Institute of Spintronics and Quantum Information
Faculty of Physics and Astronomy
Adam Mickiewicz University, Poznań

# Symposium on Spintronics and Quantum Information 2026

## Book of Abstracts

Faculty of Physics and Astronomy
Adam Mickiewicz University, Poznań
April 23-25, 2026

## Symposium Venue

The Symposium on Spintronics and Quantum Information will take place at the Campus of the Faculty of Physics and Astronomy, Adam Mickiewicz University, Poznań, Collegium Physicum, Uniwersytetu Poznańskiego 2 (https://www.fizyka.amu.edu.pl/strona-glowna/kontakt).

## About Symposium

The Symposium is organized by the Institute of Spintronics and Quantum Information (ISQI) at the Faculty of Physics and Astronomy, Adam Mickiewicz University in Poznań. Since its establishment on January 1, 2021, ISQI has held annual symposia covering a broad range of topics in condensed matter physics and quantum information.

The first Symposium took place on October 21–23, 2021, at the Faculty of Physics of AMU in Poznań and was accompanied by the official inauguration of the Institute. The second Symposium was also held at the Faculty, on December 8–9, 2022. The third and fourth editions (2024 and 2025), took place for the first outside the Faculty premises—at the Palace in Będlewo.

This year, the Organizing Committee has decided to hold the fifth Symposium in the spring—from April 23–25.

The aim of the Symposium is to provide a platform for the presentation and discussion of novel scientific ideas at the intersection of the fields of quantum information and condensed matter physics, including among others:

- Spintronics and molecular magnetism,
- Magnonics, spin waves and magnonic crystals,
- Quantum information and quantum physics,
- Quantum optics, cavity and circuit QED,
- Strongly correlated systems,
- Quantum simulators and quantum matter,
- Nonlinear dynamics,
- Topological states of matter,
- Quantum transport in low-dimensional systems,
- 2D materials and spin-orbit phenomena,
- Bound states in superconductors.

The Symposium brings together young scientists, their supervisors and senior colleagues from ISQI, along with collaborators from research teams across Poland and abroad. While it serves as a platform for presenting the latest research developments at the Institute, the event goes beyond mere reporting—it fosters scientific exchange and actively promotes the establishment of new collaborations with research institutions, scientific groups, and independent researchers.

# Information for presenters

- The registration desk is located near Reception A, close to the lecture room (room 16).
- The slides for the talks should be prepared in PPTX or PDF format and uploaded to the local computer in the lecture room before the scientific session at which they will be presented. The projector supports presentation of slides in a 16:9 aspect ratio.
- Please keep to the allotted time for your talks (12 minutes for contributed talks, 30 minutes for invited talks).
- Posters should be placed on the stands no later than the lunch break on Friday (April 24). However, you are encouraged to do this earlier—the poster stands will be ready on Thursday at 12:00. The stands accommodate posters of A0 size in portrait orientation and are located in the room below the lecture room (at ground level). Posters should be collected after the last session.
- The authors of the posters should participate in the poster session.
- Coffee breaks will be served near Reception A.
- The barbecue and poster session will take place in the room below the lecture room.

More information can be found on the conference webpage: https://isik-sym.web.amu.edu.pl/.

## Organizing Committee:

- Karol Bartkiewicz
- Anna Dyrdał
- Konrad J. Kapcia
- Jarosław W. Kłos (director of ISQI)
- Aleksandra Trzaskowska

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- Karol Bartkiewicz
- Agnieszka Cichy
- Anna Dyrdał
- Paweł Gruszecki
- Konrad Kapcia
- Bivas Rana

# Invited speakers

**Mirosław Łabuz**
Institute of Physics, Faculty of Exact and Technical Sciences, University of Rzeszow, Pigonia 1, 35-310 Rzeszów, Poland

**Galois symmetry of TQ Baxter relation for the XXX model for the pentagonal magnetic ring**

**Jan Martinek**
Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179 Poznań, Poland

**Exchange interactions in a magnetically contacted quantum dot: from the Kondo effect to an all-electric ESR-STM mechanism**

**Piotr Mazalski**
Faculty of Physics, University of Bialystok, Bialystok, Poland

**Magnetic domains in W/Co($d_{Co}$)/Pt ultrathin epitaxial layers while approaching the transition from ferromagnetic to superparamagnetic state**

**Grzegorz Michałek**
Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179 Poznań, Poland

**Dynamical current correlations in Cooper pair splitters with quantum dots**

**Krzysztof Ptaszyński**
Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179 Poznań, Poland

**Dissipation enables robust extensive scaling of multipartite correlations**

**Paweł Sobieszczyk**
Institute of Nuclear Physics Polish Academy of Sciences, Radzikowskiego 152, 31-342 Krakow, Poland

**Designing non-collinear spin-textures in directly written magnets**

**Maciej Urbaniak**
Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179, Poznań, Poland

**Perpendicular anisotropy substrates for topologically controlled magnetophoresis**

**Krzysztof P. Wójcik**
Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179, Poznań, Poland

**Kondo singlet from ferromagnetic coupling: superconductivity analogy**

# Schedule

| | **April 23 Thursday** | **April 24 Friday** | **April 25 Saturday** |
|---|---|---|---|
| | | scientific session 3 | scientific session 7 |
| **9:30 - 10:05** | | Krzysztof Ptaszyński | Piotr Mazalski |
| **10:05 - 10:20** | | Maciej Krawczyk | Konrad J. Kapcia |
| **10:20 - 10:35** | | Maciej Bąk | Antoni Jankiewicz |
| **10:35 - 10:50** | | Justyn Snarski-Adamski | Tomasz Kubiak |
| **10:50 - 11:15** | | coffee break | coffee break |
| | | scientific session 4 | scientific session 8 |
| **11:15 - 11:50** | | Maciej Urbaniak | Paweł Sobieszczyk |
| **11:50 - 12:05** | | Aleksandra Trzaskowska | Olena Tartakivska |
| **12:05 - 12:20** | | Ryszard Stagraczyński | Błażej Szablikowski |
| **12:20 - 12:35** | | Piotr Trocha | symposium closing |
| | | lunch break | |
| **13:15 - 13:30** | symposium opening | | |
| | scientific session 1 | scientific session 5 | |
| **13:30 - 14:05** | Krzysztof Wójcik | Grzegorz Michałek | |
| **14:05 - 14:20** | Jarosław W. Kłos | Karol Bartkiewicz | |
| **14:20 - 14:35** | Aleksey Alekseev | Tomasz Polak | |
| **14:35 - 14:50** | Patrycja Tulewicz | Sławomir Mamica | |
| **14:50 - 15:15** | coffee break | coffee break | |
| | scientific session 2 | scientific session 6 | |
| **15:15 - 15:50** | Jan Martinek | Mirosław Łabuz | |
| **15:50 - 16:05** | Grzegorz Kamieniarz | Paweł Gruszecki | |
| **16:05 - 16:20** | Jan Wójcik | Yeimer Zambrano Mena | |
| **16:20 - 16:35** | Yulia Kharlan | poster session | |
| **16:35 - 17:30** | barbecue | | |

| Thursday, April 23 | | |
|---|---|---|
| **Time** | **Event** | **Page** |
| 13:15 – 13:30 | **OPENING**<br>Jarosław W. Kłos, Director of the Institute of Spintronics and Quantum Information<br>Ireneusz Weymann, Dean of the Faculty of Physics and Astronomy | |
| | **SCIENTIFIC SESSION 1**<br>Chair: Konrad Kapcia | |
| 13:30 – 14:05 | **Invited:** *Kondo singlet from ferromagnetic coupling: superconductivity analogy*<br>Krzysztof Wójcik | 26 |
| 14:05 – 14:20 | *Ferromagnetic resonance control in hybrid superconductor–ferromagnet multilayers*<br>Jarosław W. Kłos | 37 |
| 14:20 – 14:35 | *Dynamical Mean-Field Investigation of Exotic Pinball-Liquid Phase*<br>Aleksey Alekseev | 29 |
| 14:35 – 14:50 | *Spin Chirality Across Quantum State Copies Detects Hidden Entanglement*<br>Patrycja Tulewicz | 48 |
| 14:50 – 15:15 | *Coffee break* | |
| | **SCIENTIFIC SESSION 2**<br>Chair: Anna Dyrdał | |
| 15:15 – 15:50 | **Invited:** *Exchange Interactions in a Magnetically Contacted Quantum Dot: from the Kondo Effect to an All-Electric ESR-STM Mechanism*<br>Jan Martinek | 20 |
| 15:50 – 16:05 | *DFT Prediction of Spin-State and Magnetic Coupling in 3D Molecular Complexes: Search for Optimal Amount of Fock Exchange in $Ni_4$ Tetramers*<br>Grzegorz Kamieniarz | 34 |
| 16:05 – 16:20 | *The Chiral Random Walk: Hybrid Quantum-Classical Approach to Odd-Diffusion*<br>Jan Wójcik | 49 |
| 16:20 – 16:35 | *Cherenkov emission of spin waves driven by oscillating Abrikosov vortices in superconducting antennas*<br>Yulia Kharlan | 36 |
| 16:35 – 17:30 | *Barbeque* | |

| Friday, April 24 | | |
|---|---|---|
| **Time** | **Event** | **Page** |
| | **SCIENTIFIC SESSION 3**<br>Chair: Karol Bartkiewicz | |
| 9:30 – 10:05 | **Invited:** *Dissipation enables robust extensive scaling of multipartite correlations*<br>Krzysztof Ptaszyński | 23 |
| 10:05 – 10:20 | *Exploiting photon-magnon coupling for transduction of microwaves signal to spin waves*<br>Maciej Krawczyk | 38 |
| 10:20 – 10:35 | *The dimensional crossover in the unconventional superfluids*<br>Maciej Bąk | 31 |
| 10:35 – 10:50 | *First-principles study of enhanced magnetocrystalline anisotropy in transition metal-doped MnBi alloys*<br>Justyn Snarski-Adamski | 42 |
| 10:50 – 11:15 | *Coffee break* | |
| | **SCIENTIFIC SESSION 4**<br>Chair: Karol Bartkiewicz | |
| 11:15 – 11:50 | **Invited:** *Perpendicular anisotropy substrates for topologically controlled magnetophoresis*<br>Maciej Urbaniak | 25 |
| 11:50 – 12:05 | *Propagation of surface acoustic waves in anisotropic layered and multilayered systems*<br>Aleksandra Trzaskowska | 47 |
| 12:05 – 12:20 | *Efficient Evaluation of Monodromy Matrix for the* $XXX_{1/2}$ *Model*<br>Ryszard Stagraczyński | 43 |
| 12:20 – 12:35 | *Magnon-Driven Cooling by Heating in a Quantum Dot Refrigerator*<br>Piotr Trocha | 46 |
| 12:35 – 13:30 | *Lunch break* | |
| | **SCIENTIFIC SESSION 5**<br>Chair: Józef Barnaś | |
| 13:30 – 14:05 | **Invited:** *Dynamical current correlations in Cooper pair splitters with quantum dots*<br>Grzegorz Michałek | 22 |
| 14:05 – 14:20 | *Feedback-activated monodromy: constructing arbitrary eigenfrequency permutations in open quantum bosonic systems*<br>Karol Bartkiewicz | 30 |
| 14:20 – 14:35 | *When Rabi Coupling Meets Mott Criticality*<br>Tomasz Polak | 41 |
| 14:35 – 14:50 | *On Some Peculiarities of Spin-Wave Hybridization in 2D Magnonic Crystals*<br>Sławomir Mamica | 40 |
| 14:50 – 15:15 | *Coffee break* | |

| Time | Event | Page |
|---|---|---|
| | **SCIENTIFIC SESSION 6**<br>Chair: Agnieszka Cichy | |
| 15:15 – 15:50 | **Invited:** *Galois symmetry of TQ Baxter relation for the XXX model for the pentagonal magnetic ring*<br>Mirosław Łabuz | 19 |
| 15:50 – 16:05 | *Dissipation-Enhanced Giant Amplification of Spin Waves near Magnetic Phase Transitions*<br>Paweł Gruszecki | 32 |
| 16:05 – 16:20 | *Probing confinement and charge order in 1D Z2 lattice gauge theories with extended interactions*<br>Yeimer Zambrano Mena | 50 |
| 16:20 – 17:30 | **POSTER SESSION** | |

