PCS NEWSLETTER

QR to PCS Webpage

December 2025

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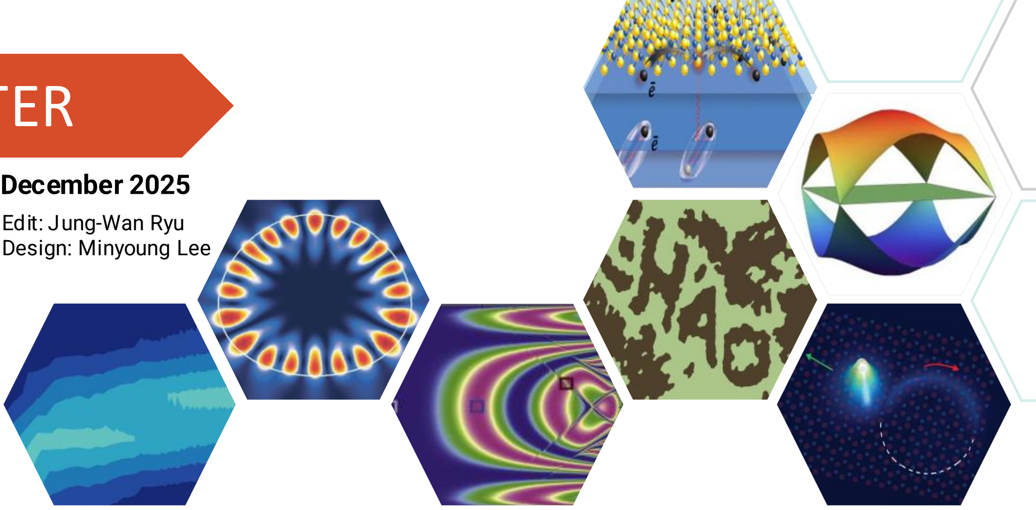


This is our last issue of the Newsletter. Surely you already know that PCS IBS is closing. A small group will continue activities at Daejeon, while most of our members moved to new positions, or are in the process of doing just that.

Despite all odds, the IBS Center for Theoretical Physics of Complex Systems flourished in 2025, publishing 49 papers (of a total of 502) in 2025, and counting 2619 citations this year (of a total of 13004). Dominik Šafránek moved to a faculty post at Charles University Prague, Jae Ho Han moved to a faculty post at Korea Military Academy Seoul, and Dung Xuan Nguyen moved to a faculty post at International Centre for Interdisciplinary Science and Education (ICISE) Quy Nhon. Two of our members have succeeded in getting tenure at IBS. We hosted and/or ran several International Workshops including the Asian Network School and Workshop on Complex Condensed Matter Systems 2025 with more than 100 participants. Find us on youtube and facebook! Stay healthy, and celebrate with us! Thank you for being part of our readership! And always remember: Forscher, forscht forscher!!!

Have a Great Year 2026!

Sergej Flach

News

We published our new PCS Scientific Reports 2022-2025.

PCS IBS Seminars

“Quantum chaos in few-body quantum gases” by Alex Kerin, Massey University, New Zealand (November 18)

“Thermal decay of breathers in Klein-Gordon and Josephson-junction lattices” by Juan Francisco Rodriguez Archilla, University of Sevilla, Spain (November 20)

“Optically induced concave mirror polaritonic cavities” by Pavel Kozhevin, St. Petersburg State University, Russia (November 25)

