PCS NEWSLETTER

QR to PCS Webpage

February 2025

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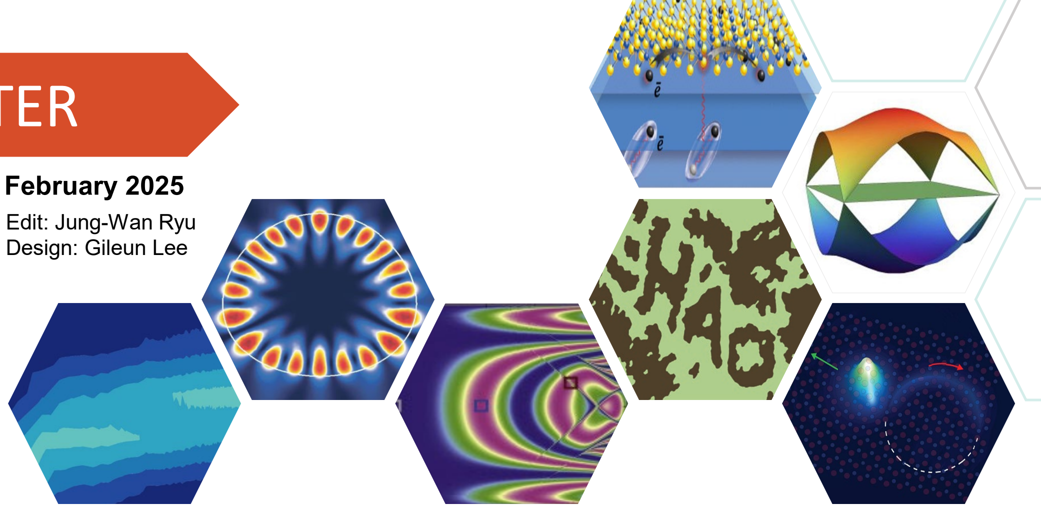
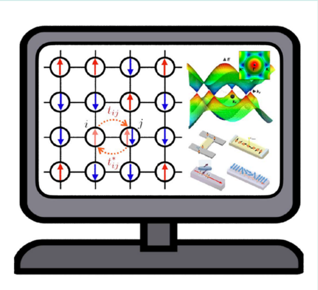


PCS Workshops and Meetings



PCS will run and host International Workshop on Computational Approaches to Magnetic Systems on **February 18 – 20, 2025.**

PCS IBS Seminars

"Master stability curves for traveling waves"
by Andrus Giraldo, Korea Institute for Advanced Study, Korea (January 23)

You can find more seminars on this page.

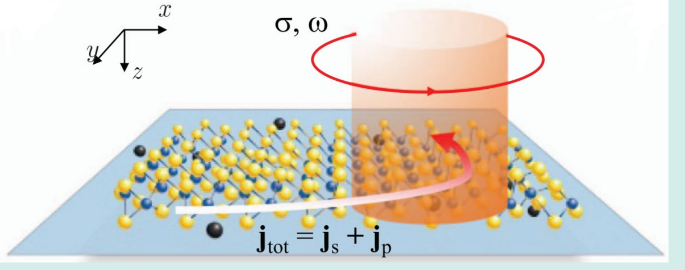
New Research Results

Proposal for superconducting photodiode

A V Parafilo, M Sun, K Sonowal, V M Kovalev and I G Savenko

[2D Mater. 12, 011001 (2024)]