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| Time | Event | Page |
|---|---|---|
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| 9:30 – 10:05 | **Invited:** *Magnetic domains in W/Co($d_{Co}$)/Pt ultrathin epitaxial layers while approaching the transition from ferromagnetic to superparamagnetic state*<br>Piotr Mazalski | 21 |
| 10:05 – 10:20 | *Variety of orders in localized-fermionic system on a geometrically-frustrated lattice with Ising-like interactions*<br>Konrad J. Kapcia | 35 |
| 10:20 – 10:35 | *Dynamics of strong correlations of a hybrid quantum dot system with superconducting and ferromagnetic electrodes*<br>Antoni Jankiewicz | 33 |
| 10:35 – 10:50 | *Electron spin resonance spectroscopy in the study of spin dynamics and magnetic anisotropy of nanostructures*<br>Tomasz Kubiak | 39 |
| 10:50 – 11:15 | *Coffee break* | |
| | **SCIENTIFIC SESSION 8**<br>Chair: Paweł Gruszecki | |
| 11:15 – 11:50 | **Invited:** *Designing Non-Collinear Spin-Textures in Directly Written Magnets*<br>Paweł Sobieszczyk | 24 |
| 11:50 – 12:05 | *Dipolar interactions in magnetic multilayers*<br>Olena Tartakivska | 45 |
| 12:05 – 12:20 | *On Novikov algebras of Stäckel type*<br>Błażej Szablikowski | 44 |
| 12:20 – 12:35 | **SYMPOSIUM CLOSING** | |

# Abstracts

# Invited speakers

# GALOIS SYMMETRY OF TQ BAXTER RELATION FOR THE XXX MODEL FOR THE PENTAGONAL MAGNETIC RING

T. Lulek[1], S. Stagraczyński[2] and M. Łabuz[3]

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We apply Baxter TQ relation, supplemented later by Baxter as a generalized eigenvalue problem, to exhibit some its consequences in the specific case of the XXX model, on example of all highest weight eigenstates of pentagonal ring. Such presentation of the TQ relation admits to replace nonlinear Bethe Ansatz equations by the system of $N+r+1=5+2+1=8$ equations which are (a) linear in integrability constants of motion $t_l$, $l=0,1,...,5$ , (b) linear and homogenous in coefficients $q_0,q_1$ of the Baxter polynomial of a requested eigenstate (that is, of the inventory of Bethe roots which define this eigenstate). Solution of this system reproduces all highest weight eigenstates of pentagon. The system admits a recursive solution, in which each quantum number $t_l$ is a polynomial of quantum numbers $q_0,q_1$ , with some hierarchy. Quantities $t_N=t_5=2$ and $t_{N-1}=t_4=0$ prove to be absolute constants of the model, $t_{N-2}=3$ is defined by the total spin of an eigenstate, $t_{N-3}=t_2$ is linear in $q_1$, and $t_1,t_0$ are polynomials. We also point out that each highest weight eigenstate in pentagon can be classified by the spectrum of a single $\hat{T}^{(2)}$ operator as a universal constant of motion.

# EXCHANGE INTERACTIONS IN A MAGNETICALLY CONTACTED QUANTUM DOT: FROM THE KONDO EFFECT TO AN ALL-ELECTRIC ESR-STM MECHANISM

P. Busz[1,2], J. Reina-Galvez[3,4,5], D. Tomaszewski[1], J. Barnaś[1,2], C. Wolf[4,6] and J. Martinek[1]

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[4] *Center for Quantum Nanoscience, Institute for Basic Science (IBS), Seoul, Republic of Korea*

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[6] *Department of Physics, Ewha Womans University, Seoul 03760, Republic of Korea*

Scanning tunneling microscopy (STM) has enabled the quantum-coherent control of individual spins of adatoms or molecules on surfaces via all-electric electron spin resonance (ESR–STM) [1]. Recent experimental studies have demonstrated the relevance of this technique for single-electron and nuclear spin spectroscopy. However, the mechanism of magnetoelectric coupling underlying this effect remains unclear. To address this issue, we develop a theoretical framework [2–5] based on the Anderson model of a localized spin coupled to a magnetic STM tip and a normal substrate. In this approach, virtual electron exchange between the magnetic tip and the localized spin generates an effective exchange field that depends on both bias and gate voltages. This exchange field was previously identified in both theoretical and experimental studies [6-8], where the Kondo effect was used as a method to detect it. In contrast, the ESR-STM reveals it through coherent spin dynamics. We employ the Gorini–Kossakowski–Lindblad–Sudarshan (GKLS) master equation formalism, which yields results equivalent to those obtained using the real-time diagrammatic technique for a single-level quantum dot coupled to noncollinear magnetic electrodes. Within this framework, we derive an effective Bloch equation describing the complex spin dynamics induced by spin-polarized currents for different transport regimes, including sequential tunneling and cotunneling. We show that the dc current encodes electrically controlled projections of the accumulated nonequilibrium spin, enabling local single-spin readout in spin-polarized STM. Furthermore, our model predicts bias-dependent resonance shifts arising from the nontrivial voltage dependence of the induced exchange field, in agreement with recent experimental observations [9,10]. Additional experiments [11] provide evidence for the Hanle effect, as predicted in Ref. [2], and confirm the exchange field as a key factor shaping the conductance peak at zero external magnetic field. The Hanle effect—manifested as a reduction of spin accumulation due to spin precession in a static magnetic field—offers a direct method for extracting the local exchange field and spin relaxation time from dc magnetoresistance measurements. We present a detailed and extended analysis of this phenomenon to facilitate its experimental interpretation. Finally, we discuss spin-pumping effects that may explain the finite dc current observed experimentally at zero bias.

**Acknowledgements:** *Supported by NCN Grant No. 2020/36/C/ST3/00539.*

**References:**

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5 P. Busz, D. Tomaszewski, J. König, J. Barnaś, and J. Martinek, in preparation.
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10 P. Greule, W. Huang, M. Stark, K. H. Au Yeung, J. Schwenk, et al., arXiv 2507.13699.
11 S. Kovarik, R. Schlitz, A. Vishwakarma, D. Ruckert, et al., Science 384, 1368 (2024).

# MAGNETIC DOMAINS IN W/Co($d_{Co}$)/Pt ULTRATHIN EPITAXIAL LAYERS WHILE APPROACHING THE TRANSITION FROM FERROMAGNETIC TO SUPERPARAMAGNETIC STATE

P. Mazalski[1], W. Dobrogowski[1], B.Sharma[1], M. Römer-Stumm[2], I. Sveklo[1], J. McCord[2], A. Wawro[3], A. Maziewski[1]

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The ferromagnetic films sandwiching between asymmetric heavy metal layers (like Ta, W, Pt, Ir, etc.) with strong spin-orbit coupling have been intensively studied over the past decade as materials with interfacial Dzyaloshinskii-Moriya interaction (iDMI). Such multilayer systems can be used for generation different interesting magnetic structures including stable skyrmions and chiral domain walls [1, 2]. The Pt(bottom)/W/Co($d_{Co}$ wedge)/Pt(top) structures were deposited on sapphire (0001) substrate by molecular beam epitaxy. For electric current studies the straight channels of 20 $\mu$m width were created by optical lithography. The influence of electric current on domain structure (DS) mobility was performed for fixed W and selected Co thicknesses at ambient conditions. Polar magneto-optical Kerr effect microscopy and magnetometry were used for magnetization characterization and DS visualization under electric current/magnetic field motion. The period $p$ of stripe DS was determined using Fast Fourier transformation. The measured dependence of $D(d_{Co})$ fit well with analytical dependence accounting iDMI contribution [3].

In the studied region of $d_{Co}$ thicknesses the samples possesses perpendicular magnetic anisotropy (PMA) and high iDMI value of 1.1 mJ/m$^2$ [4]. PMA is $d_{Co}$ sensitive and this fact was used for domain wall energy control. While $d_{Co}$ is decreasing and approaching to superparamagnetic (SP) we observed: (1) low coercivity field $H_C$ - down to fractions of Oe; (2) DS is transformed from an irregular large domains (typical for ultrathin films [3]) through labyrinth-like into a stripe/worm-like structures, (3) approaching SP state the period of worm-like domain DS strongly decreases, and real time thermal fluctuations of DS are observed. This behaviour was explained as reduction of domain wall energy due to iDMI. The lateral magnitude and frequency of DS fluctuations is increased while approaching to $d_{Co}$ SP transition thickness - similar as it was observed in Pt/Co/Os/Pt [2] and Ta/Pt/CoFeB/(Ru wedge)/Pt layers [5]. The skyrmion/bubble structures should be stabilized with application of about one Oe out-of-plane magnetic field. The skyrmion/bubble stability and their mobility were studied as a function of applied out-of-plane magnetic field and electric current density. Using electrical current pulses it was possible to find threshold current density for skyrmion/bubble motion and skyrmion Hall angle.

**Acknowledgements:** *This work was supported by the National Science Centre, Poland, M-ERA.NET 3 2022/04/Y/ST5/00164 project.*

**References:**

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3 A. Bernand-Mantel et al. Phys. Rev. B 111, 184423 (2025)
4 Z. Kurant et al. J. Magn.Mag.Mat. 558, 169485 (2022).
5 R. Mansell et al. Phys. Rev. B 106, 054413 (2022).

# DYNAMICAL CURRENT CORRELATIONS IN COOPER PAIR SPLITTERS WITH QUANTUM DOTS

Grzegorz Michałek[1]

[1] *Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179 Poznań, Poland*

Electron entanglement is investigated via frequency-dependent current correlations (noise) in Cooper pair splitter (CPS) devices based on one (1QD) and two (2QD) proximized quantum dots. The system, weakly coupled to metallic electrodes, is analyzed in the superconducting atomic limit, where transport proceeds exclusively through subgap Andreev bound states (ABS). We contrast the 1QD configuration – where Cooper pairs may be transferred locally via direct Andreev reflection (DAR) or non-locally via crossed Andreev reflection (CAR) – with the 2QD setup. In the latter, strong on-dot Coulomb repulsion forbids double occupancy, so that only the non-local CAR processes through an inter-dot singlet survive, thereby enhancing Cooper pair splitting efficiency. In the weak-coupling regime, transport is governed by sequential tunneling through proximized quantum dots. Accordingly, we employ the diagonalized master equation (DME) approach in the eigenbasis of singlet states of effective Hamiltonians that incorporate the relevant Coulomb interactions. We focus on current cross-correlations between normal leads, where the emergence of positive values provides a clear diagnostic of Cooper pair splitting and quantum entanglement. Finite-frequency correlations further resolve the intrinsic timescales and spectral signatures of the microscopic processes governing the interplay between DAR and CAR. To gain deeper insight into the dynamics of split particles, we decompose the total cross-correlation function into contributions associated with transport through individual ABS levels. This reveals a distinct interplay of microscopic processes: inter-level electron-hole (e-h) correlations are positive (bunching), characteristic of CAR, whereas intra-level electron-electron (e-e) and hole-hole (h-h) components remain negative (antibunching). Finally, spectral decomposition of the noise uncovers a hierarchy of relaxation processes, distinguishing high-frequency charge fluctuations from low-frequency polarization dynamics. In symmetric configurations, high-frequency contributions tend to compensate, so that polarization fluctuations dominate the cross-correlation noise. Our analytical results for various bias voltage regimes show how entanglement and Cooper pair splitting manifest in frequency-dependent current correlations, providing a deeper insight into microscopic transport in hybrid quantum systems.

**References:**

1 G. Michałek, B. R. Bułka, New J. Phys. 23, 023009 (2021).

# DISSIPATION ENABLES ROBUST EXTENSIVE SCALING OF MULTIPARTITE CORRELATIONS

Krzysztof Ptaszyński[1,2], Maciej Chudak[1] and Massimiliano Esposito[2]

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Information-theoretic quantities have received significant attention as system-independent measures of correlations in many-body systems, e.g., as universal order parameters of synchronisation. However, they have been studied only to a limited extent from the perspective of nonequilibrium thermodynamics. In this work [1], we investigate the multipartite mutual information between $N$ discrete-state stochastic units (e.g., spins) interacting in a network that is invariant under unit permutations. We show that when the system relaxes to fixed point attractors, multipartite correlations in the stationary state either do not scale extensively with $N$, or the extensive scaling is not robust to arbitrarily small perturbations of the system dynamics. In particular, robust extensive scaling cannot occur in thermodynamic equilibrium. In contrast, mutual information scales extensively when the system relaxes to time-dependent attractors (e.g., limit cycles), which can occur only far from equilibrium. This demonstrates the essential role of dissipation in the generation and maintenance of multipartite correlations. We illustrate our theory with the nonequilibrium Potts model – a generalisation of the Ising model. Finally, we extend our approach to open quantum collective spin systems, corresponding to atomic ensembles in optical cavities [2].

**Acknowledgements:** *K.P. and M.C. acknowledge the financial support of the National Science Centre, Poland, under the project No. 2023/51/D/ST3/01203.*

**References:**

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2 K. Ptaszyński, M. Chudak, and M. Esposito, Phys. Rev. E 112, 054137 (2025).

