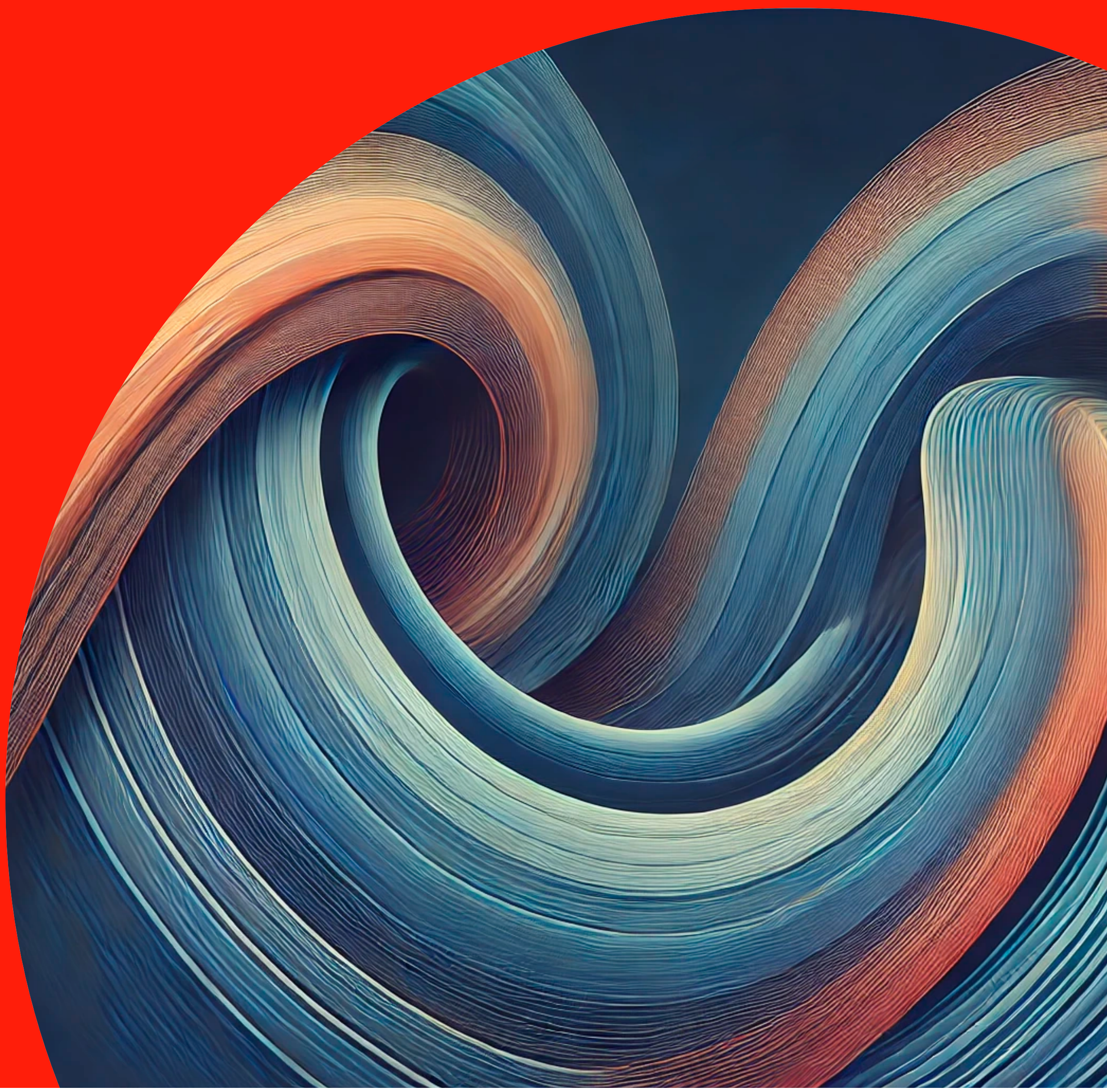
Spin Caloritronics Workshop

21–25 July 2025

University of Leeds, Leeds, UK



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	Monday 21 July	Tuesday 22 July	Wednesday 23 July	Thursday 24 July	Friday 25 July
09:00	Opening		Pickup		
09:10			*Cloth Hall Court*		
09:20	Kyung-Jin Lee	Axel Hoffmann		Eiji Saitoh	Atsushi Takahagi
09:30					
09:40					
09:50	Discussion	Discussion		Discussion	Discussion
10:00	Sadamichi Maekawa	Hide Kurebayashi		Timo Kuschel	Gerrit Bauer
10:10					
10:20					
10:30	Discussion	Discussion		Discussion	Discussion
10:40	Coffee	Coffee		Coffee	Coffee
10:50					
11:00			*Malham*		
11:10	Kei Yamamoto	Christian Back		David Waldeck	Naëmi Leo
11:20					
11:30					
11:40	Discussion	Discussion		Discussion	Discussion
11:50	Branislav Nikolic	Jiang Xiao		Angela Wittmann	Barry Zink
12:00					
12:10					
12:20	Discussion	Discussion		Discussion	Discussion
12:30	Lunch	Lunch		Lunch	Lunch
12:40					
12:50					
13:00					
13:10					
13:20					
13:30	Bart van Wees	Yaroslav Tserkovnyak		Helena Reichlova	
13:40					
13:50					
14:00	Discussion	Discussion		Discussion	
14:10	Chris Marrows			Ping Tang	
14:20					
14:30		Poster Session			
14:40	Discussion	*Bragg Building*		Discussion	
14:50	Jian-Hao Chen	*University of Leeds*		Silvia Viola Kusminskiy	
15:00					
15:10		Lab Tours			
15:20	Discussion			Discussion	
15:30	Coffee		Pickup	Coffee	
15:40					
15:50					
16:00	Hans Hubl			Carlos Rojas Sanchez	
16:10					
16:20					
16:30	Discussion			Discussion	
16:40	Matthias Althammer			Haiming Yu	
16:50					
17:00					
17:10	Discussion			Discussion	
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19:30			Dinner		
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Eating (and Drinking)

Leeds has many good places to eat and drink. It is especially famous for Indian food—which we will have for the Wednesday night banquet. Below are some of our favourite places to eat, covering different cuisines and price ranges.

Friends of Ham – Craft Beer, charcuterie and cheese platters

Bundobust – Indian street food (a lot of vegan and vegetarian options)

Rudy's Pizza Napoletana – Really good pizza

The Restaurant Bar & Grill – High end European food and wine (a little expensive)

Sous Le Nez – High end French restaurant

Fazenda Rodizio Bar & Grill – High end churrasco

Ox Club – High end modern British (fantastic meat!)

tamatanga – Great Indian food in a trendy setting

Sukhothai – Authentic Thai in a traditional setting

Lamb And Flag – Good old fashioned pub

The Northern Market – Trendy basement food court

Trinity Kitchen – Food court with many options

Stuzzi – Italian

La Piola Italian – Allegedly the best Italian in Leeds

Tattu – High end Asian fusion

Hooyah Burgers – Good burgers

Almost Famous – Good burgers

The Oxford Place – Focussing on healthy and gluten-free options

FINT – Scandinavian restaurant

House of Fu – Ramen

The Empire Café – Modern British

Mommy Thai – Thai restaurant

The Whitehall Restaurant & Bar

Mans Market – Funky Chinese restaurant

Pubs & Bars

The UK is famous for its drinking culture and as in most cities Leeds has many good options. Some of our favourites are:

The Brew Society – Great coffee, beers, cocktails and gin

North Taproom: Sovereign Street – Craft beer from North Brewing

Headrow House – Beer hall with roof terrace

Whitelock's Ale House – One of the oldest pubs in Leeds. Good beer and a connection to Joule

North Bar – Bar with a large selection of whiskies, run and beer.

Belgrave Music Hall – Busy bar over 3 floors including a roof terrace.

SALT Leeds City – Craft beer and cocktails

The Bankers Cat – Traditional pub

Tabula Rasa – Cocktail bar

Sela Bar – Occasional live music

A Nation Of Shopkeepers – Laid back pub

The Head of Steam – Nice pub, also serves food (including vegan options)

Hiking Excursion

Optional Hiking Excursion! (no extra cost)

As part of the conference social programme, we will be conducting a hike through Malham National Park (Chapel Gate, Malham BD23 4DA). PLEASE READ THIS PAGE COMPLETELY IF YOU WILL BE JOINING THE WALK

Agenda (Wednesday, 23 July 2025)

9AM: Shuttle bus pick up at University of Leeds, Cloth Hall Court, Leeds, LS1 2HA

9AM-10:50AM: Shuttle ride to Malham National Park

10:50AM - 3:30PM: Walk one of the many trails in Malham National Park

3:30PM: Shuttle bus back to University of Leeds

5:20PM: Arrive back at University of Leeds, Cloth Hall Court

Information for Attendees

Recommended packing list:

- Plenty of drinking water (recommended 1 litre minimum)
- A packed lunch (there is a cafe in the visitor's centre, but the offering may be limited)
- Snacks
- Waterproof walking shoes with good traction (as surfaces may be slippery)
- Extra layers of clothing, including a waterproof outer layer in case of rain - we recommend dressing in layers as the weather can vary from very hot to very cold
- Extra socks

Hike options:

1. Walk – Malham Moor

A chance to see the quieter side of Malham with a walk over the moors above the Tarn.

Distance: 6km (4 miles)

Time: a minimum of 1.5 hours

Accessibility: a high level exposed walk, encompassing grassy meadows and rough pasture with rocky limestone outcrops which can be slippy.

Features: High-level route (visits fellsides)

Location: Malhamdale

2. Walk – Malham Tarn circular

A circuit around the stunning Malham Tarn taking advantage of National Trust-owned open access land.

Distance: 7km (4.5 miles)

Time: a minimum of 2 hours

Accessibility: an undulating walk with a number of gates and stiles. Part of the route follows rough fields with slippy limestone outcrops.

Features: Low-level route (mostly valleys); High-level route (visits fellsides)

Location: Malhamdale

3. Walk – Malham Landscape Trail

A classic Dales walk taking in Janet's Foss and the majestic Malham Cove. A short side trip can be made to include a visit to Gordale Scar.

Distance: 4.5 miles (7.2 km)

Time: 3 hours circular

Features: Low-level route (mostly valleys)

Location: Malhamdale

4. Walk – An open access walk – Malhamdale

A circular walk using the Pennine Way and open access land with views of Malham Tarn.

Location: Malhamdale

DISCLAIMER - PLEASE READ:

Delegates may be interested in the chance of taking a hill walk in Malham National Park (Chapel Gate, Malham BD23 4DA). Some of the organisers plan to make this trip during the Wednesday afternoon, though this will depend on the weather.

Please ensure you select a hike that fits your level of physical fitness and mobility.

You will need to be reasonably fit and physically capable to undertake such a walk.

Weather in the Yorkshire Dales can vary widely, with temperatures and weather conditions changing drastically throughout the day. The temperatures in July can vary, with recorded highs around of 18 C and recorded lows of 9 C. More information on weather conditions can be found at metoffice.gov.uk

Hillwalking always brings some element of risk and, if you decide to partake in this activity, you acknowledge the inherent hazards and agree that you partake at your own risk.

Neither the conference, nor the Institute of Physics, accept any liability to delegates who choose to partake this activity, other than liability for death or personal injury which arises as a direct result of the conference's or the Institute of Physics' negligence (as appropriate).

Anyone partaking in this activity acknowledges that they are solely responsible for their personal health and safety and for their property.

It is recommended that anyone considering taking a hillwalk in Malham National Park take sensible precautions with regard to clothing, equipment and footwear, and make sure that their insurance is appropriate. It a good idea to take food, water, and warm drinks - so a thermos flask would be advisable. Heavy weather walking clothing (waterproof insulated jacket, waterproof trousers or overtrousers, boots) is appropriate in all seasons. Many paths in Malham can be slippery, so proper hillwalking boots ARE ESSENTIAL.