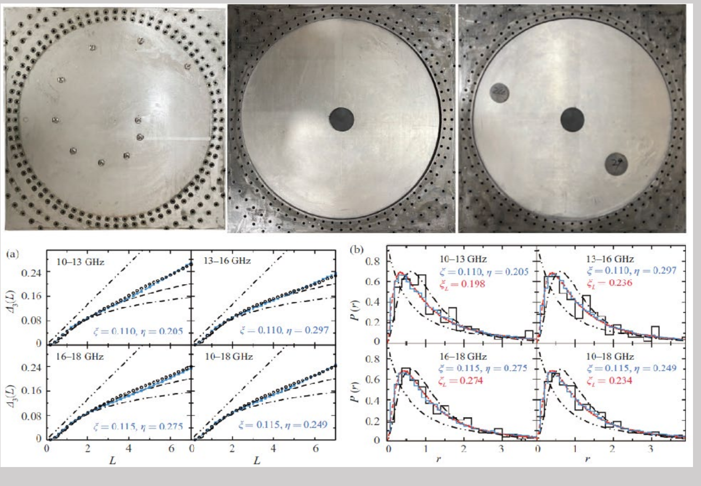
The authors propose a concept of a superconducting (SC) photodiode—a device that transforms the energy and 'spin' of an external electromagnetic (EM) field into the rectified steady-state supercurrent and develop a microscopic theory describing its properties. For this, they consider a two-dimensional thin film cooled down below the temperature of SC transition with the injected dc supercurrent and exposed to an external EM field with a frequency smaller than the SC gap. As a result, the authors predict the emergence of a photoexcited quasiparticle current, and, as a consequence, oppositely oriented stationary flow of Cooper pairs. The strength and direction of this photoinduced supercurrent depend on (i) such material properties as the effective impurity scattering time and the nonequilibrium quasiparticles' energy relaxation time and (ii) such EM field properties as its frequency and polarization.



Experimental test of an extension of the Rosenzweig-Porter model to mixed integrable-chaotic systems experiencing time-reversal invariance violation

Xiaodong Zhang, Jiongning Che, and Barbara Dietz

[Chinese Physics B, 33, 120501 (2024)]

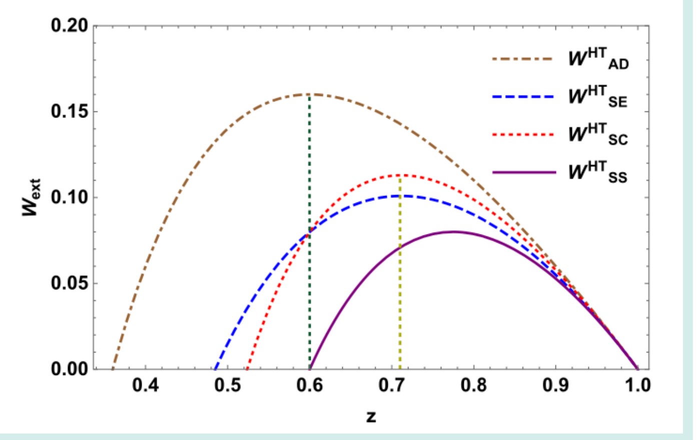


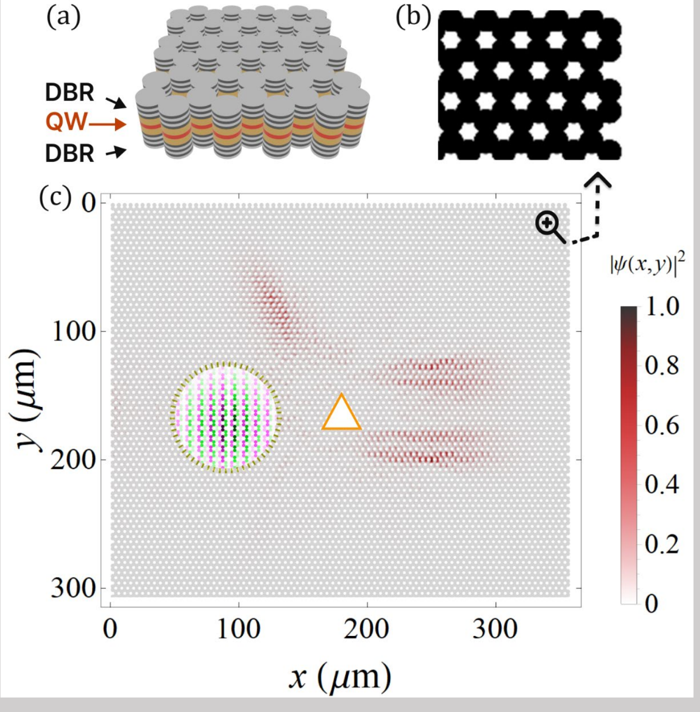
The authors report on the theoretical and experimental investigations of the transition of a typical quantum system with mixed regular-integrable classical dynamics to one with violated time-reversal (T) invariance. The measurements are performed with a flat superconducting microwave resonator with circular shape in which chaoticity is induced by using either long antennas or inserting two circular disks into the cavity, and by magnetizing a ferrite disk placed at its center, which leads to violation of T invariance. They propose an extension of the Rosenzweig-Porter (RP) model, which interpolates between mixed regular-chaotic instead of integrable dynamics and fully chaotic dynamics with violated T-invariance, and derive a Wigner-surmise like analytical expression for the corresponding nearest-neighbor spacing distribution. The authors propose a procedure involving this result and those for the RP model to determine the size of T-invariance violation and chaoticity and validate it employing the experimental eigenfrequency spectra.

