Ollantaytambo, Cusco, Peru

International workshop Spintronics 2019

October 20 – 25

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Welcome to Spin Peru

Dear Colleagues,

It is our great pleasure to welcome you to Ollantaytambo for the first international workshop on spintronics in Cusco - Peru, land of the Incas.

How it all started?
In a small workshop in Oze, a small village in a national park in the mountains of Japan, located 150 km away from Tokyo, 6 physicists were discussing random topics sitting at a tatami table. Discussion in such a village, which is considered one of the best locations for nature and hot spring in Japan, led Prof. Gen Tatara to naturally come up with the idea of organizing a similar workshop in a beautiful country like Peru. This was the beginning of a journey that started in a small village in Japan and finished in a small town in Peru. Now we are all together in Ollantaytambo, surrounded by the majestic mountains of the Andes and just a few miles away from Machu Picchu, considered one of the new 7 wonders of the world…

Peru is not only known for inheriting the Inca civilization but also for its amazing cuisine, winning multiple times the world's leading culinary destination prize; therefore, Spin Peru combines multiple aspects to give the participant an unforgettable experience where physics, and in particular, spintronics, merges with history, nature, magic, and food.

Thank you very much in advance for being part of Spin Peru, and we hope and count on each and every one of you to make this meeting very fruitful and a great experience!

Yusulpaiki!*

The organizers

Oleg A. Tretiakov (U. of New South Wales - Australia), chair
Juan Carlos Rojas-Sánchez (Jean Lamour Institute, U. Lorraine - France), co-chair
Christian Ortiz-Pauyac (RIKEN - Japan)
Gen Tatara (RIKEN - Japan)
Mathias Kläui (U. Mainz - Germany)
Javier Solano (U. Nacional de Ingenieria - Peru)

http://spinphys.riken.jp/workshop/spinperu

* "Thank you" in Quechua, the dominant language in the region during the Inca Empire.

PROGRAMME

Sunday, Oct. 20th	Monday, October 21st	Tuesday, October 22nd	Wed., Oct. 23th	Thursday, October 24th	Friday, October 25th
	8:30 - 8:40 Welcome		Social event: Tour to **Machu Picchu Citadele** **Dept: 6:00** from Train station		
9:00-15:00 Arrival of participants Bus picks up participants from Cusco airport to Ollantaytambo	8:40 - 10:00 Y. Tserkovnyak	8:40 - 9:30 M. Kläui		9:00 - 9:30 A. Slavin	9:00 - 9:30 J. Demsar
		9:30-10:00 A. Kent		9:30-10:00 G. Finocchio	9:30-10:00 J. Milano
	10:00 -10:30 G. Bauer	10:00 -10:30 O. Tretiakov		10:00 -10:30 O. Klein	10:15-10:30 M. Quintana
	Coffee Break - 15 Min.			Coffee Break - 15 Min.	
	10:45-11:00 B. Flebus	10:45-11:00 J.A. Otalora		Coffee Break - Poster	10:45-11:15 L. Vila
	11:00-11:30 S. Murakami	11:00-11:30 T. Moriyama		11:00-11:30 S. Duttagupta	11:15-11:45 free time/ lunch
	11:30-12:00 X. Wang	11:30-12:00 M. Garst		11:30-12:00 E. Fullerton	
	12:00-12:30 J. Xiao	12:00-12:30 C. O. Avci		12:00-12:30 A. O. Leonov	
	Lunch	Lunch		Lunch	Social event: Tour to **Maras /Moray Departure 12:00** from conf. venue
	14:00-14:30 M. Miron	14:00-14:30 V. Cros		14:00-14:30 Kang L. Wang	
	14:30-15:00 Rojas-Sánchez	14:30-15:00 O. Boulle		14:30-15:00 A.H.Macdonal	
15:00-16:30 Registration Located at Tawachaki Cafe and Restaurant	15:00-15:15 A.Bedoya-	15:00-15:15 L. Baldrati		15:00-15:15 A. A. Pervishko	
	15:15-15:30 S. Miyahara	15:15-15:30 Y. Yamane		15:15-15:30 S. V. Streltsov	
	15:30-15:45 K. Oyanagi	15:30-15:45 R. A. Gallardo		15:30-15:45 S. Grytsiuk	
	15:45-16:00 C. Ulloa	15:45-16:00 D. Yudin		15:45-16:00 J. Puebla	
	Coffee Break - Poster	Coffee Break - Poster		Coffee Break - Poster	
16:30-17:30 Welcome cocktail Traditional Pisco Sour	16:30-17:00 K.-J. Lee	16:30-17:00 M. Chshiev		16:30-17:00 A. Manchon	
	17:00-17:30 S. Takei			17:00-17:30 R. M. Otxoa	
	17:30-18:00 I. V. Solovyev			17:30-18:00 D. Pinna	
	18:00-18:30 L. Steren				
				19:30-22:00 Conference Dinner	

Monday October 21st

8:30 – 8:40 Welcome

8:40 – 10:00

Tutorial 1: *From quantum spintronics to topological hydrodynamics in insulators*.
Yaroslav TSERKOVNYAK UCLA, USA

10:00 – 10:30

Invited 1: *Spintronics with magnetic insulators*.
Gerrit BAUER Tohoku U., Japan

10:30 – 10:45 Coffee Break

10:45 – 11:00

Regular 1: *Probing magnetic phenomena using Nitrogen Vacancy (NV) Center in Diamond*.
Benedetta FLEBUS University of California, Los Angeles (UCLA)

11:00 – 11:30

Invited 2: *Theory of generation and conversion of phonon angular momenta*.
Shuichi MURAKAMI TIT, Japan

11:30 – 12:00

Invited 3: *Current-driving skyrmion motion in inhomogeneous films*.
Xiangrong WANG HKUST, Hong Kong

12:00 – 12:30

Invited 4: *Level attraction via dissipative coupling*.
Jiang XIAO Fudan University, China

Lunch

14:00 – 14:30

Invited 5: *Interplay of chiral energy and chiral dissipation in domain wall dynamics*.
Mihai MIRON Spintec, France

14:30 – 15:00

Invited 6: *Ferrimagnetic spintronic: From thermal contribution to the spin-orbit torque to different and efficient sources of spin currents*.
Juan Carlos ROJAS-SÁNCHEZ U. Lorraine -CNRS, France

15:00 – 15:15

Regular 2: *Spin torque ferromagnetic resonance in Weyl Semimetal/ferromagnet heterostructures*.
Amilcar BEDOYA-PINTO Max Planck of Microstructure Physics, Halle, Germany

15:15 – 15:30

Regular 3: *Electro active magnetic excitation in frustrated magnets*.
Shin MIYAHARA Fukuoka University, Japan

15:30 – 15:45

Regular 4: *Long-range spin transport in paramagnetic insulators*.
Koichi OYANAGI Institute for Materials Research, Tohoku University, Japan

15:45 – 16:00

Regular 5: *Nonlocal spin transport as a probe of viscous magnon fluids*.
Camilo ULLOA Utrecht University, Netherlands

16:00 – 16:30 Coffee Break & Posters

16:30 – 17:00

Invited 7: *Magnetization dynamics and spin transport in antiferromagnetically coupled ferrimagnets*.
Kyung-Jin LEE Korea U., South Korea

17:00 – 17:30

Invited 8: *Spin transport in an electrically-driven magnon gas near Bose-Einstein condensation: a Hartree-Fock-Keldysh theory*.
So TAKEI CUNY, USA

17:30 – 18:00

Invited 9: *Electric polarization induced by skyrmionic order in GaV4S8: from first-principles calculations to microscopic models*.
Igor SOLOVYEV NIMS, Japan

18:00 – 18:30

Invited 10: *Surface and interfaces of transition metal oxides*.
Laura STEREN CNEA, Argentina

Tutorial 1: Monday 21st, 8:50-10:00

From quantum spintronics to topological hydrodynamics in insulators

Y. TSERKOVNYAK
University of California, Los Angeles

I will review the progression of our understanding of spin transport through magnetic materials and heterostructures, with a focus geared towards collective transport in insulators. Among other issues, it will be useful to establish connections between the nondissipative aspects of magnetic dynamics and superfluid transport phenomenology. Generalizing the resultant topological characteristics uncover a broader class of robust transport phenomena in magnetic insulators, which we term topological hydrodynamics. Remarkably, the conventional spintronic tools, which were initially developed to control and measure the flows of spins, such as spin-transfer torque, spin Hall, and spin Seebeck effects, are easily adaptable for coupling directly to the topological hydrodynamics. I will summarize several specific examples that illustrate the general principles, including spin superflows, skyrmion hydrodynamics and gyrotropic elasticity, transport in spin glasses, and several types of vortex liquids. The relevant materials range from ordered to disordered ferromagnets and antiferromagnet.

Invited 1: Monday 21ST, 10:00-10:30

Spintronics with magnetic insulators

G.E.W BAUER
Institute for Materials Research, Tohoku University, Japan

Magnetic insulators are versatile materials of great technological importance. They attracted much interest from the spintronics community when K. Uchida, E. Saitoh c.s., demonstrated in 2010 thermal and electrical actuation of their magnetization dynamics that allows their integration into conventional electronic and thermoelectric devices.

The most important magnetic insulator is arguably the synthetic yttrium iron garnet (YIG), a ferrimagnet with Curie transitions far above room temperature. Its record magnetic, acoustic and optical quality as well as discovery of entirely new phenomena, such as the spin Seebeck effect, raises the hope for new applications for a sustainable future electronics. Recent progress includes an understanding of the temperature-dependent spin dynamics and the interaction of the magnetic order with the crystal lattice, lasers, and microwaves.

I will present an overview of recent progress in the theory of the spintronics with YIG and other magnetic insulators

Regular 1: Monday 21ST, 10:45-11:00

Probing magnetic phenomena using Nitrogen Vacancy (NV) Center in Diamond

B. FLEBUS[1], H. OCHOA[2], P. UPADHYAYA[3] and Y. TSERKOVNYAK[1]
[1]Department of Physics and Astronomy, University of California, Los Angeles, CA 90095, USA
[2]Department of Physics, Columbia University, New York, NY 10027, USA
[3]School of Electrical and Computer Engineering, Purdue University, West LaFayette, IN 47907, USA

Prototypes of quantum impurities (QI), such as NV centers in diamond, have been recently growing in popularity due to their minimally invasive and high-resolution magnetic field sensing. Their long coherence times and the efficient optical control of their spin states has stimulated as well a vast interest within the field of quantum computing.

In this talk, I will first discuss quantum-impurity relaxometry as a method to probe collective excitations in magnetic insulators. I will show that quantum-impurity relaxometry can be deployed as a nonintrusive probe of spin-wave transport regimes in magnetic insulators [1], as well as to image spectroscopically spin textures [2].

Then, I will discuss a proposal for coupling distant quantum impurities via the low-energy modes associated with a spatially-extended spin texture [3].

[1] B. Flebus et al., PRL 121, 187204 (2019).
[2] B. Flebus et al., PRB Rapids 98, 180409 (2018).
[3] B. Flebus et al., PRB Rapids 99, 140403 (2018).

Theory of generation and conversion of phonon angular momenta

M. HAMADA[1], M. HIRAYAMA[2] , E. MINAMITANI[3] and S. MURAKAMI[1,4]
[1]Department of Physics, Tokyo Institute of Technology, Tokyo, Japan
[2]CEMS, RIKEN, Wako, Japan
[3]Institute for Molecular Science, Okazaki, Japan
[4]TIES, Tokyo Institute of Technology, Tokyo, Japan

Phonons in crystals can have rotational motions, and can be associated with angular momenta. It is called phonon angular momenta [1]. Because it has similar symmetry properties with electron spins, one can expect phenomena analogous to those for electron spins, and conversions between the phonon angular momenta and electron spins. We explain our recent theories on predictions of such phenomena.
First we show that in nonmagnetic crystals without inversion symmetry, a heat current induces a phonon angular momentum. In such crystals, each phonon mode has an angular momentum. An example of the nuclei motions for a certain phonon mode in tellurium is shown in Fig.1(a), and one can clearly see that this mode has an angular momentum. In equilibrium, the total phonon angular momentum is zero because the contributions from k and $-k$ cancel. Meanwhile, when the heat current is flowing in the crystal, this cancellation no longer occurs, and there will be a net angular momentum of phonons [2]. We call it phonon Edelstein effect. We propose several experimental setups to measure this effect, including conversion of the phonon angular momentum into a rigid-body rotation of the crystal (Fig. 1(b)). We also propose another way of generating phonon angular momenta, by an electric field onto a multiferroic crystal. In such a crystal, time-reversal and inversion symmetries are broken but their product is preserved. In such a case, an electric field induces a phonon angular momentum, in analogy with the magnetoelectric effect [3].
We also explain our microscopic theory of coupling between the phonon angular momenta with electron spins. In a nonmagnetic system with spin-orbit coupling, we assume that the atoms are rotating due to phonons (Fig. 1(c)), and we show that its spin-polarization is nonzero when the phonons have a rotational motion [3].

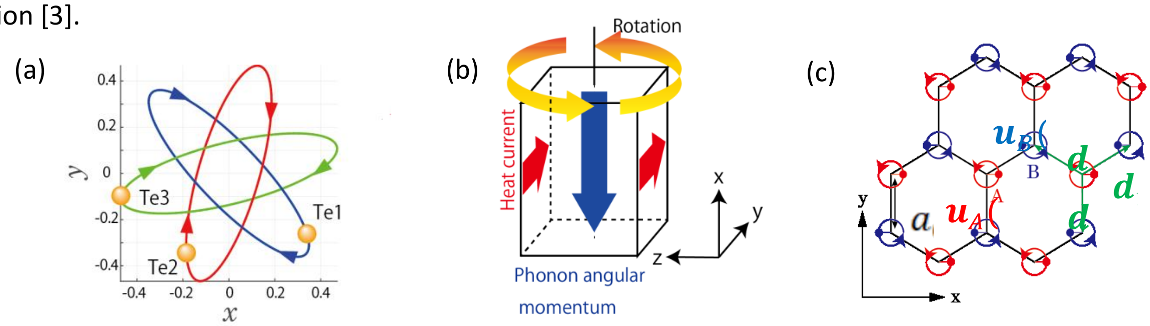

Figure 1: (a) Rotational motion of phonons in tellurium. (b) Proposal for observation of phonon Edelstein effect. (c) Atomic rotational motion by phonons, leading to spin polarization

[1] L. Zhang, Q. Niu, Phys. Rev. Lett. 112, 085503 (2014).
[2] M. Hamada, E. Minamitani, M. Hirayama, and S. Murakami, Phys. Rev. Lett. 121, 175301 (2018).
[3] M. Hamada, and S. Murakami, in preparation (2019).