For more information on what to wear and bring to the Yorkshire Dales, please visit https://www.yorkshiredales.org.uk/plan-your-visit/essential-information/take-care/

Talk Abstracts

9:20-9:50 Monday 21 July 2025

Longitudinal Spin Pumping and Quantum Spin Transfer

Kyung-Jin Lee

Department of Physics, KAIST, Daejeon, Korea

Previous spin pumping studies have focused solely on transversal spin pumping arising from classical magnetization dynamics, which corresponds to precessing atomic moments with constant magnitude. However, longitudinal spin pumping arising from quantum fluctuations, which correspond to a temporal change in the atomic moment's magnitude, remains unexplored.

We experimentally investigate longitudinal spin pumping using FeRh [1], which undergoes a first-order antiferromagnet-to-ferromagnet phase transition during which the atomic moment's magnitude varies over time. By injecting a charge current into a FeRh/Pt bilayer, we induce a rapid phase transition of FeRh in nanoseconds, leading to the emission of a spin current to the Pt layer. The observed inverse spin Hall signal is about one order of magnitude larger than expected for transversal spin pumping, suggesting the presence of longitudinal spin pumping driven by quantum fluctuations and indicating its superiority over classical transversal spin pumping.

We will also discuss quantum spin transfer from correlated electron pairs, which offers a platform to test the validity of the independent electron approximation for spin transfer and enables long-range supercurrent transport in superconductor/ferromagnet junctions without requiring magnetic inhomogeneity or spin-orbit coupling [2].

References

[1] T. Lee et al. Signatures of longitudinal spin pumping in a magnetic phase transition. Nature 638, 106 (2025).
[2] S. Hwang et al. Manuscript in preparation.

10:00-10:30 Monday 21 July 2025

Spin Caloritronic Effects in Spin Super-Solids

Sadamichi Maekawa

RIKEN Center for Emergent Matter Science (CEMS), Wako, 351-0198, Japan
Kavli ITS at University of Chinese Academy of Sciences, Beijing, China

Super-solid is a quantum state of matter which shows the spatial symmetry breaking order with superfluidity, and is a long history for search in He4 [1]. On the other hand, since the boson models can be mapped to the spin models, the spin super-solid may exist in frustrated spin lattices with triangular lattice Heisenberg antiferromagnets. Motivated by the recent experimental observation of spin super-solid in various triangular lattices [2,3], we theoretically study the magnetic-field induced spin super-solid phases in the spin 1/2 nearest neighbor Heisenberg antiferromagnets with Ising-type anisotropy. We show consistent results of the off-diagonal order and superfluid stiffness which identify two distinct super-solid phases in the magnetic field. We examine the spin caloritronic effects in spin super-solids. In particular, the spin Seebeck effect due to the spin superfluidity is proposed [4].

It was discovered that a spin-1 triangular lattice gives rise to the spin super-solid [5]. We examine the magnetic field induced supersolid phases in spin-1 lattice as well [6].

This work has been done in collaboration with Yuan Gao and Wei Li of Institute of Theoretical Physics at Chinese Academy of Sciences, and Yixuan Huang of RIKEN Center for Emergent Matter Science.

References

[1] G. Su and P. Sun, Nature (January 10, 2024)).
[2] J. Xiang, et al., Nature 625, 270 (2024)..
[3] T. Chen, et al., APS March Meeting 2025.
[4] Y. Gao, Y. Huang, S. Maekawa and W. Li, to be published.
[5] J. Sheng, et al., Nature Materials 24, 544 (2025).
[6] Y. Huang, Y. Gao, W. Li and S. Maekawa, in preparation.

11:10-11:40 Monday 21 July 2025

Quantics tensor train representation of dipole-dipole interactions

Kei Yamamoto

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Magnetic dipole-dipole interactions play important roles in deciding equilibrium states and low energy dynamics in any magnetic material with sizable net magnetisation. Yet they are so often omitted in theoretical investigations primarily due to the computational difficulties stemming from their non-local, long-range character.

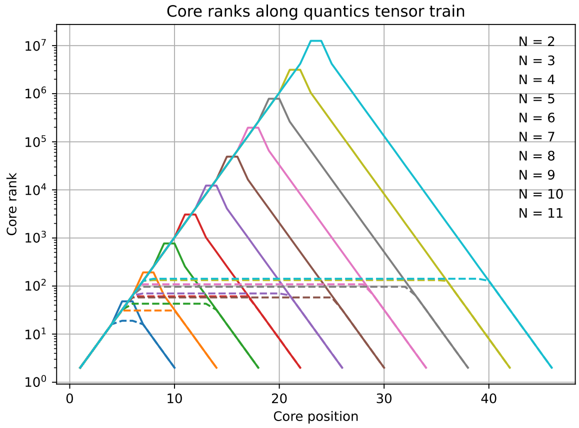

Figure 1: Core rank as a function of the core position in a quantics tensor train representation of the kernel of dipole-dipole interactions in two-dimensional square lattice. The number of spin sites per dimension is 2^N.

In this work, we propose an application to dipole-dipole interactions of a data compression method, called quantics tensor train cross interpolation [1,2,3], that has been developed over the last decade in computational mathematics. It is inspired by the matrix product representation of quantum states in 1D chains, and leverages the optimisation algorithms in linear algebra for machine learning. I introduce the technique in three steps; unfolding of large arrays into a train of smaller sized tensors, a clever rearranging of tensor indices that enable logarithmic computational complexity in the system size in many cases of physical interest, and the cross interpolation algorithm that makes the data compression suitable for iterative manipulations. I will present the tensor train representation of the kernel of dipole-dipole interactions which show a dramatic reduction of the data size (Fig. 1). Preliminary results of some model calculations that illustrate the scope of potential applications will also be discussed.

References

[1] I. Oseledets, E. Tyrtyshnikov, Linear Algebra and its Applications 432, (2010) 70-88.
[2] B. N. Khoromskij, Constructive Approximation (2011) 34:257-280.
[3] I. Oseledets, SIAM J. Sci. Comput. 33, No. 5, 2295-2317 (2011).

11:50-12:20 Monday 21 July 2025

How ultrafast demagnetization pumps charge and spin currents and their role in the ensuing THz radiation

Branislav K. Nikolić

Department of Physics and Astronomy, University of Delaware, Newark DE 19716, USA

The ultrafast demagnetization is a surprising phenomenon discovered three decades ago in which a femtosecond laser pulse (fsLP) irradiating ferromagnetic metallic (FM) layer leads to its demagnetization, where magnetization vector is shrinking in magnitude while not rotating. Despite being one of the primary experimental observables, THz electromagnetic radiation from either a single magnetic layer, or much more enhanced from FM/NM bilayers [1], where NM is normal metal with strong spin-orbit coupling (SOC), has rarely been calculated. This has forced experimentalists to rely on intuitive pictures [1] of how spin currents are generated by "spin voltage" and eventually converted into charge currents via SOC-induced mechanisms.

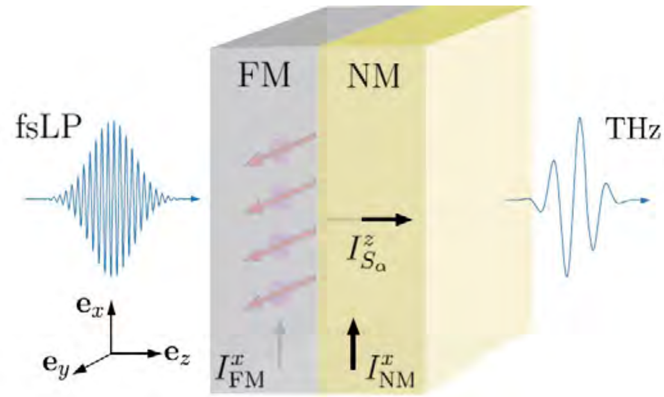

Figure 2: Schemaric view of spintronic THz emitters where TDDFT+Jefimenko approach [2,3] computes usually assumed interlayer spin current $I^z_{S\alpha}$, as well as overlooked intralayer charge current I^x_{FM} within FM layer, both of which are pumped [4] by fsLP-driven demagnetization dynamics where magnetization vector is shrinking without rotating. Jefimenko part of our approach then allows us to understand [2,3] THz emission by charge currents I^x_{FM} and I^x_{NM}.

This talk will discuss the recently developed framework [2], combining time-dependent density functional theory (TDDFT) and Jefimenko formulas for time-retarded electric and magnetic fields as proper solutions of the Maxwell equations, that makes it possible to compute emitted THz radiation from first principles. Inspection of time-dependent charge currents, as the only source of the electric field in the far-field region within Jefimenko formulas, reveals that a major contribution to THz radiation arises from completely overlooked intralayer charge current within FM layer that is pumped by demagnetization dynamic. Interlayer spin current is also pumped by ultrafast demagnetization dynamics [3], flowing toward NM layer in Fig. 1, where it is converted into charge current as often assumed. Its origin can be explained [4] by the same time-dependent quantum transport calculations which account for conventional spin pumping by rotating magnetization of fixed length when ferromagnets are driven by microwave photons of much lower energy than in ultrafast demagnetization phenomena. However, due to multiple spin-to-charge conversion processes, the connection between pumped spin current and charge current within spin-orbit-material is not as straightforward [3] as usually assumed [1]. Finally, in the case of fsLP-driven antiferromagnetic Mott insulators, as motivated by experiments on NiO [5], we replace TDDFT with tensor network calculations for Hubbard-Hund-Heisenberg model to capture [6] strongly correlated electrons whose far-from-equilibrium dynamics generates nonclassical dynamics of the Néel vector and nonequilibrium magnetization, leading to both THz radiation and peculiar high harmonic generation offering new experimental probe.

References

[1] T. S. Seifert, D. Go, H. Hayashi, R. Rouzegar, F. Freimuth, K. Ando, Y. Mokrousov, and T. Kampfrath, Nat. Nanotechnol. 18, 1132 (2023).
[2] A. Kefayati and B. K. Nikolić, Phys. Rev. Lett. 133, 136704 (2024).
[3] A. Kefayati, Y. Ren, M. B. Jungfleisch, L. Gundlach, J. Q. Xiao, and B. K. Nikolić, Phys. Rev. B 111, L140415 (2025).
[4] J. Varela-Manjarres, A. Kefayati, M. B. Jungfleisch, J. Q. Xiao, and B. K. Nikolić, Phys. Rev. B 110, L060410 (2024) (accompanied by popular highlight at https://physics.aps.org/articles/v17/s97).
[5] H. Qiu et al., Nat. Phys. 17, 388 (2021).
[6] F. Garcia-Gaitan, A. E. Feiguin, and B. K. Nikolić, arXiv:2502.00849 (2025).

13:30-14:00 Monday 21 July 2025

Towards 2-dimensional magnon transport devices: Magnon spin transport in the layered antiferromagnet $CrPS_4$

Bart van Wees

Zernike Institute for Advanced Materials, University of Groningen, The Netherlands

The transport of magnonic spins opens a new avenue for the transfer of spin currents. This is in particular useful since this also allows for signal transfer in ferro, ferri, and anti-ferromagnetic materials which are insulators (and/or low conductivity semiconductors).

Several years ago it was shown [1] that, by thermal generation as well as purely electrical means, magnons can be efficiently injected and detected in yttrium iron garnet (YIG). Electrical injection/detection has the advantage that the locations where the magnons are injected/detected are well defined. This allows for an accurate determination of transport properties such as the magnon spin conductivity and magnon relaxation length. By making the YIG thinner we observed the counterintuitive effect that the magnon spin transport actually improved by orders of magnitude [2]. This may be related to the transition from 3D to 2D transport in nm thick YIG layers

I will discuss our results obtained on magnon transport the layered anti- ferromagnet CrPS4 [3,4). Despite a clear evidence of the spin flop transition in a perpendicular magnetic field, no evidence of out-of-plane polarized magnon spin currents has been observed. However Pt electrodes can only inject and detect spins with an in-plane polarization. This is due to the symmetry constrains of the conventional spin Hall and inverse spin Hall effect. Furthermore we have found that the fabrication process for the Pt electrodes leads to a damaged layer in between the Pt and the CrPS4.