# DESIGNING NON-COLLINEAR SPIN-TEXTURES IN DIRECTLY WRITTEN MAGNETS

P. Sobieszczyk[1], M. Krupiński[1], M. Nord[2], and R. Bali[3]

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The ability to precisely manipulate spin-textures at the nanoscale is essential for the advancement of spintronic, neuromorphic, and quantum sensing technologies. It can be done with a direct magnetic writing process using a focused ion beam by locally transforming paramagnetic $Fe_{60}Al_{40}$ and $Fe_{60}V_{40}$ precursor alloys into ferromagnetic nanostructures with tailorable magnetic properties [1,2]. In $Fe_{60}Al_{40}$ systems, lateral confinement triggers anisotropic lattice relaxation, where the in-plane lattice parameter expands more significantly along the magnet's short axis than along its length. This structural anisotropy manifests as a transverse magnetic easy axis [3]. A similar mechanism is present in the ring-shaped structure, where the easy axis is normal to the circumference of the radii, stabilizing the magnetic structure. $Fe_{60}V_{40}$ nanostructures reveal a distinct confinement-driven evolution of spin-textures as dimensions are reduced toward the extreme nanoscale. While wider structures ($> 250$ nm) exhibit Landau-like domains, reducing the width to $\approx 25$ nm, comparable to the film thickness, destabilizes these patterns in favour of symmetric Néel-type domain walls [4].

Micromagnetic simulations successfully reproduce non-collinear magnetic structures with decreasing system width, which is in agreement with experimental data. By applying relaxation procedures to the ring structure, we obtained the phase diagram as a function of the uniaxial anisotropy constant and the width of the rings. It shows how anisotropy energy contribute to the formation of different number of the domains on the circumference of the ring.

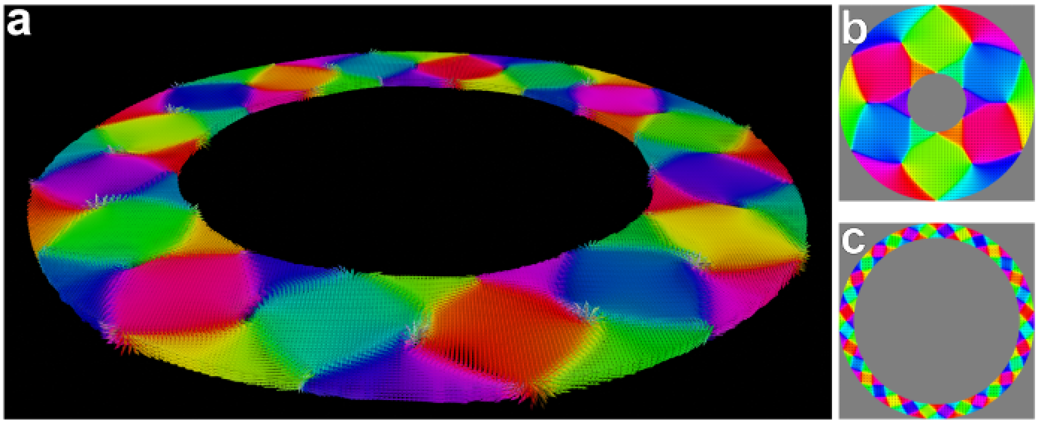


Fig. 1: Landau-like domains on circumference of the ferromagnetic $Fe_{60}Al_{40}$ ring with a different inner diameter: (a) $d = 1300$ nm, (b) $d = 600$ nm, (c) $d = 1700$ nm.

**Acknowledgements:** *Simulations were performed using the Polish high-performance computing infrastructure PLGrid (HPC Center: ACK Cyfronet AGH) for provided computer facilities and supported within a computational grant no PLG/2023/016266. The DAAD and NAWA are acknowledged for financial support (Project "Lincoln", No. 57654579). M. Nord acknowledges support from the Research Council of Norway through grants NORTEM (197405) and InCoMa (315475).*

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# PERPENDICULAR ANISOTROPY SUBSTRATES FOR TOPOLOGICALLY CONTROLLED MAGNETOPHORESIS

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Precise control of the movement of micrometer-sized particles is of practical interest, as it can be used both in lab-on-a-chip devices for the detection of tiny amounts of pathogens or harmful chemicals [1] and for the micro-assembly of polymers, nanotubes, or nanowires [2]. Independently, investigations of particle motion in various time-periodic potentials reveal a host of analogies with electronic transport in solids and with electromagnetic wave propagation [3]. One realization of such controlled transport involves the use of superparamagnetic beads (SPBs), which are transported over topographically or magnetically patterned film substrates by the application of time-varying, gradient-free magnetic fields [4].

In this talk, I will present various thin-film structures with perpendicular magnetic anisotropy that allow effective control of the two-dimensional trajectories of SPBs. Specifically, I will introduce Co/Au-based ferromagnetic multilayers (MLs) and Tb/Co-based ferrimagnetic structures. I will show how ion bombardment, both through a mask and using focused beams, can be used to locally modify their magnetic properties, namely switching fields and magnetization. Such modifications enable the fabrication of Tb/Co MLs with a reconfigurable effective two-dimensional magnetic potential symmetry [5], which could improve the versatility of lab-on-a-chip devices.

In the second part of the talk, I will walk the audience through a series of examples demonstrating the application of topological protection to achieve specific functionalities in SPB–substrate systems.

**Acknowledgements:** *We acknowledge financial support from the National Science Centre Poland (grant no. 2020/39/B/ST5/01915), funding from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under project number 531559581, and support through the Heisenberg Program of the DFG under project number 550390029 for various results presented here.*

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# KONDO SINGLET FROM FERROMAGNETIC COUPLING: SUPERCONDUCTIVITY ANALOGY

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While the conventional (antiferromagnetic) Kondo effect is a paradigmatic many-body phenomenon, its ferromagnetic counterpart, where the impurity asymptotically decouples from the band [1], remains exotic and difficult to realize. This rises questions about possible instabilities of the Kondo model with a ferromagnetic coupling. I will present our results concerning a magnetic impurity coupled to a conduction sea via fully anisotropic ferromagnetic spin-exchange term, whose strength depends on the conduction-electron modes involved in the scattering. With a plethora of methods spanning from simple mean-field analysis to perturbative and numerical renormalization techniques we show that, despite all couplings being ferromagnetic, there exist parameter regime in which the conventional Kondo effect develops at low temperatures, leading to a singlet ground state. We argue that this is an analog of Anderson-Morel superconductivity [2], and discuss the prospects of realization of this scenario in real materials.

**Acknowledgements:** *KPW was supported by by National Science Centre in Poland through grant no. 2023/51/D/ST3/00532 and acknowledges computing time at Poznań Supercomputing and Networking Center.*

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# Contibuted talks

# DYNAMICAL MEAN-FIELD INVESTIGATION OF EXOTIC PINBALL-LIQUID PHASE

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A large variety of materials have a triangular lattice which can host a number of attractive strongly correlated and frustration-induced effects. Here, we focus on the exotic frustration-induced charge order, called a pinball-liquid (PL) phase [1], where lattice sites of a particular sublattice exhibit insulating properties (act as "pins" for charge carriers), while the rest of the lattice is conducting.

To investigate the charge-ordering phenomenon we use the extended Hubbard model with repulsive onsite $(U)$ and intersite $(V)$ density-density interactions between electrons, and on the grand-canonical ensemble (arbitrary total charge density is allowed). We investigate a ground-state phase diagram of the triangular lattice with charge orders that are commensurate with a $\sqrt{3} \times \sqrt{3}$ supercell (3 sublattices). Following our work where the model is solved within the mean-field approximation (MFA) [2], we consider the possible pinball-liquid formation where the Mott localization is taken into account by means of the dynamical mean-field theory (DMFT) with the Lanczos procedure to solve Anderson impurity models [3].

The regions in the phase diagram can be outlined and identified by means of atomic-limit results [4], where the phases are named by integer occupation numbers of the three sublattices. The 200- and 220-regions are well-described within the MFA and hence, the DMFT predicts the previously found PL phase on a less-doped side of the 220-region [2]. Due to the particle-hole asymmetry, it is not found in the 200-region [2]. The 210-, 100-, and 221-regions are also found within the MFA, but without the Mott localization these regions are metallic only. The insulating and PL phases in these regions appear within the DMFT but the strong particle-hole asymmetry holds: only the 221-region and the hole-doped part of the 210-region host PL phases for $U$ at least as high as $4D$ ($D$ is a half-bandwidth of a noninteracting lattice). We have also found the intersite-interaction-driven PL phases in the 110- and 211-regions. These regions are not present in the MFA results that are generally incorrect for the $zV < 2U$ ($z$ is a coordination number). The latter PL phases are rather symmetric with respect to the change of a sign of a chemical potential despite strong particle-hole asymmetry of the 110- and 211-regions themselves.

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# FEEDBACK-ACTIVATED MONODROMY: CONSTRUCTING ARBITRARY EIGENFREQUENCY PERMUTATIONS IN OPEN QUANTUM BOSONIC SYSTEMS

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Exceptional points (EPs) are non-Hermitian degeneracies where both eigenvalues and eigenvectors coalesce. Adiabatically encircling an EP permutes the eigenfrequencies of the system—a topologically protected effect known as monodromy, demonstrated in microwave cavities, photonic waveguides, and optomechanical platforms. For two-mode systems, $\mathrm{EP}_2$ monodromy yields a simple transposition (2-cycle). However, higher-order switching—3-cycles, 4-cycles, or arbitrary permutations—requires richer EP topologies, and a constructive recipe mapping a target permutation to a physical Hamiltonian has been lacking.

We prove that closing a unidirectional $N$-mode bosonic cascade with a single feedback coupling is both necessary and sufficient to activate an $N$-cycle eigenfrequency permutation via $\mathrm{EP}_N$ cusp monodromy. Without feedback, the cascade drift matrix is upper-triangular with analytic eigenvalues and trivial monodromy. The feedback element introduces an $N$-th root Puiseux structure: the characteristic polynomial becomes the universal unfolding of the $A_{N-1}$ singularity, and a real closed loop in parameter space crosses the discriminant locus exactly $2(N-1)$ times. These crossings correspond to $N-1$ adjacent $\mathrm{EP}_2$ pairs whose composed transpositions yield the full $N$-cycle via the Coxeter element.

As a corollary, any target permutation $\sigma \in S_N$ is realized by a block-diagonal Hamiltonian of independent feedback-closed rings, one per cycle of $\sigma$. We prove the construction analytically for $N = 3$ and $N = 4$, verify it numerically up to $N = 14$, and establish the general-$N$ result via singularity theory. We contrast the ring topology with the Peřina model, where disjoint EP cones swap independent eigenvalue pairs and preclude cycles of length greater than two.

For a concrete superconducting-circuit realization with inter-mode coupling $\varepsilon = 100\,\mathrm{MHz}$, the full 3-cycle completes in $\sim$15 $\mu$s with minimum eigenvalue splitting $58\,\mathrm{MHz}$, well within current coherence times ($T_1 \approx 80\,\mu$s, coherence margin $T_1/T_{\mathrm{total}} \approx 5$). The eigenfrequency permutation is directly observable via transmission spectroscopy. The framework opens a systematic connection between the symmetric group $S_N$ and non-Hermitian topology, with applications in frequency conversion, mode switching, and quantum state engineering.

# THE DIMENSIONAL CROSSOVER IN THE UNCONVENTIONAL SUPERFLUIDS

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The lattice geometry is a fundamental characteristic of many-body systems and has large influence on their physical properties. Ultracold atomic gases in optical lattices give the opportunity of realization of systems with different geometries. The high degree of tunability of the model parameters enables to investigate systems in various regimes. Experimentally, the geometry of the lattice can be changed by different spatial arrangement of laser beams [1]. Quite recently, the occurrence of antiferromagnetic spin correlations in different lattice geometries of varying dimensionality, also including crossover configurations between different geometries, was investigated [2]. However, there exists, beside the quantum magnetism, an equally interesting phenomenon in the context of dimensionally tuneable lattices- fermionic superfluidity. It was shown that the magnetized superfluid phase in the presence of a Zeeman magnetic field (population imbalance) is unstable in two-dimensional system against the phase separation [3,4]. However, such phase is stable in simple cubic lattice, for strong attraction and low electron concentrations [5]. Hence, it is very interesting to investigate the dimensional crossover in the context of stability of exotic phases with non-trivial Cooper pairing in systems with population imbalance.

Our studies are aimed at investigating the effects of dimensional crossover (2D→3D) in the attractive Hubbard model with a Zeeman magnetic field, in the context of stability of unconventional superfluid phases.

The model is considered on $L$ layers of the square lattice ($\infty \times \infty \times L$) to investigate how geometry affects the stability of the magnetized superfluid phase. The dimensionality along the z-axis can be tuned by including the effects of adding an arbitrary number of single layers along with variable tunneling between them (including anisotropy of tunneling between and within planes) in the density of states used for solving the mean-field equations. Competition between superfluidity and CDW diagonal ordering is analysed.