Invited 3: Monday 21ST, 11:30-12:00

Current-driving skyrmion motion in inhomogeneous films

X. R. Wang
Hong Kong University of Science and Technology
HKUST Shenzhen Research Institute

In this talk, I will discuss current-driven skyrmion motion in disordered films. There are three phases: pinning phase, disorder-boosted transverse motion, and disordered-suppressed transverse motion. I will focus on the origin of the transverse motion boosting. Random potential landscape generate a force on a skyrmion. The force is perpendicular to the current direction when the skyrmion is pinned. The disorder-induced force is opposite to the skyrmion velocity when it is moving. Under a sufficient high current, disorders below a critical strength can boost the transverse skyrmion motion and hinder the longitudinal motion. The boosting comes mainly from the pinning force that is opposite to the driving force of the current. Skyrmions are pinned under a low current and above the critical disorder strength. Both transverse and longitudinal skyrmion motions are hindered at an intermediate current. The phase diagram will also be discussed.

This work is supported by the National Natural Science Foundation of China (Grants No. 11774296 and 1974296) and Hong Kong RGC (Grants No. 16301518, 16301619 and 16300117).

Invited 4: Monday 21ST, 12:00-12:30

Level attraction via dissipative coupling

W. C. YU[1,2], J. J. WANG[1], J. XIAO[1]
[1]Department of Physics, Fudan University, Shanghai, China
[2]IMR, Tohoku University, Sendai, Japan

The newly developed field of spin cavitronics focuses on the interaction between magnon inside magnetic elements and photon inside microwave cavity, which enriches the tool box for next-generation information technology. In most cases, the interaction between magnon and photon inside a cavity can be well captured by a classical model where two harmonic oscillators are coupled via an elastic spring. In such cases, the energy levels for the cavity and magnon modes show the repulsive anti-crossing behavior, as expected for the Hermitian system. Recently, the level attraction has been observed in several experiments. There are some non-Hermitian model Hamiltonian proposed showing agreement with the experiments, however the physical mechanism behind such non-Hermitian models are still unclear.

Here we propose a harmonic oscillator model composing of three elements where the magnon and photon each couple to a dissipative third-party. By identifying the third-party subject in each of the experiments, we verify that this model agrees with the experimental results on tuning from level repulsion to level attraction. We further demonstrate that a magnetic sphere can be used to synchronize adjacent cavity modes.

Invited 5: Monday 21ST, 14:00-14:30

Interplay of chiral energy and chiral dissipation in domain wall dynamics

M.A. NSIBI[1,2], C.K. SAFEER[1,2,3], J. NATH[1,2], S. AUFFRET[1,2], I. JOUMARD[1,2], G. GAUDIN[1,2], A MANCHON[4], I. M. MIRON[1,2]

[1] SPINTEC, UMR-8191, CEA-INAC / CNRS, France
[2] Université Grenoble Alpes, Grenoble, France
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[4] KAUST, Thuwal 23955-6900, Saudi Arabia

The structural inversion asymmetry gives rise to a chiral energy term as well as a chiral damping mechanism. While the former is well known (arising from the Dzyaloshinskii–Moriya interaction – DMI), the latter was recently evidenced by measuring the field-driven domain-wall (DW) motion in perpendicularly magnetized asymmetric Pt/Co/Pt trilayers [1]. The DW dynamics associated with the chiral damping and those with DMI exhibit identical spatial symmetry. However, they are differentiated by their time reversal properties: whereas DMI is a conservative effect that can be modeled by an effective field, the chiral damping is purely dissipative and has no influence on the equilibrium magnetic texture. We investigate the qualitative and quantitative differences between these two phenomena, and evidence their coexistence and interplay in field and current induced DW dynamics.

[1] Jué, Emilie, et al. "Chiral damping of magnetic domain walls." Nature materials 15.3 (2016): 272

Invited 6: Monday 21ST, 14:30-15:00

Ferrimagnetic spintronic: From thermal contribution to the spin-orbit torque to different and efficient sources of spin currents

J.-C. ROJAS-SANCHEZ
Université de Lorraine – CNRS, Institute Jean Lamour, 54011 Nancy, France

Our study [1,2] presents experimental results about the current-induced magnetization switching considering a model W/Co_xTb_{1-x} as heavy metal/ferrimagnetic bilayer for various compositions and temperatures. We demonstrate that there is a strong thermal contribution to the spin-orbit torque which allows magnetization reversal with a quite small in-plane magnetic field (i.e 2 mT). Moreover, we have found out that the devices reach a characteristic switching temperature T_{switch}(x) before the charge current generate the full magnetization reversal. This T_{switch}(x) is induced by Joule heating effect and is above the magnetic and angular compensation temperatures but below its Curie temperature [1].

In the second part of the talk we report the determination of the spin-charge conversion by the spin-orbit coupling, mainly spin Anomalous Hall effect (SAHE) [3,4], in GdFeCo ferrimagnetic thin films [5]. To do so we have deposited //GdFeCo(10 nm)/Cu(6 nm)/NiFe(4 nm)/Al (3 nm) on oxide thermalized silicon, Si-SiO_2, by magnetron sputtering. Then the samples were patterned by standard optical lithography and the conversion of a dc charge current in GdFeCo into a spin current injected into NiFe was experimentally determined by the so called spin-orbit or spin transfer ferromagnetic resonance (ST-FMR) technique. The addition of a dc current to the GHz ac current allows the study of modulation of damping or linewidth of the NiFe resonance line [4]. This so-called damping modulation technique allows a reliable determination of the charge-spin current conversion of the layer under evaluation, GdFeCo in this case. We report a quite large effective SAHE efficiency for charge-to-spin current conversion. Control experiments in different structures show a much smaller efficiency like in Pt/Cu/NiFe where the effective spin Hall effect efficiency is about 25 times smaller using Pt instead of GdFeCo [5].

This work has been performed in collaboration with colleagues at IJL in Nancy, and Spintec -first part [1,2], and CNRS-Thales and C. Panagopoulos -second part [5].

[1] Thai-Ha Pham et al. Phys. Rev. Applied **9**, 064032 (2018). ArXiv 1711.10790.
[2] Soong-Gun Je et al. Appl. Phys. Lett. **112**, 062401 (2018).
[3] T. Taniguchi et al., PRAppl 3, 044001 (2015).
[4] S. Ihama et al., Nat. Elecron. 1, 120 (2018).
[5] David Céspedes-Berrocal et al. In preparation.

Regular 2: Monday 21ST, 15:00-15:15

Spin torque ferromagnetic resonance in Weyl Semimetal/ferromagnet heterostructures

A. BEDOYA-PINTO[1], A. K. PANDEYA[1] D. LIU[1] and S.S.P. PARKIN[1]
[1]NISE-Department, Max-Planck Insitute of Microstructure Physics, Halle, Germany

Weyl Semimetals, materials with three-dimensional topologically protected electronic states, show highly interesting physical properties including Fermi-arcs, the Adler-Jackiw (chiral) anomaly in magnetotransport and extremely high electron mobilities. Still, its potential for device applications needs to be addressed through the preparation of thin films, which would enable the design of functional heterostructures and new device paradigms. One promising application field of Weyl Semimetals is spin-orbitronics, as the Fermi-surface topology is expected to play an important role in spin-to-charge conversion efficiency, according to theoretical investigations [1,2].

In this work, we report the growth of epitaxial Weyl Semimetal thin films [3], namely NbP and TaP, by means of molecular beam epitaxy, and their successful integration in spin-torque devices. As shown in Figure 1a, we have assessed the structural quality of the films featuring an atomically flat, ordered surface, essential for the observation of topological bands by photoemission (Fig. 1b). Furthermore, we rely on the preparation of high-quality in-situ TaP (NbP)/Permalloy interfaces (Fig. 1c) to explore the spin-orbit torques produced by the topological Weyl semimetal, by means of spin-torque ferromagnetic resonance (ST-FMR). Preliminary ST-FMR results of TaP/Py/MgO device structures at room temperature show readily signatures of sizable spin-orbit torques induced by the WSM layer: (i) a very strong symmetric component of the voltage lineshape across the resonance (Fig.1e), much different to the FMR response of the Py layer only (Fig. 1d), and (ii) a clear increase of the resonance linewidth by applying an external DC bias through the bilayer (Fig. 1f). The link between Fermi-surface topology and spin-to-charge conversion will be studied by performing photoemission experiments on the TaP (NbP) thin film surfaces prior to the deposition of the magnetic layers.

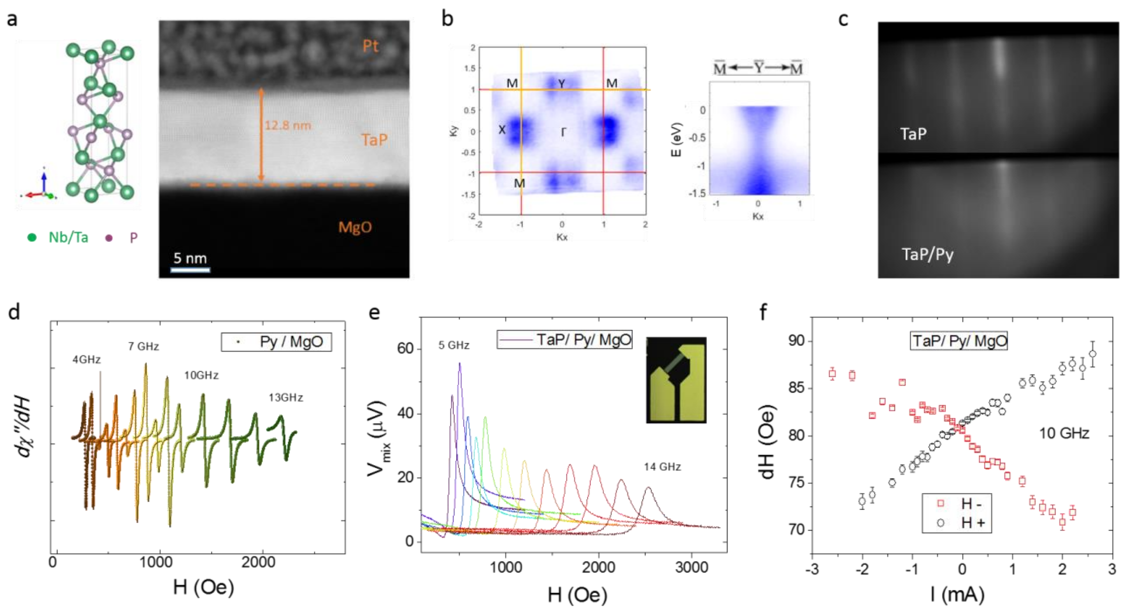

Figure 1: (a) Transmission electron microscopy image of a TaP thin film, showing ordered epitaxial lattice planes and an atomically flat surface. The unit cell is drawn for clarity. (b) Photoemission measurements of the TaP thin films, showing four-fold symmetric electronic pockets and linear dispersive bands. (c) RHEED pattern of the TaP surface and Permalloy overgrowth, characteristic of an ordered interface. (d) Frequency-dependent FMR response of a Permalloy layer capped with MgO, showing an antisymmetric lineshape. (e) Spin-torque FMR of a full TaP/Py/MgO device, evidencing a large symmetric lineshape component. An optical image of the device structure is shown as inset. (f) Linewidth dependence of the ST-FMR signal, showing a consistent increase (decrease) with applied DC bias. The slope is proportional to the magnitude of the spin-orbit torques per charge unit.

[1] Sun, Y, et.al. Strong Intrinsic Spin Hall Effect in the TaAs Family of Weyl Semimetals. Phys. Rev. Lett. 117, 146403 (2016).
[2] Johannson, A. et.al. Edelstein effect in Weyl semimetals. Phys. Rev. B 97, 085417 (2018).
[3] A. Bedoya-Pinto, et.al. (in preparation).

Regular 3: Monday 21ST, 15:15-15:30

Electro active magnetic excitation in frustrated magnets

S. Miyahara

Department of Applied Physics, Fukuoka University, Fukuoka 814-0180, Japan

In magnetoelectric mulitferroics, there is a strong coupling between magnetization and electric polarization. Such a coupling induces magnetoelectric effects, i.e., the electric polarization can be controlled by the external magnetic fields and vice versa. Even in dynamical processes, such couplings induce anomalous effects, e.g., an electro active spin wave excitation (so called electromagnon excitation) [1], where electric component of light can excite a spin wave excitation through the magnetoelectric couplings.

The typical example of the electromagnon is electro active spin wave excitation in helical magnets. We investigate the dynamical magnetoelectric effects in the J_1-J_2 classical Heisenberg model and clarify that the electromagnon in helical magnets show anomalous features. The spin wave can be simultaneously excited by oscillating magnetic and electric fields and the cross correlation effects of them can be observed as nonreciprocal direction dichroism in absorption under external magnetic fields [2]. Moreover, the spin wave spin current in the helical magnets under the external magnetic fields shows the non-reciprocal property, i.e., the way of the propagation of the spin wave depends on the direction of the propagation. Such nonreciprocal properties can be tuned not only by the external magnetic fields but also the external electric fields due to the magnetoelectric coupling.

The electro active spin excitation can be observed even in spin gapped system. In the Heisenberg system, the spin gap excitation from the singlet ground state cannot be excited by oscillating magnetic fields. However, such a spin gap excitation can be excited as an electro active process through the magnetoelectric couplings. As a typical example, we show that the spin gap excitation in Shastry-Sutherland material $SrCu_2(BO_3)_2$ [3] can by excited by the electric components of light.

[1] H. Katsura, A.V. Balatsky, and N. Nagaosa, Phys. Rev. Lett. **98**, 027203 (2007).
[2] S. Miyahara and N. Furukawa, Phys. Rev. B **89**, 195145 (2014).
[3] S. Miyahara and K. Ueda, J. Phys.:Condens. Matter **15**, R327 (2003).

Regular 4: Monday 21ST, 15:30-15:45

Long-range spin transport in paramagnetic insulators

K. Oyanagi[1], S. Takahashi[1,2,3], L. J. Cornelissen[4], J. Shan[4], S. Daimon[1,2,5], T. Kikkawa[1,2], G. E. W. Bauer[1,2,3,4], B. J. van Wees[4], and E. Saitoh[1,2,3,5,6]

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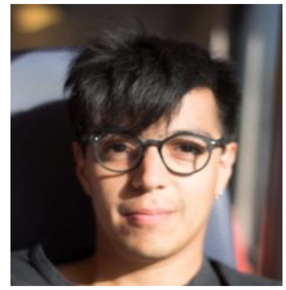
2Advanced Institute for Materials Research, Tohoku University
3Center for Spintronics Research Network, Tohoku University
4 Zernike Institute for Advanced Materials, University of Groningen, Groningen
5Department of Applied Physics, The University of Tokyo
6Advanced Science Research Center, Japan Atomic Energy Agency

Up to now, long-range spin transport in insulators has been reported in magnetically ordered materials, such as $Y_3Fe_5O_{12}$ (YIG) via spin waves [1,2], while a paramagnetic insulator is considered as an inactive material for spin transport. Here, we report that a paramagnetic insulator $Gd_3Ga_5O_{12}$ (GGG), which has been used for growing YIG, transmits spin current far away. Our results suggest that the exchange stiffness is not indispensable for spin transport [3].