To solve these problems we replaced Pt by injector and detector strips etched out of WTe2 flakes [5]. In principle this allows to make thinner electrodes and to have clean atomically smooth interfaces. Also this prepares the way towards atomically thin two-dimensional magnon transport devices which are fully based on van der Waals materials.

We find that the efficieny of the WTe2 electrodes is comparable to Pt for in-plane spin injection/detection. However the out-of-plane injection/detection efficiency is considerably larger. This establishes WTe2 as a replacement of Pt electrodes. Finally I will discuss the future prospects and challenges for these type of devices

References

[1] L. Cornelissen et al., Nature Physics (2015)
[2] X.-Y. Wei et al., Nature Materials 21, 1352 (2022)
[3] D.K. de Wal et al., Phys. Rev. B 107, L180403 (2023)
[4] D.K. de Wal et al., Phys. Rev B 110, 17440 (2024)
[5] K. Sundararajan, et al., in preparation

Temperature gradient-driven motion of magnetic domains in a magnetic metal multilayer by entropic forces

Christopher Marrows

University of Leeds, Leeds, United Kingdom

We studied the displacement of magnetic domains under temperature gradients in perpendicularly magnetized Ta/[Pt/$Co_{68}B_{32}$/Ir]×10/Pt multilayer tracks with microfabricated Pt heaters/thermometers by magnetic force microscopy (MFM). Subtracting out the effects of the Oersted field from the heating current reveals the pure temperature gradient-driven motion, which is always towards the heater. The larger the thermal gradient along the track (owing to proximity to the heater or larger heater currents), the larger the observed displacements of the domains, up to a velocity of around 1 nm/s in a temperature gradient of 20 K/μm. Quantitative estimates of the strength of different driving mechanisms shows that entropic forces dominate over spin Seebeck (magnon) and spin-dependent Seebeck (electron) effects.

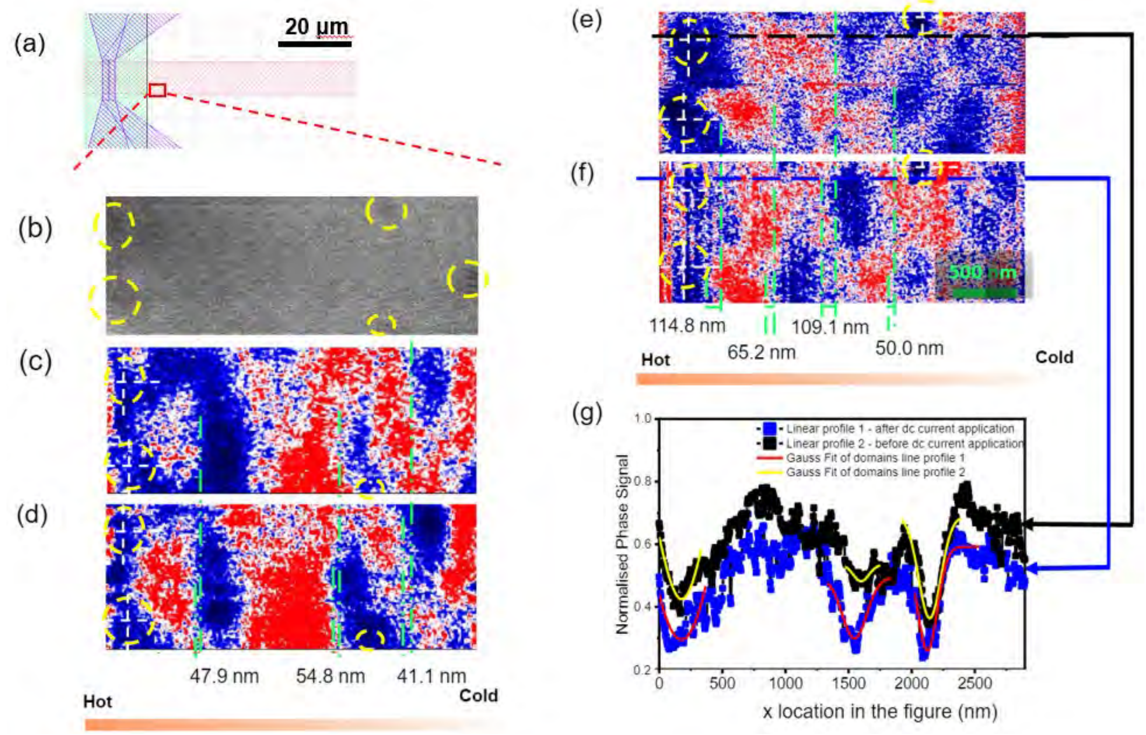

Fig 1: MFM imaging of thermally-induced domain motion. (a) Schematic of magnetic track (red) spanned by electrically isolated (green) Pt heater/thermometer (purple). (b) MFM image when the track is fully saturated in +700 Oe. The dark regions in the dashed yellow circles are defects on the track surface. (c) and (d) are the MFM images in +30 Oe before and after a +30 mA current was applied to the heater, respectively. Dashed green lines indicate position of the leading edge of the reverse domains. (e) and (f) MFM images in +30 Oe before and after a -30 mA current was applied to the heater, respectively. Dashed blue and black lines indicate the positions of the line profiles that are shown in (g).

14:50-15:20 Monday 21 July 2025

Spin caloritronic devices with magnon-flat bands and spin-spin correlations

Jian-Hao Chen

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Beijing Academy of Quantum Information Sciences, Beijing, China
Hefei National Laboratory, Hefei, China

van der Waals magnets have been a fertile playground for low-dimensional spin excitation and spin-based device applications; spin-spin correlations in complex spin structures provide exotic correlated states that might facilitate spin excitation and transport. We will discuss our recent process in a long distance, quasi-1D magnon transport in a 2D spin lattice, aid by the formation of a flat magnon band; short introduction of an electrically operated digital magnon NOT gate[1] and an electrically operated magnon anisotropic read-only memory [2] will also be provided; lastly, we will discuss an ultra-long distance spin transport phenomena based on spin-spin correlation instead of conventional exchange interactions (Figure 1). These results unveil the potential of van der Waals anti-ferromagnets and complex magnetic materials for studying highly tunable spin physics and for application in magnon-base circuitry in future information technology.

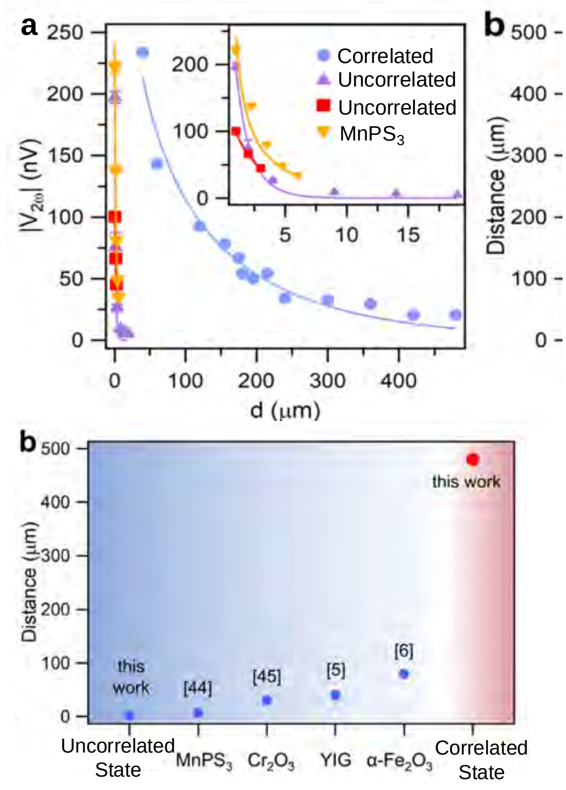

Figure 3: a. Spin transport signal vs. distance of the correlated state, the uncorrelated states as well as an antiferromagnetic insulator ($MnPS_3$). **b**. Comparison of spin transport distance of thermal magnons in various materials.

References

[1] Guangyi Chen et al., Nature Communications 12:6279 (2021)
[2] Shaomian Qi et al., Nature Communications 14: 2526 (2023)

16:00-16:30 Monday 21 July 2025

Engineering magnetization dynamics via phonons

Hans Huebl

Walther-Meißner-Institut, Walther-Meißner-Str. 8, 85748 Garching

The coupling of different degrees of freedom is a key ingredient of solid-state physics. Some questions, however, require the control over the coupling strength, which is typically realized in so-called hybrid systems. Here, the interaction between excitations, such as magnons, phonons, photons, or spins, are reliably engineered. Quantum sciences and applications harness these settings for information conversion, storage, sensing applications, or for investigating the quantum properties of these excitations. In addition, the hybrid systems are interesting from the perspective of novel functionalities arising from the emerging, mixed character of the participating modes.

In my presentation, I will discuss a hybrid system based on phonons and magnons. This system is interesting from a magnon-damping perspective, as phonons are considered a dominant magnon relaxation channel. Moreover, a large coupling between magnons and phonons can create a magnon-phonon hybrid. Thus, the magnons are expected to imprint the angular momentum properties onto the phonons, which is interesting in the context of phonon-mediated angular momentum transport. I will present our results on controlled magnon-phonon interaction using a heterostructure consisting of a magnetic thin film integrated in a phononic resonator.

16:40-17:10 Monday 21 July 2025

All-electrical angular momentum transport experiments between isolated ferromagnetic metal strips

Matthias Althammer

Walther-Meißner-Institut, Bavarian Academy of Sciences and Humanities, Garching, Germany
TUM School of Natural Sciences, Physics Department, Technical University of Munich, Garching, Germany

Pure spin currents, i.e., the flow of angular momentum without an accompanying charge current, represent a new paradigm in spintronics. Here, I present our recent progress in probing angular momentum transport via all-electrical measurements in isolated metallic ferromagnet strips [1].

In this talk, I will highlight our recent progress toward separating electronic and magnonic contributions to angular momentum transport in metallic ferromagnets [1]. To this end, we electrically excite and detect spin transport between two parallel and electrically insulated ferromagnetic metal strips on top of a diamagnetic substrate. We observe a finite angular momentum flow to the second ferromagnetic strip across a diamagnetic substrate over micron distances. We discuss phononic and dipolar interactions as the likely cause of angular momentum transfer between the two strips. Next, I will show how different diamagnetic substrates influence the spin transport signal. Finally, I will provide an outlook on our current efforts to separate dipolar and phononic contributions in these transport experiments.

References

[1] R. Schlitz et al., Phys. Rev. Lett. 132, 256701 (2024).

Tuesday 22 July 2025

9:20-9:50 Tuesday 22 July 2025

Unconventional Spin-Orbit Torque

Axel Hoffmann

Department of Materials Science and Engineering and Materials Research Laboratory, University of Illinois Urbana-Champaign, Urbana, IL 61801, USA

Spin-orbit torques allow very energy-efficient electrical manipulation of magnetization states and provide the key to many modern spintronics developments [1]. Generally, spin-orbit torques originate from electrically generating a spin accumulation in a conducting layer that can be transferred to an adjacent ferromagnetic layer. Ordinarily, due to symmetry considerations, the spin accumulations that provide the torque on the magnetization have spin polarizations that are confined to directions within the interfacial plane and are perpendicular to the electric current directions, which is only suitable for deterministic switching of in-plane magnetizations. However, materials with lower symmetries may also allow unconventional spin-orbit torques, which are suitable for deterministic switching of magnetic layers with perpendicular magnetic anisotropy. I will demonstrate different examples of such unconventional spin-orbit torques, where the symmetries are either reduced through magnetic structures in the metallic antiferromagnets $IrMn_3$ [2] and FeRh [3], or via the crystal structure in $CrPt_3$ [4], $MoTe_2$ [5], and Te.