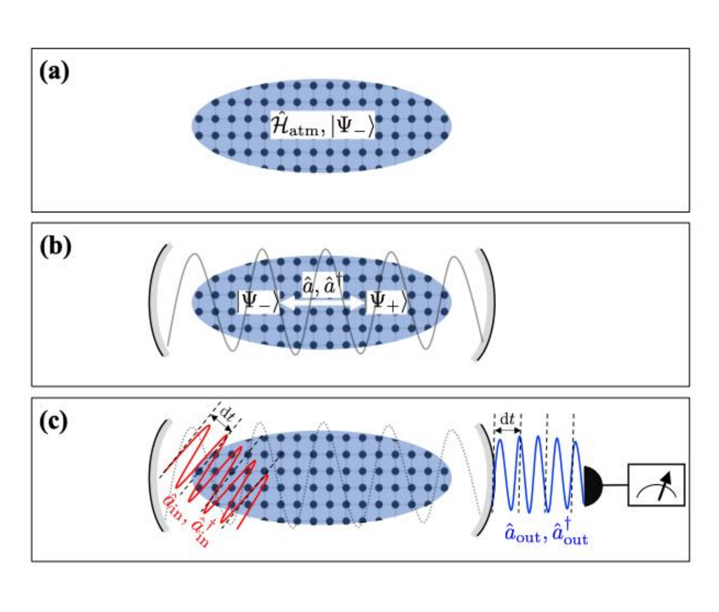
“Detecting classicality using local perception operator witness” by Rohit Kishan Ray, Virginia Tech, USA (November 27)

One can find more seminars on this page.

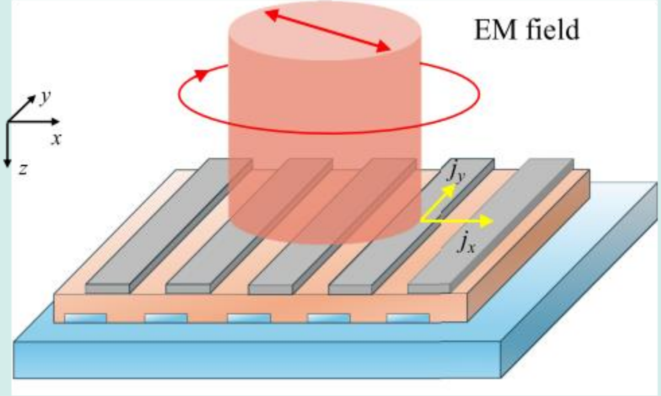
New Research Results

Stochastic Schrödinger equation for homodyne measurements of strongly correlated systems
Aniket Patra, Felix Motzoi and Klaus Mølmer
J. Phys. B: At. Mol. Opt. Phys. 58, 195302 (2025)

The authors derive a stochastic Schrödinger equation (SSE) that describes the homodyne measurement record of a strongly interacting atomic system coupled to a single-mode optical cavity. Starting from a general atom–light Hamiltonian and using the rotating-wave approximation and adiabatic elimination of the excited state, they obtain an effective dispersive atom–light interaction and express the SSE purely in terms of atomic operators. In the setup, an input laser field populates the cavity, the output field becomes entangled with the strongly correlated atoms, and a homodyne detector measures a suitable quadrature of this output field. The authors show that, in the appropriate limit, the resulting SSE coincides with the one describing a Gaussian continuous quantum measurement of an atomic observable $\widehat{M}_0$ associated with the strongly correlated Hamiltonian $\widehat{\mathcal{H}}_{\mathrm{atm}}$.



Ratchet Hall effect in fluctuating superconductors
A. V. Parafilo, V. M. Kovalev, and I. G. Savenko
Phys. Rev. B 112, 104501 (2025)



The paper predicts a ratchet Hall effect in superconducting films that are slightly above their critical temperature, where fluctuating Cooper pairs still exist. When both the film's critical temperature and the strength of an applied electromagnetic field are spatially modulated, this broken inversion symmetry produces a directed (rectified) current of fluctuating Cooper pairs. Linearly polarized light drives the current along the direction of the modulation, while circularly polarized light generates a transverse current, constituting a nonlinear Hall effect without a magnetic field. The effect is strongly enhanced near the superconducting transition because the lifetime of fluctuating Cooper pairs increases sharply. Overall, the work proposes a new mechanism for nonlinear photoresponse in superconductors, offering a disorder-robust platform to study anomalous Hall phenomena.