We investigate spin transport through GGG using a typical nonlocal device [2,3] comprising two Pt wires on top of a GGG slab. One Pt wire is a spin injector and the other is a spin detector. At the injector, the spin Hall effect (SHE) injects a spin current into GGG as a result of the application of a charge current. The injected spin current flows in GGG and is electrically detected via the inverse SHE at the detector as a nonlocal voltage. Comparison between the experimental results and theoretical modeling clarifies that the spin conductivity of GGG is at low temperatures and high magnetic field larger than that of YIG, supposedly the best material for spin transport.

[1] Y. Kajiwara, K. Harii, S. Takahashi, J. Ohe, K. Uchida, M. Mizuguchi, H. Umezawa, H. Kawai, K. Ando, K. Takanashi, S. Maekawa & E. Saitoh, Nature 464, 262–267 (2010).
[2] L. J. Cornelissen, J. Liu, R. A. Duine, J. B. Youssef & B. J. van Wees, Nat. Phys. 11, 1022 (2015).
[3] K. Oyanagi, S. Takahashi, L. J. Cornelissen, J. Shan, S. Daimon, T. Kikkawa, G. E. W. Bauer, B. J. van Wees, and E. Saitoh, arXiv: 1811.11972 (2018).

Regular 5: Monday 21ST, 15:45-16:00



Nonlocal spin transport as a probe of viscous magnon fluids

C. ULLOA[1], A. TOMADIN[2], J. SHAN[3], M. POLINI[4], B. J. VAN WEES[3], and R. A. DUINE[1,5]

[1]Institute for Theoretical Physics, Utrecht University.
[2] Department of Physics, Lancaster University.
[3]Zernike Institute for Advanced Materials, University of Groningen.
[4]Istituto Italiano di Tecnologia, Graphene Labs, Genova.
[5]Department of Applied Physics, Eindhoven University of Technology.

Magnons in ferromagnets behave as a viscous fluid over a length scale, the momentum-relaxation length, below which momentum-conserving scattering processes dominate[1]. In this work[2] we show theoretically that in this hydrodynamic regime viscous effects lead to a sign change in the magnon chemical potential, which can be detected as a sign change in the non-local resistance measured in spin transport experiments[3]. This sign change is observable when the injector-detector distance becomes comparable to the momentum-relaxation length. Taking into account momentum and spin relaxation processes, we consider the quasi-conservation laws for momentum and spin in a magnon fluid. The resulting equations are solved for non-local spin transport devices in which spin is injected and detected via metallic leads. Due to the finite viscosity we also find a backflow of magnons close to the injector lead. Our work shows that non-local magnon spin transport devices are an attractive platform to develop and study magnon-fluid dynamics.

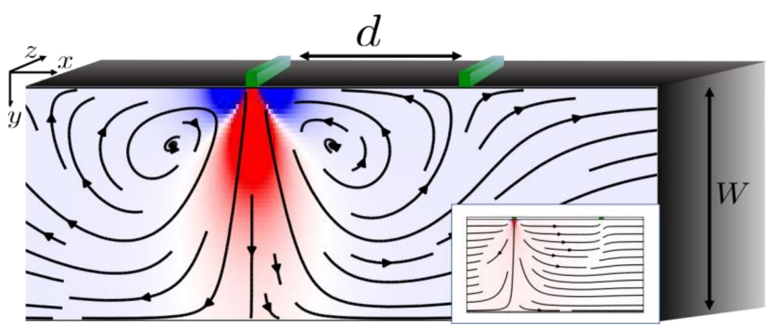


Figure 1: Schematic of a nonlocal spin transport device. Two metallic leads, depicted in green, separated by a distance d are placed on top of a ferromagnetic insulator (FMI) of width W depicted in gray. The left lead hosts a spin accumulation μ_s which injects spin into the FMI. The right lead is modeled as a spin sink ($\mu_s = 0$) and acts as spin detector. Due to viscous effects the magnon current has nonzero vorticity close to the injector, leading to local changes in its direction and to sign changes in the magnon chemical potential of the magnons. The current streamlines are depicted in black while the color code shows the behavior of the normalized variations of the magnon chemical potential. The main panel shows the result for viscous magnons, while the inset panel shows the results in the diffusive regime.

[1] B. I. Halperin and P. C. Hohenberg, Phys. Rev. **188**, 898 (1969).
[2] C. Ulloa, A. Tomadin, J. Shan, M. Polini, B. J. van Wees, and R. A. Duine, Phys. Rev. Lett. **123**, 117203 (2019).
[3] L. J. Cornelissen, J. Liu, R. A. Duine, J. Ben Youssef, and B. J. Van Wees, Nat. Phys. **11**, 1022 (2015).

Invited 7: Monday 21ST, 16:30-17:00

Magnetization dynamics and spin transport in antiferromagnetically coupled ferrimagnets

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Spintronics is a multidisciplinary field whose central theme is the active manipulation of spin degrees of freedom in solid-state systems. The core magnetic system for spintronics research has been ferromagnets since they serve as efficient spin-polarizers/detectors and offer non-volatile memory and logic technologies. Recently, much effort has been expended in exploiting antiferromagnetic nature for spintronic applications because of their fast dynamics. This talk will discuss the underlying mechanism of fast dynamics and efficient spin-current generation in antiferromagnetically coupled ferrimagnetic systems [1-9].

[1] T. Shiino et al, Phys. Rev. Lett. **117**, 087203 (2016).
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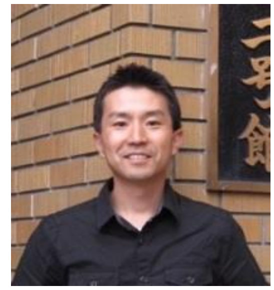
[3] S.-H. Oh et al., Phys. Rev. B **96**, 100407(R) (2017).
[4] K.-J. Kim et al., Nat. Mater. **16**, 1187 (2017).
[5] J. Yu et al., Nat. Mater. **18**, 29 (2019).
[6] Y. Hirata et al., Nat. Nanotechnol. **14**, 232 (2019).
[7] D.-H .Kim et al., Phys. Rev. Lett. **122**, 127203 (2019).
[8] T. Okuno et al, arXiv:1903.03251 (2019).
[9] D.-H. Kim et al., Nat. Mater. **18**, 685 (2019).

Invited 8: Monday 21ST, 17:00-17:30



Spin transport in an electrically-driven magnon gas near Bose-Einstein condensation: a Hartree-Fock-Keldysh theory

S. TAKEI

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A planar ferromagnetic insulator in a uniform external magnetic field and in contact with a phonon bath and a normal metal bath is studied theoretically in the presence of dc spin current injection via spin Hall effect in the metal. The Keldysh path integral formalism is used to model the magnon gas driven into a nonequilibrium steady state by mismatched bath temperatures and/or electrical spin injection, and we analyze the magnon system in the normal (uncondensed) state, but close to the field- and electrically-driven instability to Bose-Einstein condensation (BEC), within the self-consistent Hartree-Fock approximation. We show that the BEC instability in the electrically-driven magnon system is signaled by a sign change in the imaginary part of the poles for long-wavelength magnon modes and by the divergence of the nonequilibrium magnon distribution function. We find that the correlation length of the critical superfluid fluctuations exhibits nontrivial finite temperature crossover behavior in the presence of two bath temperatures that is richer than the standard thermal crossovers obtained for the vacuum-superfluid transition in an equilibrium dilute Bose gas. We study the consequences of these thermal crossovers on the magnon spin conductivity, compute the power-law divergence in the spin conductivity in the vicinity of the electrically-induced BEC instability, and identify the relevant exponent. Inspired by a recent experiment [1], a spintronics device capable of testing our spin transport predictions is discussed.

[1] T. Wimmer, M. Althammer, L. Liensberger, N. Vlietstra, S. Geprägs, M. Weiler, R. Gross, and H. Huebl, arXiv:1812.01334.

Electric polarization induced by skyrmionic order in GaV_4S_8: from first-principles calculations to microscopic models

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[1]National Institute for Materials Science, Japan
[2]Tokyo Institute of Technology, Japan

The lacunar spinel GaV_4S_8 was recently suggested to be a prototype multiferroic material hosting skyrmion lattice states with a sizable electric polarization $\boldsymbol{P}$ coupled to magnetic order. We explain this phenomenon on the microscopic level. On the basis of density functional theory, we construct an effective model describing the behavior of magnetically active electrons in a weakly coupled lattice formed by molecular orbitals of the $(V_4S_4)^{5+}$ clusters. The model is formulated in the basis of Wannier functions for the low-energy molecular states (Figure 1).

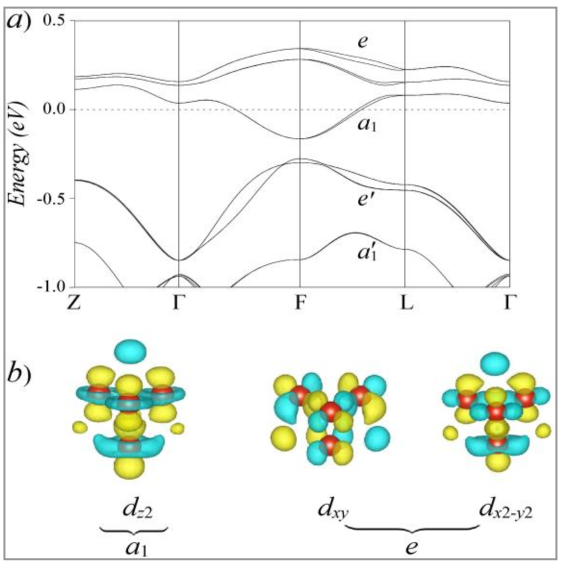

Figure 1: (a) Bands located near the Fermi level as calculated within local density approximation including spin-orbit coupling for the low-temperature GaV_4S_8. (b) Wannier functions representing the target a_1 and e molecular states.

Then, by applying superexchange theory combined with the Berry-phase theory for the electric polarization, we derive a compass-type model relating the energy and polarization change with the directions of spins $\boldsymbol{e}_i$ in magnetic bonds. They can be presented in the form:

$$H^S = \sum_{<ij>} \left(-J_{ij}\boldsymbol{e}_i\boldsymbol{e}_j + \boldsymbol{\mathcal{D}}_{ij}\boldsymbol{e}_i \times \boldsymbol{e}_j + \boldsymbol{e}_i \mathbb{\Gamma}_{ij}\boldsymbol{e}_j\right)$$

and

$$P = \sum_{<ij>} \boldsymbol{\varepsilon}_{ji}\big(-P_{ij}\boldsymbol{e}_i\boldsymbol{e}_j + \boldsymbol{\mathcal{P}}_{ij}\boldsymbol{e}_i \times \boldsymbol{e}_j + \boldsymbol{e}_i \mathbb{\Pi}_{ij}\boldsymbol{e}_j\big),$$

for the energy and electric polarization, respectively, in terms of isotropic (J_{ij} and $\boldsymbol{\varepsilon}_{ij}P_{ij}$), antisymmetric ($\boldsymbol{\mathcal{D}}_{ij}$ and $\boldsymbol{\varepsilon}_{ij}\boldsymbol{\mathcal{P}}_{ij}$), and symmetric anisotropic ($\mathbb{\Gamma}_{ij}$ and $\boldsymbol{\varepsilon}_{ij}\mathbb{\Pi}_{ij}$) parameters, where $\boldsymbol{\varepsilon}_{ij}$ is the unit vector in the direction of the bond.

We argue that, although each skyrmion layer is mainly formed by superexchange interactions in the same plane, the spin dependence of $\boldsymbol{P}$ arises from the stacking misalignment of such planes in the perpendicular direction, which is inherent to the lacunar spinel structure. We predict a strong competition of isotropic, $\sim\boldsymbol{e}_i\boldsymbol{e}_j$, and antisymmetric, $\sim\boldsymbol{e}_i\times\boldsymbol{e}_j$, contributions to $\boldsymbol{P}$ that explains the experimentally observed effect [1]. Finally, we consider how all these properties will change in the series of lacunar spinels GaV_4S_8, GaV_4Se_8, and $GaMo_4S_8$, which differ by the ferroelectric distortion and the number of magnetically active electrons.

[1] S. A. Nikolaev and I. V. Solovyev, Phys. Rev. B **99**, 100401(R) (2019).

Invited 10: Monday 21ST, 17:30-18:30

Surface and interfaces of transition metal oxides

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[2]Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina.
[3] Unité Mixte de Physique CNRS/Thales, 1 ave. A. Fresnel, 91767 Palaiseau, France.
[4]Instituto Universitario de Nanociencia de Aragón, Laboratorio de Microscopías Avanzadas y Dpto. Física de la Materia Condensada, Universidad de Zaragoza, Zaragoza, Spain

The rich variety of physical properties of transition metal oxides (TMO) made these materials attractive not only for fundamental science but also for the design of multifunctional devices [1]. Left aside in the first studies, the relevance of surface and interfaces on the properties of complex oxides thin films became evident after the discovery of unexpected phenomena like exchange bias in ferromagnetic/paramagnetic structures [2] and 2D electron gases at insulator/insulator bilayers interfaces [3]. Complex oxides are considered a model of strongly-correlated electron materials, in which the charge, orbital and spin degrees of freedom are closely related and extremely sensitive to strain and surface symmetry breaking effects.[4]

During the last five years our work has been focused on the investigation of magnetic and multiferroic heterostructures, in particular to their interfacial and surface properties. We have particularly investigated the influence of different type of coupling through interfaces, i.e. magnetic, magneto-elastic and magneto-electric, on the properties of the whole structure. In my talk I will first introduce the general characteristics of complex oxide thin films outlining the strong influence of strains onto their physical properties. Then I will present in detail our last results regarding the characterization and study of magnetic and multiferroic interfaces. In the first case, $La_{0.66}Sr_{0.33}MnO_3/La_{1-x}Sr_xMnO_3$ (LSMO/LSxMO with X<0.1), we have analysed the strains, charge distribution and spin polarization through these interfaces using surface sensitive techniques combined with high-resolution transmission electron microscopy. We have examined the surface spin-polarization (Figure 1) and lattice strains (Figure 2) at LSMO/LSxMO interfaces changing the thickness of the low-doped LSxMO capping layer. The spin-polarization was found to be enhanced at a critical capping thickness that depends on the Sr doping, owing to the combined effects of charge doping and structural strain. More recently, we revisited the complex interfacial magnetic effects arisen at $La_{0.66}Sr_{0.33}MnO_3/SrTiO_3$ interfaces using Polarized Neutron Reflectometry in epitaxial heterostructures in order to quantify the magnetic moment at the LSMO interfaces with a high spatial resolution. We have found, in these experiments new elements that provide us a deeper insigth in the LSMO interfacial magnetism and its correlation between local structural strains.