References

[1] Q. Shao, et al., IEEE Trans. Magn. 57, 800439 (2021).
[2] J. Holanda, et al., Phys. Rev. Lett. 124, 087204 (2020).
[3] J. Gibbons, et al., Phys. Rev. Appl. 18, 024075 (2022).
[4] R. Klause, et al., Phys. Rev. Appl. 22, 044043 (2024).
[5] S. Li, et al., Phys. Rev. B 110, 024426 (2024).

10:00-10:30 Tuesday 22 July 2025

Spintronic Kapitza pendulum: dynamical stability by spin transfer

Hidekazu Kurebayashi

London Centre for Nanotechnology, University College London
Institute for Materials Research, Tohoku University

Spin transfer torques (STTs) [1] control magnetisation by electric currents, enabling a range of spintronic applications [2]. STTs are in general employed for switching the magnetisation from one local energy minima to the other or in entering auto-oscillation, but so far only these two have been mainly studied as non-linear dynamics driven by STTs. Inspired by the Kapitza pendulum [3] where a high potential energy state can be stabilised by dynamical injection of mechanical force, here we study the spintronic analogue of such a state achieved by nonequilibrium excitation of STTs.

To achieve the same potential landscape with only one global potential minimum, and to maximise the efficiency of current-driven STTs, we made a dedicated CoFeB thin film layer with a characteristic property of the nearly-isotropic magnet. We use STTs generated by spin-Hall effect in the adjacent W layer to de-stabilise the energy minimum state achieved by an external field and observed the experimental signature of stabilising the state at the energy maxima, i.e. the moment pointing at the direction opposite to the external field, when the STT drive is strong enough to compensate the material damping. One such observation is the sign reversal of ferromagnetic resonance voltage amplitude when increasing the STT drive [4].

We will discuss more technical details of these measurements, quantitative analysis and results by stochastic Landau-Lifshitz-Gilbert equation. The discovery of a nano- scale rigid pendulum with dynamical stabilisation and controllable stochasticity is an ideal platform for studying dynamical systems with promising functionalities for probabilistic computing applications [5] and anti-magnonics [6].

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11:10-11:40 Tuesday 22 July 2025

Controlling Magnetic Properties by Spin Currents

Christian Back

Technical University of Munich, Germany

Many aspects of spin current applications—such as spin current-induced magnetization dynamics and switching—have been extensively studied in recent years. In this work, we demonstrate fundamental effects that arise from the application of spin currents. Specifically, we show that both magneto-crystalline anisotropies and magnetization can be controlled via spin currents in conventional magnetic ferromagnets. Furthermore, we reveal that the injection of angular momentum into the ferromagnetic layer of an all-2D heterostructure enables electrical control of the anomalous Hall effect.

11:50-12:20 Tuesday 22 July 2025

Magnons as information carriers in hybrid quantum architectures

Silvia Viola Kusminskiy

Institute for Theoretical Solid State Physics, RWTH Aachen University, DE-52074 Aachen, Germany

In this talk I will explore the possibilities and limitations of using magnons as mediators of quantum information in hybrid quantum systems at the nanoscale. In particular, I will discuss our recent theoretical results on implementing magnon-mediated quantum gates for superconducting qubits [1] and, complementary, the possibility of engineering quantum states of magnons via their coupling, either direct or mediated by a microwave cavity, to a superconducting qubit [2,3,4]. Further, I will discuss the prospect of using Brillouin light scattering for performing quantum tomography of magnons [5].

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13:30-14:00 Tuesday 22 July 2025

Vortexo-electric ZT for energy-storage devices

Yaroslav Tserkovnyak

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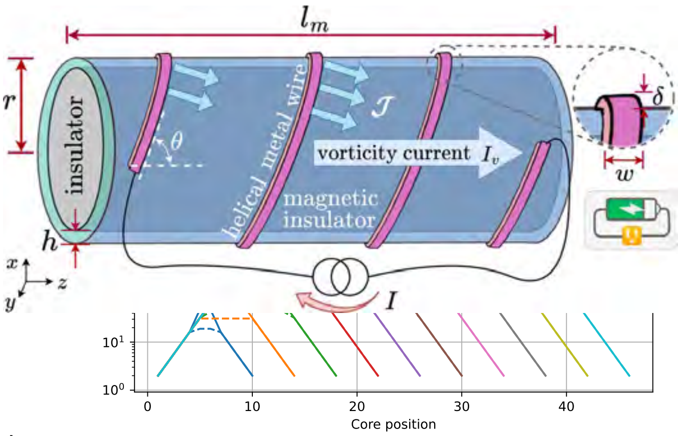

We discuss performance and efficiency of free-energy-storage devices based on electrically-controlled magnetic-vortex transport. In particular, we propose that vorticity transport can be controlled by geometrically reducing symmetries in curved films, enabling spin-torque processes absent from flat magnetic systems. To this end, the vorticity 3-current is constructed for magnetic membranes, which obeys a continuity equation immune to local disturbances of the magnetic texture and spatiotemporal fluctuations of the membrane. We show how electric current can manipulate vortex transport in geometrically nontrivial magnetic systems. As an illustrative example, we propose a minimal setup that realizes an experimentally feasible energy storage device and discuss its thermodynamic efficiency in terms of a vortexo-electric counterpart of the thermo-electric figure of merit ZT.

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14:30-17:00 Tuesday 22 July 2025

Poster Session

University of Leeds, Sir Henry William Bragg Building

Excursion

Meet at Cloth Workers Court 8:30-9:00

9:20-9:50 Thursday 24 July 2025

Polar Order Electronics

Eiji Saitoh

University of Tokyo, Japan

When polar order induced by electron correlation coexists with weak electrical conductivity, it opens the possibility of electrically manipulating this order, leading to new types of electronics. If the polar order is regarded as a pseudo-spin, one can draw analogies with various phenomena in spintronics, which can be referred to as "pseudo-spin electronics." In this talk, I will introduce several experiments that mark the initial steps in this direction.

Suppression of spin Seebeck effect by the increase of saturation magnetization studied in $NiFe_2O_4$ thin films

Timo Kuschel

Faculty of Physics, Bielefeld University, 33615 Bielefeld, Germany
Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany

The ferrimagnetic insulator $NiFe_2O_4$ (NFO) is a prototype thin-film material for thermally induced spin transport phenomena. We have studied spin Seebeck effect (SSE) [1] and non-local magnon spin transport [2] in recent years. When grown on lattice-matched substrates such as $MgGa_2O_4$, the magnetic properties of NFO such as switching field or magnetic damping become comparable to the standard spin-transport material $Y_3Fe_5O_{12}$ due to reduction of anti-phase boundaries [3]. With these films, we recently performed SSE-based vectorial magnetometry for magneto-crystalline anisotropy studies [4].

While thermally induced spin transport via SSE has been explored in plenty of various materials in the recent decade, fundamental dependencies of SSE on individual material parameters have been studied only rarely. In order to name an example, we prepared $NiFe_2O_x$ thin films and varied the oxygen content x. Thus, we were able to study the SSE dependence on charge conductivity [5]. Within our current investigation, we varied the NFO lattice parameters systematically by in situ post-annealing the NFO films in oxygen atmosphere. We observe a linear dependence of the lattice constant on the annealing temperature. The saturation magnetization M_s detected by superconducting quantum interference device magnetometry also varies but not as systematically as the lattice parameters do.

The SSE measurements reveal a suppression of the SSE with increasing M_s similar to the SSE suppression that has been reported for higher external magnetic field as a consequence of the Zeeman gap in magnon excitation [6]. In addition, a reduced precession cone angle related to larger M_s causes a decreased spin polarization of the thermally induced spin current and, thus, a reduced signal at the spin current detector material Pt. We can further identify a clear $1/M_s$ dependence of the SSE which agrees with the $1/M_s$ term in the Landau-Lifshitz-Gilbert equation, and, finally, confirms the theory of the longitudinal SSE developed by Rezende et al. [7].

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Probing Chiral-Induced Spin Selectivity through Comparisons of Spin-Polarized Charge Currents and Pure Spin Currents

David H. Waldeck

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The chiral-induced spin selectivity (CISS) effect offers new approaches for manipulating spin-dependent processes in both chemistry and physics, yet the physical mechanism(s) underpinning CISS are still debated. After introducing the CISS effect, I will discuss studies aimed at elucidating features of CISS through comparisons of spin-polarized electron currents and pure spin currents in chiral materials. First, I will discuss studies into the pure spin and spin-polarized charge currents of chiral metal oxide films, which display colossal anisotropic damping for spin currents.[1] Second, I will discuss unpublished work that is quantifying structure-property relationships for spin currents and spin-polarized charge currents in chiral quantum dot assemblies. The studies on these different systems show that the spin-polarized charge current reverses its sign with the handedness of the material whereas the pure spin current does not. In addition, the quantum dot studies show that the circular dichroism (CD) strength of chiral CdSe QDs' primary exciton transition correlates with magnitude of the CISS response. Lastly, I will suggest a simplified model for rationalizing our findings.

References

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11:50-12:20 Thursday 24 July 2025

Chiral-induced Unidirectional Spin-to-charge conversion

Angela Wittmann

Johannes Gutenberg University Mainz, Germany

The chiral-induced spin selectivity (CISS) effect has recently gained significant attention in the field of spintronics. The remarkably high polarization efficiency of chiral molecules via the CISS effect paves the path toward novel, sustainable hybrid chiral molecule magnetic applications. While research has predominantly focused on transport properties so far, in our work, we explore spintronic phenomena at hybrid chiral molecule magnetic interfaces to elucidate the underlying mechanisms of the chiral-induced spin selectivity effect. For this, we investigate the interfacial spin-orbit coupling in chiral molecule/metal thin film heterostructures by probing the chirality and spin-dependent spin-to-charge conversion. Our findings validate the central role of spin angular momentum for the CISS effect, paving the path toward the functionalization of hybrid molecule-metal interfaces via chirality.

13:30-14:00 Thursday 24 July 2025

Magneto-thermal transport is compensated magnetic systems

Helena Reichlova

Institute of Physics ASCR, Prague, Czech Republic

Materials with compensated magnetic order, such as antiferromagnets, offer distinct advantages, including faster dynamics and a broader selection of available materials. This has driven significant research in antiferromagnetic spintronics, leading to exciting discoveries. Recently, a new class of compensated magnets—altermagnets—has been identified, further expanding the potential of compensated magnetic materials [1,2]. Similar to spintronics, spin caloritronics has long been dominated by ferromagnets. However, in recent years, the potential of antiferromagnets has gained attention, particularly in the context of the anomalous Nernst effect [3,4]. In this talk, I will first discuss the advantages of compensated magnets for spin caloritronic research. I will briefly introduce the concept of altermagnetism and focus on some of the first experimental verifications of altermagnetic materials [5,6] and their spin caloritronic responses [7]. Finally, I will explore the implications of altermagnetism for magnon-mediated spin currents [8].

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Exchange Surface Spin Waves in Type-A van der Waals Antiferromagnets

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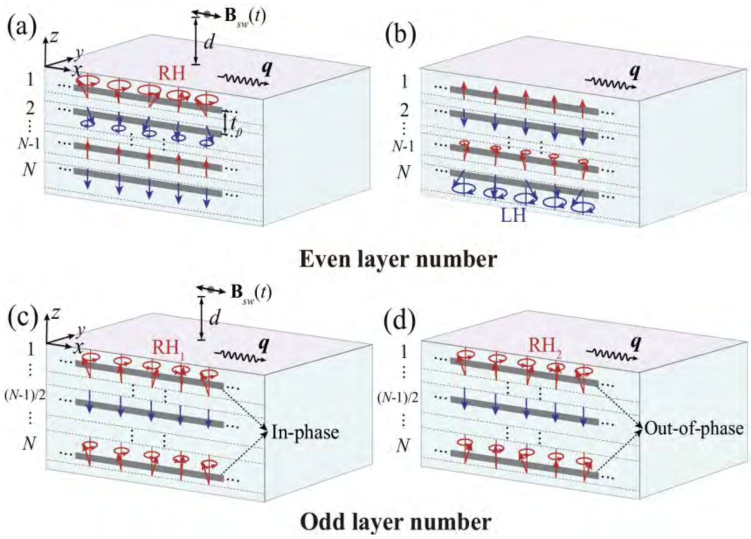

Figure 4: Surface spin waves in perpendicularly magnetized A-type van der Waals antiferromagnets. (a), (b) For an even number of monolayers, two surface modes are localized at opposite surfaces with opposite chiralities. (c),(d) For an odd number of monolayers, there are two surface modes of the same (right-handed) chirality with in-phase (c) and out-of-phase (d) spin dynamics between the top and bottom surface amplitudes.