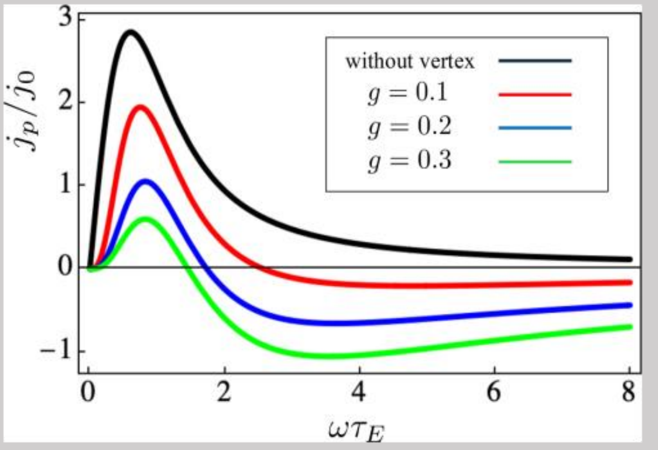
New Research Results

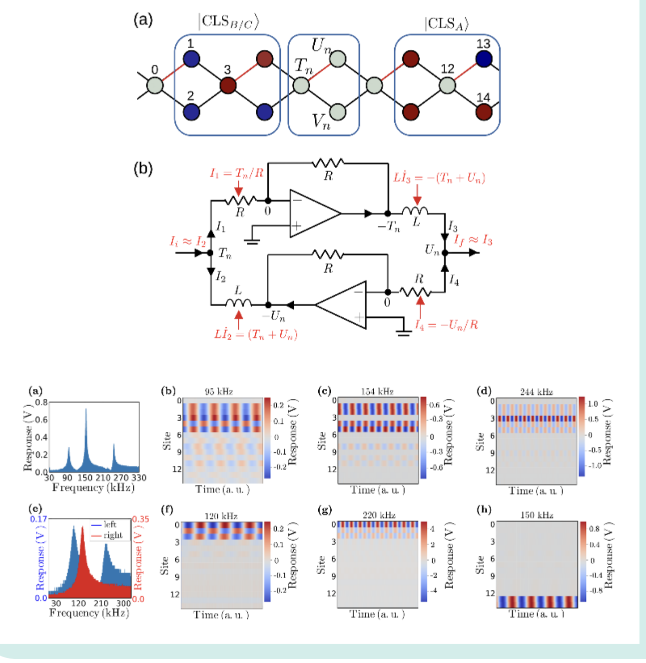
Vertex corrections to nonlinear photoinduced currents in two-dimensional superconductors

A. V. Parafilo, V. M. Kovalev, and I. G. Savenko

[Phys. Rev. B 112, 134513 (2025)]

The paper develops a gauge-invariant theory of nonlinear photoinduced currents in a two-dimensional superconductor carrying a built-in supercurrent and illuminated by circularly polarized light. Because impurities break momentum conservation, quasiparticles can absorb light and generate a transverse, steady (rectified) current—an effect referred to as a superconducting photodiode. The authors show that correctly accounting for the BCS interaction requires a self-consistent vertex correction, which significantly modifies the magnitude and frequency dependence of the nonlinear current. They compute contributions from all leading diagrams and find that photoinduced current $\sim\tau_E/\tau_i$ dominates in realistic films (τ_E, τ_i are energy and impurity relaxation times, respectively), while photo-current $\sim(\tau_i T)^{-2}$ becomes relevant only in strongly disordered samples. Overall, the work demonstrates that the photodiode supercurrent is highly sensitive to impurity and relaxation times, enabling its use as a spectroscopic probe of superconducting dynamics.





Realization and characterization of an all-bands-flat electrical lattice

Noah Lape, Simon Diubenkov, L. Q. English, P. G. Kevrekidis, Alexei Andreanov, Yeongjun Kim, and Sergej Flach

[Phys. Rev. B 112, 184309 (2025)]

In this work, the authors design and experimentally realize a diamond chain electrical lattice with a π-flux configuration that hosts all energy bands perfectly flat. Using capacitors, inductors, and inverting-amplifier circuits to implement both positive and negative couplings, they drive the lattice and observe compact localized states whose spatial profiles and frequencies closely match the tight-binding predictions. The authors further investigate boundary configurations, confirming that the ABF lattice supports compact edge modes consistent with theory. Through this platform, the authors demonstrate that electrical circuits provide a versatile route for exploring flat bands, disorder, and synthetic gauge fields.

