-dimensional quantum materials. The findings offer new insights into light-matter interaction mechanisms and open opportunities for developing advanced optoelectronic and quantum devices based on angular momentum control.

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KEYWORDS
Structured light, Orbital angular momentum, Spin angular momentum, Monolayer MoS_2, Optoelectronics

Engineering Light-Matter Interactions via Orbital Angular Momentum

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ABSTRACT

Light with orbital angular momentum (OAM), often referred to as twisted light, carries a well-defined angular momentum of (lh_bar) per photon, where the topological charge can reach thousands of integer states. Such twisted light provides a versatile platform for tuning light–matter interactions, particularly through OAM-enhanced exciton dissociation, or dipole and quadrupole transitions that can significantly influence light-induced electronic signals in materials. In this talk, we will present recent advances on OAM-driven optical, magnetic, and electrical responses in nanoelectronic systems [1-7]. Our results reveal intriguing phenomena that highlight the rich potential of OAM-matter interactions, pointing toward a promising research frontier that remains largely unexplored. Beyond fundamental interest, these findings also suggest new opportunities for next-generation optoelectronic and quantum devices, including information processing, high-density data storage, and multifunctional photonic systems.

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KEYWORDS

Orbital angular momentum of light, twisted light, light–matter interactions, optoelectronics, quantum devices.

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Quantum Simulations in Condensed Matter: Artificial Gauge Fields and Multifractal-enriched Mobility Edges

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ABSTRACT

Laser-cooled and trapped ultracold atoms, owing to their exceptional quantum coherence and remarkable controllability, have emerged as one of the most powerful platforms for quantum science and technology, with applications ranging from quantum computing and simulation to quantum communication and precision measurement. In this talk, I will present two illustrative examples of quantum simulation using atomic systems. The first involves the realization of artificial gauge fields and their application in exploring the atomic spin Hall effect and topological vacuum states. The second focuses on the observation of localization, extended states, and mobility edges—demonstrating the coexistence of all three phases in quasicrystalline systems.

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KEYWORDS

Quantum simulation, Ultracold atoms, Artificial gauge fields, Topological vacuum, Localization.

Spatial Correlation at the Boson Peak Frequency in Amorphous Materials

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ABSTRACT

The Boson peak (BP), an excess of vibrational density of states, is ubiquitous for amorphous materials and is believed to hold the key to understanding the dynamics of glass and glass transition. Previous studies have established an energy scale for the BP, which is ~1-10 meV or ~THz in frequency. However, so far, little is known about the momentum dependence or spatial correlation of the BP. Here, we report the observation of the BP in model Zr-Cu-Al metallic glasses over a wide range of momentum transfer, using inelastic neutron scattering, heat capacity, Raman scattering measurements, and molecular dynamics (MD) simulations. The BP energy is largely dispersionless; however, the BP intensity is found to scale with the static structure factor. Additional MD simulations with a generic Lennard-Jones potential confirm the same. Based on these results, an analytical expression for the dynamic structure factor is formulated for the BP excitation. Further analysis of the simulated disordered structures suggests that the BP is related to local structure fluctuations (e.g., in shear strain). Our results offer insights into the nature of the BP and provide guidance for the development of theories of amorphous materials.

KEYWORDS
Boson Peak, Neutron Scattering, Molecular Dynamics Simulations, Glass

Mitigating precision tradeoff in multi-parameter quantum metrology

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ABSTRACT

Quantum metrology for single parameter estimation has achieved great success. Yet many practical applications involve multiple parameters. Therefore, extending quantum metrology to multi-parameter estimation will greatly enlarge its scope. However, not only the quantum-enhanced estimation of multiple parameters is technically more challenging, but the fundamental limit of its precision remains elusive. In particular, due to the incompatibility in quantum mechanics, there are tradeoffs between the precisions of different parameters. Therefore the fundamental bound of precision limit in the single parameter case, i.e., the quantum Cramer-Rao bound (QCRB), may not be saturated in multi-parameter estimation. In this talk I will present our recent work the joint estimation of both a phase and its fluctuation. We will show how collective measurement on multiple copies of the probe states reduces the tradeoffs between the two parameters and improves the precision. We further show that antiunitary symmetry, originating from the time-reversal symmetry, can be used to eliminate the tradeoffs between different parameters and achieve the optimal precision simultaneously for all parameters. Inspired by this result, we develop a strategy that employs the classically correlated probe states to achieve QCRB for a large range of parameters

REFERENCE STYLE

Experimental Joint Estimation of Phase and Phase Diffusion via Deterministic Bell Measurements, *Advanced Science*, 13, e18375, 2026, B. Wang, M. Mi, H. Wang, Q. Xie, L. Zhang

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Approaching Multi-parameter Quantum Cramér-Rao Bound via Classical Correlation and Entangling Measurements, *Physical Review Letters* 135, 110804, 2025, M. Mi, B. Wang, L. Zhang

KEYWORDS

Quantum metrology, quantum optics, interferometry

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Alteraxial phonons in collinear magnets

Axial phonons, carrying angular momentum through rotational lattice vibrations, offer a promising platform for exploring phonon-magnetic coupling effects. However, how the interplay of lattice and magnetism determine the phonon angular momentum (PAM) of axial phonons remains elusive. Here, based on magnetic point group theory, we establish a symmetry framework to classify phonons in collinear magnets (e.g. ferromagnets, antiferromangets, altermagnets) into three distinct categories: ferroaxial, antiferro-nonaxial, and alteraxial phonons, which are distinguished by their different PAM patterns. Beyond the ferroaxial phonons featuring s-wave PAM, we reveal a complete series of alteraxial phonons, characterized by higher-order-wave PAM patterns ranging from p- to j-wave. Notably, alteraxial phonons are not limited to altermagnets, but also emerge in ferromagnets and antiferromagets. Our high-throughput search predicts hundreds of candidate magnetic materials hosting alteraxial phonons. Ab initio calculations on representative magnets further confirm the distinct nodal structures of PAM in alteraxial phonons. Our work provides a complete classification for axial phonons in collinear magnetic systems and paves the way for engineering magneto-phononic phenomena.