Surface waves, the evanescent solutions of the wave equation at planar discontinuities, are of fundamental importance in surface physics, optics, phononics, electronics, and magnetism. Here we predict the emergence of surface spin-wave excitations within the bulk magnon band gap of type-A van der Waals antiferromagnets. In contrast to conventional magnetostatic Damon-Eshbach modes, they are pure exchange modes owing to reduced interlayer exchange coupling at the surface layers, and thus persist in ultrathin multilayer stacks and at large wave numbers. We show that they can be efficiently excited by electromagnetic waves, with absorption power comparable to or even exceeding that of bulk modes. Moreover, their emitted magnetic stray fields exhibit pronounced even-odd oscillations with the number of monolayers that should be observable by NV-center magnetometry [1].

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14:50-15:20 Thursday 24 July 2025

Spin Wave Dissipation and Polarization: from Classical to Quantum

Jiang Xiao

Fudan University, China

Spin wave dissipation and polarization, often considered distinct phenomena, are inherently linked in magnetic systems. In the linear spin wave regime, research shows that the dissipation rate of a mode—measured by the ratio of linewidth to frequency—is directly related to the mode's average polarization. This average is determined by a non-positive-definite weight whose magnitude indicates local magnon density, and whose sign represents the chirality of polarization. This dissipation-polarization connection offers a universal way to understand spin wave behavior across different magnetic interactions and materials, enhancing our grasp of spin wave dynamics and dissipation.

On a quantum level, the polarization of classical spin waves mirrors squeezing phenomena observed in quantum systems. Specifically, quantum entanglement or two-mode squeezing of magnons can be realized with antiparallel magnetization, while parallel configurations enable magnon beam-splitting. Moreover, this approach allows for quantum teleportation using magnon propagation, marking a significant advance in the manipulation and understanding of quantum spin information.

16:00-16:30 Thursday 24 July 2025

Gr-based Rashba interfaces and van der Waals low-symmetry materials for spin-orbitronics

Carlos Rojas-Sánchez

Institut Jean Lamour, France

Spin current has different symmetries. In 5d transition metals with a cubic structure, we find the orthogonal or "conventional" spin Hall effect (SHE) symmetry as in Pt, Ta, and W [1]. Here, when a charge current Jc is injected along x, the transverse spin current Js generated along z transports electrons with y spin polarization [1]. In magnetic materials, Js might transport electrons with spin polarization parallel to their magnetization. However, if they have strong spin-orbit coupling, Js with the orthogonal SHE symmetry also survives. We have shown that for GdFeCo [2].

In the first part of my talk, I will present results on a new heterostructure combining 2D materials such as graphene (Gr) and 3D materials such as Fe and Pt. Through spin pumping ferromagnetic resonance, we show a record efficiency for charge current production at room temperature in Fe/Gr/Pt. The gain is 34 times over Fe/Pt. The charge current production is anisotropic, following the hexagonal symmetry of Gr. The experimental results are supported by first-principles calculations [3].

In the second part, I will present results with the van der Waals topological semimetal $NbIrTe_4$, which has an orthorhombic crystallographic structure and a missing reflection plane. This allows the production of spin current along z with spin polarization also along z. The bulk topological Weyl semimetal nature of NbIrTe4, characterized by its Weyl cone, significantly enhances the out-of-plane (OOP) spin Berry curvature, enabling an unprecedented OOP spin Hall conductivity exceeding 105 $\hbar/2e\cdot\Omega^{-1}m^{-1}$. This enhancement enables efficient and field-free spin-orbit torque switching of perpendicular magnetization with a low current density of 1.4 MA/cm^2. The improved spin Hall conductivity reduces the overall power consumption by more than two orders of magnitude compared to existing systems, such as heavy metals [4].

Thanks to H2020-RISE ULTIMATE-I (ID 101007825), ERC CoG MAGNETALLIEN (ID 101086807) projects for financial support and to all collaborators [1-5].

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16:40-17:10 Thursday 24 July 2025

Control of spin currents in a canted antiferromagnet

Haiming Yu

Beihang University, China

Controlling the spin current lies at the heart of spintronics and its applications [1]. In ferromagnets, the sign of spin currents is fixed once the current direction is determined. However, spin currents in antiferromagnets can possess opposite polarizations, but this usually requires enormous magnetic fields to lift the degeneracy between the two modes. Therefore, controlling spin currents with opposite polarization is still a challenge.

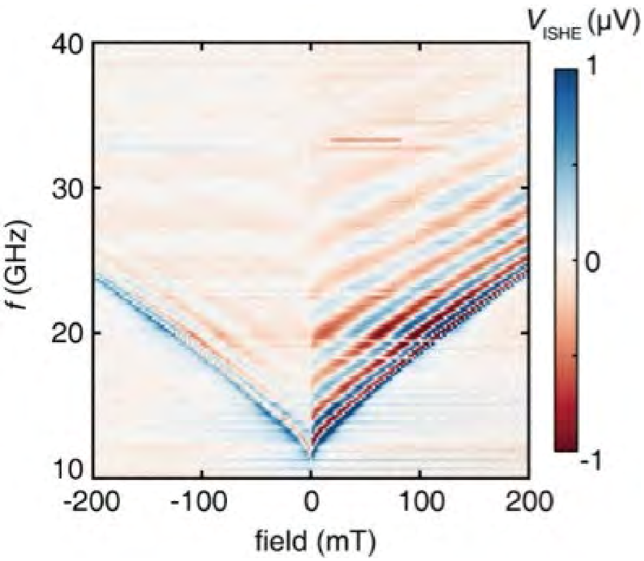

Figure 5: The inverse spin-Hall voltages (V_{ISHE}) probed by a Pt bar on hematite as a function of the applied magnetic field and excitation microwave frequency. The blue and red colors represent positive and negative ISHE voltages, respectively. The alternating sign of V_{ISHE} exhibit the oscillation between right-handed and left-handed spin current originated from magnon interference in the canted antiferromagnet.

In this talk, I will present our recent work demonstrating the control of spin currents at room temperature by magnon interference in a canted antiferromagnet hematite [2]. Magneto-optical characterization by Brillouin light scattering reveals that the spatial periodicity of the beating patterns is tunable via the microwave frequency. We further observe that the inverse spin Hall voltage changes sign as the frequency is tuned, evincing a frequency-controlled switching of polarization of pure spin currents. Our work highlights the use of antiferromagnetic magnon interference to control spin currents, which substantially extends the horizon for the emerging field of coherent antiferromagnetic spintronics [3].

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Friday 25 July 2025

9:20-9:50 Friday 25 July 2025

Transverse Thomson effect

Atsushi Takahagi

Department of Mechanical Systems Engineering, Nagoya University, Nagoya, Japan

The thermoelectric effects have attracted attention as principles for energy harvesting and thermal management technologies. The Seebeck, Peltier, and Thomson effects, categorized as longitudinal thermoelectric effects, were discovered in 19th century and have been systematically studied for a long time. The Thomson effect generates volumetric heating or cooling in a conductor when a charge current and temperature gradient are applied in the same direction. The heat source of the Thomson effect is determined solely by the temperature derivative of the Seebeck coefficient; this is known as the first Thomson (Kelvin) relation. On the other hand, the transverse thermoelectric effects including the Nernst and Ettingshausen effects were discovered in the same century, but the transverse Thomson effect (TTE) has only been predicted theoretically and has not yet been observed experimentally [1]. According to the analogy with the Thomson effect, TTE should be related to the temperature derivative of the Nernst coefficient. The observation of TTE is an important task for systemizing the transverse thermoelectric effects.

In this study, we directly observed the thermal response of TTE by applying a charge current, temperature gradient, and magnetic field in the orthogonal directions to a nonmagnetic conductor, using thermoelectric imaging based on the lock-in thermography method [2]. We measured the dependence of TTE on the charge current, temperature gradient, and magnetic field systematically and performed numerical simulations for TTE based on the thermoelectric transport model. Our experimental and numerical results clarified that TTE is determined not only by the temperature derivative of the Nernst coefficient but also the Nernst coefficient itself, which essentially differs from the conventional Thomson effect. Thus, materials with the large Nernst coefficient could be promising candidates for realizing large TTE. This result fills a missing piece in thermoelectrics and spin caloritronics, and further unobserved phenomena such as anomalous TTE are expected to be demonstrated in the future.

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10:00-10:30 Friday 25 July 2025

Advances in Magnon Caloritronics

Gerrit Bauer

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AIMR, Tohoku University, Sendai, Japan

Spin caloritronics is about the heat and spin transport in magnetic materials and devices. The spin dependent spin Seebeck effect in metallic ferromagnets and its multilayers are believed to be dominated by mass transport of conduction electrons while spin waves in magnetic insulators cause the spin Seebeck effect. Here I would like to discuss two new insights.

The first one is the magnetothermal resistance in spin valves and multilayers of magnetic insulators separated by normal metal spacers, which is caused by the spin Seebeck effect [1].

The second topic is the tomography of the non-equilibrium magnon distribution function by Inelastic Resonant X-Ray Scattering (RIXS) [2].

References

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Magneto-Thermoplasmonics

Naëmi Leo

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While a moderate temperature increase usually does not alter a micromagnetic state directly it does modify material properties and can affect magnetisation dynamics and switching kinetics. As such, local heating can provide an interesting means to enhance nanomagnetic functionalities. However, contemporary heating methods have significant drawbacks when considering integration in nanoscale devices, as they are either slow, prone to damage, or cannot be reliably aligned with nanoscale magnetic features (such as domain walls or other spin textures). Furthermore, the respective spatial temperature profiles of conventional heating methods cannot be adapted in-situ.

Disadvantages of global heating schemes can be overcome by drawing inspiration from the emerging field of thermoplasmonics [1]. Here, light-induced excitation of localised surface plasmon resonances and subsequent dissipation of internal currents results in fast (down to ps) and effective local heating (with temperature increases of several 100 K possible). Using experimental degrees of freedom, thermoplasmonic nanoparticles thus allow versatile temperature control on nano- to millimetre length scales, which can be reconfigured via light wavelength, light polarisation, and focal position.

In this talk I will introduce the basic concepts to creating hybrid magneto-thermoplasmonic devices [2]. As a new pathway to combining opto-electronics with spintronics, I will discuss potential applications that might benefit from light-induced thermal remote control, including non-conventional computing devices [3].

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Spin conversion and magnon contributions in metallic antiferromagnets probed via the longitudinal spin Seebeck effect

Barry L. Zink

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The spintronic and spin caloritronic properties of antiferromagnets continue to be a topic of interest, motivated by the promise of high frequency, potentially high speed, magnons and low stray fields. Though much of this interest understandably focuses on insulating antiferromagnets or more complicated states with antiferromagnetic exchange interactions, important open questions remain in the realm of metallic antiferromagnets.