The second case I will discuss is the artificial hybrid multiferroic interface, $BaTiO_3$/FePt (BTO/FEPT). Depending on strains, the FePt alloy can be ordered or disordered on two different crystalline structures. In spite of the fact that our study has been performed on polycrystalline samples, our results reveal an important magneto-elastic coupling through these interfaces.

In summary, I will show along my presentation that surfaces and interfaces of transition metal oxides are a source of very interesting physics to learn and take advantage of.

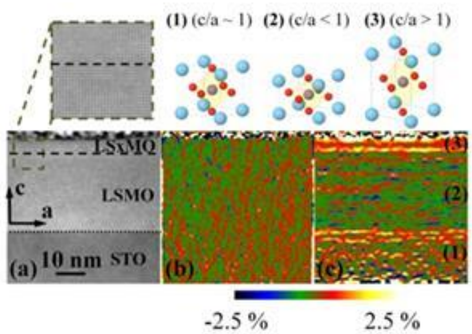

Figure 1. (a) Cross sectional STEM-HAADF image of a LSxMO/LSMO bilayer. HRSTEM-HAADF-GPA strain analysis maps of the components (b) parallel and (c) perpendicular to the interfaces. (from Ref. [4])

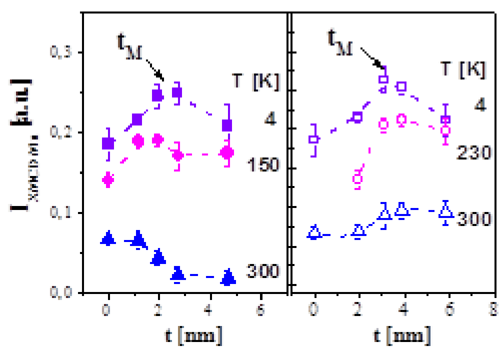

Figure 2. Dichroic integrated intensity, $I_{XMCD\ Mn}$ as a function of the barrier thickness for the (left) *t*-LMO and (rigth) t-LS0.1MO samples at a temperature range 4-300K.

[1] S. Rahman Bakaul *et al.*, Nature Communications **7**, 10547 (2016)
[2] J. C. Rojas Sanchez *et al*. Phys. Rev. B. 85, 094427 (2012).
[3]N. Reyren *et al*., Phys. Rev. Lett. **108**, 186802
[4] S. J. Carreira, M. H. Aguirre,J. Briatico,E. Weschke, and L.B. Steren, Appl. Phys. Lett.**112**, 032401 (2018)

Tuesday October 22nd

8:40 – 9:30
Tutorial 2: *Topological Spin Dynamics in ferro- and antiferromagnets*.
Mathias KLÄUI Mainz U., Germany
9:30 – 10:00
Invited 11: *Spin-transfer switching and magnetic interactions in perpendicular magnetic tunnel junctions nanopillars*.
Andrew KENT NYU, USA
10:00 – 10:30
Invited 12: *Antiferromagnetic Spintronics with (Anti)Skyrmions and Bimerons*.
Oleg TRETIAKOV U. of New South Wales, Australia
10:30 – 10:45 Coffee Break
10:45 – 11:00
Regular 6: *Spin waves in magnetic nanotubes*.
Jorge A. OTALORA-ARIAS Universidad Católica del Norte, Antofagasta Chile
11:00 – 11:30
Invited 13: *Spintronic operations with antiferromagnets*.
Takahiro MORIYAMA U. of Kyoto, Japan
11:30 – 12:00
Invited 14: *Solitary wave excitations of skyrmion strings in chiral magnets*.
Markus GARST U. of Karlsruhe, Germany
12:00 – 12:30
Invited 15: *Chiral magnetism, current-driven domain walls and thermal spin drag in magnetic insulators with perpendicular anisotropy*.
Can Onur AVCI ETH Zürich, Switzerland

Lunch

14:00 – 14:30
Invited 16: *Antiferromagnetic spin spiral and magnetic skyrmions in synthetic antiferromagnetic multilayers*.
Vincent CROS UMPhi CNRS-Thales, France
14:30 – 15:00
Invited 17: *Manipulation of magnetic skyrmions in ultrathin films by current and light*.
Olivier BOULLE Spintec, France
15:00 – 15:15
Regular 7: *Manipulating and transporting spins in antiferromagnetic insulators/heavy metal bilayers*.
Lorenzo BALDRATI Johannes Gutenberg Universität-Mainz, Germany
15:15 – 15:30
Regular 8: *Dynamics of noncollinear antiferromagnetic domain walls driven by spin current injection*.

Yuta YAMANE RIKEN, Japan

15:30 – 15:45

Regular 9: *Spin waves in thin films and magnonic crystals with Dzyaloshinskii-Moriya interactions*.

Rodolfo GALLARDO Universidad Técnica Federico Santa María, Valparaíso, Chile

15:45 – 16:00

Regular 10: *A microscopic theory of Gilbert dampings and spin-orbit torques in antiferromagnets*.

Dmitry YUDIN Uppsala University, Uppsala, Sweden

16:00 – 16:30 Coffee Break & Posters

16:30 – 17:00

Invited 18: *Theory for spin torque in Weyl semimetal with magnetic textures*.

Mair CHSHIEV Spintec, France

Tutorial 2: Tuesday 22nd, 8:50-9:30

Topological Spin Dynamics in ferro- and antiferromagnets

M. KLÄUI[1,2,3]

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[2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany
[3]QuSpin, NTNU, 7491 Trondheim, Norway

In our information-everywhere society IT is a major player for energy consumption. Novel spintronic devices can play a role in the quest for GreenIT if they are stable and can transport and manipulate spin rapidly and with low power.

Firstly, to obtain ultimate stability, topologically stabilized spin structures, such as chiral domain walls and skyrmions can be used [1-3]. We have investigated in detail their dynamics and find that it is governed by the topology of their spin structures [1]. By designing the materials, we can even obtain a skyrmion lattice phase as the ground state of the thin films [2]. By analyzing the thermal energy landscape, we find that depending on the parameters (field, temperature, etc.), stripe domain or skyrmion phases constitute the lowest energy state [3].

Secondly, for ultimately efficient spin manipulation, we use spin-orbit torques: we combine ultimately stable skyrmions with spin orbit torques into a skyrmion racetrack device [2,4]. By optimizing the acting torques [5], we can obtain fast skyrmion motion [4] and real time imaging of the trajectories allows us to quantify the novel skyrmion Hall effect [4]. By studying the temperature dependence of the skyrmion Hall effect, we identify the acting mechanisms that lead to different dependences of the skyrmion Hall angle on the current density for the creep and the viscous flow regime [4].

Finally, we recently observed thermally activated skyrmion dynamics showing that skyrmions exhibit diffusion and this is applied to a skyrmion reshuffler device for stochastic computing [6].

Beyond using ferromagnets, antiferromagnetic systems exhibit faster dynamics in the THz regime [7]. We study the properties of these systems and find that surprisingly long spin diffusion lengths are found for instance in insulating antiferromagnetic hematite [8], the main constituent of rust.

[1] F. Büttner et al., Nature Phys. 11, 225 (2015).
[2] S. Woo et al, Nature Mater. 15, 501 (2016).
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[7] T. Kampfrath et al., Nature Photon. 5, 31 (2011).
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Topological spin structures are reviewed in the Perspectives Article:
K. Everschor-Sitte et al., J. Appl. Phys. 124, 240901 (2018).

Invited 11: Tuesday 22nd, 9:30-10:00

Spin-transfer switching and magnetic interactions in perpendicular magnetic tunnel junctions nanopillars

A. D. KENT
Center for Quantum Phenomena, Department of Physics, New York University,
New York, NY 10003 USA

Perpendicularly magnetized magnetic tunnel junctions (pMTJs) are very promising candidates for high-density and non-volatile random access data storage [1]. In order to achieve reliable and fast devices, as well as long-term thermal stability, the magnetization reversal mechanisms [2] and material parameters of the pMTJ's free layer need to be characterized. We study material properties and the reversal mechanisms by several means. First, we determine the exchange constant and magnetic anisotropy of free layers incorporated in full magnetic tunnel junction layer stacks, specifically CoFeB free layers with W insertion layers, by magnetization measurements and ferromagnetic resonance spectroscopy (FMR) in a broad temperature range [3]. A significant finding is that the exchange constant decreases significantly and abruptly with W insertion layer thickness, while the perpendicular magnetic anisotropy shows the opposite trend; it initially increases with W insertion layer thickness and shows a broad maximum for approximately one monolayer (0.3 nm) of W. Second, we conduct micromagnetic modeling to examine the reversal modes and micromagnetic instabilities that develop during spin transfer driven reversal. Third, we perform single-shot time-resolved measurements of circular pMTJs of varying sizes, allowing for precise extraction of the time when switching occurs as well as the time needed to complete the switching process from 25% to 75% of the conductance change between the parallel and antiparallel magnetization states [4]. Together, these results indicate that nanopillars with diameters greater than about 50 nm switch by domain nucleation and reversed domain expansion.

Research was supported by Spin Memory and conducted in collaboration with Jamileh Beik Mohammadi, Laura Rehm and Christian Hahn, at NYU and Georg Wolf, Bartek Kardasz, Steve Watts and Mustafa Pinarbasi at Spin Memory.

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[2] G. D. Chaves-O'Flynn *et al.*, Phys. Rev. Applied **4**, 024010 (2015).
[3] J. B. Mohammadi *et al., arXiv:1905.09329.*
[4] C. Hahn *et al.*, Phys. Rev. B **94**, 214432 (2016).

Invited 12: Tuesday 22nd, 10:00-10:30

Antiferromagnetic Spintronics with (Anti) Skyrmions and Bimerons

O. A. TRETIAKOV
School of Physics, University of New South Wales, Sydney, NSW 2052 Australia

Skyrmions are topologically protected spin textures, which may be used in spintronic devices for information storage and processing. However, skyrmions in ferromagnets have some intrinsic difficulties, which must be overcome to use them for spintronic applications, such as the inability to move along electric current due to skyrmion Hall effect [1]. I will discuss how to work around this problem by using instead of skyrmions different anisotropic topological objects – antiskyrmions, recently observed in systems with anisotropic Dzyaloshinskii-Moriya interaction [2]. I will explain their current-driven dynamics in both ferromagnets and antiferromagnets based on the transformation between skyrmion and antiskyrmion. Yet as another solution to eliminate the skyrmion Hall effect, I will also talk about skyrmions in antiferromagnetic materials [3]. We demonstrate how they can be stabilized [4] and manipulated at finite temperatures [3]. An antiferromagnetic skyrmion is a composite topological object with a similar but of opposite sign spin texture on each sublattice, which results in a complete cancellation of the Magnus force and as a result absence of skyrmion Hall effect. However, the topological spin Hall effect of antiferromagnetic skyrmion texture is nonzero and enhances the spin transfer torques acting on skyrmions [5]. Finally, I will describe the existence in antiferromagnets of bimerons [6], a pair of two merons that can be understood as the in-plane magnetized version of a skyrmion [7].

[1] K. Litzius, I. Lemesh, B. Kruger, P. Bassirian, L. Caretta, K. Richter, F. Buttner, K. Sato, O. A. Tretiakov, J. Forster, R. M. Reeve, M. Weigand, I. Bykova, H. Stoll, G. Schutz, G. S. D. Beach, and M. Klaui, Nature Physics **13**, 170 (2017).
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[4] P. F. Bessarab, D. Yudin, D. R. Gulevich, P. Wadley, M. Titov, and O. A. Tretiakov, Phys. Rev. B **99**, 140411(R) (2019).
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Regular 6: Tuesday 22nd, 10:45-11:00

Spin waves in magnetic nanotubes

J.A. OTALORA,[1,2] H. SCHULTHEISS,[2] K. LENZ,[2] J. LINDNER,[2] A. THOMAS,[1] K. NIELSCH[1,3] and A. KAKAY[2]
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[2]Universidad Católica de Chile, Antofagasta Chile
[3]Technische Universität Dresden, Institute of Materials Science, 01062 Dresden, Germany
[4]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstr. 400, 01328 Dresden, Germany

Curving a two-dimensional magnetic membrane gives rise to asymmetries in the spin-waves (SWs) properties. Ferromagnetic nanotubes provide an example, for which SWs properties are fundamentally different than in flat thin films as shown recently [1]. The mean curvature of the tubular shape creates asymmetries in frequency and lifetime in a similar fashion like the interfacial Dzyaloshinskii-Moriya interaction or for crystals with a special symmetry (Cnv) and bulk Dzyalonshiinsky-Moriya interaction in flat films [2]: SWs properties are asymmetric regarding the sign of the wave vector and as a consequence, spin waves traveling in opposite directions have different wavelength. This purely curvature induced effect originates from the dipole-dipole interaction, namely from the dynamics dipolar volume charges. We will discuss the role of the nanotube curvature on dipolar interaction, therefore on the spin-wave dispersion, frequency linewidth and decay length. We will emphasise the importance of the curvature and show that by tailoring it the asymmetry of the dispersion relation, frequency linewidth and decay length can be tuned or even suppressed. We further discuss means to access the SWs asymmetrical properties in curved membranes, in particular, focusing on an inductive transducer composed of two coplanar wave-guides and a magnetic nanotube for a straightforward access to the curvature-induced asymmetric properties of SWs (whether induced by exchange or dipolar interaction) via detecting the reflection/transmission parameters of the device.

[1] J.A. Otálora, et. al., Phys. Rev. Lett. 117, 227203 (2016).
[2] K. Zakeri, et. al., Phys. Rev. Lett. 104, 137203 (2010).