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Ultra-nonlocal non-Hermitian skin effect in two and higher dimensions

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ABSTRACT

The non-Hermitian skin effect (NHSE) can significantly reshape the energy spectrum, eigenstate profiles and even topological phases of non-Hermitian systems. Here we discover a surprising ultra-nonlocal behavior occurs in a broad class of two- and higher-dimensional non-Hermitian lattices. In this ultra-nonlocal NHSE, small geometric modifications made far from the corner where eigenstates predominantly accumulate can nevertheless induce drastic, qualitative changes in the entire spectrum and in the eigenstate distributions, a sensitivity that is absent in conventional NHSE. We show that the emergence of this ultra-nonlocal behavior is captured by the emergence of a global biorthogonal current carried by the eigenstates, and that both spectral features and spatial profiles can be understood from the associated current trajectories. Building on this framework, we study a representative two-dimensional topological model with NHSE and develop a universal algorithm that predicts the spectra for arbitrary geometries, thereby demonstrating this new nonlocal mechanism.

REFERENCE STYLE

Ultra-nonlocal non-Hermitian skin effect in two and higher dimensions, in preparation, W.T. Xue, W.J. Chan, H. Jiang, C.H. Lee.

KEYWORDS

Non-Hermitian skin effect, ultra-nonlocality, higher-dimensional non-Hermitian systems, biorthogonal current

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Topological magnons with scalar spin chiralities in a centrosymmetric magnetic vortex lattice

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ABSTRACT
Two-dimensional magnetic materials with mixed spins serve as fertile platforms for exploring nontrivial magnetic states and collective excitations. Here we investigate a centrosymmetric honeycomb A_3B superlattice consisting of two different elements A and B with mixed spins, arranged in a hexagon-within-hexagon pattern. We first identify that such a lattice harbors radially-distributed Dzyaloshinskii-Moriya interaction, which in turn stabilizes noncollinear magnetic ground states featuring periodic arrays of hexagonal vortices. Based on linear spin-wave theory, we further demonstrate that the system harbors elementary collective excitations in the form of topological magnons with quantized Chern numbers, enabling dissipationless spin and heat transport via chiral edge states. Notably, the magnon dynamics is characterized by scalar spin chiralities, revealing circularly polarized precessions of the vortices with counterclockwise and clockwise chirality. These findings help to enrich physics of binary spins systems with prospective applications in spintronics and magnonics.

REFERENCE STYLE
Topological Magnons with Scalar Spin Chiralities in a Centrosymmetric Magnetic Vortex Lattice, *to be submitted*, J.Y. Bu, S.H. Zhang, Z.Y. Zhang.

KEYWORDS
Topological magnon, Chirality, Magnetic vortex

The Temporal Resolution Limit in Quantum Sensing

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ABSTRACT
Temporal resolution is a critical figure of merit in quantum sensing. This study combines the distinguishable condition of quantum states with quantum speed limits to establish a lower bound on interrogation time. When the interrogation time falls below this bound, the output state becomes statistically indistinguishable from the input state, and the information will inevitably be lost in noise. Without loss of generality, we extend these conclusions to time-dependent signal Hamiltonian. In theory, leveraging certain quantum control techniques allows us to calculate the minimum interrogation time for arbitrary signal Hamiltonian. Finally, we illustrate the impact of quantum speed limits on magnetic field measurements and temporal resolution.

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KEYWORDS
Quantum Sensing, Temporal Resolution, Quantum Speed Limits

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Rotational anisotropy Raman spectrometer for high-sensitivity crystallographic symmetry analysis

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ABSTRACT

Raman spectroscopy is a versatile probe of lattice, charge, and spin excitations in solids and has long been used for crystallographic symmetry analysis. In conventional polarization-resolved Raman scattering (P-Raman), the incident and scattered light wavevectors are fixed, and the Raman intensity is measured as a function of polarization angle. In this geometry, the polarization states are confined to the plane perpendicular to the fixed wavevector, so the measurement samples only a single two-dimensional projection of the full Raman tensor. In addition, rotating the polarizations by π reproduces an equivalent optical configuration, restricting the measured anisotropy to twofold rotational (C_2) symmetry for all crystal classes. To overcome these limitations, we developed a prototype rotational-anisotropy Raman (RA-Raman) spectrometer. Using controlled oblique incidence, it records Raman intensity as the optical scattering plane rotates azimuthally about the sample surface normal, while the incident and analyzed polarization states remain fixed relative to that plane. This geometry lifts the C_2 restriction of P-Raman, probes a series of distinct two-dimensional tensor projections, and simultaneously sweeps the direction of the probed phonon wavevector, thereby enhancing sensitivity to crystal symmetry and wavevector-dependent anisotropy.

We validate the setup using benchmark single crystals from both centrosymmetric and noncentrosymmetric classes. In sapphire and silicon, the measured anisotropy patterns directly identify phonon symmetries and crystallographic axes, including surfaces whose symmetry is difficult to resolve using conventional P-Raman. In GaP, α-quartz, and $LiNbO_3$, the method reveals wavevector-dependent anisotropy and phonon-polariton effects that are inaccessible in fixed-geometry measurements. In particular, RA-Raman enables separation of deformation-potential and electro-optic scattering contributions, quantitative extraction of the Faust-Henry coefficient, and mapping of the angular dispersion of polariton modes.