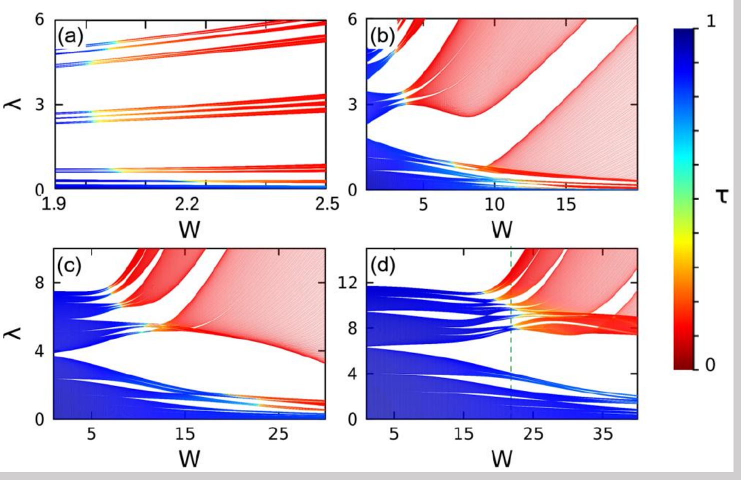
New Research Results

Mobility edges and fractal states in quasiperiodic Gross-Pitaevskii chains

Oleg I. Utesov, Yeongjun Kim, and Sergej Flach

[Phys. Rev. B 112, 174207 (2025)](https://doi.org/)

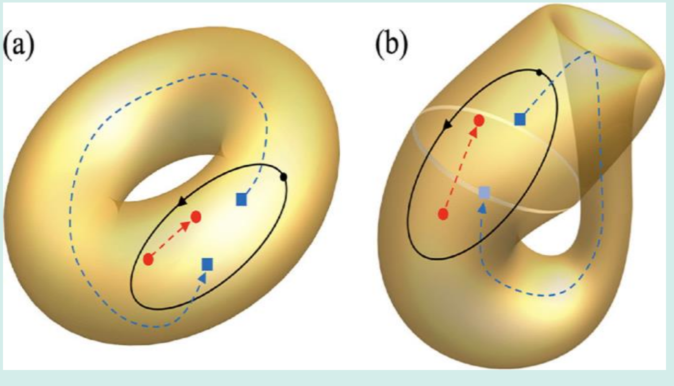
The authors explored the properties of a Gross-Pitaevskii chain subject to an incommensurate periodic potential, i.e., a nonlinear Aubry-André model. It was shown that the condensate crucially impacts the properties of the elementary excitations. In contrast to the conventional linear Aubry-André model, the boundary between localized and extended states (mobility edge) exhibits nontrivial branching. The authors also observed critical fractal states separating extended and localized ones.



Nonorientable exceptional points in the Klein Brillouin zone

Jung-Wan Ryu, Jae-Ho Han, Moon Jip Park, Hee Chul Park, and Chang-Hwan Yi

Phys. Rev. A 112, 052223 (2025)