New Research Results

The asymmetric quantum Otto engine: frictional effects on performance bounds and operational modes
Varinder Singh, Vahid Shaghaghi, Tanmoy Pandit, Cameron Beetar, Giuliano Benenti & Dario Rosa
[Eur. Phys. J. Plus 139, 1020 (2024)]

The authors present a detailed study of an asymmetrically driven quantum Otto engine with a time-dependent harmonic oscillator as its working medium. They obtain analytic expressions for the upper bounds on the efficiency of the engine for two different driving schemes having asymmetry in the expansion and compression work strokes. The authors show that the Otto cycle under consideration cannot operate as a heat engine in the low-temperature regime. Then, they show that the friction in the expansion stroke is significantly more detrimental to the performance of the engine as compared to the friction in the compression stroke. Further, by comparing the performance of the engine with sudden expansion, sudden compression, and both sudden strokes, the authors uncover a pattern of connections between different operational points.





Skew scattering and ratchet effect in photonic graphene
O. M. Bahrova and S. V. Koniakhin
[Phys. Rev. B 110, 205405 (2024)]

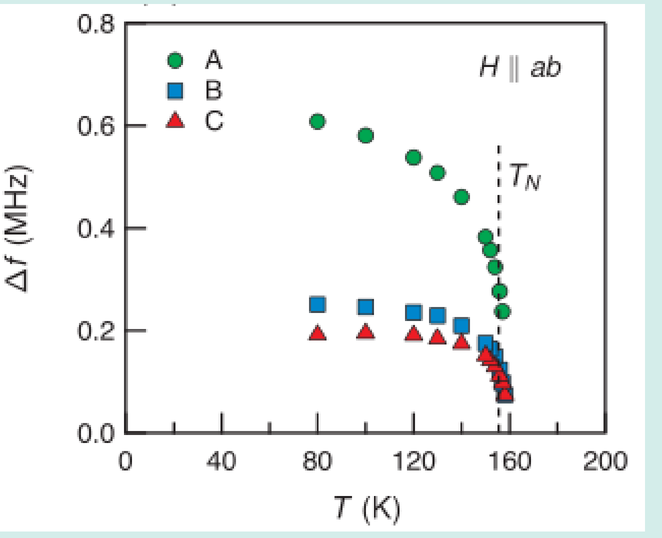
The authors consider ratchet effect originated from the asymmetric (skew) scattering in photonic graphene, with the main focus on its realization with semiconductor microcavity exciton-polaritons. Triangular defects in the form of missing micropillars in a regular honeycomb lattice are considered as ones that break the spatial inversion symmetry, thus providing the possibility of the ratchet effect. By means of the numerical solution of the effective Schrodinger equation and utilization of the stochastic random walks approach, the microscopical insight into the process of skew scattering is provided, and the corresponding indicatrices, cross-sections, and asymmetry parameters are determined. In a system with multiple coherently oriented triangular defects, a macroscopic ratchet effect occurs as a unidirectional flux upon noise-like initial conditions. This study broadens the concept of ratchet phenomena in the field of photonics and optics of exciton-polaritons.