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These results establish RA-Raman as an effective platform for symmetry analysis and point to broader applications in studies of symmetry-breaking phases and chiral or topological collective excitations in quantum materials.

KEYWORDS
Raman spectroscopy, rotational anisotropy, crystal symmetry, phonon-polariton

A Family Of Quantum Speed Limits For Evolution Of Quantum States And Operators

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ABSTRACT
Quantum speed limit (QSL) aims to study the fundamental evolution speed of a quantum system given a partial description of the system itself. For example, the well-known Mandelstam-Taam bound states that the evolution time for a system to evolve from an initial state to another state under the action of a time-independent Hamiltonian obeys is lower-bounded by the energy standard deviation of the state. In this talk, I review the recent developments in QSL as well as report an interesting result from our group on a family of QSLs based on weighted ℓ^p_w-seminorms. Our bounds are applicable to time dependent Hamiltonian, open system dynamics for finite- and infinite-dimensional systems as well as general linear operators. They are also efficiently and accurately computable under a modest technical condition. It is the best bound available to date in a few cases of practical importance.

REFERENCE STYLE
Quantum Speed Limits For Open System Dynamics Based On A Representation-Basis-Dependent ℓ^p_w-Seminorm', Physical Review A, in press, 2026 (arXiv:2508.17053), H. F. Chau, J. Li

KEYWORDS
Quantum speed limits, open system dynamics, representation-basis-dependent l^p_w-seminorm

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Fine Memory Tuning in Zinc-Based Memtransistors via Elaborate Optical Wave Structures

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ABSTRACT

Memtransistor architectures based on zinc-based organic-inorganic hybrid perovskites (OIMHPs), differing from widely studied Pb-based systems, integrated with organic semiconducting channel, provide a platform for investigating optically driven charge transport and synaptic-like memory effects. Owing to strong optical absorption and complex carrier relaxation pathways, these systems exhibit tunable responses to illumination, enabling control over synaptic weights.

Here, we examine the influence of structured optical fields on OIMHP memtransistors using Laguerre–Gaussian (LG) beams carrying orbital angular momentum (OAM). Compared with conventional Gaussian excitation, the azimuthally varying phase and angular momentum of LG modes introduce additional interaction channels, modifying synaptic plasticity and the evolution of nonlinearity of conductivity evolutions. By varying the topological charge, the device response can be systematically tuned, indicating that memory operation is coupled to the optical phase topology.

These effects are attributed to activation of charge trapping sites, which mediates the transfer of angular momentum and spatial phase information from the optical field to the electronic system, enhancing accessible charge carrier storage. This highlights structured light as a means to access additional degrees of freedom in hybrid materials and suggests pathways for optically programmable functionalities.

To enable reproducible studies, we develop a compact structured-light module utilizing spatial light modulator (SLM), capable of generating LG modes within a simplified optical setup. The platform has been applied to additional contexts, including Hall voltage modulation in MoS_2 and hydrogen evolution reaction, demonstrating its versatility. By reducing experimental complexity while maintaining control over optical parameters, this approach facilitates broader exploration of structured light–matter interactions.

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Ultrafast Responsive Non-Volatile Flash Photomemory via Spatially Addressable Perovskite/Block Copolymer Composite Film, *Advanced Functional Materials*, 30, 2000764, 2020, Y.-H. Chang, C.-W. Ku, Y.-H. Zhang, H.-C. Wang, J.-Y. Chen.
Orbital angular momentum–driven multistate photomemory, *Science Advances*, 11, eadx8795, 2025, Y.-R. Chen, P.-W. Wang, W.-H. Chang, J. Prasad, Y.-Y. Chen, Y.-C. Chiu, T.- H. Lu, Y.-W. Lan.

KEYWORDS
Photomemory, OAM of light, Synaptic device, Metal-halide material, Memtransistor

Quantum Geometry in Non-Linear Optics with Excitons

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ABSTRACT

The quantum geometry of single-particle Bloch states has played a central role in the description of emergent phenomena in condensed matter. In this work, we provide fresh perspectives on the concept of quantum geometry in correlated exciton states. We show that the quantum geometry of the many-body state cannot be simply attributed to the quantum geometry of the constituent single-particle states, but additional physics arises from the phase coherence of the many-body state. The quantum geometry of excitons plays a key role in experimentally accessible non-linear optical properties and can lead to an enhancement in the non-linear optical response. In the case of the shift current (a direct current arising from optically-induced real-space shifts of the charge centres), the quantum many-body geometric term may be interpreted as a many-body analogue of the well-known Berry phase. Predictions from first principles calculations within the GW-BSE approximation will be presented for a range of non-linear optical responses and the many-body quantum geometric contribution will be quantified.

KEYWORDS

Non-linear optics, quantum geometry, first principles calculations

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SYMMETRY AND NON-HERMITICITY CONTROLLED MAJORANA BRAIDING

Chengzhi Tang[1,2,*], Peng Song[3,1,2,*,†], Feilong Luo[1,2], Rui Wang[1,2,4,5,‡], and Baigeng Wang[1,2,§]