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# DISSIPATION-ENHANCED GIANT AMPLIFICATION OF SPIN WAVES NEAR MAGNETIC PHASE TRANSITIONS

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We present a theoretical and computational framework for spin-wave amplification exploiting temporal modulation of the bias magnetic field near a field-driven phase transition in ultrathin magnetic films with perpendicular magnetic anisotropy (PMA) and interfacial Dzyaloshinskii–Moriya interaction (DMI). At a temporal interface—an abrupt or adiabatic change of material parameters in time—wavevector is conserved while frequency adjusts to the new dispersion, enabling efficient frequency conversion analogous to time refraction in photonics. We establish temporal magnonic impedance that governs the transmission and reflection amplitudes at temporal boundaries, providing a direct analogy with electromagnetic impedance matching.

The central finding is a counterintuitive slow-instability regime that emerges between the exceptional point and the critical field exclusively in the presence of Gilbert damping. In this regime, the exponential growth rate scales linearly with the damping constant $\alpha$, so dissipation acts as the engine of amplification rather than its obstacle. Using micromagnetic simulations of CoFeB film, we demonstrate up to 175-fold spin-wave amplitude gain via a temporal-slab protocol (high-field $\rightarrow$ low-field $\rightarrow$ high-field) without continuous pumping. This substantially exceeds existing parametric and spin-torque schemes, which typically reach 10–50-fold gain. The amplification is wavevector-selective, peaked near $k_{\mathrm{soft}} \approx 49\,\mathrm{rad}/\mu\mathrm{m}$.

These results establish temporal magnonics as a route toward reconfigurable magnonic devices in which gain, frequency conversion, and wavevector filtering are programmed dynamically through field modulation rather than fixed during fabrication. The framework applies broadly to any PMA system exhibiting field-driven stripe-domain transitions, including CoFeB/Pt multilayers and iron garnets with interfacial DMI.

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# DYNAMICS OF STRONG CORRELATIONS OF A HYBRID QUANTUM DOT SYSTEM WITH SUPERCONDUCTING AND FERROMAGNETIC ELECTRODES

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We theoretically explore the non-equilibrium dynamics of a quantum dot coupled to both superconducting and a metallic ferromagnetic electrodes. Such a hybrid setup provides a robust platform to investigate the interplay between strong correlations, superconductivity, and ferromagnetism at the nanoscale, leading to complex quantum phenomena. We employ the numerical renormalization group (NRG) [1][2] and its time-dependent extension (td-NRG) [3][4] as our core methods.

These methods enable us to capture the subtle nature of dynamical quantum phase transitions [5] induced by abrupt changes in Hamiltonian parameters, known as quantum quenches. Such transitions are crucial for the understanding of the stability and evolution of many-body states in response to external perturbations. Specifically, we obtain the time dependence of the key observables, including the quantum dot's spin, on-dot pairing, and the Loschmidt echo [6]. Our results reveal competition between these correlations as they oscillate in counter-phase.

The main aims of this work are to thoroughly examine the competition between superconducting pairing, which favors local singlet formation on the dot, and the quantum dot's spin, which is influenced by magnetic exchange interactions from the ferromagnetic lead. Furthermore, we characterize the dynamical quantum phase transitions using the Loschmidt echo and the return function, which provide direct measures of the system's sensitivity to quenches. Our findings shed light on the emergent non-equilibrium phases and their characteristic timescales in these technologically relevant hybrid nanostructures.

**Acknowledgements:** *NCN OPUS 2022/45/B/ST3/02826*

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# DFT PREDICTION OF SPIN-STATE AND MAGNETIC COUPLING IN 3D MOLECULAR COMPLEXES: SEARCH FOR OPTIMAL AMOUNT OF FOCK EXCHANGE IN $Ni_4$ TETRAMERS

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Reliable prediction of the ground-state spin and magnetic couplings in transition-metal complexes described by the Heisenberg model is a well-known challenge [1] for density functional theory (DFT). Here a popular strategy for addressing this long-standing issue, relying on the modification of the fraction of Fock exchange in a hybrid functional, is pursued.

We explore the viability of this approach referring to three polynuclear metal-organic complexes (Fig. 1) based on a $Ni_4O_4$ cubane motif. Owing to different organic ligands, these tetramers are suitable objects for this DFT study [2] as they exhibit different ground state spin values ($S = 0, 2, 4$, respectively, considering the compounds shown in panels Fig. 1a–Fig. 1c).

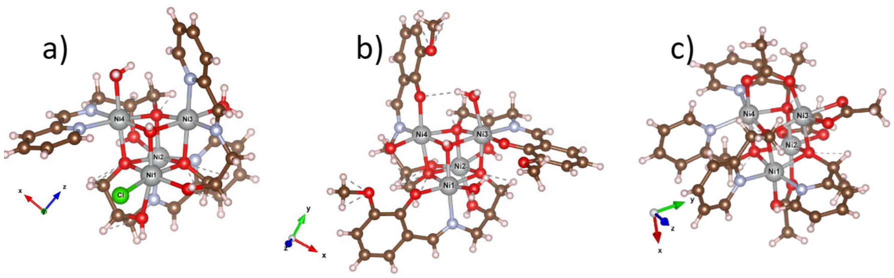


Fig. 1: $Ni_4$ complexes studied: a) $[Ni_4(\ldots)_3(Cl)(\mu_3\text{-OH})(H_2O)_2]$, b) $[Ni_4(\ldots)_3(\mu_3\text{-OH})(H_2O)_2]$, c) $[Ni_4(\ldots)_4(CH_3COO)_4]$, where red – oxygen; brown – carbon; white – hydrogen; grey – nickel; purple – nitrogen; green – chlorine.

We systematically search [2] for an optimum fraction of Fock exchange capable of recovering the experimental findings for all the compounds, via various global, range-separated, and double hybrid functionals. We show that for all functionals tested, there only exists a very narrow range of Fock exchange fractions providing correct values of the ground-state spin for all complexes in question. However, while some general trends are discerned, the required range is functional dependent. Importantly, at least two similar systems must be used in order to determine both an upper and lower limit of the optimal fraction. This outcome is attributed to conflicting demands. Minimization of delocalization errors typically requires a higher percentage of Fock exchange, whereas addressing static correlation usually requires a lower one.

We find [2] that within the optimal range of Fock exchange for a given functional, both the sign and the magnitude of magnetic couplings can be reasonably well reproduced for the complexes considered. However, there is still space for further improvement in order to obtain quantitative agreement with experiment. Thus, the prediction of spin-state and magnetic coupling in polynuclear 3d complexes remains an ongoing challenge for DFT.

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# VARIETY OF ORDERS IN LOCALIZED-FERMIONIC SYSTEM ON A GEOMETRICALLY-FRUSTRATED LATTICE WITH ISING-LIKE INTERACTIONS

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A generalized fermionic lattice gas model in the form of the extended Hubbard model with intersite Ising-like interactions (between nearest neighbors, both antiferromagnetic and ferromagnetic) at the atomic limit on the triangular lattice is studied [1-5]. The Hamiltonian of the system consists of the following terms: nearest-neighbor Isinglike magnetic $J$ interactions and onsite Coulomb $U$ interactions. The model is investigated for both signs of $J$, arbitrary $U$ interaction, and arbitrary chemical potential $\mu$ (or, equivalently, arbitrary particle concentration $n$) using two complementary methods: (i) Monte Carlo simulations in the grand canonical ensemble [1,3-5] and (ii) the variational method within the mean-field decoupling of the intersite term and exact treatment of the onsite interaction [2,3]. Both methods yield the exact ground-state phase diagram as a function of $\mu$ [1,2]. For antiferromagnetic coupling, a nontrivial ordered phase with coexistence of metamagnetic and charge ordering is found. The finite-temperature phase diagram is complex, with phase transitions between the ordered and nonordered phases being of first as well as second order (i.e., discontinuous and continuous, respectively), depending on the model parameters. The results are contrasted with the findings for the two-dimensional square lattice [3–5].

**Acknowledgements:** *The work was partialy financed by Polish National Agency for Academic Exchange (NAWA) in the frame of the Bekker program (Grant No. PPN/BEK/2020/1/00184) and National Component of the Mieczysław Bekker program (2020 edition) (Grant No. BPN/BKK/2022/1/00011)*

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# CHERENKOV EMISSION OF SPIN WAVES DRIVEN BY OSCILLATING ABRIKOSOV VORTICES IN SUPERCONDUCTING ANTENNAS

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The last two decades have witnessed significant advances in magnonics [1], moving beyond CMOS-based electronics toward energy-efficient logic and non-Boolean computing at the nanoscale. Further progress in this field faces fundamental challenges, including the need to increase spin-wave (SW) frequencies to tens or even hundreds of GHz to meet the growing demand for high-speed information processing. However, generating high-frequency (short-wavelength) SWs using microwave excitation remains challenging, as the efficiency of conventional antennas decreases with their size.

In this work, we propose an alternative antenna design and a novel mechanism for SW generation based on Cherenkov radiation induced by the stray fields of oscillating Abrikosov vortices in a superconducting (SC) antenna acting on an adjacent ferromagnetic (FM) layer. The considered system consists of a ferromagnetic film with perpendicular-to-plane magnetization, placed beneath a superconducting stripe hosting a single row of Abrikosov vortices, induced by a static magnetic field applied perpendicular to the stripe plane.

The mechanism of SW generation is as follows: an alternating current flowing through the SC stripe produces a Lorentz force that drives vortex oscillations. When the vortex velocity exceeds the phase velocity of spin waves, Cherenkov emission of SWs occurs.

The concept of SW Cherenkov radiation has previously been proposed for a vortex lattice moving at constant velocity in a superconducting film [2]. However, that approach suffers from two key limitations: (i) excitation occurs throughout the entire FM film, hindering spatial localization, and (ii) efficient SW generation is restricted to conditions where the vortex velocity matches the minimum SW phase velocity, leading to a single, strongly excited mode. At higher velocities, additional modes appear, but their intensities are negligible due to wave-vector mismatch imposed by the lattice periodicity.

In contrast, our approach overcomes these limitations. Replacing the SC film with stripe geometry enables localized excitation and detection of SWs. Furthermore, the absence of a periodic vortex lattice (i.e., the use of a single vortex row) removes wave-vector constraints, allowing efficient excitation of higher-frequency spin waves at elevated vortex velocities.

**Acknowledgements:** *The work was supported by the National Science Center, Poland, Grants No. UMO-2021/43/I/ST3/00550 and No. UMO-2023/49/B/ST3/02920.*

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# FERROMAGNETIC RESONANCE CONTROL IN HYBRID SUPERCONDUCTOR–FERROMAGNET MULTILAYERS

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Hybrid ferromagnet–superconductor (FM–SC) systems have attracted considerable attention because they enable control of the magnetization dynamics in a ferromagnet through its electromagnetic interaction with a superconductor [1]. The temperature-dependent magnetic properties of superconductor/ferromagnet/superconductor (SC/FM/SC) trilayers have been investigated both experimentally [2] and theoretically [3], with particular emphasis on ferromagnetic resonance (FMR). In particular, the influence of the SC and FM layer thicknesses on the FMR field has been analyzed [3].

To distinguish between the underlying mechanisms, we additionally study related multilayer structures containing either a nonmagnetic metallic spacer (M) or an insulating spacer (I), namely SC/FM/M/SC and SC/FM/I/SC [4]. All studied multilayers exhibit a pronounced reduction of the FMR field below the superconducting critical temperature, except for the structure with the insulating spacer (SC/FM/I/SC). The superconductivity-induced FMR shift of the resonance field or frequency increases with both SC and FM thickness and approaches saturation for sufficiently thick layers.

To explain these results, we develop an analytical model in which the precession of the FM magnetization modulates the magnetic flux in the system, thereby inducing an alternating supercurrent in the SC. This supercurrent, in turn, generates a dynamic back-action magnetic field acting on the FM and shifts its resonance frequency. The model assumes closed current loops in which the FM layer conductively connects the supercurrents flowing in opposite directions in the two outer SC layers.

These results provide a practical route toward increasing the operating frequency of magnonic devices.

**Acknowledgements:** *The authors acknowledge the support from the grant of the National Science Center – Poland, No. 2021/43/I/ST3/00550.*

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# EXPLOITING PHOTON-MAGNON COUPLING FOR TRANSDUCTION OF MICROWAVES SIGNAL TO SPIN WAVES

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One of the main challenges in magnonics is efficiently converting microwave signals into spin waves. The low efficiency is due to the significant mismatch between the wavelengths of microwaves and spin waves in the GHz range: $10^{-8}$ m and $10^{-10}$ m, respectively. This mismatch leads to high energy consumption in magnonic circuits. We propose an approach based on a planar inverse split-ring resonator (ISRR) loaded with a thin ferromagnetic film that exploits the coherent coupling effect between photons and magnons. Our numerical simulations show that the ISRR-based antenna achieves a fourfold improvement in conversion efficiency compared to a conventional single microstrip transmission line antenna when operating at frequencies and bias magnetic fields around the anti-crossing frequency gap, i.e., the photon-magnon coupling range [1]. This has been demonstrated in the weak photon-magnon coherent coupling regime for a nanometer-thin permalloy (Py) film with micrometer lateral dimensions. Further optimization of the ISRR could help achieve the strong coherent coupling regime, making the system more efficient at converting microwave signals into spin waves. Our compact, efficient antenna design offers significant advantages over standard microstrip line antennas and paves the way for powerful magnonic circuits for microwave signal processing.