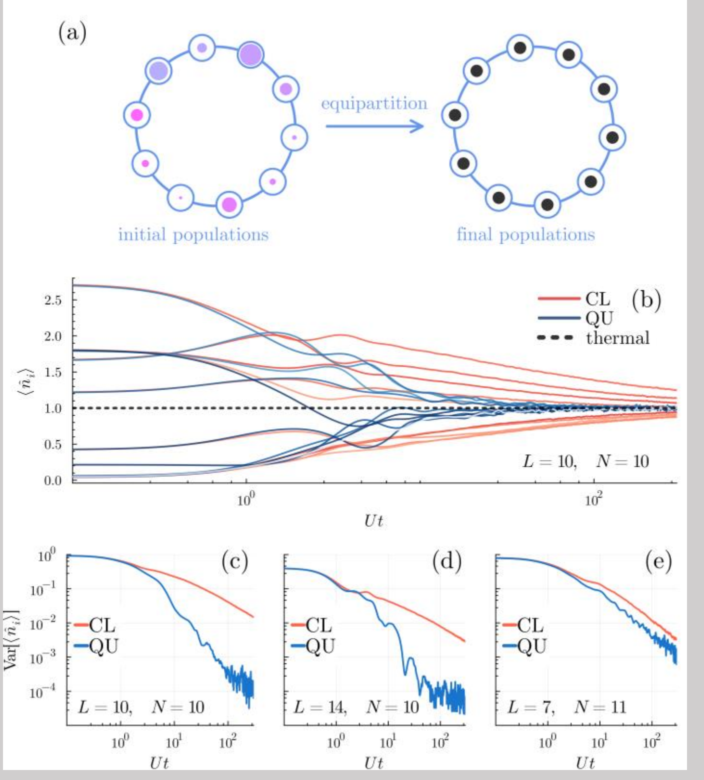


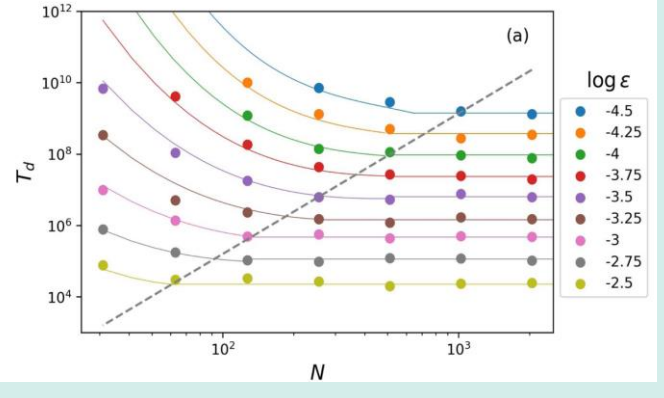
Nonorientable manifolds, such as the Möbius strip and the Klein bottle, defy conventional geometric intuition through their periodic boundary condition with a twist. As a result, topological defects on nonorientable manifolds give rise to novel physical phenomena. The authors study the adiabatic transport of exceptional points (EPs) along nonorientable closed loops and uncover distinct topological responses arising from the lack of global orientation. They further demonstrate the adiabatic evolution of EPs and the emergence of orientation-sensitive observables in a Klein Brillouin zone, described by an effective non-Hermitian Hamiltonian that preserves momentum-space glide symmetry. Finally, the authors numerically implement these ideas in a microdisk cavity with embedded scatterers using synthetic momenta.

New Research Results

Quantum Enhancement of Thermalization
Yulong Qiao, Frank Großmann, Peter Schlagheck and Gabriel M. Lando
[Phys. Rev. Lett. 135, 060404 (2025)]

Equilibrium properties of many-body systems with a large number of degrees of freedom are generally expected to be described by statistical mechanics. Such expectations are closely tied to the observation of thermalization, as manifested through equipartition in time-dependent observables, which takes place both in quantum and classical systems but may look very different in comparison. By studying the dynamics of individual lattice site populations in ultracold bosonic gases, the authors show that the process of relaxation toward equilibrium in a quantum system can be orders of magnitude faster than in its classical counterpart. Classical chaos quantifiers reveal that this is due to a wave packet in a quantum system being able to escape regions of inefficient classical transport by a mechanism akin to tunneling.