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ABSTRACT [*major heading style: Bold 12 pt, UPPERCASE*]
THE BRAIDING OF MAJORANA ZERO MODES (MZMS) PAVES THE WAY FOR REALIZING FAULT-TOLERANT TOPOLOGICAL QUANTUM COMPUTATION (TQC). WE PROPOSE A REINTERPRETATION OF MZM MIGRATION AND BRAIDING PHENOMENA IN 1D TOPOLOGICAL SUPERCONDUCTORS (TSCS), BASED ON A MZM DECONFINEMENT-RECONFINEMENT TRANSITION IN OPEN QUANTUM SYSTEMS, WHICH CAN BE EQUIVALENTLY EXPLAINED VIA SYMMETRY PERSPECTIVES FROM A HERMITIAN PICTURE, OR VIA NON-HERMITIAN SKIN EFFECT (NHSE) PERSPECTIVES FROM A NON-HERMITIAN PICTURE. IN THE DECONFINEMENT-RECONFINEMENT TRANSITION, THE MZM IN THE SYSTEM FIRST EVOLVES INTO A DECONFINED MODE IN THE ENVIRONMENT, BEFORE RECONFINES INTO A LOCALIZED MODE AT THE EDGE OF THE ENVIRONMENT. FROM THE SYMMETRY PERSPECTIVE, THIS IS BECAUSE COUPLING WITH THE ENVIRONMENT BREAKS THE SYMMETRY OF THE SYSTEM THAT PROTECTS THE MZM AS A TOPOLOGICAL EDGE STATE WITHIN THE SYSTEM, SO THE MZM DIFFUSES INTO THE ENVIRONMENT. FROM THE NHSE PERSPECTIVE, THIS IS BECAUSE NHSE HAS PULLED THE MZM FROM THE SYSTEM INTO THE ENVIRONMENT. THIS

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SYMMETRY/NHSE CONTROLLED DECONFINEMENT-RECONFINEMENT PROCESS CAN BE EXPLOITED TO PHYSICALLY MIGRATE THE MZM, WHICH EVENTUALLY RESULTS IN THEIR BRAIDINGS. WE ALSO PROVE THAT ADIABATICITY IS PRESERVED IN THE BRAIDING PROCESS, REALIZING A PROMISING AVENUE FOR ACHIEVING TQC. [*leave one blank line between the abstract and "Reference Style"*]

REFERENCE STYLE

Symmetry and non-Hermiticity controlled Majorana braiding, *Physical Review B,* 112, 144505, 2025, C. Tang, P. Song, F. Luo, R. Wang, B. Wang.

KEYWORDS

Topological Quantum Computation, Majorana braiding, Symmetry, Open systems, Non-Hermitian Physics

Quantum Transport in High Mobility 2D Semiconductors

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ABSTRACT

Few-layer metal chalcogenides are promising material platforms for electronic, optoelectronic, and thermal applications, due to their high mobility, substantial band gap, and demonstrated synthesis in the wafer scale. Here I will present our recent work in two members of the material family with unprecedented mobility. In few-layer InSe quantum wells, we demonstrate gate-tunable Rashba spin-orbit coupling[1], and electrostatic population and characterization of the second subband, with giant tunability of its energy, population, and spin-orbit coupling strength, via the control of not only layer thickness but also out-of-plane displacement field[2]. A modulation of as much as 350% or over 250 meV is achievable, underscoring the promise of InSe for tunable infrared and THz sources, detectors and modulators. Moreover, for few-layer $PdSe_2$ field effect transistors, we demonstratde large saturation current >350 mA/mm, and high field effect mobilities of ~ 700 and 10,000 cm^2/Vs at 300K and 2K, respectively. At low temperatures, magnetotransport studies reveal unique octets in quantum oscillations that persist at all densities, arising from 2-fold spin and 4-fold valley degeneracies, which can be broken by in-plane and out-of-plane magnetic fields toward quantum Hall spin and orbital ferromagnetism[3]. Lastly, I will discuss our latest work that reveals layer parity-dependent spin splitting, spin-valley locking, and evidence for fractional quantum Hall effect in few-layer PdSe2.

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KEYWORDS

2D materials, 2D semiconductors, spin-orbit coupling, quantum Hall ferromagnetism

Tuning Unconventional Superconductor Sr_2RuO_4 by Uniaxial Stress

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ABSTRACT

My research over the last decade has primarily focuses on the control of unconventional superconductors, specifically utilizing uniaxial stress—a technique that has recently emerged as a highly effective experimental tool. In this talk, I will demonstrate the versatility of uniaxial stress applications. Recently, it has been shown that the electronic structure of Sr_2RuO_4 can be tuned across Van Hove singularity (VHS) [1] and an enhancement of T_c is observed around VHS [2]. To obtain thermodynamic information, we have developed heat capacity and elastocaloric effect (ECE) under uniaxial stress [3,4]. We map out the phase diagram of Sr2RuO4, which remains unknown for decades, and we can place a strong constraint on its superconducting order parameters with inputs from theoretical calculations.

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KEYWORDS
Unconventional Superconductors, Uniaxial Stress, Van Hove Singularity, Elastocaloric Effect

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Title: Quantum metric length and quantum metric localization

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Abstract:
In most solid state systems, the Fermi velocity combined with energy gives rise to many important length scales such as the coherence length and the superconducting coherence length. As Fermi velocity goes to (nearly) zero in flat band materials, these conventional length scales vanish. The question is: in flat band materials, what gives rise to the important length scales?

In this talk, we show that the quantum metric length, which was known to determine the size of the optimally localized Wannier functions, is indeed the fundamentally important length scale in flat band materials. We show that, while the quantum metric length can be exceedingly long, it determines the superconducting coherence length of flat band superconductors [1,2], the coherence length of a flat band Josephson junction [3], the decay length of Majorana modes in flat band topological superconductors [4] and more. The critical current anomaly had been observed experimentally in flat band Josephson junction can be explained by quantum metric contributions [5].

Recently, we showed that the quantum metric length determines the localization length of disorder flat band materials. Take a 1D system with a flat band (with a small dispersion) as an example. As disorder increases, the localization length decreases as expected from Anderson localization. However, as disorder further increases, the localization length reaches a plateau where the localization length is about twice the quantum metric length. The plateau is extremely wide for an isolated flat band. We call this regime where the localization length is governed by the quantum metric length, the quantum metric localization regime [6].