**Acknowledgements:** *The research has received financial support from the National Science Center of Poland, OPUS-LAP Grant No. 2020/39/I/ST3/02413.*

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# ELECTRON SPIN RESONANCE SPECTROSCOPY IN THE STUDY OF SPIN DYNAMICS AND MAGNETIC ANISOTROPY OF NANOSTRUCTURES

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Electron spin resonance (ESR) and ferromagnetic resonance (FMR) experiments play an important role in the study of the various properties of magnetic nanostructures. Possible ESR/FMR research topics include the characterization of core-shell materials, determination of magnetic free energy and magnetization dynamics in thin-film heterostructures, study of magnon and spin transport in magnetic nano-networks and investigation of the location and field dependence of spin wave modes.

Our research, conducted using the X-band (9.4 GHz) Bruker EMX-10 spectrometer, focused on examining the properties of nanostructures containing iron oxides (magnetite $Fe_3O_4$, maghemite $\gamma$-$Fe_2O_3$, or a combination of both). Experiments were carried out over a wide temperature range. Field cooling procedure, in which samples were frozen in an external magnetic field (0.5 or 1 T) and then measured for different angular positions, was also applied. The analysis of the recorded broad signals allowed to determine spectroscopic splitting factors and spectral parameters (peak-to-peak linewidth, intensity, etc.) along with their dependence on temperature. In-depth investigations enabled us to characterize the magnetization relaxation processes and estimate anisotropy constants [2]. For spherical ferrite nanoparticles, in addition to both angular-dependent and -independent anisotropy fields, it was necessary to take into account the surface anisotropy field. The discontinuity of the magnetic interactions between surface spins plays a significant role in describing the structure and dynamic behavior of nanoparticles. Structural defects related to the presence of $Fe^{3+}$ ions resulting from surface oxidation were also reflected in the ESR/FMR spectra.

Iron oxide nanoparticles with a diameter below $\approx 30$ nm acted as single-domain magnets with superparamagnetic behaviour [2]. Interestingly, the properties of samples differed slightly at various stages of their life cycle due to the maghemitization process of magnetite. Our experiments showed that electron spin resonance and ferromagnetic resonance techniques proved to be effective tools for analyzing the magnetic properties of ferrite nanostructures.

**Acknowledgements:** *This research was partially funded by National Science Centre, Poland, grant no. 2025/09/X/ST3/00576* (*NCN Miniatura*).

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# ON SOME PECULIARITIES OF SPIN-WAVE HYBRIDIZATION IN 2D MAGNONIC CRYSTALS

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Spin-wave hybridization is one of the key phenomena in modern magnonics, as it plays an essential role in controlling dispersion, energy transport, and mutual interactions between modes [1]. This presentation reports on peculiar features of spin-wave mode hybridization in two-dimensional bicomponent permalloy–cobalt magnonic crystals (MCs). The analysis is carried out using the plane-wave method, with particular emphasis on the role of the external magnetic field and the demagnetizing field, which strongly modifies the local conditions for spin-wave excitation and energy concentration in both constituents of the composite.

Our starting point is the observation that variations of the external magnetic field lead to non-uniform frequency shifts of individual modes. As a result, modes of compatible symmetry may approach each other in the spectrum, become coupled, and eventually hybridize. In the conventional picture, such hybridization is manifested through avoided crossing of spectral branches, interchange of mode order, and mixing of spatial profiles. The present results show, however, that in magnonic crystals this picture can be significantly more complex. In particular, the introduction of a coefficient describing the concentration of spin-wave excitation energy in one of the constituent materials proves especially useful. This parameter, which quantifies the fraction of spin-wave energy concentrated in cobalt or permalloy, is shown to be a sensitive and reliable indicator of hybridization, even in cases where branch repulsion is weak and a full interchange of spatial profiles cannot be identified unambiguously [2].

An important part of the presentation is devoted to a comparison between the base structure and structures geometrically compressed along the direction of the external magnetic field. Such compression enhances the demagnetizing field and produces an additional frequency shift that depends on the concentration of a given mode in one of the materials. As a consequence, hybridization regions may be shifted towards higher magnetic fields, and new pairs of coupled modes may emerge within a given field interval. Particularly intriguing are more complex multimode interaction regimes, in which no complete profile interchange is observed, while a clear exchange of the concentration coefficient and a reorganization of local amplitude maxima still take place. These findings demonstrate that spin-wave hybridization in two-dimensional magnonic crystals is a subtler phenomenon than suggested by the standard picture based solely on avoided crossings and profile mixing.

Beyond their fundamental relevance, the obtained results are also of practical importance. They show that, by an appropriate choice of geometry, material contrast, and external-field range, it is possible to deliberately tailor the coupling conditions between selected spin-wave modes. This opens the way to the design of reconfigurable magnonic structures in which controlled hybridization may be exploited in functional elements such as resonators, switches, directional couplers, frequency filters, and wave-based logic devices..

**Acknowledgements:** *This work was supported by the National Science Centre of Poland under grant No. UMO-2020/37/B/ST3/03936.*

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# WHEN RABI COUPLING MEETS MOTT CRITICALITY

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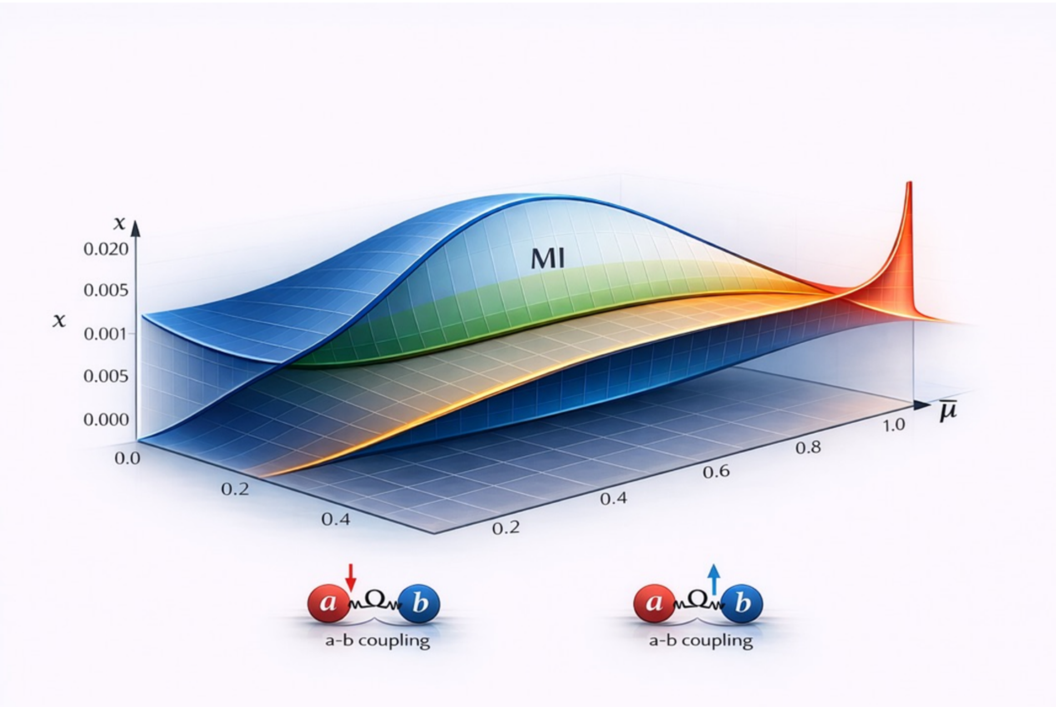
We investigate the Mott–superfluid transition in a two-component Bose–Hubbard model with local Rabi coupling, focusing on the asymmetric regime where interaction, hopping, and chemical-potential imbalances compete with coherent interconversion. We show that the critical behavior is most naturally described in terms of susceptibility reconstruction: the transition is governed by the softening of the lowest eigenmode of the full two-component response kernel rather than by atomic gaps alone. This viewpoint clarifies the role of the symmetric common-mode channel and explains how local Rabi mixing reshapes the Mott lobes beyond the standard two-component Hubbard scenario. Combining analytical reductions with exact local susceptibility calculations and numerical phase-boundary reconstruction, we demonstrate that the first-lobe tip may evolve non-monotonically with increasing Rabi coupling. In particular, the minimum of the lobe tip coincides with the maximum of the dominant susceptibility mode, revealing a crossover between softening and re-stiffening of the critical collective response. These results provide a susceptibility-based interpretation of Mott criticality in Rabi-coupled lattice bosons and identify clear signatures distinguishing the Rabi-coupled system from the conventional two-component Bose–Hubbard model.



# FIRST-PRINCIPLES STUDY OF ENHANCED MAGNETOCRYSTALLINE ANISOTROPY IN TRANSITION METAL-DOPED MNBI ALLOYS

Justyn Snarski-Adamski[1], Zbigniew Śniadecki[1], and Mirosław Werwiński[1]

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MnBi is considered one of the most promising rare-earth-free compounds for high-temperature permanent magnet applications, owing to its strong uniaxial magnetocrystalline anisotropy and its unusual positive temperature coefficient of coercivity [1]. In discussed, we performed fully relativistic PBE+U calculations (with $U = 3.6$ eV applied to the Mn 3d orbitals) to systematically investigate the effect of substituting 6.25 at.% of Bi with all 3d, 4d, and 5d transition metals [2-3]. Calculations were performed using the FPLO18 code [4].

Fixed-spin-moment calculations on pure MnBi show that the magnetocrystalline anisotropy energy (MAE) can reach approximately 3 MJ $m^{-3}$ when both thermal lattice expansion and electronic correlations are properly taken into account. Upon transition-metal alloying, the MAE exhibits a non-monotonic behavior. The highest MAE value of 13.5 MJ $m^{-3}$ — roughly four times higher than that of pure MnBi — is obtained with Hf substitution, followed by W, V, Zr, Ir, Co, Rh, and Pt.

After alloying, the magnetic hardness parameter exceeds 4.2 for these MnBi-based alloys, representing some of the highest values predicted to date for rare-earth-free magnetic materials. These findings highlight Hf, W, V, Zr, Ir, Co, Rh, and Pt as highly effective substitutions that significantly enhance the intrinsic magnetocrystalline anisotropy of MnBi, offering a promising pathway toward the development of next-generation high-temperature permanent magnets free of rare-earth elements.

**Acknowledgements:** *We acknowledge the financial support of the National Science Center Poland under the decision DEC-2021/41/B/ST5/02894 (OPUS 21).*

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# EFFICIENT EVALUATION OF MONODROMY MATRIX FOR THE $\mathrm{XXX}_{1/2}$ MODEL

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The Algebraic Bethe Ansatz (ABA) is a unique tool for obtaining exact results for quantum integrable spin chains [1]. This work introduces an efficient algorithm for evaluating the elements $A(\lambda)$, $B(\lambda)$, $C(\lambda)$, and $D(\lambda)$, of the monodromy matrix $M(\lambda)$ for the $\mathrm{XXX}_{1/2}$ model [2]. The proposed method is based on elementary constituents that are easy to classify and implement symbolically. We provide a complete combinatorial description of these objects and discuss their role for determining the transfer matrix $T(\lambda)$, as well as creation $B(\lambda)$ and annihilation $C(\lambda)$ operators of Bethe pseudoparticles.

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# ON NOVIKOV ALGEBRAS OF STÄCKEL TYPE

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In my talk, I will explain the main ideas behind my recent results obtained in collaboration with Maciej Błaszak (UAM) and Krzysztof Marciniak (Linköping University) [1]. In this work, we study a particular class of associative Novikov algebras, which we call Novikov algebras of Stäckel type because of their connection to classical Stäckel metrics written in Viète coordinates. We identify conditions under which pencils of such algebras allow the corresponding Dubrovin-Novikov Hamiltonian operators to have central extensions. This yields families of pairwise compatible Poisson operators, which in turn provide a natural framework for constructing the associated integrable soliton hierarchies.

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# DIPOLAR INTERACTIONS IN MAGNETIC MULTILAYERS

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Magnetic multilayers have been studied for decades. Interest in them has recently increased due to new quasy-2D materials with multilayer structures, specifically van der Waals magnets [1].

Dipolar interaction can play a different role depending on whether it is intralayer or interlayer. Intralayer dipolar interaction leads to a modification of the dispersion law of spin waves, especially for FMR modes, resulting in the appearance of an additional term corresponding to the shape anisotropy. At the same time, interlayer dynamic dipolar interaction leads to such interesting dispersion features as nonreciprocity [2] and negative group velocity [3].