Invited 13: Tuesday 22nd, 11:00-11:30

Spintronic operations with antiferromagnets

T. MORIYAMA
Institute for Chemical Research, Kyoto University

For a long time, there have been no efficient ways of controlling antiferromagnets. Quite a strong magnetic field is required to manipulate the magnetic moments because of a high molecular field and a small magnetic susceptibility. It was also difficult to detect the orientation of the magnetic moments since the net magnetic moment is effectively zero. Nevertheless, the microscopic magnetic moments should in principle exhibit a similar spintronic effect, such as various magnetoresistance effects and the spin torque effect, as seen in ferromagnets [1]. Various spintronic operations with antiferromagnets (AFMs), including static and dynamic controls of the magnetic moments, are therefore a key for emerging antiferromagnetic spintronics.

The talk will describe our recent results on spin torque control of the magnetization dynamics with antiferromagnetic materials. We will discuss the demonstrations of sequential antiferromagnetic memory operations with a spin-orbit-torque write, by the spin Hall effect, and a resistive read in various antiferromagnets [2,3]. We will also discuss the magnetic damping modification of a ferromagnet (FM) reflecting the Neel order in the AFM in exchange coupled FM/AFM bilayers. A wide range control of magnetic damping is shown to be possible by utilizing antiferromagnets, which is quite beneficial for spintronic applications [4,5].

[1] T. Jungwirth, X. Marti, P. Wadley, and J. Wunderlich, Nat. Nanotechnol. 11, 231 (2016).; V. Baltz, A. Manchon, M. Tsoi, T. Moriyama, T. Ono, and Y. Tserkovnyak, Rev. Mod. Phys. 90, 015005 (2018).
[2] T. Moriyama, K. Oda, T. Ohkochi, M. Kimata, and T. Ono, Sci. Rep. 8, 14167 (2018).
[3] T. Moriyama, W. Zhou, T. Seki, K. Takanashi, and T. Ono, Phys. Rev. Lett. 121, 167202 (2018).
[4] T. Moriyama, M. Kamiya, K. Oda, K. Tanaka, K.-J. Kim, and T. Ono, Phys. Rev. Lett. 119, 267204 (2017).
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Invited 14: Tuesday 22nd, 11:30-12:00

Solitary wave excitations of skyrmion strings in chiral magnets

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Field-polarized chiral magnets possess topological line excitations where the magnetization within each cross section forms a skyrmion texture. We study analytically and numerically the low-energy, non-linear dynamics of such a skyrmion string, and we demonstrate that it supports solitary waves. Theses waves are in general non-reciprocal, i.e., their properties depend on the sign of their velocity v, but this non-reciprocity diminishes with decreasing |v|. An effective field-theoretical description of the solitary waves is derived that is valid in the limit v→0 and gives access to their profiles and their existence regime. Our analytical results are quantitatively confirmed with micromagnetic simulations for parameters appropriate for the chiral magnet FeGe. Similarities with solitary waves found in vortex filaments of fluids are pointed out.

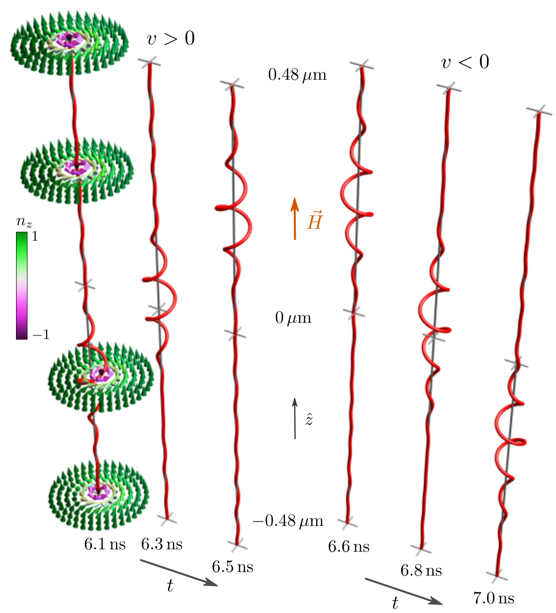

Figure 1: Solitary wave excitation of an isolated skyrmion string in a field-polarized cubic chiral magnet. The string is aligned with the magnetic field, and the solitary wave is propagating in a direction parallel (v > 0) and antiparallel (v < 0) to it. The figure is produced by micromagnetic simulations with parameters typical for the chiral magnet FeGe. The magnetic field is 0.8 T resulting in a skyrmion string radius of approximately 5 nm. Solitary waves with amplitude 5.8 nm are created at time t = 0 and propagate with velocity |v| ≈ 1 km/s.

[1] V. P. Kravchuk, U. K. Rößler, J. van den Brink, and M. Garst, arXiv:1902.01420.

Invited 15: Tuesday 22nd, 12:00-12:30

Chiral magnetism, current-driven domain walls and thermal spin drag in magnetic insulators with perpendicular anisotropy

C. O. AVCI[1,2], E. ROSENBERG[2], L. CARETTA[2], F. BÜTTNER[2], J. BAUER[2], M. HUANG[2], P. GAMBARDELLA[1], C. A. ROSS[2], G. S. D. BEACH[2]
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Magnetic insulators (MIs), especially iron-based garnets, possess remarkable properties such as low damping, long magnon decay lengths, and high structural quality, providing a suitable playground for spintronics research and potential applications. Recently, robust perpendicular magnetic anisotropy is obtained in ferrimagnetic thin films of thulium, europium, and terbium iron garnet (TmIG, EuIG, and TbIG) grown on Gadolinium Gallium Garnet (GGG) substrates down to a thickness of 5.1 nm with saturation magnetization close to the bulk value [1]. By using the spin Hall effect in Pt, we have demonstrated efficient spin current injection through the TmIG/Pt interface quantified by the spin Hall magnetoresistance and harmonic Hall effect measurements. This spin current is strong enough to achieve spin-orbit torque-driven magnetization switching of TmIG(~10 nm)/Pt bilayer with efficiencies comparable to or exceeding that of, e.g., Pt/Co [2]. We then investigated the magnetic texture and current-driven dynamics of domain walls in this system. We found that the domain walls can be efficiently moved using electrical currents in the absence of external fields, indicating the presence of Néel-type domain wall textures. Further analysis revealed that the chiral domain walls are stabilized due to the Dzyaloshinkii-Moriya interaction at the substrate GGG/TmIG interface. We found that these chiral domain walls can be propelled faster than 800 m/s per current densities as low as 1.2×10^{12} A/m2, one of the highest reported in any ferromagnetic system thus far [4].

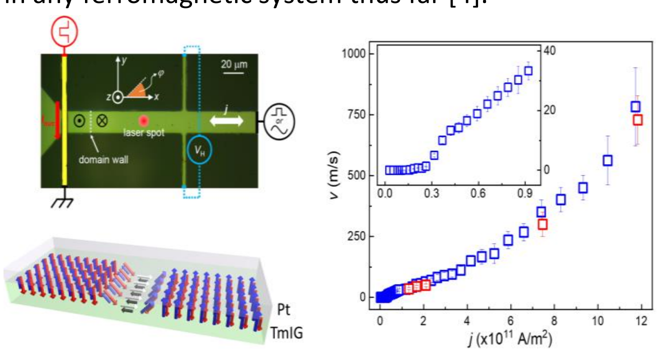

Figure 1 - Upper left: Typical domain wall device and electrical connections. Lower left: Domain wall configuration in TmIG/Pt bilayer at zero external field. Right: Domain wall velocity versus injected current density through Pt overlayer.

Finally, we will discuss a new thermoelectric effect that we have recently discovered, which allows electrical detection of out-of-plane magnetization component in magnetic insulators by using temperature gradients in a nonlocal device. The effect relies on efficient spin pumping and spin drag, respectively driven by out-of-plane and in-plane temperature gradients, generated by a single heater source. We measure an inverse spin Hall effect voltage in Pt, orthogonal to both the MI magnetization vector and the in-plane temperature gradient, to which we coin the name thermal *spin drag voltage*, highlighting its origins.

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Invited 16: Tuesday 22nd, 14:00-14:30

Antiferromagnetic spin spiral and magnetic skyrmions in synthetic antiferromagnetic multilayers

V. CROS[1], W. LEGRAND[1], F. AJEJAS[1], E. BURGOS[1,3], A. HAYKAL[2], Y. SASSI[1], D. MACCARIELLO[1], A. FINCO[2], S. CHOUAIEB[2], S. COLLIN[1], A. VECHIOLA[1], K. BOUZEHOUANE[1], N. JAOUEN[3], V. JACQUES[2], N. REYREN[1] AND A. FERT[1]

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Large interfacial Dzyaloshinskii-Moriya interaction (DMI) existing in magnetic multilayers has focused a large interest in the last couple of years as it allows the stabilization of novel chiral magnetic textures such as chiral magnetic domain walls [1] or recently room-temperature skyrmions in ferromagnetic films [2]. Despite many recent progresses [3], ferromagnetic order in thick layers or multilayers generates dipolar fields that prevent from reaching expected ultra-small skyrmion sizes. Moreover, in ferromagnetic systems, a transverse deflection of moving skyrmions is present that hinder their efficient manipulation [4]. Antiferromagnetic skyrmions could lift these limitations [5-6].

Here we will present how we elaborate a material system based of a synthetic antiferromagnetic stacking (SAF) in which perpendicular magnetic anisotropy, antiferromagnetic coupling and chiral order can be adjusted concurrently. In the case of cancelled magnetic anisotropy, we are able to image by MFM and NV microscopy a spin spiral configuration. Complementary XRMS experiments allow us to investigate the chiral properties of these spin spiral. Then, utilizing interlayer electronic coupling to an adjacent bias layer, we also demonstrate by Magnetic Force Microscopy that the spin-spiral state can be turned into isolated antiferromagnetic skyrmions. This first observation of small AF skyrmions as small as 25 nm radius in SAF has been also achieved using NV microscopy, a technique in which the potential perturbations from the tip are not existing. In addition to the experimental observations, we also provide model-based estimations of their size and stability, showing that room-temperature stable antiferromagnetic skyrmions below 10 nm in radius can be anticipated in further optimized SAF systems [6]. Antiferromagnetic skyrmions in SAF systems may thus solve major issues associated to ferromagnetic skyrmions for low-power spintronic devices [7].

French ANR grant TOPSky TOPSKY (ANR-17-CE24-0025), DARPA TEE program grant (MIPR#HR0011831554) and EU grant SKYTOP (H2020 FET Proactive 824123) are acknowledged for their financial support.

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[2] C. Moreau-Luchaire et al., Nat. Nanotechnol. 11, 444 (2016).
[3] S. Woo et al, Nature Materials 15, 501 (2016). W. Legrand et al., Nano Letters 17, 2703 (2017).
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[5] J. Barker, O. Tretiakov, Phys. Rev. Lett. 116, 147203 (2017). R. Tomasello et al, Scien. Rep. 4, 6784 (2014).
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Invited 17: Tuesday 22nd, 14:30-15:00

Manipulation of magnetic skyrmions in ultrathin films by current and light

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Magnetic skyrmions are nanoscale whirling spin configurations. Their small size, topological protection and their manipulation by electrical current have opened a new paradigm to manipulate magnetization at the nanoscale. This has led to novel proposal of memory and logic devices in which the magnetic skyrmions are the information carriers [1]. The recent observation of room-temperature magnetic skyrmions [2,3,4] and their current-induced manipulation [4,5,6] in magnetic nanotracks have lifted an important bottleneck toward the practical realization of such devices.

Recently, we have shown that magnetic skyrmions can be stabilized at room temperature in magnetic nanostructures patterned in an ultrathin Pt/Co/MgO trilayer stack with diameters around 100 nm. Using high spatial resolution X-ray magnetic microscopy technique, we were able to observe the internal topological spin texture of the skyrmion as well as its homochiral Néel internal structure [3]. In this talks, I will show that skyrmions can be manipulated with small electrical currents with velocities up to 100 m/s in this ultrathin trilayer which is promising for lower power skyrmion-based memory and logic devices. The skyrmion mobility and trajectory (skyrmion Hall effect) is drive-dependent and exhibits different dynamical regimes. These observations are well substantiated by a simple analytical model and micromagnetic simulations, which is enabled by the simple skyrmion spin structure and an accurate characterization of its magnetic and transport properties [6].

I will also report on the observation of reproducible current-induced nucleation/annihilation of antiferromagnetic skyrmions in synthetic antiferromagnetic multilayers at room temperature and zero external magnetic field, where no skyrmion Hall effect is expected.

Finally, I will show that skyrmions can be controllably created using ultrafast laser pulses [7], which can be used for the writing operations in memory and logics devices.

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Regular 7: Tuesday 22nd, 15:00-15:15

Manipulating and transporting spins in antiferromagnetic insulators/heavy metal bilayers

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[4]Diamond Light Source, Chilton, Didcot, Oxfordshire OX11 0DE, United Kingdom
[5]Helmholtz-Zentrum Berlin fur Materialien und Energie, Berlin 12489, Germany
[6]Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan
[7]Advanced Science Research Center, Japan Atomic Energy Agency, Tokai 319-1195, Japan
[8]Center for Spintronics Research Network, Tohoku University, Sendai 980-8577, Japan
[9]Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan
[10]Center for Quantum Spintronics, NTNU, Trondheim, Norway

Antiferromagnets have potential to be the next building blocks of spintronic devices, thanks to the resonance frequencies in the THz regime, the absence of stray magnetic fields and the resulting resilience against external magnetic fields. These particular properties might enable ultrafast operation combined with high packing density, while spin transport in this class of materials is of interest for spin-logic based devices and was recently demonstrated to be possible over distances of 40 µm in hematite single crystals. [1] We have previously probed the spin transport properties of thermal magnons in crystalline epitaxial NiO(001) thin films [2], and found that the electrical reading of the magnetic moments is possible via spin Hall magnetoresistance (SMR) [3]. The SMR relies on a different absorption/injection of spin currents depending on the orientation of the magnetic moments, due to a combination of spin Hall and inverse spin Hall effects. Here we show that one can electrically switch the orientation of the antiferromagnetic Néel vector via current pulses in the same system, without any ferromagnetic element. The switching of the antiferromagnetic moments is probed electrically and by direct imaging via x-ray magnetic linear dichroism – photoemitted electron microscopy (see Fig. 1). Both non-deterministic switching below the current threshold and deterministic switching above the current threshold are observed. We explain our results with a theoretical model involving spin torques acting directly on the domain walls and a ponderomotive force that drives the antiferromagnetic domain walls. Resistance changes not related to the magnetic order are also induced by high density current pulses, as seen in a control sample with Pt only, which have to be considered to correlate the measured transverse resistance to the orientation of the Néel vector. This writing method using spin torques acting on antiferromagnetic materials can be exploited to realize antiferromagnetic memory elements with Hall cross shape, where combined electrical reading and writing operations are possible. [4,5] See also Ref. [6] (under revision).