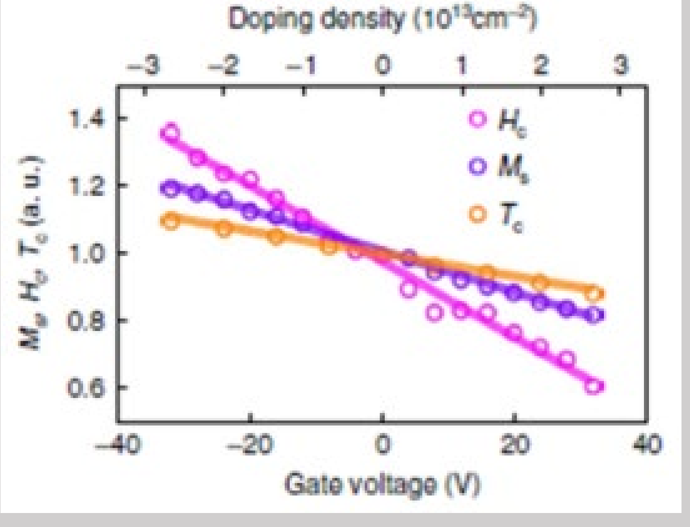
Charge-driven first-order magnetic transition in NiPS3

Junik Hwang, Seonghoon Park, Beom Hyun Kim, Junghyun Kim, Je-Geun Park and Seung-Ho Baek

J. Phys.: Condens. Matter 37, 055801 (2025)

The authors conducted nuclear magnetic resonance (NMR) experiments on the van der Waals magnet $NiPS_3$. The NMR signals revealed a discontinuity in the order parameter (see Figure) and the absence of critical slowing down of spin correlations near the critical temperature. These findings strongly support the characterization of the magnetic transition as first-order. A complementary Landau mean-field study suggested that the first-order transition is driven by a charge stripe instability, arising from self-doped ligand holes.





Magnetoelectric effect in van der Waals magnets

Kai-Xuan Zhang, Giung Park, Youjin Lee, Beom Hyun Kim & Je-Geun Park

npj Quantum Materials 10, 6 (2025)

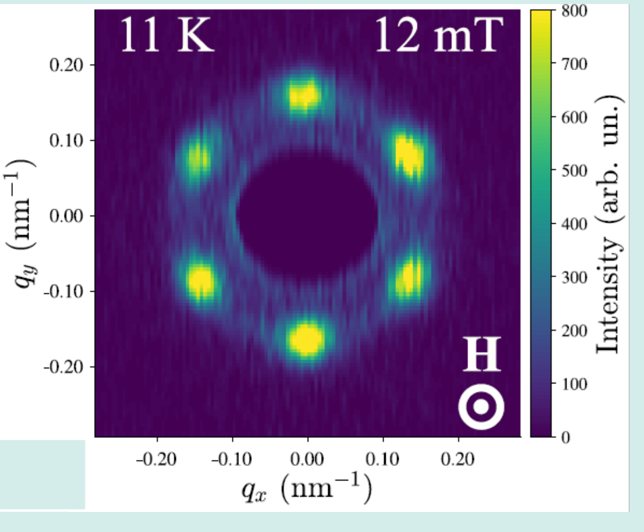
The magnetoelectric (ME) effect is a fundamental phenomenon that enables the electrical control of magnetic polarization or vice versa. In this review, the authors emphasize recent discoveries in two-dimensional van der Waals materials, such as NiI_2, $NiPS_3$, and Fe_3GeTe_2, which exhibit multiferroicity in two dimensions, spin-charge correlation, and the atomic ME effect. The authors also highlight their potential applications in spintronic and optoelectronic devices.

Observation of magnetic skyrmion lattice in $Cr_{0.82}Mn_{0.18}Ge$ by small-angle neutron scattering

Victor Ukleev, Tapas Samanta, Oleg I. Utesov, Jonathan S. White & Luana Caron

Scientific Reports 15, 2865 (2025)

A comprehensive SANS study of the B20-type chiral magnet $Cr_{0.82}Mn_{0.18}Ge$ is reported. The authors explore its magnetic phase diagram and confirm the stabilization of conventional hexagonal skyrmion lattice in the external magnetic field. Despite the polycrystalline nature of the sample, it is stabilized in a rather large region of the phase diagram. Low-temperature metastable skyrmion lattice is shown to persist even in zero field.