We investigate these phenomena depending on the magnetic order, external field and material parameters of the magnetic multilayer.

**Acknowledgements:** *National Science Centre of Poland, Project No. UMO-2023/49/B/ST3/02920.*

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# MAGNON-DRIVEN COOLING BY HEATING IN A QUANTUM DOT REFRIGERATOR

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We introduce a solid-state refrigeration scheme based on the unconventional concept of cooling through heating. In this approach, a quantum dot facilitates energy exchange between two ferromagnetic metals, powered by a hot magnetic insulator. Thermal energy carried by magnons selectively removes high-energy electrons from the cold electrode and transfers them to the hot electrode, enabling cooling without the need for external work. In the tight-coupling limit, achieved with fully spin-polarized electrodes, each absorbed magnon corresponds to the transfer of a single electron, resulting in optimal cooling efficiency. However, deviations from full spin polarization give rise to unwanted spin-down currents that oppose the cooling process, significantly reducing both the cooling power and the achievable temperature range. These findings highlight magnon-assisted, spin-dependent transport as a promising and tunable strategy for solid-state refrigeration, particularly for applications in low-temperature quantum technologies.

**Acknowledgements:** *The work was supported by the National Science Centre, Poland, under project no. 2018/31/D/ST3/03965.*

# PROPAGATION OF SURFACE ACOUSTIC WAVES IN ANISOTROPIC LAYERED AND MULTILAYERED SYSTEMS

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Surface acoustic waves (SAWs) are widely used to probe the elastic properties of low-dimensional systems, particularly where anisotropy plays a crucial role. In this work, we investigate the propagation of SAWs in selected van der Waals layered materials ($WTe_2$, $Sb_2Te_3$) and engineered multilayer structures using Brillouin light scattering (BLS) spectroscopy supported by finite element modeling (Fig. 1) [1].

The measured dispersion relations reveal a pronounced in-plane anisotropy of acoustic wave velocities, strongly dependent on the propagation direction. In van der Waals crystals, this behavior is governed by intrinsic crystallographic symmetry and layered structure, leading to a characteristic angular dependence of SAW velocities. In contrast, in multilayer systems, the acoustic response is mainly controlled by interfacial coupling, layer thickness, and elastic contrast.

Additionally, multilayer structures support guided modes, such as Sezawa waves, arising from wave confinement and interface effects. A comparative analysis shows that, despite different microscopic origins, both natural layered crystals and artificial multilayers can be consistently described within a common framework of anisotropic lattice dynamics [2].

Our results demonstrate the capability of BLS spectroscopy to resolve direction-dependent acoustic properties and provide a unified approach to analyzing surface phonons in complex layered systems.

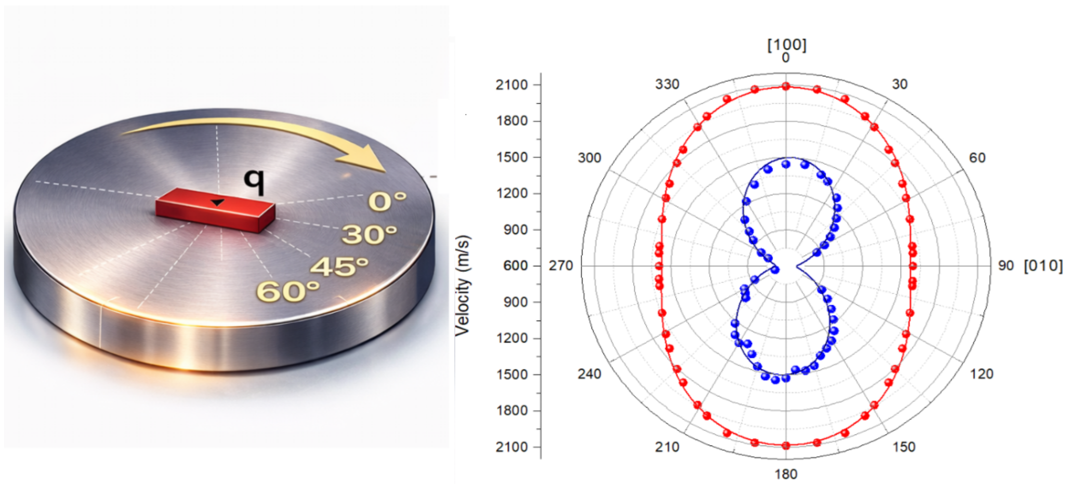


Fig. 1: Schematic illustration of phonon anisotropy measurements and representative results for $WTe_2$.

**Acknowledgements:** *This work was supported by the Polish National Science Centre under grant no: UMO-2020/37/B/ST 3/03936 and The National Centre for Research and Development of Poland, projects no CONCERT-JAPAN/9/91/PETITE/2023*

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# SPIN CHIRALITY ACROSS QUANTUM STATE COPIES DETECTS HIDDEN ENTANGLEMENT

Patrycja Tulewicz[1], Karol Bartkiewicz[1], and Franco Nori[2]

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Entanglement can hide from standard detection in two fundamentally different ways: as multi-copy correlations invisible to any single-copy measurement on an unknown state, and as bound entanglement invisible to the Peres–Horodecki criterion. We show that both forms share a common origin in spectral structures accessible only through joint measurements on multiple state copies, and can be detected by a unified architecture built on controlled-SWAP circuits.

We prove that the difference between partial transpose moments and purity moments, $C_k = \mu_k - I_k$, decomposes exactly as a chirality–chirality correlator—the same scalar spin chirality that governs chiral spin liquids and the topological Hall effect—revealing the specific physical content that multi-copy entanglement detection probes. For two-qubit states, chirality measures the signed volume of the correlation tensor parallelepiped, providing a geometric entanglement signature from just two measurements.

Using the same circuit infrastructure, we develop a multi-channel spectral classifier for bound entanglement that combines realignment spectral features with chirality corrections. This classifier achieves $100\%$ recall at zero false positives across all known $3\times3$ bound entangled families—compared with $\sim50\%$ for the computable cross-norm or realignment (CCNR) criterion, which certifies entanglement when the trace norm of the realignment matrix exceeds unity, and $\sim58\%$ for the range criterion, which certifies entanglement through the structure of product vectors in the state's range. A new marginal-noise construction produces states where the CCNR trace norm drops below the detection threshold, rendering them invisible to CCNR and to all other single-parameter criteria, while the non-Hermiticity gap between singular values and eigenvalues of the realignment matrix persists—enabling detection through the multi-channel approach. These CCNR-invisible states are still detected by the range criterion, but evade the PPT test and all moment-based witnesses.

We demonstrate both capabilities experimentally on IBM Quantum processors: negativity reconstruction with mean errors of $0.002$–$0.027$, chirality detection for pure and mixed states, and bound entanglement detection across two structurally distinct families (Horodecki and chessboard) using a single family-agnostic classifier on a gate-based superconducting processor.

# THE CHIRAL RANDOM WALK: HYBRID QUANTUM-CLASSICAL APPROACH TO ODD-DIFFUSION

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We present a model for an isotropic chiral random walk on a lattice. Inspired by the quantum random walk framework, we equip the walker with an internal degree of freedom representing chirality and show, both numerically and analytically, that this model resembles odd transport properties on the continuum level. Chirality further acts as a control parameter, and the model resembles unitary transport in the strong-chirality regime. Building on established results from Quantum Random Walk theory, we analyse features such as topologically protected transport in this limit. We find that this qualitative persists also into the dissipative regime, allowing us to theoretically ground edge transport phenomena, characteristics of dissipative odd systems. We illustrate our approach in spatially confined geometries and in systems with random chirality.

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# PROBING CONFINEMENT AND CHARGE ORDER IN 1D Z2 LATTICE GAUGE THEORIES WITH EXTENDED INTERACTIONS

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We investigate the phase structure of a one-dimensional Z2 lattice gauge theory coupled to hard-core bosons at half-filling, systematically exploring the effects of extended interactions [1]. Using matrix product state methods within the density matrix renormalization group (DMRG) framework, we map the low-energy physics across a wide range of parameters, including competing signs for nearest-neighbor V1 and second-nearest-neighbor V2 interactions, as well as varying transverse field strengths h. Beyond the standard Luttinger liquid and Mott insulating regimes, we demonstrate that the interplay between attractive and repulsive couplings, combined with second-neighbor effects, qualitatively alters the stability of the phases. Specifically, we show that V2 can either reinforce or destabilize the Mott insulator, occasionally driving the system into intermediate Luttinger liquid regimes or robust charge-ordered insulating (COI) phases. By analyzing the charge gap, static structure factor, and pair-pair correlations, we characterize the competition between gauge-induced confinement and density-driven ordering. Our results provide a comprehensive map of how the sign and range of interactions, alongside the gauge-field dynamics, enrich the landscape of 1D Z2 lattice gauge theories [2].

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# Posters

# MULTILAYER REPETITION CONTROLS SURFACE ACOUSTIC WAVE PROPAGATION AND ANISOTROPIC ELASTIC RESPONSE IN COFEB/AU SYSTEMS

A. V. Achuthan[1], S. Janardhanan[1], P. Kuświk[2], A. Trzaskowska[1]

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Nanoscale multilayer (ML) architectures strongly influence surface acoustic wave (SAW) propagation, which is critical for acousto-electronic and sensing applications [1]. In this study, we examined the effect of repetition number in [CoFeB/Au] multilayers on SAW dispersion and elastic anisotropy on Si (001) using Brillouin light scattering, supported by finite-element simulations. Increasing the number of bilayers reduced SAW phase velocity and progressively weakened elastic anisotropy due to the transition from substrate-dominated to multilayer-dominated response with increasing thickness [2]. The most pronounced changes occurred at low repetition numbers, while thicker films approached an elastically homogeneous limit. These findings establish multilayer repetition as an effective parameter for tuning acoustic and elastic properties in nanoscale systems.

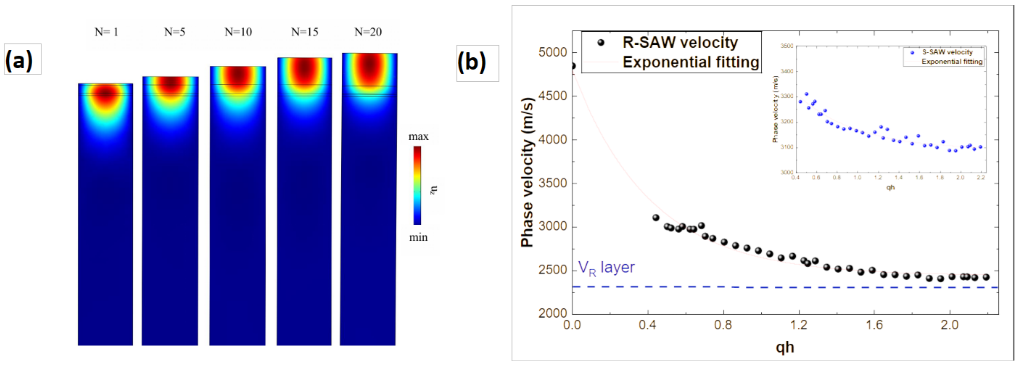


Fig. 1: (a) Schematic view of the $z$-component of displacement field of the studied samples by R-SAW for different numbers of repetitions $N$ with $q = 20.6\,\mu\mathrm{m}^{-1}$. The coloured scale shows the maximum and minimum of the displacement field component. (b) Dependence of the phase velocity of Rayleigh (R-SAW) and Sezawa (S-SAW, inset) SAWs on the wavenumber $(qh)$, where $h$ is the total thickness excluding the substrate.

**Acknowledgements:** *This work was supported by the Polish National Science Centre under grant no: UMO-2020/37/B/ST3/03936*

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# STABILIZATION OF THE ANTIFERROMAGNETIC CONFIGURATION IN IN-PLANE MAGNETIZED SYNTHETIC ANTIFERROMAGNETS

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Synthetic antiferromagnets (SAFs) [1] are magnetic nanostructures composed of two or more ferromagnetic layers coupled antiferromagnetically. Depending on the applied magnetic field, a SAF can be switched between three magnetic configurations: antiferromagnetic (AF), canted (C), and ferromagnetic (FM) (Fig. 1). In in-plane magnetized SAFs, the AF configuration can be stabilized at finite magnetic fields due to in-plane uniaxial anisotropy [1]. A similar effect can also be achieved through shape anisotropy in SAF waveguides formed by two flat ferromagnetic strips.

We consider SAF waveguides to be promising candidates for magnonic applications. Compared with conventional bilayer SAFs, they offer several important advantages: (i) enhanced static and dynamic dipolar coupling, which complements the standard Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction mediated by a spacer layer such as Ru; (ii) stabilization of the AF-configuration at finite bias fields; (iii) multimode spin-wave propagation in two distinct channels, namely acoustic and optical modes [2]; and (iv) nonreciprocal spin-wave transmission in the C-configuration [3], which is more easily controlled.