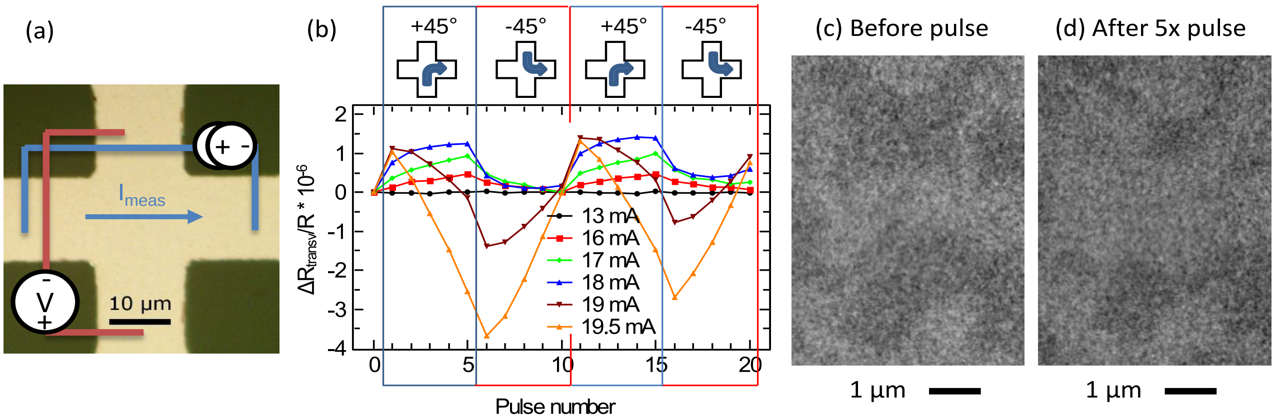

Figure 1: (a) Optical micrograph of the patterned devices. (b) Electrical measurements of the variation of the transverse resistance after 1 ms long pulses at different current. (c) Image of the antiferromagnetic domains before pulses. (d) Image of the antiferromagnetic domains after pulses.

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Regular 8: Tuesday 22nd, 15:15-15:30

Dynamics of noncollinear antiferromagnetic domain walls driven by spin current injection

Y. YAMANE[1], O. GOMONAY[2] and J. SINOVA[2]
[1]Institute RIKEN Center for Emergent Matter Science (CEMS), Japan
[2]University of Mainz, Germany

Since the prediction of staggered magnetic order and its experimental observation through 1930-50s, antiferromagnetic (AFM) materials have occupied a central place in the study of magnetism. The absence of macroscopic magnetization in AFMs, however, indicates that they cannot be effectively manipulated and observed by use of external magnetic field, the fact that has hindered active applications of AFMs in today's technology. Research in the emergent field of antiferromagnetic spintronics has revealed that electric and spin currents are capable of accessing AFM dynamics via spin-transfer torques and Neel spin-orbit torques. The studies on current-driven dynamics of AFM textures have opened an avenue toward AFM-based technologies.

Recently, AFMs with noncollinear magnetic orders are generating increasing attention as they exhibit large magneto-transport [2] and thermomagnetic [3] effects. In the context of current-driven dynamics of AFMs, however, the studies have thus far mostly focused on collinear structures. Understanding the effects of electric and spin currents in noncollinear AFMs is being a crucial issue in the community.

In this presentation, we discuss the dynamics of noncollinear AFMs induced by spin current injection [4], which may be realized by exploiting spin Hall effect in an adjacent nonmagnetic metal layer. We derive sin-Gordon type effective equations of motion for the AFMs, including forces originating from spin current injection, external magnetic field and internal dissipation. Our model is applicable to technologically important materials such as Mn3Ir and Mn3Sn, enabling an analytical approach to domain wall dynamics in those materials. We obtain an expression for DW velocity driven by spin current, which is compared to numerical simulations.

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Regular 9: Tuesday 22nd, 15:30-15:45

Spin waves in thin films and magnonic crystals with Dzyaloshinskii-Moriya interactions

R. A. GALLARDO[1,2], D. CORTES-ORTUÑO[3], R. E. TRENCOSO[4], and P. LANDEROS[1,2]

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[2]Center for the Development of Nanoscience and Nanotechnology (CEDENNA), Santiago, Chile.
[3]Faculty of Engineering and Physical Sciences, University of Southampton, Southampton, United Kingdom.
[4]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway.

The influence of the Dzyaloshinskii-Moriya interaction (DMI) on the behavior of spin waves in ultra-thin ferromagnetic films and chiral magnonic crystals is reviewed [1]. During the last decade, it has been shown, both theoretically and experimentally, that this anisotropic exchange interaction produces non-reciprocal features on the spin-wave spectrum of a magnetic system, a phenomenon that occurs both for bulk [2-4] and interfacial Dzyaloshinskii-Moriya coupling [5-8]. More recently, the concept of a chiral magnonic crystal has been introduced, where the interfacial Dzyaloshinskii-Moriya interaction is periodic. The effect of this periodicity includes additional features such as flat bands, indirect gaps, and an unusual spin-wave evolution [9], with standing waves showing finite phase velocities in the zones where the DMI is nonzero [10]. These results have been obtained with micromagnetic simulations and using a theoretical approach based on the plane-wave method. These chiral magnonic crystals with periodic DMI, which may be attained for instance by covering a thin ferromagnetic film with an array of heavy-metal wires [9], host interesting physical properties, encouraging future experimental studies to prove and evidence these phenomena.

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Regular 10: Tuesday 22nd, 15:45-16:00

A microscopic theory of Gilbert dampings and spin-orbit torques in antiferromagnets

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Over the last few decades achievements in ferromagnetic spintronics and related areas greatly contributed to enormous technological progress. In the meantime, the request for higher performance computation and big data analytics requires for much higher operating frequency than that can be achieved at the moment, thus pushing forward the idea of using purely electrical read and write in magnetic memory devices. It is therefore not surprising that the focus of research activity has recently shifted towards antiferromagnetic systems which can be used in storing and processing information. Indeed, utilizing antiferromagnetic components makes it possible to integrate these technologies within existing microelectronic circuitry, and simultaneously enjoy advantages of both charge electronics and spintronics, including non-volatility, lower dissipation rate, and faster dynamics. In this talk, we address the structure of Gilbert damping tensor and spin-orbit torques within the framework of microscopic theory for a two-dimensional Rashba antiferromagnet.

Invited 18: Tuesday 22nd, 16:30-17:00

First principles insights into spin-orbit phenomena in nanostructures comprising transition metals, oxides and 2D materials

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In recent years, spin-orbit coupling based phenomena at interfaces comprising ferromagnetic (FM) metal, oxide (O) and nonmagnetic metal (NM) have been an object of great interest for spintronics including spin-orbitronics [1]. At the same time, a major attention of scientific community has been devoted to developments of emerging field of 2D and graphene spintronics [2]. Here, we provide *ab initio* insights into perpendicular magnetic anisotropy (PMA) [1,3-8] and Dzyaloshinskii-Moriya interaction (DMI) [9-12] at interfaces comprising transition metals, insulators, and graphene.

First, the nature of PMA at Fe|MgO interfaces is unveiled by evaluating orbital and layer resolved contributions to PMA in Fe/MgO interfaces and MTJs with different interfacial conditions [1,3,4]. Mechanisms of the optimization of effective anisotropy via introducing V or Cr impurities into FM metal are discussed [5] followed by clarifying details of physical picture of electric field control of magnetic anisotropy (VCMA) both using charge addition/depletion [6] and ionic migration [7]. Furthermore, we demonstrate that graphene can dramatically boost the surface anisotropy of Co films up to twice the value of its pristine counterpart and thus graphene/FM interfaces represents a viable alternative for advancing spintronic applications [8].

Next, the main features and microscopic mechanisms of DMI behavior are elucidated in Co/Pt and other FM/NM bilayers [9,10]. In particular, we demonstrate from first-principles that while the DMI at FM/NM interfaces is consistent with the Fert-Levy model [9], in case of FM/O [10] or FM/graphene [11] interfaces the dominating mechanism of the DMI is due to Rashba spin-orbit coupling. Furthermore, several approaches for DMI enhancement and manipulation are be presented [10]. This includes inverse geometrical stacking and electric field control of DMI, or voltage controlled DMI (VCDMI) [10]. In particular, we demonstrate enhanced DMI in Pt/Co/MgO structures [10,12] that allowed observation of room temperature skyrmions [12]. Finally, graphene/FM metal heterostructures offering a possibility to induce giant correlated PMA and DMI values are proposed [8,11].

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Thursday October 24th

9:00 – 9:30
Invited 19: *Spectrum analysis using vortex-state spin-torque nano-oscillators*.
Andrei SLAVIN Oakland University, Rochester, Michigan, USA
9:30 – 10:00
Invited 20: *New directions for microwave and THz detectors based on spintronic diodes*.
Giovanni FINOCCHIO Messina U., Italy
10:00 – 10:30
Invited 21: *Long range coupling of magnetic bi-layers by coherent phonons*.
Olivier KLEIN Spintec, France
10:30 – 11:00 Coffee Break & Posters
11:00 – 11:30
Invited 22: *Spin Hall Magnetoresistance in antiferromagnet/nonmagnet metallic structures*.
Samik DUTTAGUPTA CSIS, Tohoku University, Japan
11:30 – 12:00
Invited 23: *Chiral magnetism and skyrmion nucleation in Pt/Co/Ni based thin-film heterostructures*.
Eric FULLERTON UCSD, USA
12:00 – 12:30
Invited 24: *Clusters with mutually orthogonal skyrmion tubes: theoretical prediction and real-space observation*.
Andrey LEONOV Hiroshima U., Japan

Lunch

14:00 – 14:30
Invited 25: *Spin-Orbit Torque in Ferri- and Antiferromagnetism*.
Kang L. WANG UCLA, USA
14:30 – 15:00
Invited 26: *Spin-Orbit Torques from a Microscopic Point of View*.
Alan MACDONALD UT, Austin, USA
15:00 – 15:15
Regular 11: *Gilbert damping in low-dimensional magnetic systems: microscopic approach*.
Anastasiia PERVISHKO Uppsala University, Uppsala, Sweden
15:15 – 15:30
Regular 12: *Orbital-selective behavior and suppression of the double exchange in 4d and 4d transition metal oxides*.
Sergey STRELTSOV URAN, Russia
15:30 – 15:45
Regular 13: *Topological-chiral magnetic interactions driven by emergent orbital magnetism*.
Sergii GRYTSIUK Peter Grümberg Institute, Germany

15:45 – 16:00
Regular 14: *Photoinduced Rashba Spin-to-Charge Conversion via an Interfacial Unoccupied State*.
Jorge PUEBLA Center for Emergent Matter Science, RIKEN, Japan

16:00 – 16:30 Coffee Break & Posters

16:30 – 17:00
Invited 27: *Theory of Spin Transport and Torque in Non-Collinear Antiferromagnets*.
Aurelien MANCHON KAUST, Saudi Arabia
17:00 – 17:30
Invited 28: *Domain Walls dynamics in an Antiferromagnet*.
Ruben OTXOA Hitachi Cambridge Laboratory, UK
17:30 – 18:00
Invited 29: *Reservoir Computing with Random Magnetic Textures*.
Daniele PINNA Mainz U., Germany

19:30 – 22:00 Conference Dinner!

Invited 19: Thursday 24th, 9:00-9:30

Spectrum analysis using vortex-state spin-torque nano-oscillators

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Spin torque nano-oscillators (STNO) are promising for wireless communication schemes due to their nano-scale size, as well as their broadband and fast (nanosecond range) frequency tunability. So far only few system-level applications were demonstrated using STNOs, such as operation within a phase locked loop [1] for frequency stabilization, or communication using amplitude modulation [2].

Recently, STNOs have been proposed for fast spectrum analysis [3]. Common spectrum analyzers (SA) use a swept-tuned frequency approach to achieve a wide frequency bandwidth, high dynamic range and low noise floor. However, they are limited to sweep times of 10-100 microseconds determined by the VCOs and YIG-tuned oscillators. This does not permit analyzing signals that contain fast-changing frequency components. In contrast, STNOs are characterized by much faster frequency tuning times that can reach the nanosecond scale. This property of STNOs gives promise to significantly improve the performances of swept-tuned SAs, making them suitable for analysis of fast-changing signals in modern communication protocols, such as Bluetooth, Zigbee, and Wireless LAN.

Here we implemented and experimentally verified the spectrum analyzing technique proposed in [3] for STNOs (see Fig.1). The STNO is used as a frequency-tunable local oscillator, whose frequency is swept periodically by injecting a saw-tooth signal. The STNO output (a) is, then, mixed with the input signal (b), that is to be analyzed. The mixed signal (c) is processed by a matched , compressing it into a peak (d). The temporal position of the peak is proportional to the frequency of the measured input signal.

For the demonstration of the STNO-SA principle we chose magnetic-tunnel-junction-based vortex-state STNOs, because of their relatively fast frequency tuning [4], low phase noise [5] and signal stability. We performed a systematic study on the STNO-SA performances, demonstrating a maximum scanning rate of 1.5 MHz, and a resolution bandwidth (RBW) that is close to the theoretically predicted values, and limited only by the STNO phase noise. To obtain real-time parallel processing at the scanning rate, the matched filter is designed using direct finite impulse response (FIR) topology, and is implemented in FPGA Xilinx XC6SLX9.

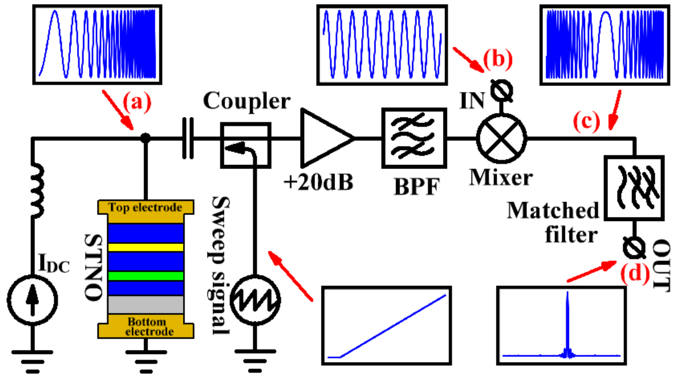

Fig. 1. Schematic of the ultra-fast spectrum analyzer

Financial support is acknowledged from the French space agency CNES, ERC MagiCal 669204, and grants Nos. EFMA-1641989 and ECCS-1708982 from the NSF of the USA.