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COMPLETE K-UNIFORM HYPERGRAPH STATES AS A RESOURCE FOR QUANTUM METROLOGY

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ABSTRACT

Quantum metrology exploits quantum entanglement to enhance parameter-estimation precision, but realistic noise can substantially degrade the quantum Fisher information (QFI). Among hypergraph states, complete k-uniform hypergraph states are particularly attractive for metrological applications because they are permutation invariant and highly symmetric. Here, we derive analytical expressions for their QFI and extend the analysis to erasure, dephasing, and global depolarizing noise. We show that complete k-uniform hypergraph states exhibit near-Heisenberg-limited QFI in the noiseless regime, are especially robust against erasure noise, and remain competitive with bundled star-graph benchmarks under dephasing and depolarizing noise. Furthermore, we investigate weighted hypergraph states and find that combining multiple complete k-uniform components can outperform graph states in noiseless QFI at suitable phases ϕ, while including more components generally enhances the maximum attainable QFI, but not erasure robustness. These results suggest that complete k-uniform hypergraph states are promising metrological resources for future quantum sensing.

KEYWORDS

Quantum metrology, Hypergraph states, Quantum Fisher information, Noise robustness, Multipartite entanglement

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Abelian and non-Abelian fractional Chern insulators in non-Chern bands

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ABSTRACT

The fractional quantum Hall effect was initially discovered in a two-dimensional electron gas subjected to a strong magnetic field, which quantizes the kinetic energy of the electrons into discrete, highly degenerate Landau levels (LL). Its extension beyond the LL paradigm was first made possible by noting the topological equivalence of Chern bands in crystals to LLs, which can be further engineered in the isolated flat band limit to mimic LLs both in energy landscape and in quantum geometry. This has led to the ground breaking discovery of fractional Chern insulators at zero magnetic field. We will discuss possibilities to go beyond the Chern band and LL paradigm, and present findings in lattice models that demonstrate fermionic and bosonic Laughlin and Moore-Read states in exact flat bands where band topology is trivial, critical, or ill-defined [1-4].

The works are supported by the National Natural Science Foundation of China (No. 12425406), the Research Grant Council of Hong Kong (AoE/P-701/20, HKU SRFS2122-7S05, A-HKU705/21), and New Cornerstone Science Foundation.

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Probing magnons and its coupling with phonons in 2D van der Waals magnets via inelastic scattering spectroscopies

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ABSTRACT

This report focuses on two cutting-edge studies utilizing inelastic scattering spectroscopies—micro-focused Brillouin light scattering and circular-polarization-resolved magneto-Raman spectroscopy—on van der Waals layered magnetic materials (the monolayer ferromagnet CrSBr and the antiferromagnet $FePSe_3$). It details the first direct observation and elucidation of low-frequency magnons governed by anisotropy in the monolayer limit, as well as the chemically doped and magnetically co-tunable strong coupling between magnons and chiral phonons. This work deepens the understanding of magnetic interactions, spin-lattice coupling, and topological states at the two-dimensional limit, providing crucial physical insights and material platforms for developing the next generation of low-power spintronic and quantum devices based on angular momentum transport.

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Quantum sensing for physics beyond classical probes

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ABSTRACT
Even a single qubit's quantum properties can confer a sensing advantage. I will illustrate this with two examples. First, using qubit decoherence to probe physics in the complex plane of control parameters—specifically, to detect Lee-Yang zeros of an environment's partition function, in tribute to the late Professor Chen-Ning Yang. Second, using weak measurements with a quantum sensor to selectively access higher-order correlations in a quantum system.

KEYWORDS
Quantum sensing, Decoherence, Lee-Yang zeros, correlations

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Quantum Christoffel Nonlinear Magnetization

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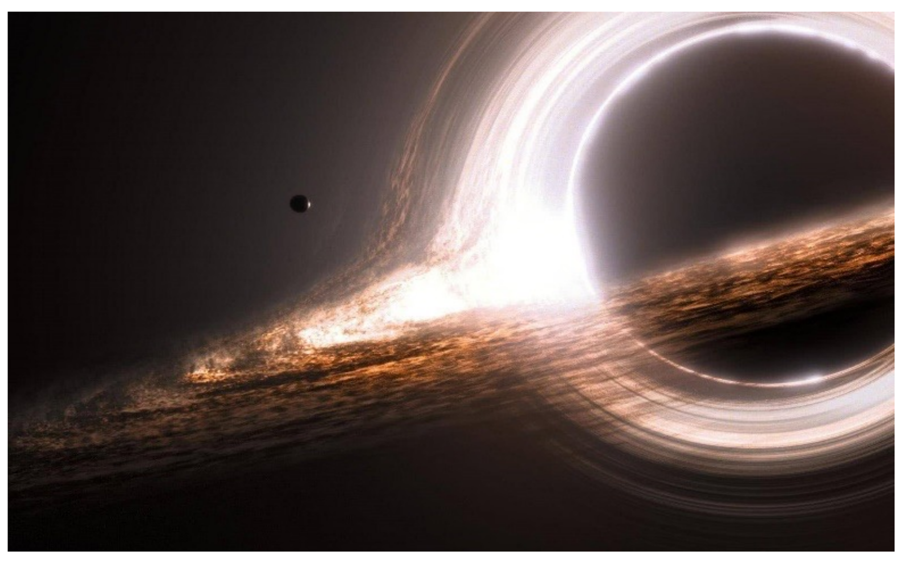
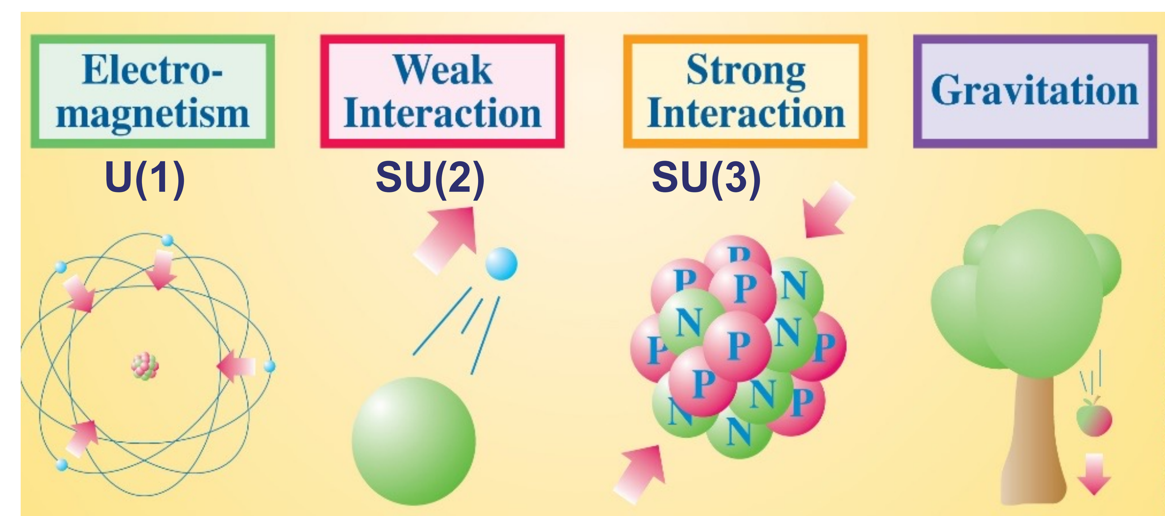
Geometry in Physics