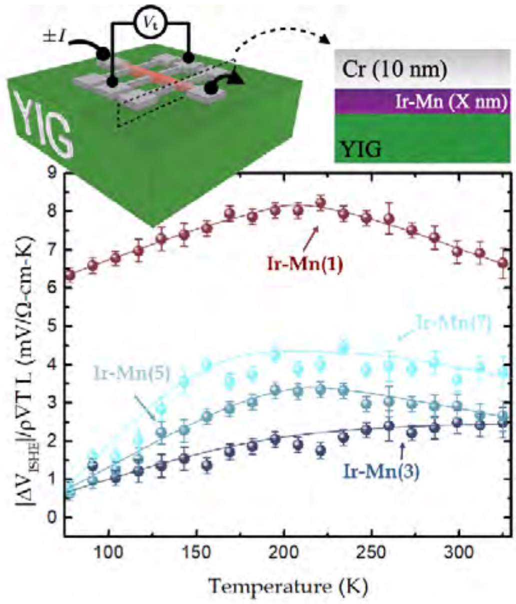

Figure 6: Absolute value of spin conversion efficiency in Sputtered Cr/Ir-Mn/YIG heterostructures for varying thickness of Ir-Mn. At low thickness adding the Ir-Mn drives increased spin conversion efficiency, exceeding the values for sputtered Cr alone at all T.

Here I discuss our continuing investigation of the role of antiferromagnetic order, and potential of antiferromagnetic magnons, in spin conversion and transport in two metallic antiferromagnetic systems. This work uses thermal gradients generated locally in a self-heated metallic Hall bar structure, allowing direct calibration of the thermal gradients generated. I will first review the results for chromium thin films, prepared via two different growth techniques that suggests that antiferromagnetism plays a role in the significant spin-charge conversion we see in Cr [1].

After briefly pointing out a puzzling result in the spin Hall magnetoresistance measured on sputtered Cr, which we have tied to oxidation of the material, I will the present SSE-probed spin conversion efficiency in heterostructures formed from two metallic antiferromagnets, Cr and Ir-Mn. These results show dramatic enhancement for a certain range of Ir-Mn thickness, and an intriguing sign change in the SSE signal. This suggests a role for antiferromagnetic magnon transport across the Ir-Mn.

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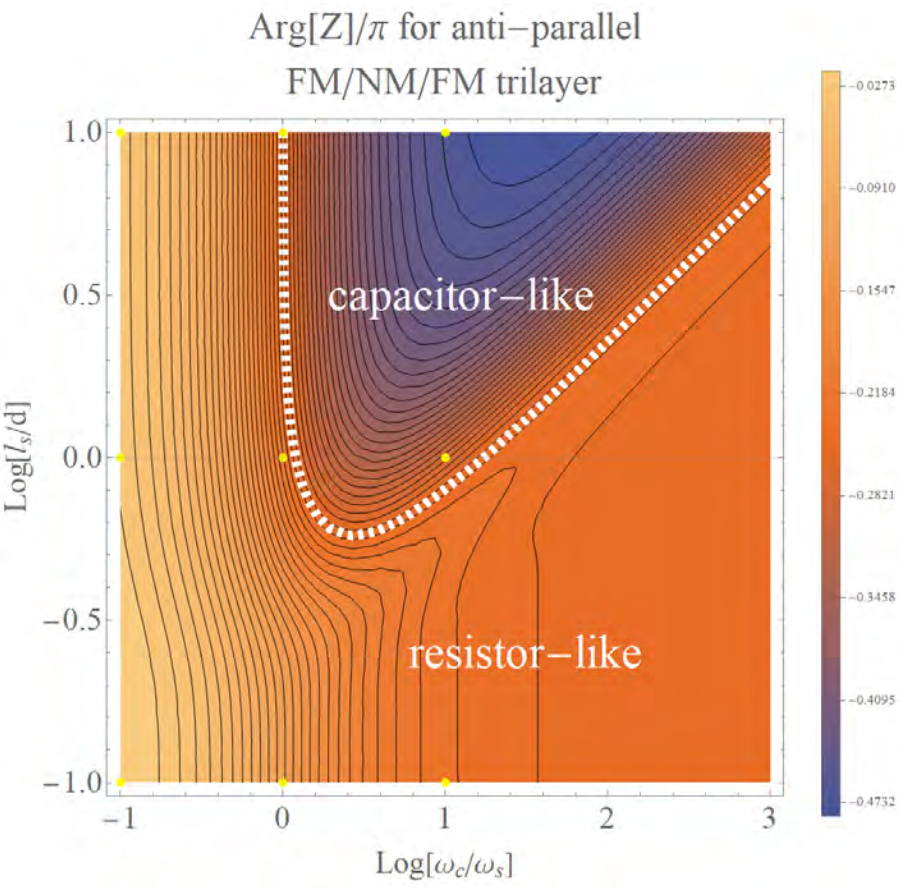
Poster Abstracts

Alternating Spintronics: Magneto-Impedance in Magnetic Heterostructures

Dr Yunwen Liu[1], Jiang Xiao[1,2,3,4]

1 Department of Physics and State Key Laboratory of Surface Physics, Fudan University,
2 Institute for Nanoelectronic Devices and Quantum Computing, Fudan University,
3 Shanghai Research Center for Quantum Sciences, 4 Shanghai Branch, Hefei National Laboratory

Spin transport research within magnetic systems has predominantly concentrated on steady-state conditions driven by direct (DC) spin currents. This study shifts the focus to the effects of alternating (AC) spin currents, particularly when their driving frequency approaches the spin relaxation rate. In this context, we investigate the magneto-impedance of magnetic heterostructures, revealing that these systems exhibit not only resistive but also significant capacitive characteristics. By employing the time dependent spin diffusion model, we analyze time-dependent spin accumulation and impedance in configurations such as ferromagnet-normal junctions and spin valves. In the specific case of spin valves, our findings suggest that the device can behave almost entirely like a capacitor, deviating from the conventional magneto-resistance behavior typically expected. Notably, the capacitive response is enhanced in anti-parallel magnetic configurations, which could lead to innovative applications in terahertz (THz) technology as well as the efficient AC readout of magnetic state.



Alternative injector/detector platform for magnons: WTe_2

Mr. Krishnaraajan Sundararajan[1], Bart van Wees[1]
1 University Of Groningen

The modern challenge in computing lies in Moore's law reaching its physical limits hindering further predicted exponential growth in computational power. In the frontiers of research aimed at alternative solutions to this, magnonics focuses on information transport utilizing the spin rather than the charge of the electron. Towards this, two dimensional van der Waals (vdW) materials, with weak interlayer forces, offer an intriguing platform for the study of magnonics with flexibility in the possible heterostructures from combining these atomically flat materials, opening up avenues for exploration of new physics. The electrical study of magnons have so far relied on heavy metals like platinum which makes it difficult to study the magnon transport in air unstable systems like CrI_3, a potential topological magnon insulator.

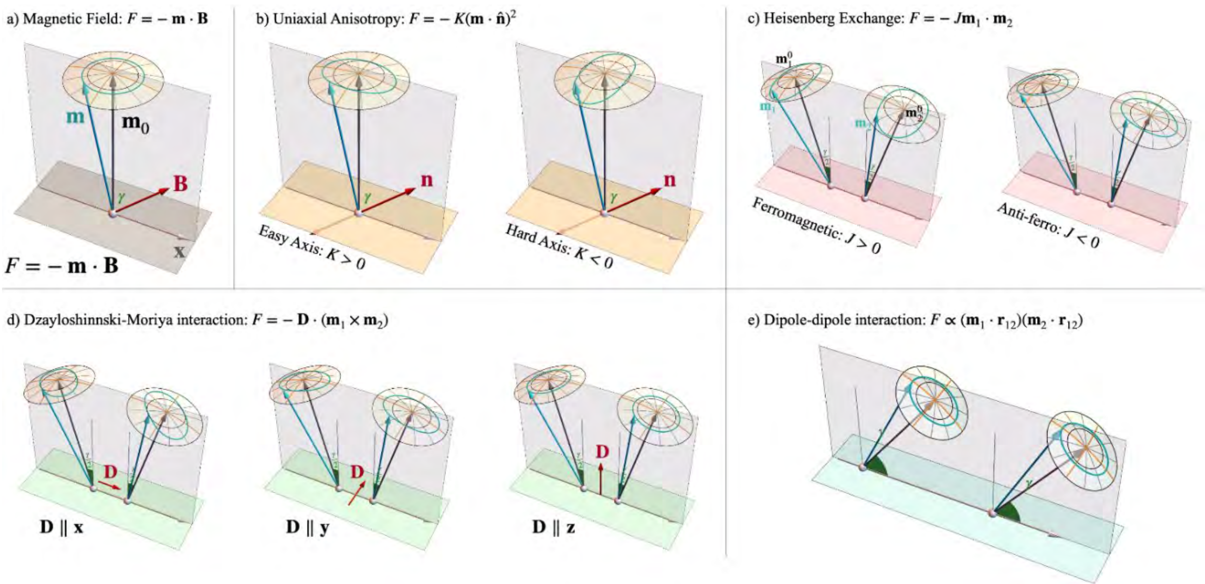
Alternative to the traditional heavy metal electrode, WTe_2: a topological Weyl semi-metal from the vdW family is explored. The observed signal is consistent with an excitations of magnons by the conventional spin hall effect from WTe_2. This opens up avenues to electrically address the magnon transport in systems like CrX_3.

Anatomy of spin wave polarization and its connection to dissipation

Yutian Wang[1], Jiang Xiao[1]
1 Fudan University

Spin waves in ferromagnetic materials are predominantly characterized by right-handed circular polarization due to symmetry breaking induced by net magnetization. However, magnetic interactions, including the external magnetic field, Heisenberg exchange, Dzyaloshinskii-Moriya interaction, and dipole-dipole interaction, can modify this behavior, leading to elliptical polarization, as shown in figure. This study provides a systematic analysis of these interactions and their influence on spin wave polarization, establishing principles to predict traits such as polarization degree and orientation based on equilibrium magnetization textures [1].

Furthermore, we establish a fundamental connection between the dissipation and polarization of spin waves, which are often treated as independent phenomena. We demonstrate that within the linearized spin wave regime, a spin wave mode's dissipation rate, defined as the ratio of linewidth to the resonance frequency, exceeds Gilbert damping by a factor given by its spatially averaged polarization [2]. This average is governed by a non-positive definite weight, whose magnitude depends on the magnon density of the local excitation, while its sign is dictated by the local polarization handedness. Remarkably, this universal connection applies across diverse magnetic interactions and textures.



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Anomalous Nernst Effect in Epitaxially Grown Mn_3Sn Thin Films

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Recent advancements in magnetic information storage technologies focus precisely on the control over movement and positioning of magnetic domain walls. Both ferromagnetic and antiferromagnetic materials are being actively investigated for their potential in energy harvesting and memory applications, especially for spin caloritronics. Recently, Antiferromagnets, characterized by their non-collinear spin arrangements, are notable for producing significant Berry curvature due to spin-orbit coupling. This Berry curvature, originating from magnetic multipole moments have a great role in both the anomalous Hall Effect (AHE) and the anomalous Nernst Effect (ANE). Mn_3Sn, a non-collinear antiferromagnet having hexagonal structure. In the ab-plane, Mn atoms form a Kagome lattice. Mn_3Sn has gained attention in thermoelectric research as an ideal candidate due to its unique characteristics, nearly zero net magnetization coupled with a large Berry curvature. Our study explores the potential implementation of the anomalous Nernst effect along different crystallographic directions in Mn3Sn thin films, in which a temperature gradient (∇T) and magnetic field perpendicular to each other produce a transverse thermoelectric voltage signal. The anomalous Nernst coefficient along $[11\bar{2}]$, $[11\bar{2}3]$, and [0001] has a significant value of 0.589 μV/k, 0.519 μV/k, and 0.585 μV/k respectively, showing a strong crystallographic dependance. Our findings could offer valuable insights in understanding the crystallographic dependance of ANE in epitaxially grown Mn3Sn thin films and their potential in thermoelectric applications.

Extending Path Integral Spin Dynamics: capturing thermal effects in interacting quantum spin systems.