Measuring FPUT thermalization with Toda integrals
H. Christodoulidi, S. Flach
[Chaos 35, 113127 (2025)]

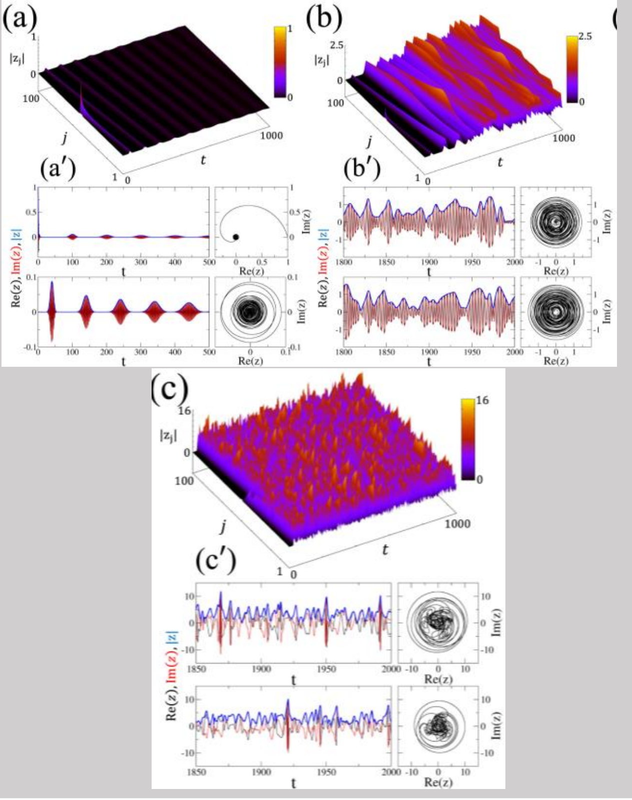
The authors assess the ergodic properties of the Fermi–Pasta–Ulam–Tsingou-α model for generic initial conditions using a Toda integral. It serves as an adiabatic invariant for the system and a suitable observable to measure its equilibrium time. Over this time scale, the onset of action diffusion results in ergodic temporal fluctuations. They compare this time scale with the inverse of the maximum Lyapunov exponent λ and its saturation time, which are systematically shorter. The Toda integral ergodization/equilibrium time is system size independent for long chains but show dramatic growth when the system size is smaller than a critical one, whose value depends on the energy density. The authors measure the dependence of energy density on the critical system size and relate this observation to the possible emergence of a Kolmogorov–Arnold–Moser regime. The authors numerically determine the critical energy density of this regime, finding that it approximately decays as $1/N^2$ with the number of particles N.

New Research Results

Nonreciprocity induced spatiotemporal chaos: Reactive vs dissipative routes

Jung-Wan Ryu

[Chaos, Solitons & Fractals 203, 117647 (2026)]



Nonreciprocal interactions fundamentally alter the collective dynamics of nonlinear oscillator networks. The author investigates Stuart–Landau oscillators on a ring with nonreciprocal reactive or dissipative couplings combined with Kerr-type or dissipative nonlinearities. Through numerical simulations and linear analysis, the author uncover two distinct and universal pathways by which enhanced nonreciprocity drives spatiotemporal chaos. The findings establish a minimal yet general framework that goes beyond case-specific models and demonstrate that nonreciprocity provides a universal organizing principle for the onset and control of spatiotemporal chaos in oscillator networks and related complex systems. These insights suggest potential applications for controlling coherence and chaos in active, photonic, and other nonequilibrium systems.

Puzzle of the Month

November solution puzzle:

We need the number to be divisible by 9 and by 4. So, we need at least 2 zeros in the end, and the sum of the digits should be divisible by 9. Then, the minimal number is 9 digits equal to 1 and two zeros at the end: 11111111100

The correct solution was sent in by Oleg Utesov, congratulations!

Final puzzle of the final month in the final issue:

What is the last digit of 777^{333} ? Have fun with solving, no need to send solutions, since our Newsletter story ends here.

We thank all puzzle enthusiasts who contributed to this section of our Newsletter. Well done! Continue!

As a final gift, here is a real life physics puzzle:

FIGURE 1. Photograph of the moon tilt illusion. Picture taken one hour after sunset with the moon in the southeast. Camera pointed upwards 45° from the horizon with bottom of camera parallel to the horizon.

You can observe similar situations if you check for a half moon shortly after sunset. You will see that the moon appears to receive light from a sun light source which is located way above the horizon, despite the fact that the sun is below the horizon. How comes?