Gravitational field
=
Geometry of spacetime

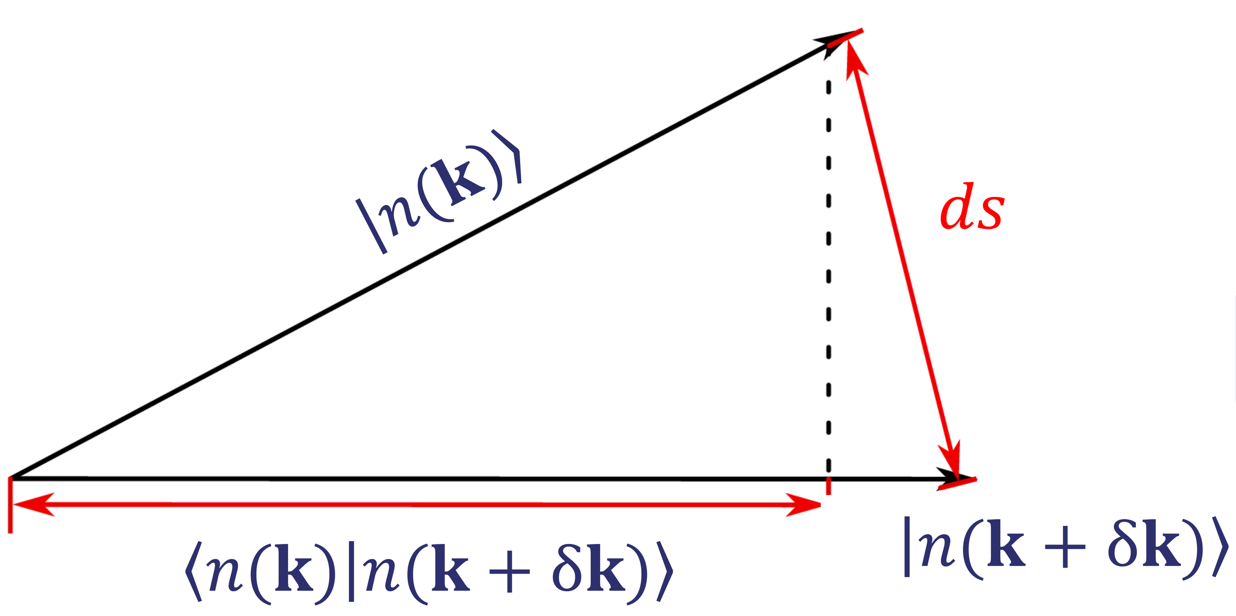


Yang-Mills theory

Interactions are connections on manifolds respect different local gauge invariance

Quantum Geometry

Tianyu Liu*, Xiao-Bin Qiang*, Hai-Zhou Lu†, X. C. Xie
National Science Review 12, nwae334 (2025)