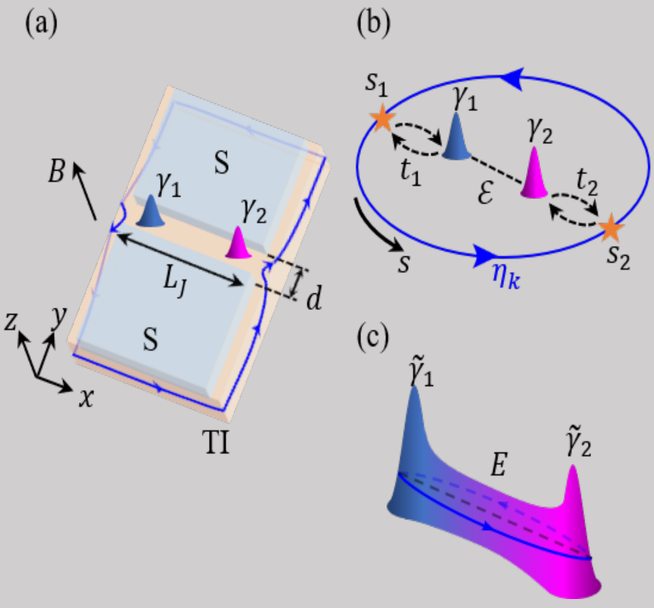
New Research Results

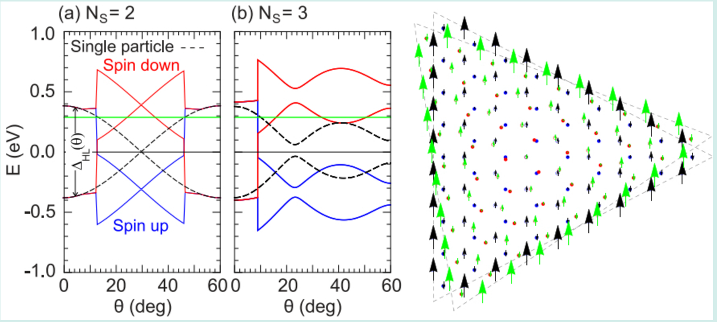
Boundary-induced Majorana coupling in a planar topological Josephson junction

Hyeongseop Kim, Sang-Jun Choi, H.-S. Sim, and Sunghun Park

[Phys. Rev. B 111, 045414 (2025)]

This work considers a planar Josephson junction (JJ) made of the surface states of a three-dimensional topological insulator and s-wave superconductors, focusing on the influence of the boundary modes residing outside the junction on the signatures of Majorana fermions appearing inside JJ. By analyzing the effective Hamiltonians describing the JJ and boundary channels, the authors found that the coupling between the JJ and boundary modes mediates an effective coupling between the Majorana modes in JJ, even in the absence of the direct spatial overlap of their wave functions inside JJ. The resulting energy splitting of the states formed by the Majorana zero modes (MZMs) weakens 4π-periodicity of the Josephson current, one of the key experimental signatures of Majorana fermions. Such boundary-mediated energy splitting is also found in presence of the magnetic field perpendicular to JJ, where mobile MZMs appear in JJ. Their results thus reveal an additional effect that hinders the unambiguous detection of Majorana fermions in topological planar Josephson junctions, necessitating more elaborate signals or device designs in future experiments.