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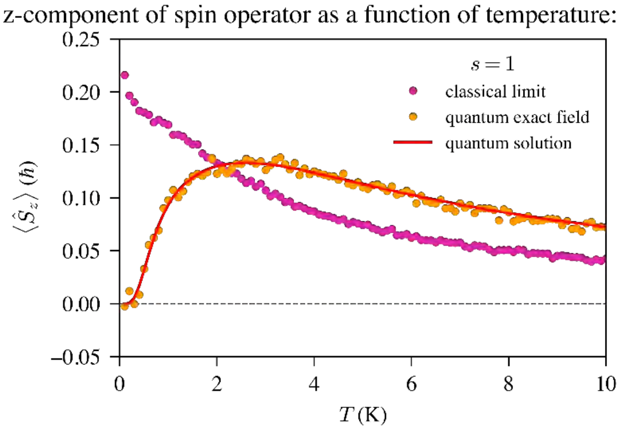
In recent years, the rise of artificial intelligence and related numerical methods has yet again significantly increased the demand for computational power and data storage. As a result, electronic components are becoming progressively smaller, more densely packed, and, in some cases—such as qubits based on superconducting Josephson junctions—operating at increasingly low temperatures. Additionally, these devices must function at ever shorter timescales in order to accelerate the operating speed of next generation electronics. All these factors contribute to making devices more susceptible to quantum fluctuations [1], which can no longer be assumed to be suppressed by a thermal bath or averaged out over space and time, e.g. due to decoherence effects [2].
For spin systems, it is well established that purely classical models fail to capture key experimental results, especially at low temperatures, such as Bloch’s law for magnetization as a function of temperature [3]. To address this, hybrid approaches incorporating quantum statistical effects into classical simulations have been developed [4], offering valuable insights into the fundamental properties of these systems. However, we aim to go further by constructing a method that starts from a fully quantum spin system expressed in a spin coherent state basis [5-6]. From this, we derive an effective Hamiltonian suitable for classical atomistic spin dynamics simulations, enabling the direct computation of quantum expectation values without additional assumptions about how thermal states are populated as temperature increases.
In this latest step, we extend our model to interacting spin systems coupled via isotropic Heisenberg exchange [7]. Notably, we demonstrate that when the external field and the system’s quantization axis are collinear, the effective classical simulation fully captures the thermal behaviour of the underlying quantum system, even in the antiferromagnetic case.

Expectation value of z-component of spin operator as a function of temperature: antiferromagnetic spin system.



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Nonlinear thermoelectric transport properties induced by orbital magnetic moment in B20 compound CoSi

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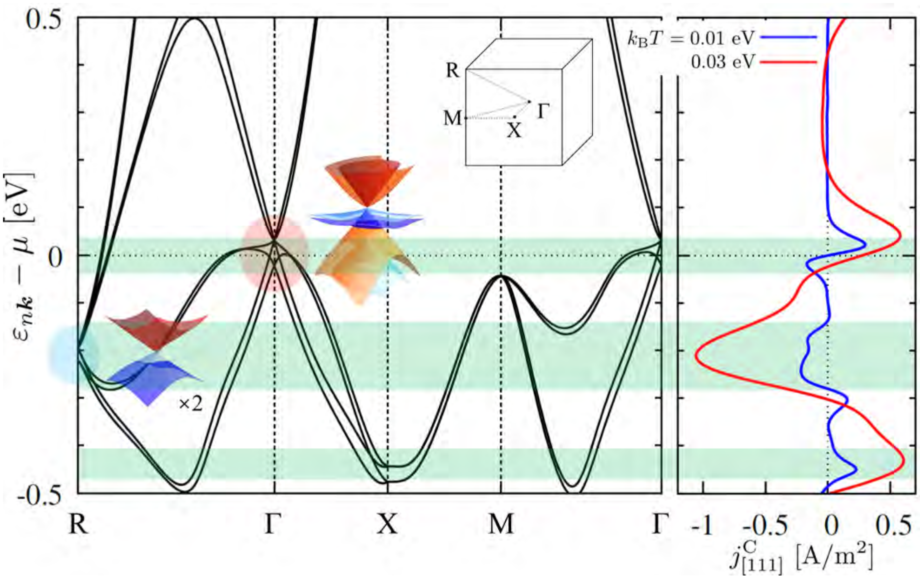
To investigate exotic phenomena in nonmagnetic B20-type compounds, the existence of unconventional singularities in momentum space—such as spin-1 excitations and Rarita-Schwinger-Weyl (RSW) fermions—has been theoretically proposed. Meanwhile, the nonlinear thermoelectric transport phenomena proportional to the cross product of an electric field and a temperature gradient, which will be responsible in the chiral materials, have been proposed; we term the phenomena as nonlinear chiral thermoelectric (NCTE) Hall effect, which remains largely unexplored in B20 compounds.
In this work, we conduct a comprehensive analysis of the nonlinear transport phenomena in CoSi, a prototypical nonmagnetic B20 compound, using ab initio calculations and symmetry-based analysis. We find that the NCTE Hall current yield measurable signals along the [111] direction, which is absent for second-order response to the electric field. Also, the NCTE Hall current is significantly enhanced near the momentum-space singularities associated with RSW fermions and spin-1 excitations. Moreover, we reveal that the contribution from the Berry curvature to the NCTE Hall effect is exactly canceled, leaving the orbital magnetic moment as the sole origin of the NCTE Hall effect in cubic chiral crystals. Our findings highlight the critical role of exotic quasiparticles in amplifying such nonlinear transport phenomena.



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Observation of D’yakonov-Perel’-type Magnon Spin Relaxation in Uniaxial Antiferromagnetic Insulators

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Long-distance transport of magnon spin currents in antiferromagnetic (AFM) insulators is essential for the development of magnonics, however, their relaxation mechanisms remain elusive. Here, we report that the D’yakonov-Perel’-type magnon spin relaxation mechanism governs the spin current transport in two prototypical uniaxial AFM insulators, Cr_2O_3 and α-Fe_2O_3. Three key pieces of evidence will be presented. (1) An over 450% enhancement of the first-harmonic non-local resistance induced by a magnetic field is observed prior to the spin-flop transition, which cannot be fitted by an established magnon-gap-closure model but is well-interpreted by our model incorporating D’yakonov-Perel’-type magnon spin relaxation. (2) We find that the magnon spin diffusion length in Cr_2O_3 increases by 35% at 35 K, from 0.63 μm at zero magnetic field to 0.85 μm above 1.00 Tesla, consistent with the D’yakonov-Perel’-type magnon spin relaxation model. (3) Temperature dependence of the zero-field magnon spin diffusion length in both AFM insulators can be qualitatively explained very well through our model. This work presents a promising approach to effectively control magnon spin relaxation, paving the way for applications that leverage long-distance spin current transport in AFM insulators.

Observation of magnon polaritons with ultrastrong coupling in thin ferromagnetic films

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Magnon-photon polariton, a strong coupling between electromagnetic microwave (photons) and quantized spin waves (magnons), has been fascinating research with regard to the light-matter interaction. In the context of light-matter interaction, the achievement of the ultrastrong coupling regime represents a crucial milestone for exploration of the veiled quantum phenomena induced by counter-rotating terms (CRTs) [1]. The CRTs have been expected to be the fundamental physics in the next generation quantum technologies. Despite the existence of multiple reports on the realization of ultrastrong coupling in magnon polaritons, the majority of studies have been constrained to bulk $Y_3Fe_5O_{12}$ [2, 3]. Here we present the experimental demonstration of ultrastrong coupling magnon-photon interaction between a thin metallic ferromagnetic film on superconducting high-Tc $YBa_2Cu_3O_7$ (YBCO) resonator. In particular, we observe the Bloch-Siegert shift, a key signature of the existence of CRTs [4].

For our experiment, we use ferromagnetic thin films of NiFe (Permalloy) embedded in a layer stack of SiO_2 (10 nm) / MgO (2 nm) / Py (30 nm) / Ti (3 nm) / SiO_2 (20 nm), which has been deposited onto the superconducting resonator made of high-Tc YBCO. We perform our microwave transmission experiment in a cryogenic environment (T=10K, see Fig. 1) and apply the magnetic field in-plane. Figure 2 shows the normalized transmission spectra, ΔS_{21}. The dispersion of the magnon photon polariton manifests as an absorption signature. A quantitative analysis of the data allows to estimate the coupling strength (g) to be 674 MHz, corresponding to a g/ω-ratio exceeding 0.1. Thus the hybrid system enters the ultrastrong coupling regime. The system also shows the expected Bloch-Siegert shift originating from the counter rotating terms of the coupling. In the presentation, we will discuss the experiment, data analysis and the implications of the results regarding the generation of non-classical states.

Fig. 1

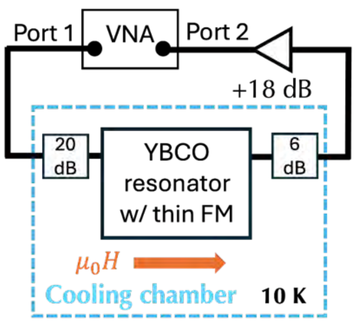
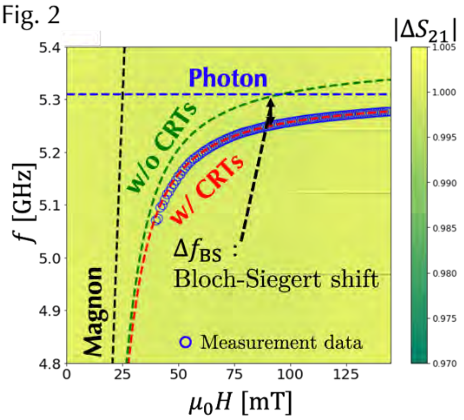


Fig. 2



Observation of magnon polarons in non-local spin transport in an antiferromagnetic crystal Cr_2O_3

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Magnon polarons are hybridized excitations between magnons and phonons due to magnetoelastic coupling in magnetic materials. Although magnon polarons in antiferromagnetic (AFM) insulator Cr_2O_3 has been observed in spin Seebeck measurements, their impact on long-distance spin current transport in antiferromagnets remains unclear. Here, we report the observation of AFM magnon polarons in non-local spin current transport in a uniaxial AFM insulator Cr_2O_3. In non-local devices with injector-detector-distance of 1.5 µm, the magnon polarons signatures present in second-harmonic channel, instead of first-harmonic channel, of the non-local voltage. Anomalies related to magnon polaron are evident in both field-sweeping and angular-dependent measurements. In field-sweeping measurements, kinks appear at magnetic fields before and after spin-flop transition, as left-handed magnon spectrum shifts down to hybridize with the acoustic phonons to form AFM magnon polarons. Angular-dependent measurements reveal further anomalies when the magnetic field deviates from the easy axis, because field angle could tune the magnon gap as well as the hybridize intensity between left-handed magnons and acoustic phonons. The magnon polaron signals observed before and after the spin-flop transition disappear at 7 K and 2.2 K, respectively. These results demonstrate a unique way to manipulate the non-local spin current transport using AFM magnon polarons.

Observation of precessional modes in epitaxial CoO/NiO based structures

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Antiferromagnetic (AFM) materials show great promise for use in spintronics due to their insensitivity to stray magnetic fields, low intrinsic damping, and THz frequency resonant modes. Thin-films of NiO are particularly interesting due to their ability to propagate and amplify spin current [1,2]. By integrating lattice-matched CoO, NiO, and Fe layers, functional materials with tunable magnetic properties may be created. Here we examine epitaxial MgO(001)/CoO(3 nm)/NiO(8 nm)/Fe(3 nm)/MgO(2 nm)/Al_2O_3(5 nm) structures. Using the magneto-optical birefringence effect (MOBE) in wide-field optical microscopy measurements [3,4], we demonstrate control of AFM domains using alternating magnetic fields, enabling the exploration of mono-domain and multi-domain state dynamics. A time-resolved optical pump-probe setup was used to excite the sample with pulses of 50 fs duration, 800 nm wavelength, and 1.24 mJ/cm² fluence at 100 kHz repetition rate. The sample was probed at 15º angle of incidence with a 400 nm wavelength pulse. The sample was aligned so that the Néel vector ([110] MgO axis) lies either within or at 45º to the plane of incidence of the probe so as to distinguish between MOBE and magneto-optical Kerr effect (MOKE) contributions to the measured optical rotation. Exchange coupling between Fe and AFM layers allows detection of the AFM resonance modes in the MOKE response of the Fe layer. Our results reveal a reduced out-of-plane mode frequency (0.75 THz) compared to the bulk NiO value (1.07 THz). We discuss the possible cause of this shift and the absence of the expected in-plane NiO mode at 140 GHz.