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Invited 20: Thursday 24th, 10:00-10:30

New directions for microwave and THz detectors based on spintronic diodes

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Microwave detectors based on the spin-torque diode effect are among the key emerging spintronic devices. By utilizing the spin of electrons in addition to their charge, they have the potential to overcome the theoretical performance limits of their semiconductor (Schottky) counterparts. In the first part of the talk, I will discuss our recent results in the field of microwave detectors based on spin diodes.[1] Those devices realized with magnetic tunnel junctions exhibit high-detection sensitivity >200kV/W at room temperature, without any external bias fields, and for low-input power (micro-Watts or lower).[2] This sensitivity, achieved taking advantage of the injection locking, is significantly larger than both biased state-of-the-art-Schottky diode detectors and other existing spintronic diodes. Another application of spintronic diodes is the electromagnetic energy harvesting. Here I will show the development of a bias-field-free spin-torque diodes that could be an efficient harvester of broadband ambient RF radiation, capable to efficiently harvest microwave powers of microWatt and below and to power a black phosphorous nanodevice.[3] Finally, the talk will discuss the promising directions of THz detectors based on antiferromagnetic materials including their unique properties such as resonance response and tunability and the remaining challenges to face.

This work was supported by the project "ThunderSKY" funded from the Hellenic Foundation for Research and Innovation and the General Secretariat for Research and Technology, under Grant No. 871.

H.F.R.I. Hellenic Foundation for Research & Innovation GSRT GENERAL SECRETARIAT FOR RESEARCH AND TECHNOLOGY

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Long range coupling of magnetic bi-layers by coherent phonons

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Spintronics has proven its worth by revolutionizing the data storage industry. Nevertheless, the majority of spintronic devices continue to operate via conduction electrons, which inherently dissipate power due to their resistive losses. Collective excitations of localized magnetic moments can also convey spin information. However, in the case of metals, the spin excitations are greatly attenuated due to the tremendous viscous damping inside electrical conductors. Only in magnetic insulators, spin currents propagate with considerably reduced dissipation because there are no conduction electrons to absorb angular momentum.

The material of choice for magnonics is yttrium iron garnet (YIG) with the lowest magnetic damping reported so far [1,2]. It turns out that the acoustic attenuation coefficient in garnets is also exceptionally small: up to an order of magnitude lower than the acoustic attenuation in monocrystalline quartz [3,4]. The low acoustic damping factor η_a also benefits the interconversion into spin-waves (with damping η_s) as measured by cooperativity, C $=\Omega^2/(2\,\eta_a\,\eta_s)$ leading to a strong coupling defined by C>1 even when the magneto-acoustic coupling force Ω is small. It turns out that spin waves (magnons) hybridize with the vibrations of the lattice (phonons) through magneto-crystalline anisotropy. Although often weak in absolute terms, magneto-elasticity leads to new hybrid quasi-particles ("magnon polarons") when the dispersion relations of the spin and acoustic waves s' (anti) cross [5,6]. Our recent highlight is to have provided experimental evidence of

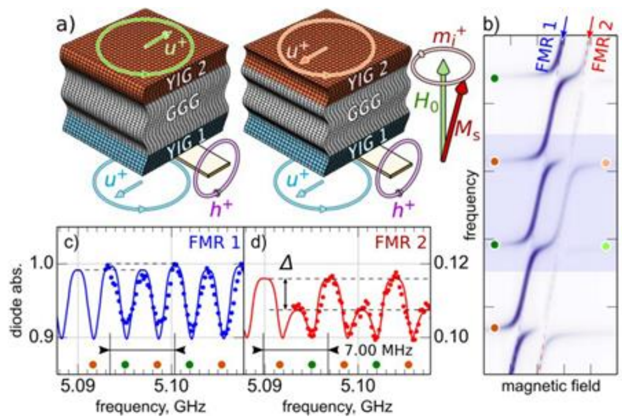

Figure 1: a) Schematic diagram of the dynamical coupling between two magnetic layers inside a dielectric 'spin-valve': a top YIG layer (YIG2) and a bottom YIG layer (YIG1) are coupled by the exchange of coherent phonons: the magnetic precession m^+ generates a circular shear deformation μ^+ of the crystal lattice which can be coherently tuned with the movement of all other fields and can cause constructive or destructive interference between the dynamics of the two layers. The signature is a contrast Δ in the microwave power absorbed between two frequency tones separated by half a phonon wavelength, corresponding to 2 modes having either even or odd mode numbers.

coherent spin transport over millimeter distances via sound wave coupling [1], which exceeds previous records of magneto scattering spin information transfer by several orders of magnitude.

The experimental evidence came from a ferromagnetic magnetic resonance study of two YIG films formed by epitaxial growth on both sides of a non-magnetic gadolinium garnet garnet substrate (GGG) [1]. We show that stationary transversal sound waves can couple the coherent magnetization dynamics of the two YIG films at a distance of half a millimeter by the magnetoelastic interaction, periodically modulating the absorption of microwaves as a function of frequency.

The acoustic modes with odd and even symmetry couple to the magnets with opposite signs, i.e. $\Omega_2 = (-1)^n \Omega_1$ (see Figure 1c), which affects the dynamics as sketched in Figure 1b. When n is odd (even), the top layer returns (absorbs) the power from the electromagnetic field, because the phonon amplitude is out-of(in) phase with the direct excitation, corresponding to constructive (destructive) interference. In other words, the phonons pumped by the dynamics of the layer 1 are absorbed vs. reflected by layer 2. A contrast Δ emerges between tones separated by half a wavelength, that is proportional to the amplitude ratio of the microwave magnetic fields felt by the two YIG layers. To observe this contrast Δ we perform a FMR study on a YIG crystal having two YIG layers with slightly different resonant resonant frequencies and we employ a stripline that couples strongly to the lower layer YIG1. The slightly different resonance frequencies (see below) allow monitoring the FMR absorption of YIG2 with weaker coupling.

The data shown in Figure1 are evidence that magnets are a source and detector for phononic angular momentum currents and that these currents provide a coupling, analogous to the dynamic coupling in metallic spin valves [8] but with an insulating spacer, over much larger distances, and in the ballistic/coherent rather than diffuse regime. This coherent, long-range coupling of phononic momentum currents through a non-magnetic dielectric waveguide provides novel functionalities for insulating hybrid spin circuits and devices. The record coupling length scale might even be enhanced further by reducing the contact to the crystal [18]. These findings might have implications on the non-local spin transport experiments, in which phonons provide a parallel channel for the transport of angular momentum [9]. While the present experiments are carried out at room temperature and interpreted classically, the high acoustic quality of phonon transport and the strong coupling to the magnetic order in insulators may be useful for quantum communication.

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Invited 22: Thursday 24th, 11:00-11:30

Spin Hall Magnetoresistance in antiferromagnet/nonmagnet metallic structures

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The possibility for utilization of antiferromagnets (AFMs) as multifunctional components of spintronic devices has opened new directions in the field of spintronics [1-4]. The major hurdles concerning the realization of pure antiferromagnetic spintronics concerns electrical reading and writing of antiferromagnetic bits having no net magnetization. Recent results have revealed that the interaction of antiferromagnetic moments with charge/spin currents might serve as a robust electrical probe for detection [5-7]. However, an investigation concerning the magnetoresistance (MR) effects in AFM/NM metallic structures have remained elusive. Here, we study magnetoresistive effects in PtMn/Pt and show the existence of an appreciable MR in this metallic structure.

Heterostructures of sub./Ta/Pt/MgO/$Pt_{0.38}Mn_{0.62}$/Pt/Ru [PtMn/Pt, hereafter] and sub./Ta/Pt/MgO/$Pt_{0.38}Mn_{0.62}$/Ru [sub./PtMn, hereafter] are patterned into μm-sized devices by photolithography and Ar ion milling. We investigate PtMn thickness (t_{PtMn}) dependence of longitudinal and transverse MR for applied magnetic field rotations along three mutually perpendicular (x-y, y-z and x-z) planes. Quantification of the various MR effects in PtMn/Pt and sub./Pt structures are obtained from t_{PtMn} dependence of MR and their respective functional dependencies. Our experimental results indicate a dominant role played by spin Hall magnetoresistance towards the observed MR behavior in PtMn/Pt [8]. The present study highlights the possibility of electrical detection schemes in AFM/NM metallic structures offering an unexplored pathway for antiferromagnetic spintronics.

A portion of this work was supported by the ImPACT Program of CSTI, JST-OPERA, Core-to-Core Project of JSPS, JSPS KAKENHI 17H06093, 17H06511, 19H00858 and Cooperative Research Projects of RIEC and CSRN, Tohoku University.

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Invited 23: Thursday 24th, 11:30-12:00

Chiral magnetism and skyrmion nucleation in Pt/Co/Ni based thin-film heterostructures

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In recent years, the implications of the interfacial Dzyaloshinskii-Moriya interaction (DMI) in thin films has attracted significant attention given that DMI can give rise to non-collinear magnetic structures such as chiral Neel-type domain walls and skyrmions. These magnetic features exhibit several interesting properties, such as efficient motion in response to electrical currents and purported "topological protection" [1]. As a result, significant interest in understanding how these chiral magnetic states form and how they behave in response to external stimuli, such as applied magnetic fields and electrical currents.

We studied sputter-deposited samples based on a [Co (0.7 nm)/ Ni (0.5)/ Pt (0.7)]N ($1 \leq N \leq 30$) stack structure to impart DMI via structural inversion asymmetry between the Pt-Co and Ni-Pt interfaces [2]. Lorentz transmission electron microscopy (LTEM) measurements indicate that domain walls with a significant Neel component form in samples with $N \leq 5$, whereas Bloch-type walls form in samples with $N \geq 10$. By examining magnetic domain expansion in the presence of a symmetry breaking in-plane magnetic field, samples with $N < 3$ exhibit asymmetric growth of circular domains having in agreement with reports on similar systems [3]. However, when increasing the number of repetitions to $3 \leq N \leq 5$, dendritic stripes become the reversal mechanism. At low in-plane fields, the domains grow perpendicular to the in-plane field – unexpected behavior for a Neel-walled system. As the in-plane magnetic field increases, the domains begin to grow towards the in-plane field, before suddenly reversing growth direction 180°, opposed to the in-plane field at some critical field strength.

Using full-field resonant soft X-ray transmission microscopy (performed at Beamline 6.1.2, Advanced Light Source), it was found that the samples with N = 20 and 30 exhibit stripe domains of width 150 – 200 nm at remanence. However, when electrical current pulses of sufficient density (order of 10 MA/cm2) and length are applied in the presence of out-of-plane magnetic fields, various states of skyrmion population/density can be created. The degree of transformation from stripe domains to skyrmions is sensitive to the degree of Joule heating. In certain cases, the skyrmions formed are stable over a 6000-Oe range of applied fields. Furthermore, these systems allow for statistical studies of the hopping-like behavior of tightly-packed, skyrmions in a thin film system.

By reducing the magnetic moment and effective perpendicular anisotropy in samples of the form [Co(0.7 nm)/ Tb(0.4 nm)/ Ni(0.5 nm)/ Pt(0.7 nm)]20, the current density and magnetic field necessary to accomplish the same transition reduces to 1×10^9 A/m^2 and 350 Oe, respectively. In both systems, the skyrmions formed by such pulses remain stable over a wide range of magnetic fields, including at zero field. Additionally, by exploring different magnitude current pulses, pulse durations, and the magnetic, a sub-mJ difference in the associated Joule heating needed to completely transform stripe domains in to skyrmions and that which nucleates zero skyrmions is found (Fig. 2). This suggesting that Joule heating may not completely explain the energetic impetus of the stripe-to-skyrmion transition in these materials. This work is supported by the United States Department of Energy Office of Basic Sciences under grant DE-FOA-0001810.

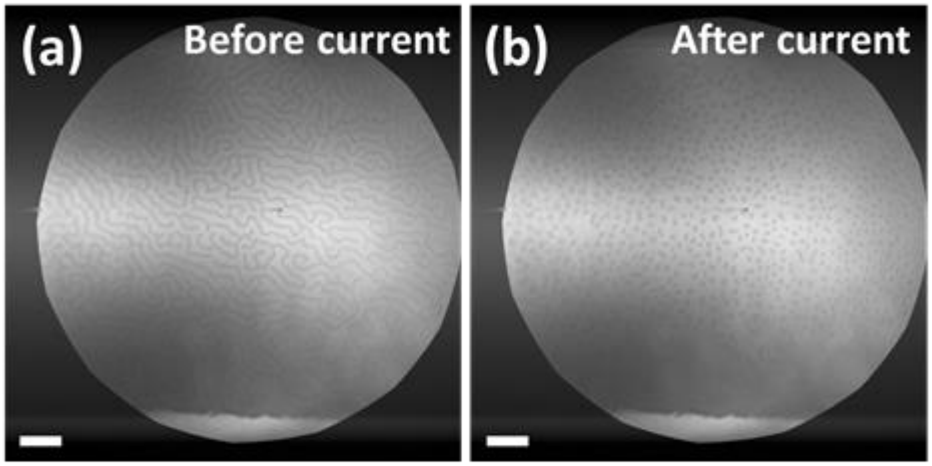

Figure 1: X-ray microscopy images of a [Co (0.7 nm)/ Ni (0.5)/ Pt (0.7)]N=30 sample in a magnetic field of 1800 Oe before (a) and after (b) a 50-µs-long current pulse of current density 50 MA/cm^2. (Scale bar = 1 µm)

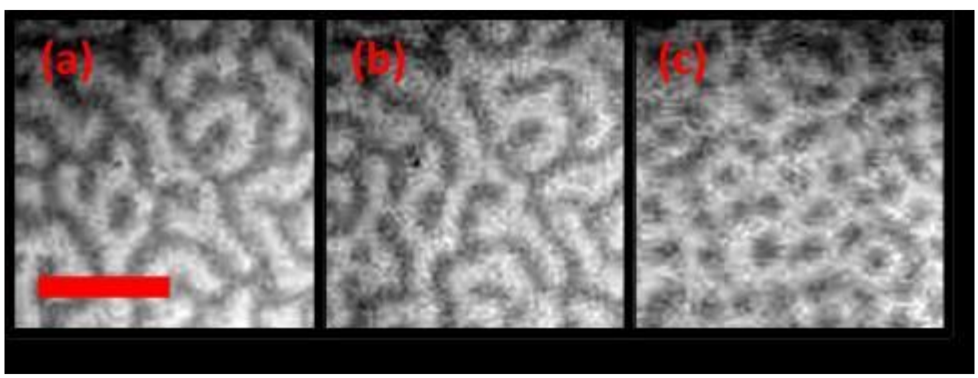

Figure 2: X-ray microscopy images in an out-of-plane magnetic field of 500 Oe, MTXM images (collected at the Co L-edge) of the magnetic features present in the [Co(0.7 nm)/ Ni(0.5 nm)/ Pt(0.7nm)]N=20 sample (a) before current pulses are applied, and after a current pulse of density 2.5 x 10^{11} A/m^2 was applied for (b) 50 µs and (c) 60 µs. (Scale bar = 500 nm).