Magnetism in twisted triangular bilayer graphene quantum dots

Mohammad Mirzakhani, Zebih Cetin, Mehmet Yagmurcukardes, Hee Chul Park, Francois M. Peeters, and Diego R. da Costa

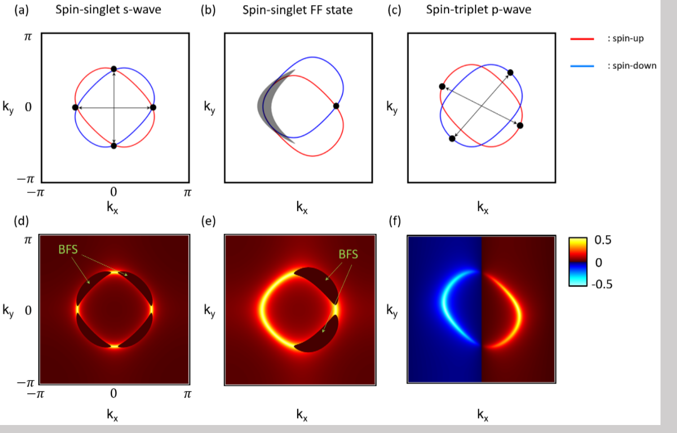
[Phys. Rev. B 111, 024417 (2025)]

The authors conduct a detailed investigation of twisted bilayer (tBLG) quantum dots using a combination of a tight-binding model and mean-field theory. They examine the emergence of magnetism driven by the Stoner instability—a phenomenon naturally captured within a mean-field framework. The important issue addressed in the paper is the effect of the twist angle on the magnetic properties of the tBLG quantum dots. Their results demonstrate that, at a finite twist angle, magnetism originates at the edge of the quantum dot. This behavior is explained using the Stoner criterion, which involves comparing single-particle energy level spacings with the Hubbard interaction.

New Research Results

Unconventional *p*-wave and finite-momentum superconductivity induced by altermagnetism through the formation of Bogoliubov Fermi surface
SeungBeom Hong, Moon Jip Park, and Kyoung-Min Kim
Phys. Rev. B 111, 054501 (2025)

The unique spin-splitting pattern in Fermi surfaces induced by altermagnetism is believed to promote intriguing forms of unconventional superconductivity, such as topological p-wave states and finite-momentum Cooper pairing. In this study, the authors demonstrate that the formation of a Bogoliubov Fermi surface is crucial for suppressing conventional Bardeen–Cooper–Schrieffer states, thereby stabilizing the topological p-wave states. Additionally, their theory predicts an unprecedented coexistence of finite-momentum Cooper pairing and the Bogoliubov Fermi surface as a consequence of altermagnetism. These insights extend beyond conventional models of superconductivity, paving the way for exploring fascinating phenomena of unconventional superconductivity in emerging materials exhibiting altermagnetism.



Puzzle of the Month

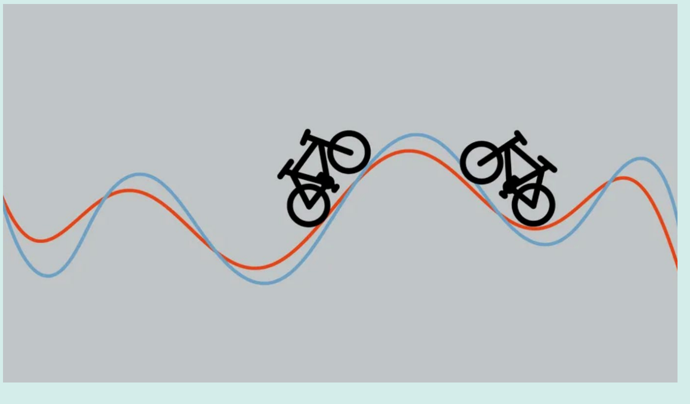
January puzzle solution:

100 seconds. This is a classical physics example of the equivalence of 1d hard core bosons and 1d noninteracting spinless fermions. Since we do not know who Alice is, we say it could be any of the ants. and so we need to figure how long it takes for all ants to fall down, at most. Since all ants move with the same absolute velocities, they are indistinguishable. If so, a collision (aka hard core bosons) is identical to passing through each other without interactions (aka noninteracting fermions). Well, then it takes at most 100 seconds for an ant to fall down - in case it started its journey at the end of the stick and moves in the direction of the other end.

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

February puzzle:

A bike left the tracks in the snow, artificially colored red and blue in the picture. The bike is long gone. Can you tell which direction it was moving?



Send your solution to eun@ibs.re.kr
The winner will be announced in the next issue.