In this contribution, we move toward a systematic study of SAF waveguides by investigating magnetization switching and the stabilization of the AF-configuration in a SAF bilayer with in-plane uniaxial anisotropy. We will present results for a pair of CoFeB strips coupled by RKKY interaction, taking into account the effects of external magnetic field, static strain, and geometry. Static strain modifies the effective magnetic anisotropy through magnetoelastic coupling. First, the results reported in [4] for an Fe-based SAF bilayer with in-plane uniaxial anisotropy were reproduced using numerical simulations performed with MuMax$^+$ to validate our model. The study was then extended to examine the influence of bilayer width (i.e., the SAF waveguide geometry) and variations in external control parameters (magnetic field and strain). We use CoFeB as the base material due to its low Gilbert damping, which is important for future magnonic applications of SAF waveguides.

The switching process between the magnetic states can be characterized by two critical fields: the spin-flop field, $H_{SF} = 25.5$mT, corresponding to the AF $\rightarrow$ C transition and an abrupt reorientation of the magnetizations, and the saturation field, $H_{sat} = 97$mT marking the C $\rightarrow$ FM transition and the parallel alignment of both magnetizations.

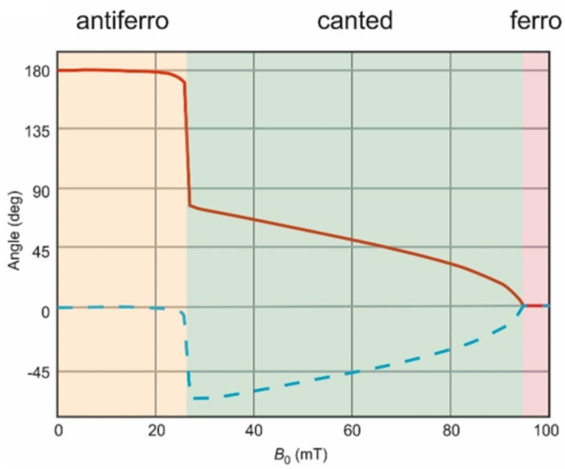


Fig. 1: Stabilized magnetic state of CoFeB bilayer coupled by RKKY interaction. As applied magnetic field increases, orientation between magnetization of layers shifts. This plot is an accurate reconstruction of results obtained in [4].

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# REVISITING THE MINIMUM ACTION METHOD FOR GENERAL MAGNETIZATION DYNAMICS

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Thermally activated transitions in micromagnetic systems are governed by dynamics described by the stochastic Landau–Lifshitz–Gilbert equation, which is intrinsically non-gradient due to the coexistence of dissipative and precessional contributions. In the small-noise regime, transition pathways are characterized by minimizers of the Freidlin–Wentzell action functional. For a stochastic system of the form the action is given by and its minimizers define most probable transition paths (minimum action paths, MAPs). In such systems, the associated quasipotential cannot, in general, be expressed solely in terms of the micromagnetic energy functional.

In this poster, we revisit the application of the geometrical minimum action method (gMAM) to magnetization dynamics, with a focus on clarifying the role of the underlying dynamical structure. In particular, we emphasize the decomposition of the effective drift into curl-free (gradient-like) and divergence-free (precessional) components, and analyze how this structure governs thermally activated transitions. This perspective provides a novel and unified interpretation of earlier minimum-action computations in spin-torque-driven and thermally activated switching processes.

A central point of this work is the distinction between minimum energy paths (MEPs), obtained from methods such as the Nudged Elastic Band method, and MAPs arising from large deviation theory. While MEPs are appropriate for gradient systems, they do not, in general, capture the most probable transition pathways in the presence of divergence-free dynamics. In contrast, MAPs incorporate both dissipative and precessional effects, leading to qualitatively different transition mechanisms and saddle configurations.

This synthesis highlights the necessity of action-based approaches such as gMAM for a consistent description of rare events in general magnetization dynamics and provides a conceptual framework for interpreting thermally activated switching beyond energy-based approximations. and elastic properties in nanoscale systems.

**Acknowledgements:** *This work was supported by the Polish National Science Centre under grant no: UMO-2020/37/B/ST3/03936*

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# FIELD-INDUCED PHENOMENA IN THE PHASE STRUCTURE OF A ONE-DIMENSIONAL Z2 GAUGE THEORY WITH SECOND-NEIGHBOR INTERACTIONS

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One-dimensional Z2 lattice gauge theory provides a simplified and versatile framework for exploring fundamental phenomena in quantum field theory and condensed matter physics. In this work, we investigate the ground-state phase diagram of a onedimensional Z2 lattice gauge theory with hard-core bosons at half filling, extending previous studies [1,2] by incorporating second-nearest-neighbor (2NN) interactions. Using matrix product state techniques within the density matrix renormalization group framework, we compute the charge gap, static structure factor, and pair-pair correlation functions over a wide range of interaction strengths and field parameters. We place particular emphasis on the role of the magnetic field sign in determining the stability of the emergent phases, including the Luttinger liquid, Mott insulating, and charge-ordered insulating phases.

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# STUDY OF TIME-VARYING SCATTERING BY SMALL DIELECTRIC PARTICLES

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Time-varying wave processes have attracted a lot of attention in the last decade, promising new solutions for reciprocity breaking, frequency transition and emulation of spatial structures [1]. Space-time metamaterials (STM) were suggested in which meta-atoms may change their properties in time (e.g., using microwave diodes or optical pumping), regardless of whether the incident electromagnetic wave (EMW) is polychromatic or monochromatic [2]. Functionality of STMs depends on the scattering and localization properties of individual meta-atoms.

In this study, we consider scattering of time-dependent EMWs on electrically small dielectric dimers comprising both time-independent and time-varying components, with the key varied parameters being the relative permittivity of the time-varying part after switching ($\varepsilon_2$), the ratio of the side lengths of the time-varying and time-independent parts of the particle ($\eta$), and the time instance of switching. The performed parametric study has unveiled the basic effects of variations of the dimer sizes and waveform shape. It was shown that the stepwise switching of permittivity of the time-varying part exerts a noticeable effect on scattering, even when the effect exerted by the time-independent component is insignificant. Besides, the effect of delay of permittivity switching with respect to the incident wave's arrival time has been clarified. Amplitude of electric field has been shown to increase due to the time-varying part of the particle. The examples are presented in Fig. 1.

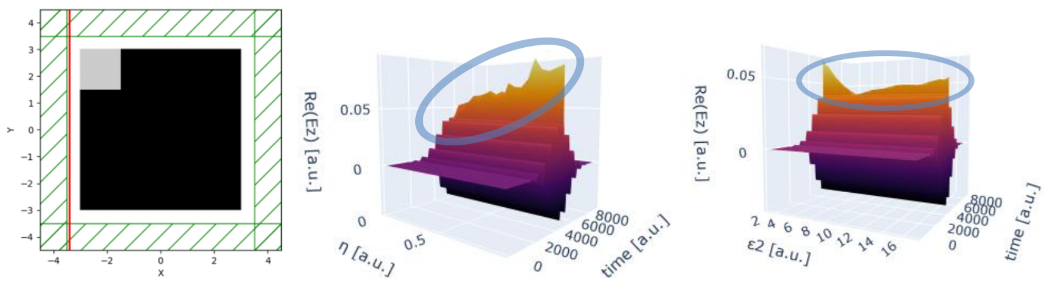


Fig. 1: (left) Basic geometry and examples of electric field depending on (middle) time and $\eta$ and (right) time and $\varepsilon_2$.

In the geometry diagram in Fig. 1, the red straight line shows the source location of the EMW, while time-independent and time-varying parts of the dimer are indicated by black and grey, respectively. The simulation results have been obtained by using MEEP open-source software [3], which is based on finite-difference time-domain technique.

The obtained results like the ones presented in Fig. 1 constitute a good starting point for the study of metasurfaces based on the proposed and similar dimers at the next steps of this research program.

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# STUDY OF THE INTERACTION BETWEEN DOMAIN WALLS AND SPIN WAVES IN FERROMAGNETIC NANOSTRIPES

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In magnonics, spin waves serve as low-loss carriers of information, enabling the operation of wave-based devices. Interactions between magnons and domain walls offer great potential for enhancing the capabilities of magnonic and spintronic devices. Using micromagnetic simulations, we study the interaction between domain walls (DWs) and propagating spin waves (SWs) in a magnetic thin nanostrip. We demonstrate that the velocity and direction of DW motion, which can reach 1–100 m/s [1], depend on the frequency and amplitude of SWs, particularly on the DW type. We systematically investigate the correlation between the transmission and reflection of SWs from the DW and the speed and direction of DW propagation in the low-frequency (GHz) range. We also extend our investigation to study the interaction of propagating spin waves with multiple DWs in the nanostrip [2]. Our analysis reveals DW-type-specific behavior, providing insight into magnon-DW interactions and their potential exploitation for energy-efficient, reconfigurable magnonic devices [3], [4].

**Acknowledgements:** *The research has received financial support from the National Science Center of Poland, OPUS-LAP Grant No. 2020/39/I/ST3/02413.*

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# MONOGAMY OF SIMULATED PARTICLE STATISTICS IN MULTI-PHOTON SYSTEMS

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When two identical particles are sent onto a balanced beam splitter, their dynamical behaviour depends on their type: bosons bunch (exit together), while fermions antibunch (exit separately). This effect can be simulated using distinguishable particles prepared in symmetric or antisymmetric entangled states. Previous work showed that already for three particles (A, B, and C), such a simulation is restricted by a trade-off relation: if both pairs A, B and A, C behave like bosons, then the pair B, C cannot perfectly antibunch like fermions [1]. In this work, we characterize these restrictions for systems consisting of an arbitrary number of identical photons and one additional distin- guishable particle - the simplest irreducible configuration beyond fully identical or fully distinguishable.

Our main result shows that all allowed collections of pairwise indistinguishability measures can be interpreted as distances between points consistent with an ordinary Euclidean geometry, in the sense of Schoenberg [2]. Mathematically, the set of achievable vectors of mean transposition values is the joint numerical range [3] of the pairwise swap operators restricted to the standard representation of the symmetric group - a convex body whose geometry we characterize completely. This provides a simple and testable consistency condition:instead of checking many constraints, one verifies that a single matrix derived from the data is positive. As a result, our approach yields experimentally accessible bounds on partial indistinguishability in multi-photon systems [4,5]. Moreover, it enables certification of genuinely many-particle interference effects that cannot be detected from pairwise or few-particle tests alone.

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# GIANT THERMOPOWER OF IMPURITY COUPLED TO VAN HOVE SINGULARITY IN 1D SYSTEMS

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We discuss conductance and thermoelectric power of a magnetic impurity coupled to 1-dimensional carbon based systems, such as zigzag graphene nanoribbons or armchair carbon nanotubes. In general, multi-band 1-dimensional systems exhibit asymmetric Van Hove singularities at the subband edges, whose position we propose to shift to the Fermi level with a gate voltage. We demonstrate that in such conditions the local spectral density of the impurity exhibits a sharp and asymmetric pseudo-gap, despite complete Kondo screening. This ensures weak charge conductance and a large Seebeck coefficient at low and moderate temperatures, leading to a high figure of merit over a wide range of temperatures and gate voltages. A similar enhancement of the Seebeck coefficient is observed in magic-angle twisted bilayer graphene with a highly particle-hole asymmetric band, though it occurs at a different energy scale [1].

**Acknowledgements:** *This work received support from National Science Center in Poland through the research Project No. 2023/51/D/ST3/00532.*

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# SPIN-WAVE PHASE SHIFTING IN YIG FILM VIA PERMALLOY RACETRACK

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Magnonic and spintronic devices based on propagating spin waves are considered promising building blocks for energy-efficient information processing and neuromorphic computing [1,2]. Non-linear spin-wave interference has already enabled functional nanoscale neural networks [3]. A reconfigurable phase control of spin waves is therefore essential and has recently been achieved using programmable Fabry–Pérot–type YIG–metal resonators [4]. In parallel, magnetic racetrack structures that utilize controllable domain-wall (DW) motion provide robust bistable magnetic textures for memory and logic applications [5]. Placing the uniformly magnetized stripe above a thin YIG layer alters the spin-wave dispersion in the layer, particularly in the Damon-Eshbach configuration, making it asymmetric, which indicates strong and weak dynamical coupling between waves in YIG and stripe, depending on the sign of the wavenumber. Guided by this behaviour, we intentionally select the positive-k side of the dispersion, for which the bilayer dispersion relation nearly coincides with that of the bare YIG layer.

Introducing two DWs into the racetrack generates strong stray magnetic fields that locally increase or decrease the effective field in the YIG layer depending on the relative orientation of the magnetization in YIG and domain in the stripe (Fig. 1). This influences the wavenumber of propagating spin-wave under this part of the racetrack, resulting in a large phase shift approaching $\pm\pi/2$ in the broad frequency range 2.0-5.0 GHz range, while maintaining almost constant transmitted. This defines two well-separated operational states which can be suitable for binary phase encoding in magnonic circuits.