Quantum Geometric Tensor

$$ds^2 = Q_n^{ab} dk_a dk_b$$

$$Q_n^{ab} = g_n^{ab} - \frac{i}{2}\Omega_n^{ab}$$

g_n: **Quantum metric**

$$= \mathrm{Re}\sum_{m\neq n} \mathbf{A}_{nm}\mathbf{A}_{mn}$$

Ω_n: **Berry curvature**

$$= \nabla\times\mathbf{A}_n$$

$\mathbf{A}_{nm}$: **Berry connection**

$$= \langle n|i\nabla_{\mathbf{k}}|m\rangle$$

Nonlinear transport

Flat-band superconductor

Fractional Chern insulator

Christoffel Symbol

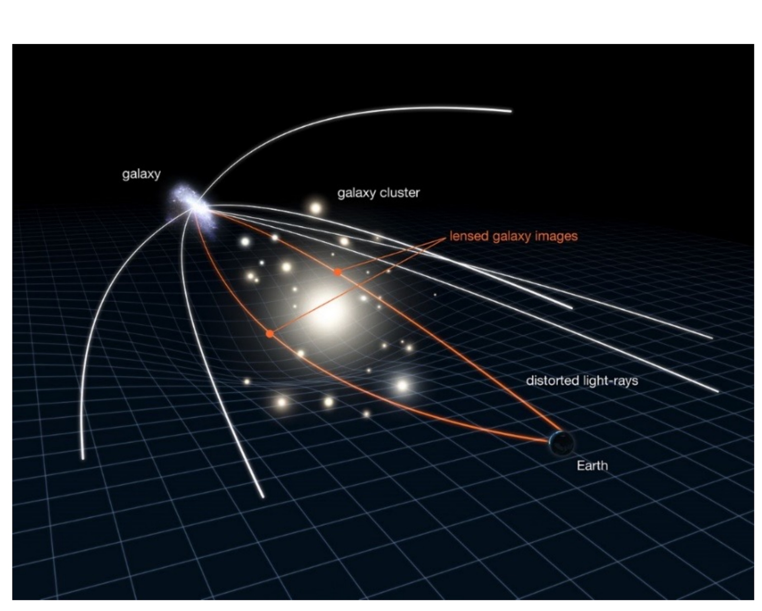
Geodesic equation in Einstein's general relativity

$$\ddot{x}_a + \Gamma^a_{bc}\dot{x}_b\dot{x}_c = 0$$

Γ^a_{bc}: **Christoffel Symbol**

$$\Gamma^a_{bc} = \frac{1}{2}g^{da}(\partial_c g_{bd} + \partial_b g_{dc} - \partial_d g_{bc})$$

3+1D curved spacetime



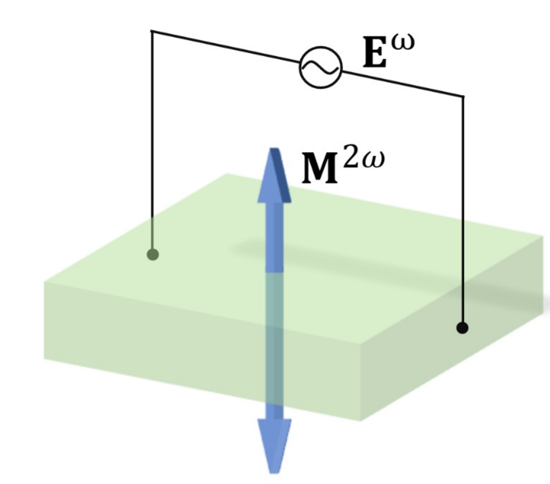
Light travels along geodesics

Quantum Christoffel Nonlinear Magnetization

Xiao-Bin Qiang*, Xiaoxiong Liu*, Hai-Zhou Lu†, X. C. Xie
Phys. Rev. Lett. 136, 056302 (2026)
Xiao-Bin Qiang*, Tianyu Liu*, Hai-Zhou Lu†, X. C. Xie
Appl. Phys. Lett. 128, 010501 (2026)

$$M_a = \alpha_{abc}E_bE_c$$

Magnetization **Electric field**



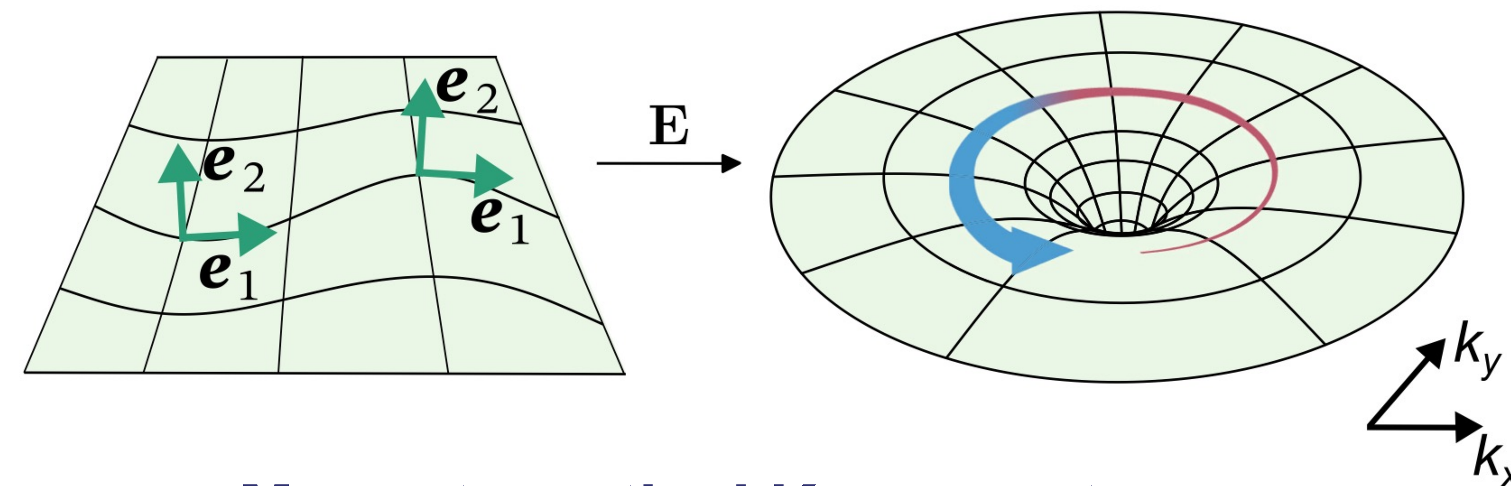
Nonlinear Magnetization coefficient

$$\alpha_{abc} = -\frac{\tau e^3}{2\hbar V}\sum_{n,\mathbf{k}} f_0'\epsilon_{ade}\Gamma_n^{edb}v_n^c$$