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Simulation of Dipolar-Exchange Spin Waves in Antiferromagnetic Thin Films

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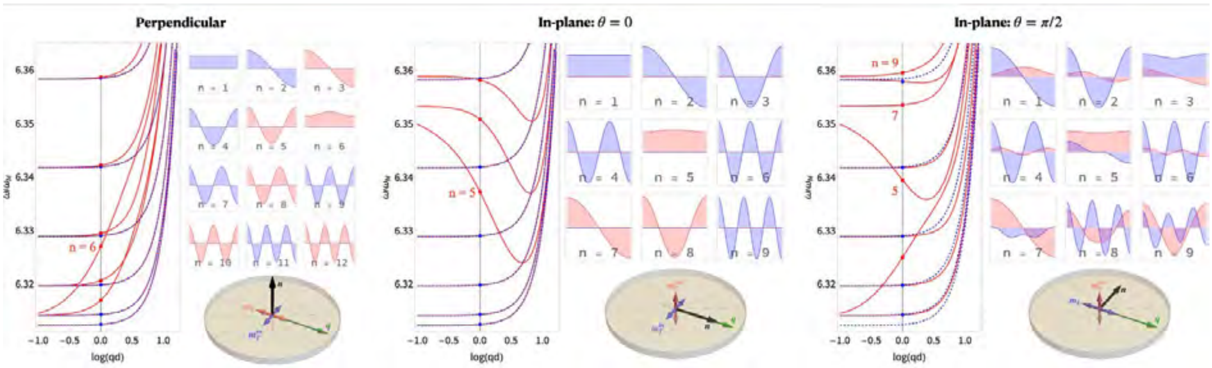
Spin waves, as a fundamental excitation mode in magnetic materials, possess properties of great significance. Particularly, when spin waves are used as carriers for information or energy, the study of their dispersion relations is indispensable. Spin waves are typically categorized into two types: dipolar spin waves, which dominate at long wavelengths, and exchange spin waves, which dominate at short wavelengths.
The comprehensive theory of dipolar-exchange spin waves in ferromagnetic thin films has been well-established by De Wames and Wolfram [1] since the 1970s, providing valuable insights into their behavior and applications in various magnetic systems. It was subsequently extended to antiferromagnets by Stamps and Camley [2].
Antiferromagnets are characterized by compensating magnetic sublattices, which often leads to the neglect of dipolar effects in static conditions due to the cancellation of net magnetic moments. However, in dynamic excitations, the cancellation between the two sublattices does not hold, resulting in a residual net magnetic moment. This residual moment gives rise to dipolar fields, which can significantly impact the dispersion relations of the antiferromagnetic spin waves.
We leverage numerical micromagnetic simulations conducted through COMSOL Multiphysics, which enables a detailed exploration of the complex interactions within antiferromagnetic systems. The results match well with semi-analytical calculations. By analyzing the simulation results, we were able to group and describe the properties of different dispersion curves.



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Spin Seebeck effect in a Berezinskii-Kosterlitz-Thouless magnet candidate BaNi2V2O8

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The spin Seebeck effect (SSE) serves as a useful method for elucidating spin excitation and spin transport in magnetic materials. Among exotic magnetic states, two-dimensional (2D) spin systems, where magnetic interactions are dominant within a two-dimensional plane due to the very weak interlayer interactions, are particularly intriguing because of their enhanced spin fluctuations.
In this study, we investigate the SSE in a quasi-2D antiferromagnet $BaNi_2V_2O_8$. $BaNi_2V_2O_8$ has been reported to exhibit Berezinskii-Kosterlitz-Thouless (BKT) transition, highlighting its distinct 2D character and quasi-long-range order [1,2]. We experimentally found that the SSE in Pt/$BaNi_2V_2O_8$ persists well above the Néel temperature, significantly different from the behavior of 3D-ordered magnets. Our numerical analysis for a 2D microscopic spin model confirms that the observed SSE is linked to the gapless magnon excitations and strong magnetic correlations characteristic of BKT magnets.

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Spin Seebeck effect in graphene

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The Spin Seebeck Effect (SSE) converts thermal energy into spin currents in ferromagnetic materials, establishing spin caloritronics, a field that studies thermoelectric phenomena mediated by spins. In metal/magnet bilayers, a thermal gradient excites magnetic dynamics, transferring angular momentum to conduction electrons and generating spin currents. Spin pumping (SP), driven by microwave irradiation, also generates spin currents by exciting magnetic dynamics via ferromagnetic resonance. SSE is thermally driven, while SP is coherently excited, and both share similar mechanisms.

This study develops a microscopic theory for SSE at the interface of a ferromagnetic insulator and graphene, using the Schwinger-Keldysh formalism. The large Landau-level separations of graphene enable the observation of Landau quantization at higher temperatures and lower magnetic fields. We examine SSE in graphene for quantum Hall and plane wave states, comparing spin currents generated by SSE and SP. The results show that SSE exhibits quantum oscillations similar to SP, with peak shifts due to higher-frequency thermally excited magnons.

This framework offers insights into spin-thermal interconversion in atomic-layer materials, supporting the development of spin caloritronic devices.

Spin-S Kitaev-Heisenberg model on the honeycomb lattice: A high-order treatment via the many-body coupled cluster method

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We study the spin-S Kitaev-Heisenberg model on the honeycomb lattice for S = 1/2, 1, and 3/2, by using the coupled cluster method (CCM) [1]. This system is one of the earliest extensions of the Kitaev model and is believed to contain two extended spin liquid phases for any value of the spin quantum number S. We show that the CCM delivers accurate estimates for the phase boundaries of these spin liquid phases, as well as other transition points in the phase diagram. Moreover, we find evidence of two unexpected narrow phases for S = 1/2, one sandwiched between the zigzag and ferromagnetic phases and the other between the Néel and the stripy phases. The results establish the CCM as a versatile numerical technique that can capture the strong quantum-mechanical fluctuations that are inherently present in generalized Kitaev models with competing bond-dependent anisotropies.

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Thermal scanning probe lithography for magneto-thermoplasmonic devices

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By combining key concepts from both photonics and magnetism, hybrid thermoplasmonic-magnetic devices enable optically-controlled fast, precise, and reconfigurable optical control of nano- to microscale temperature distributions for magnetic and spintronic applications [1-3]. Such devices can be fabricated using elliptical gold nanoparticles with precise sizes and aspect ratios determining the peak position and shape of the plasmonic resonances [1].

Here, we apply thermal scanning probe microscopy (t-SPL) using the Heidelberg NanoFrazor Scholar to write high-resolution patterns via a heated AFM tip [4]. In contrast to more traditional techniques, such as e-beam lithography, the NanoFrazor does not require the presence of a vacuum with a minimal sacrifice in pattern resolution (20 nm pixel size). The NanoFrazor furthermore provides simultaneous reading and writing in-situ, allowing for real-time control of patterning and multi-layer nanolithography on conductive and non-conductive substrates, as well as two-dimensional materials.

Of particular interest to magneto-thermoplasmonics are hybrid devices patterned on optically transparent glass substrates (with low refractive index). Therefore, we focus on optimising the patterning parameters of gold nanoellipses via the NanoFrazor using a PPA/PMMA bilayer. This work highlights a novel approach towards the fabrication of nanoscale thermoplasmonic devices, particularly useful for creating precise patterns on non-conductive, transparent substrates as well as alignment with magnetic and spintronic devices.

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Tomography measurement of squeezed thermal magnons in Y3Fe5O12

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Squeezed states are a key concept underpinning quantum technologies and thermodynamics, widely employed to enhance measurement precision and enable novel information processing methods.
While photon-based squeezed states have been extensively studied, magnetic systems remain an underutilized resource for the engineering of squeezed states.

In this study, we achieved squeezing of thermal magnons, creating correlations between magnetization dynamics at different surfaces of the magnetic thin film. To realize this, we used parametric excitation, where an oscillating magnetic field with twice the ferromagnetic resonance frequency generates magnetization oscillations. In terms of quasiparticles, this corresponds to a process where one microwave photon produces two magnons. When the magnons have different frequencies but their sum matches the oscillating field's frequency, this is called a non-degenerate process, which can lead to the formation of correlations between the magnons.

We used a thin film of the ferromagnetic insulator $Y_3Fe_5O_{12}$ (YIG) with a thickness of 1.4 µm, fabricated into a disk shape and coated with platinum. Due to asymmetry in electromagnetic boundary conditions on the film's surfaces, the dispersion relation for magnons breaks spatial inversion symmetry, resulting in different frequencies for surface-localized magnon modes on the top and bottom surfaces. By applying a microwave magnetic field with twice the resonance frequency, we excited magnetization dynamics and, by slightly adjusting the external magnetic field strength, successfully achieved non-degenerate parametric excitation, generating magnons localized on different surfaces.

The results demonstrate magnon squeezing and its ability to generate correlations in magnetic systems, offering new opportunities for studying correlated dynamics. Further details will be presented during the discussion.

This research is supported by JST-CREST(JPMJCR20C1), JST-PRESTO(JPMJPR24F9), and JSPS-KAKENHI(JP21K13847, JP22K14584).

Towards simulating coupled ferroelectric magnetic interfaces

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We employ atomic scale spin and molecular dynamics to investigate the dynamics of interacting ferroelectric and magnetic thin films. Specifically, we use a coupled spin lattice Hamiltonian model that introduces, in the framework of molecular dynamics, an extra degree of freedom for the spins of magnetic ions. The motions of the spins is described by the stochastic Landau - Lifshitz - Gilbert equation as from spin dynamics. We are particularly interested in simulating perovskite oxides, such as $BaTiO_3$ and $BiFeO_3$. For these materials we describe the ferroelectric subsystem with the adiabatic core-shell model, or non-linear oxygen polarisability model, where the parameters have been derived from first-principle calculations. The ferroelectric and magnetic subsystems are coupled to separate thermostats that control a core-shell and a spin temperature.

With this spin lattice Hamiltonian model we will investigate the effect of moving ferroelectrics domain walls, and of applied electric fields, on the spin textures near the interface.

Vortex Nernst effect in ferrimagnetic insulator/high-temperature superconductor heterostructures

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The injection of pure spin current into superconductors is an active research area for the potential realization of low-dissipation spintronics devices. Around the superconducting transition temperature (Tc), pronounced enhancements of the thermoelectric voltage and ferromagnetic resonance linewidth have been reported in the heterostructure composed of ferromagnets and conventional superconductors[1-3]. However, such studies are still lacking in high-temperature superconductors.

In this work, we report the successful growth of $YBa_2Cu_3O_7$(YBCO) epitaxial film on spinel ferrimagnetic insulator $Li_{0.5}AlFe_{1.5}O_4$ (LAFO) film, and thermal transport measurements are performed to check whether pure spin current can be injected into the cuprate. A hysteresis loop in the magnetic-field-dependent transverse thermoelectric voltage is observed only around the superconducting Tc, at which the Vortex Nernst effect (VNE) in a single YBCO layer also predominates. In order to disentangle the contribution from the VNE and spin Seebeck effect (SSE), an insulating MgO layer is inserted at the LAFO/YBCO interface to block spin current injection. Interestingly, the hysteresis transverse thermoelectric signal persists despite the barrier, suggesting that it stems from the modulation of the VNE by the magnetic stray field generated by the ferrimagnetic insulating layer, rather than SSE from spin current.

This work highlights that cuprates such as YBCO are not ideal candidates for spin current injection due to their weak spin-orbit coupling. Instead, the Vortex Nernst effect in YBCO can be effectively modulated by the stray field from neighboring ferrimagnetic insulators like LAFO.

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