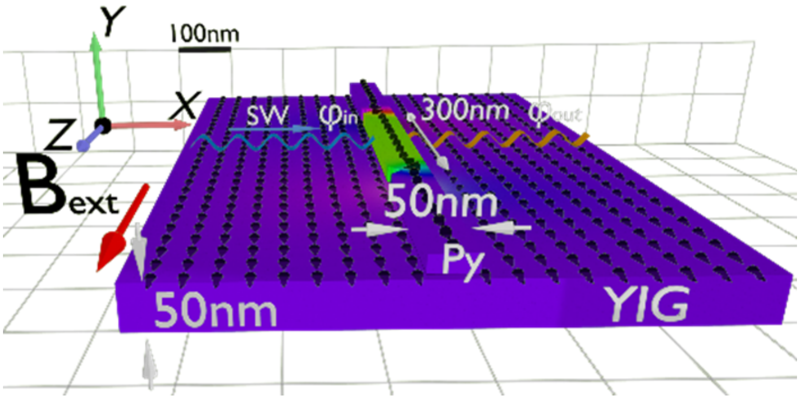


Fig. 1: Schematic of the Py racetrack over the YIG layer.

**Acknowledgements:** *The research leading to these results has received funding from the Polish NCN project PRELUDIUM 23 no 2024/53/N/ST3/03244, OPUS No. UMO-2024/55/D/ST3/02079 and the European Union's Horizon Europe research and innovation program under GA 101070347 MANNGA. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.*

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# THE ROLE OF THE DEMAGNETIZING FIELD IN SHAPING THE SPIN-WAVE SPECTRUM IN TWO-DIMENSIONAL MAGNONIC CRYSTALS

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This presentation reports theoretical studies of spin-wave dynamics in two-dimensional (2D) bicomponent magnonic crystals (MCs), with particular emphasis on the role of the demagnetizing field in shaping the band structure and the conditions for mode coupling. The analysis has been carried out using the plane-wave method, which makes it possible to determine both the spin-wave frequency spectra and the corresponding profiles of dynamic magnetization. It is shown that the demagnetizing field arising at interfaces between materials with different saturation magnetization has a decisive influence on the distribution of excitation energy between the constituents of the composite and, consequently, on the evolution of the spin-wave spectrum under an external magnetic field.

The results demonstrate that, upon decreasing the external field, non-uniform mode softening occurs, depending both on the mode number and on the wave vector [1]. This effect results from the interplay of the local demagnetizing field, the concentration of the spin-wave amplitude in one of the constituent materials, and the spatial confinement of the excitations. As a consequence, complete magnonic band gaps can be opened and reversibly tuned by relatively small changes in the external magnetic field [2]. An appropriate choice of the degree of structural squeezing makes it possible to control both the position and the width of the gaps, as well as their sensitivity to changes in the magnetic field, via enhancement of the demagnetizing field. This makes the studied systems promising candidates for applications in tunable in operando magnonic devices.

An important part of the presentation is also devoted to mode coupling and hybridization in the same systems. It is shown that an enhancement of the demagnetizing field induced by structural squeezing shifts the hybridization regions towards higher field values and may lead to the appearance of new pairs of coupled modes [3]. A particularly useful indicator of hybridization is provided by the excitation-energy concentration coefficient in one of the constituents of the composite [4]. Its exchange between interacting modes makes it possible to identify coupling even in cases where the avoided crossing is weakly pronounced or the interchange of spatial profiles is incomplete. These results indicate that the demagnetizing field should be regarded as one of the key mechanisms governing both the formation of magnonic band gaps and the conditions for mode hybridization in 2D magnonic crystals.

The majority of the results presented in this contribution reproduce those previously reported in Refs. [1–4], but are obtained here within a model extended to include damping. The calculated spectra remain very close to those obtained within the damping-free approximation, which not only confirms the robustness of the main physical mechanisms identified in Refs. [1–4], but also provides additional validation of the implementation of the model including damping.

**Acknowledgements:** *This work was supported by the National Science Centre of Poland under grant No. UMO-2020/37/B/ST3/03936.*

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# THE IMPACT OF SPIN-WAVE HYBRIDIZATION ON FMR SPECTRA IN 2D MAGNONIC CRYSTALS

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Ferromagnetic resonance (FMR) spectra are among the most important experimental tools used to investigate spin-wave dynamics in magnonic structures. At the same time, spin-wave hybridization, as an important factor determining the possibilities for controlling dispersion, energy transport, and mutual mode interactions, is one of the key phenomena in modern magnonics. For this reason, identifying the signatures left by hybridization in FMR spectra is of both fundamental and practical importance, as it may provide useful criteria for detecting mode coupling directly from spectral data. In the present study, we analyse the influence of spin-wave hybridization on FMR spectra in two-dimensional bicomponent cobalt–permalloy magnonic crystals, using the plane-wave method, which allows us to determine both the spin-wave frequency spectra and the dynamic magnetization profiles.

Our starting point is the fact, established in previous studies [1], that changes in the external magnetic field lead to non-uniform shifts of mode frequencies and, consequently, to mode approaching, coupling, and hybridizing. It was shown that a useful and sensitive indicator of hybridization is the concentration coefficient of excitation energy in one of the constituents of the composite, which is exchanged between the coupled modes [2]. In the case of FMR line intensities, however, the situation turns out to be different. The calculations indicate that these intensities are not always “shared” by the hybridizing modes and may, in some cases, not undergo a simple exchange analogous to that of the concentration coefficient. Hybridization clearly affects the evolution of the spectral lines, but this effect does not always follow the intuitive picture of a gradual transfer of intensity from one mode to the other. In the analysed cases, both smooth changes and more complex behaviours are observed, including situations in which the evolution of the lines deviates from the simplest expectation. These findings indicate that the relationship between mode hybridization and the FMR response is subtle and requires further detailed investigation. At the same time, the obtained results confirm that an appropriate analysis of FMR line intensities may become a valuable tool for identifying spin-wave hybridization in complex magnonic systems.

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# INTERACTION BETWEEN A FERROMAGNETIC AND A SUPERCONDUCTING SPHERE IN THE MEISSNER STATE

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A magnetic dipole, as a fundamental magnetic entity, generates a non-uniform and anisotropic magnetic field [1]. This anisotropy - i.e., the dependence of properties on orientation - leads to complex interactions between two magnetic dipoles. For example, in the familiar case of two bar magnets, when they are aligned parallel to each other, they tend to repel, whereas when aligned antiparallel, they attract. Thus, their interaction depends strongly on their relative orientation.

Realistic systems, however, have finite dimensions. The magnetic field around an extended magnetic body generally differs in spatial distribution from that of an ideal point dipole and depends strongly on the object's shape and the internal distribution of magnetic dipoles. An exceptional case is a uniformly magnetized sphere. Moreover, for a pair of such spheres, the magnetic energy, forces, and torques are identical to those between two point dipoles [2].

Another important aspect in realistic calculations is whether the magnetism of materials is permanent or induced. Permanent magnets are typically made of ferromagnetic materials such as iron, cobalt, or nickel, and they retain their magnetic moment even in the absence of an external field. In contrast, most materials are diamagnetic, meaning that their magnetic moment is induced only in the presence of an external magnetic field and is proportional to, but opposite in direction to, that field. Diamagnetism is generally a weak effect, but it is most prominently observed in superconductors. When cooled below their critical temperature, superconductors expel magnetic fields from their interior due to the formation of persistent surface currents of Cooper pairs. These currents generate a magnetic field that cancels the external field inside the material. This phenomenon is known as the Meissner effect.

The aim of this research is to determine and analyze the magnetic field distribution in a system consisting of a uniformly magnetized ferromagnetic sphere and a superconducting sphere in the Meissner state. Both spheres are modeled as magnetic dipoles in terms of their external field. The magnetic moment of the superconducting sphere is oriented such that it compensates for the field induced by the ferromagnetic sphere within its interior. We present the resulting magnetic field distribution as a function of (i) the orientation of the ferromagnetic sphere's magnetic moment relative to the line connecting the sphere centers, and (ii) the distance between the spheres. The study was conducted using the Mathematica environment.

**Acknowledgements:** *The authors acknowledge the support from the grant of the National Science Center– Poland, No. 2021/43/I/ST3/00550.*

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# IMPACT OF ANISOTROPIC POLAR AND ANDERSON–BRINKMAN–MOREL PHASES OF $P$-WAVE SUPERCONDUCTORS ON THERMOELECTRIC PROPERTIES OF QUANTUM DOT BASED HYBRID

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$p$-wave superconductors [1] host rich quantum phenomena arising from odd-parity, anisotropic, spin-triplet pairing, including nontrivial topology, Majorana physics, and time-reversal symmetry breaking. In particular, chiral and anisotropic $p$-wave phases strongly influence quasiparticle transport and Andreev reflection, offering promising routes for superconducting spintronics. However, theoretical/computational studies of quantum dot (a mesoscopic scatterer) based hybrid systems incorporating $p$-wave superconductors remain comparatively underexplored [2][3].

We theoretically study thermoelectric transport in a hybrid device consisting of a quantum dot coupled to a ferromagnetic lead and a spin-triplet $p$-wave superconductor. Focusing on the Polar and Anderson–Brinkman–Morel (ABM) phases, we incorporate momentum-dependent tunneling via an angle-dependent coupling modelling and analyze configurations where the superconducting symmetry axis is parallel or perpendicular to the tunneling direction. Using Keldysh Green's function formalism in the linear-response regime, we compute electrical and thermal conductances, thermopower, and the thermoelectric figure of merit.

Our results demonstrate that gap anisotropy and orientation play a decisive role in transport, producing strong phase- and geometry-dependent signatures. In particular, anisotropy governs the balance between Andreev reflection and quasiparticle tunneling, allowing the effective triplet Andreev reflection to be suppressed or enhanced by rotating the superconducting axis. In the ABM phase, this behavior is traced to the azimuthal phase structure of the order parameter. Additionally, thermal conductance is enhanced by orders of magnitude compared to the $s$-wave case [4]. These findings establish thermoelectric transport as a sensitive probe of triplet pairing symmetry and nodal structure in $p$-wave superconductors.

We note that the approach can be extended for non-equilibrium studies and any superconducting states for which the gap function angular dependence is predicted. These results may assist experimental efforts.

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# PROGRESS ON PLASMON-ENHANCED BRILLOUIN LIGHT SCATTERING SPECTROSCOPY

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Brillouin light scattering (BLS), i.e., inelastic light scattering by acoustic phonons or magnons in the gigahertz (GHz) frequency range, is a core experimental technique across various fields, including phononics [1], spintronics [2], polymer physics, glasses and colloids [3]. In nanotechnology, BLS provides a remote, contactless, and non-destructive way to characterize the elastic properties of low-dimensional materials and delicate, ultrathin nanostructures [4]. However, the limited mass and light-absorbing properties of many nanomaterials make their BLS characterization particularly challenging. In this poster presentation, we will illustrate how plasmons can be used to enhance the BLS signal in various nanostructures and metamaterials.

In polymer nanocomposites loaded with plasmonic gold (Au) nanorods (NRs), plasmon-enhanced BLS revealed coupled nanorod bending modes that would otherwise be forbidden by BLS selection rules [5]. Light resonant with the NR transverse plasmons captured the normal vibrational modes of individual NRs, while excitation near the longitudinal plasmon resonance revealed coupled bending modes in NR dimers. Beyond localized nanoparticle vibrations, plasmon-enhanced BLS can assess propagating acoustic phonons and translationally symmetric optomechanical interactions in extended colloidal crystals: self-assembled monolayers of polymer-grafted Au nanospheres [6]. With plasmon-resonant excitation, BLS captured propagating vibrational modes, corresponding to rattling and torsional nanosphere motions. Finally, we have demonstrated a top-down acoustoplasmonic metasurface – i.e., a nanostructured surface combining surface lattice plasmon resonances with surface acoustic waves (SAWs) – which has enabled enhanced optomechanical coupling of propagating SAWs through the co-localization of plasmonic and acoustic fields [7]. Our work shows that plasmon-enhanced BLS serves as a sensitive probe of acoustoplasmonic interactions, paving the way for its application on other systems, e.g., optomechanical structures or spin waves in magnetic thin films [2].

**Acknowledgements:** *This poster presentation was supported by the National Science Center (NCN) of Poland with the SONATA grant no. UMO-2021/43/D/ST3/02526. We acknowledge the collaboration with Piotr Graczyk (IFM PAN), Adnane Noual (Université Mohammed Premier), as well as with the group of Prof. Shu Yang (University of Pennsylvania), and the group of Prof. Robert J. Macfarlane (MIT).*

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