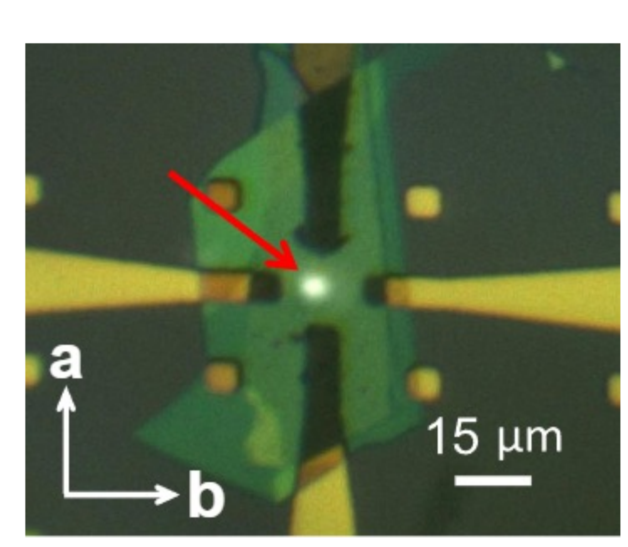
Quantum Christoffel Symbol

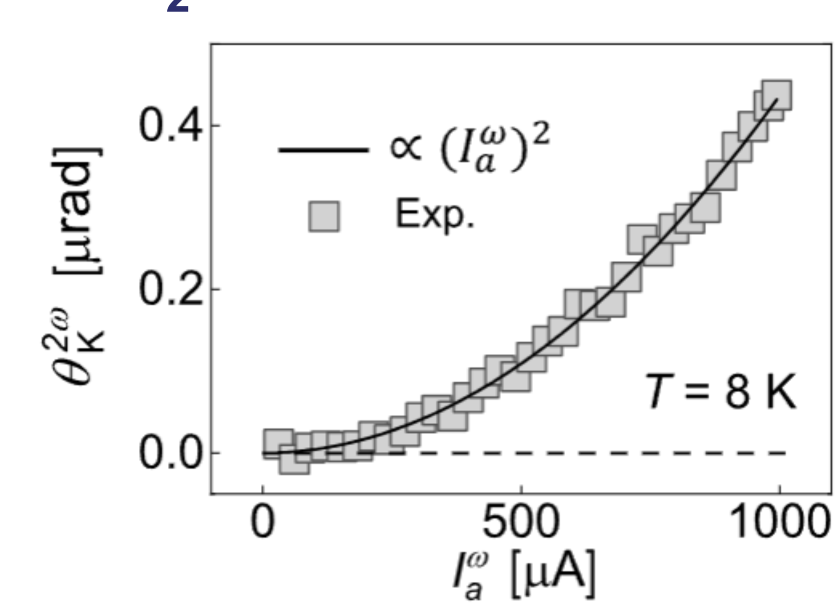
$$\Gamma_n^{abc} = \frac{1}{2}(\partial_c g_n^{ba} + \partial_b g_n^{ac} - \partial_a g_n^{bc})$$

Effective loop current



Magneto-optical Kerr spectroscopy in WTe_2





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Phys. Rev. B 113, L041407 (2026)

Engineering Blue Emission in $CsPbBr_3$ via Rb-doped Multiple Quantum Wells

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ABSTRACT

Despite its importance for full-colour display technologies, stable and efficient blue emission in halide perovskites remain challenging to achieve compared to its red and green counterparts. Compositional engineering approaches used to blue-shift emission often come at the cost of instability, ion migration, and defect sensitivity with a limited control over carrier confinement. Multiple quantum wells (MQWs) offer an alternative strategy, enabling emission tuning through structural design and interface engineering rather than relying only on chemical modification.

In this work, we demonstrate controllable emission in $CsPbBr_3$ by combining Rb^+ cation substitution with quantum confinement in MQWs, using TPBi as the barrier material. The structures were fabricated via a modified thermal evaporation method with systematically varied Rb concentration and layer thicknesses.

As the well thickness decreases and Rb concentration increases, the bandgap of Rb-doped $CsPbBr_3$ MQWs shifts from the green region (~520 nm) toward the blue region (≤495 nm). Density functional theory (DFT) calculations further reveal that Rb substitution only induces a minor effect on interfacial dipole interactions with TPBi, resulting in limited electron transfer and weak band bending, while preserving the type-I band alignment beneficial for efficient radiative recombination. However, in both simulations and experiments, Rb incorporation reduces radiative strength and photoluminescence intensity, which is attributed to lattice distortion and dopant-induced nonradiative recombination channels. Importantly, this limitation can be mitigated in MQWs, where reducing the quantum well thickness or increasing the number of alternating well-barrier layers can effectively recover emission intensity.

Overall, this work establishes cation-doped MQW design as a versatile route to achieve blue emission in perovskites, offering fine control over emission properties through tuning of well thickness, number of layers, and composition. These insights provide a

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practical pathway toward stable and efficient blue perovskite light sources for next-generation optoelectronic applications.

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KEYWORDS
Blue emission, Halide perovskites, Multiple quantum wells, Density functional theory, Optoelectronic applications

Reliable Quantum Steering Detection under Imperfect Measurement

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ABSTRACT

Quantum steering, a fundamental manifestation of nonlocal quantum correlations, plays a vital role in quantum key distribution, quantum randomness generation, and quantum metrology. Reliable experimental detection of quantum steering is therefore a key task in quantum information science, but it is often hindered by measurement imperfections. Here, we introduce a randomized measurement protocol designed to mitigate the effects of imperfect measurements and enhance detection reliability. We theoretically prove that this approach effectively suppresses measurement errors by requiring only local operations on the trusted party; moreover, its dimension-independent nature ensures ready adaptability to quantum systems of arbitrary finite size. We experimentally validate the method using polarization-entangled photons, demonstrating consistent performance under controlled misalignments for both 2- and 3-setting configurations. Our results provide a practical and reliable framework for steering detection in realistic experimental conditions, paving the way for its integration into quantum certification and communication protocols.

KEYWORDS

Quantum steering, randomized measurement, photic experiment

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