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Invited 24: Thursday 24th, 12:00-12:30

Clusters with mutually orthogonal skyrmion tubes: theoretical prediction and real-space observation

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Magnetic chiral skyrmions are particle-like topological solitons with complex non-coplanar spin structures stabilized in noncentrosymmetric magnetic materials by specific Dzyaloshinskii-Moriya interaction (DMI). The energy contributions phenomenologically analogous to DMI also arise in chiral liquid crystals (CLC) [1,2].

The complex three-dimensional internal structure of isolated skyrmions (IS, Figure 1) and character of IS-IS interaction are imposed by a surrounding "parental" state, e.g., a state homogeneously magnetized along the field (repulsive interskyrmion potential [3]) or a conical phase with the wave vector along the magnetic field (attraction [4]).

Additionally, magnetic (or CLC) skyrmion tubes may orient either along or perpendicular to an applied magnetic field (to glass substrates). The first type of ISs (vertical skyrmions, marked by V in Figure 1) perfectly blend into the homogeneously saturated state whereas the second one (horizontal skyrmions) - into the spiral state. Then, a crossover between the two takes place for an intermediate value of an applied magnetic field (or carefully adjusted values of an electric field, surface anchoring, and film thickness in CLC) and enables complex cluster formation with mutually perpendicular arrangement of skyrmions (Figure 1).

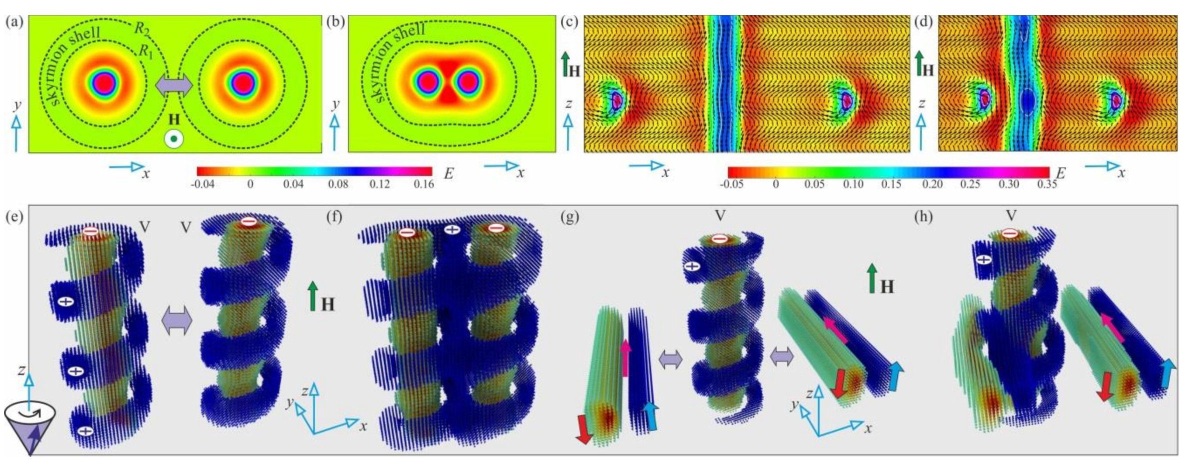

Figure 1: skyrmion clusters with mutually orthogonal skyrmion tubes.

Within the standard phenomenological model for magnetic states in cubic non-centrosymmetric ferromagnets and CLC, we systematize the principles of a field-driven cluster formation and closely investigate the structure of resulting skyrmion superstructures [5]. In particular, we show that horizontal ISs couple with the vertical ISs and form two configurations distinguishable in their pair energy and relative distance (Figure 1 (g), (h)). The regimes of IS-IS interaction are switched according to the angle of the surrounding conical phase. At the verge of the homogeneous state, the ISs develop repulsive interaction with distant mutual location. On the contrary, with the increase of the conical angle, the ISs enter an extreme regime of attraction leading to their undulations (Figure 2 (e)).

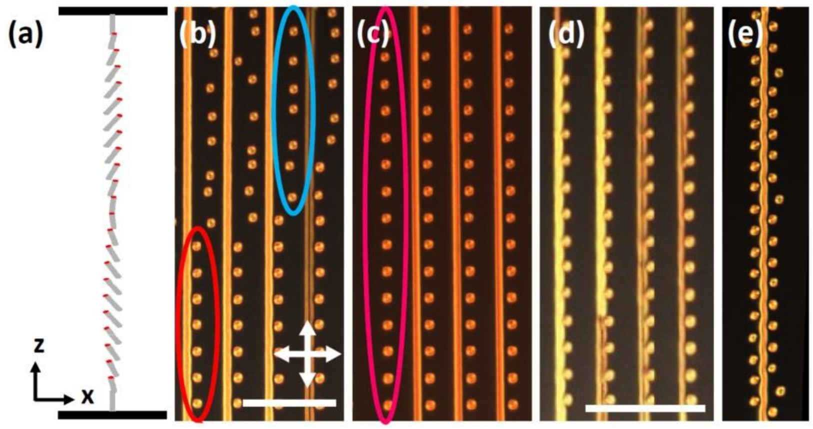

Figure 2: Experimental demonstration of orthogonal skyrmion interactions in chiral nematic liquid crystals. Vertical skyrmions within the red oval in (b) occupy the minimum of the interaction potential with the horizontal skyrmion located to the left. Vertical skyrmions in the blue oval in (b), however, have not overcome the potential barrier and are located at larger distances from the horizontal skyrmion to the left. These skyrmions are also distant from the horizontal skyrmion to the right owing to their very weak coupling. Such an anisotropic skyrmion interaction is additionally proven by the skyrmions in the pink oval of (c).

By employing analogies between the topology and energetics of CLC and ferromagnets, we have provided experimental evidence for the rich behavior of skyrmionic structures (Figure 2). We argue that despite the different length-scales on which they occur, the interacting horizontal and vertical skyrmions in LCs exhibit behavior closely matching that of the analogous skyrmions in the non-centrosymmetric B20 magnets. Our study further reinforces the notion that chiral LCs can be used as a model system for probing the behavior of skyrmionic structures on the mesoscopic scale. The aforementioned skyrmion traits do not only open up new routes for manipulating these quasi-particles in energy-efficient spintronics applications, but also highlight a paramount role of cluster formation within the A-phases of bulk cubic helimagnets near the ordering temperature (e.g., in B20 magnets MnSi and FeGe), the fundamental problem that gave birth to skyrmionics.

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Invited 25: Thursday 24th, 14:00-14:30

Spin-Orbit Torque in Ferri- and Antiferromagnetism

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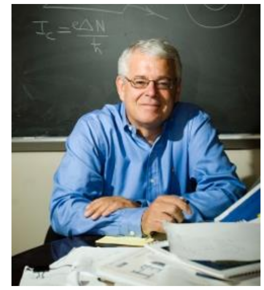
Energy dissipation has become a major challenge for today's electronics. With nonvolatile magnetic memory, logic and alike, leakage current may be minimized and the voltage scaling may be further advanced. Recent advances in the physics of spintronics have made spin-transfer torque, spin-orbit torque and voltage controlled magnetic memory devices possible. The operation speed of these above devices is limited by the ferromagnetic resonance frequency. Antiferromagnetic (AFM) and ferri-magnetic materials (FRM) offer the speed advantage to THz and in particular, insulating materials provide an additional advantage of low energy operation, allowing for information propagation in the form of spin current, spin waves, *i.e.*, magnons, like magnetic metals but without electrical charge current loss. First, I will discuss some of the recent progress and results. A topological insulator/AFM (MnTe) heterostructure will be described to show the use of the induced exchange bias via interface proximity effect to control the topological charge number via field cooling. Then, we will discuss the exchange coupling of the two sub-lattices of FRM and AFM, in particular, the heavy metal/TmIG bilayer as probed by XMCD (X-ray magnetic circular dichroism), neutron scattering, and anomalous Hall. The temperature and layer thickness dependences show the dominant exchange coupling of the Fe sublattice. Spin-orbit torque and switching of FRM will be illustrated in both Bi_2Se_3/GdFeCo and Pt/TmIC structures, showing the much-improved energy. Insulating AFM and FRM SOT offer advantageous spintronics devices. Likewise, the AFM and FRM Skyrmions offer the potential of using Skyrmions for low energy dissipation systems.

*The work was in part supported by ERFC-SHINES, MURI-ARO, TANMS, and NSF.

Invited 26: Thursday 24th, 14:30-15:00

Spin-Orbit Torques from a Microscopic Point of View



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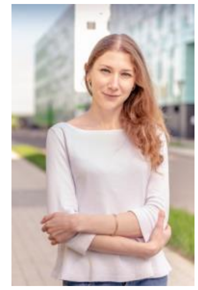
When a thin-film hybrid system is formed by placing a ferromagnetic metal layer on top of a heavy metal layer that has strong spin-orbit interactions, a lateral bias voltage drives a spin-current across the heavy-metal/ferromagnet boundary and influences the magnetization dynamics of the ferromagnet. Under some circumstances, this effect can [1,2] be described in terms of the spin-Hall conductivity, a bulk property of the heavy metal. More generally, the influence of the lateral bias voltage on magnetization dynamics is a joint property of the hybrid system which depends on the interplay between the transport steady state and collective magnetization dynamics. I will discuss i) when the spin-Hall effect picture is adequate and when it is not, and ii) whether or not it is misleading to apply the spin-Hall effect picture when it is not, strictly speaking, justified.

Figure 1: Inca people moving and spinning in response to the sun

[1] MI Dyakonov and VI Perel (1971). "Current-induced spin orientation of electrons in semiconductors". Phys. Lett. A. 35, 459.
[2] J Sinova, SO Valenzuela, J Wunderlich, CH Back, T Jungwirth. “Spin hall effects” Reviews of Modern Physics 87, 1213.

Regular 11: Thursday 24th, 15:00-15:15



Gilbert damping in low-dimensional magnetic systems: microscopic approach

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In recent years the field of spintronics attracts considerable attention owing to its potential to supersede functionality of modern electronic devices. However theoretical description of spin-orbit driven magnetization dynamics is usually given by a Landau-Lifshitz-Gilbert equation and require a proper theoretical description, particularly by a microscopic approach. In the current study, we derive a microscopic Kubo-Středa formula for the components of the Gilbert damping tensor and use the developed formalism to a two-dimensional Rashba ferromagnet in the weak disorder limit. The results of our calculations reveal that an exact analytical expression corresponding to the Gilbert damping parameter manifests linear dependence on the scattering rate and retains the constant value up to room temperature when no vibrational degrees of freedom are present in the system.

Regular 12: Thursday 24th, 15:15-15:30

Orbital-selective behavior and suppression of the double exchange in 4d and 4d transition metal oxides

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The 4d and 5d transition metal compounds attracts nowadays considerable attention due to their specific properties, such as large covalency, strong spin-orbit coupling, the possibility to observe topological effects, etc. Magnetic ordering in these systems often displays strong suppression of magnetic moments, becoming (much) less than the nominal ones. One usually explains this by single-site effects: possible role of the spin-orbit coupling, with orbital contribution opposite to the spin one, or by strong hybridization with ligands e.g. oxygens. We show that there exist in such systems an intersite mechanism which, in particular, can lead to suppression or at least strong reduction of magnetism: the orbital-selective formation of covalent bonds (molecular orbitals) between metal ions, leading to "exclusion" of corresponding electrons from magnetic subsystem [1,2]. Especially spectacular these effects are in the situation with noninteger electron occupation, in which case this mechanism leads to suppression of the famous double exchange – the main mechanism of ferromagnetism in transition metals and compounds, including well-known colossal magnetoresistance manganites [3]. We demonstrate this novel mechanism by analytical and numerical model calculations, and show by ab-initio calculations that it explains magnetic behavior of several materials, including $Nb_2O_2F_3$ and $Ba_5AlIr_2O_{11}$[1-3]. Special attention will be paid to $Ba_3CeIr_2O_9$, for which recent neutron and RIXS experiments demonstrates strong reduction of magnetic moments on Ir [4].

Our results thus demonstrate that the strong intersite interaction, typical for 4d and 5d compounds, may invalidate the standard single-site starting point for considering magnetism, and can lead to qualitatively different behavior. More specifically, they also show yet one more unexpected effect in the rich field of orbital physics.

*This work was supported by the Russian Science Foundation through Project No. 17-12-01207.

[1] S. V. Streltsov and D. I. Khomskii, Physics-Uspekhi 60, 1121 (2017).
[2] M. Harland, A. I. Poteryaev, A. I. Lichtenstein, and S. V. Streltsov, Phys. Rev. B 99, 045115 (2019).
[3] S. V. Streltsov and D. I. Khomskii, PNAS 113, 10491 (2016).
[4] A. Revelli et al., Science Advances 5, eaav4020 (2019).

Regular 13: Thursday 24th, 15:30-15:45

Topological-chiral magnetic interactions driven by emergent orbital magnetism

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O. GOMONAY[2], G. BIHLMAYER[1], S. LOUNIS[1],
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Exotic magnetic textures with particle-like [1] properties offer a great potential for innovative spintronic applications [2] and brain-inspired computing [3]. They can be stabilized by the intricate interplay between magnetic interactions of diverse origin. Magnetic skyrmions, two-dimensional localized solitons, are a prominent realization of chiral spin structures, first observed in the material class of non-centrosymmetric B20 bulk compounds [1]. One of the key ingredients for the formation of skyrmions is the Dzyaloshinskii-Moriya interaction (DMI) [4-5].

Here, based on microscopic arguments and systematic total energy expansion, further validated by first-principles density functional theory calculations, we discover a conceptually new class of chiral interactions between spins on triangular plaquettes that originate from the so-called topological orbital moment (TOM) of electrons, emerging as a result of finite scalar spin chirality $\chi = \boldsymbol{S}_i \cdot [\boldsymbol{S}_j \times \boldsymbol{S}_k]$, as depicted in Fig. 1. We refer to these interactions as topological-chiral interactions.

The first type of topological-chiral interactions is the rotationally invariant chiral-chiral interaction, which in its general form corresponds to the interaction between pairs of topological orbital currents in a magnet, just in analogy to Ampere's currents interacting with each other. The second type of topological-chiral interactions is the rotationally anisotropic spin-chiral interaction, which arises as a result of a direct coupling between the TOM and local spins, mediated by the spin-orbit interaction.

We show that new chiral interactions can dominate over the DMI, thus opening a path for the realization of new classes of chiral magnetic materials with three-dimensional magnetization textures such as magnetic hopfions.

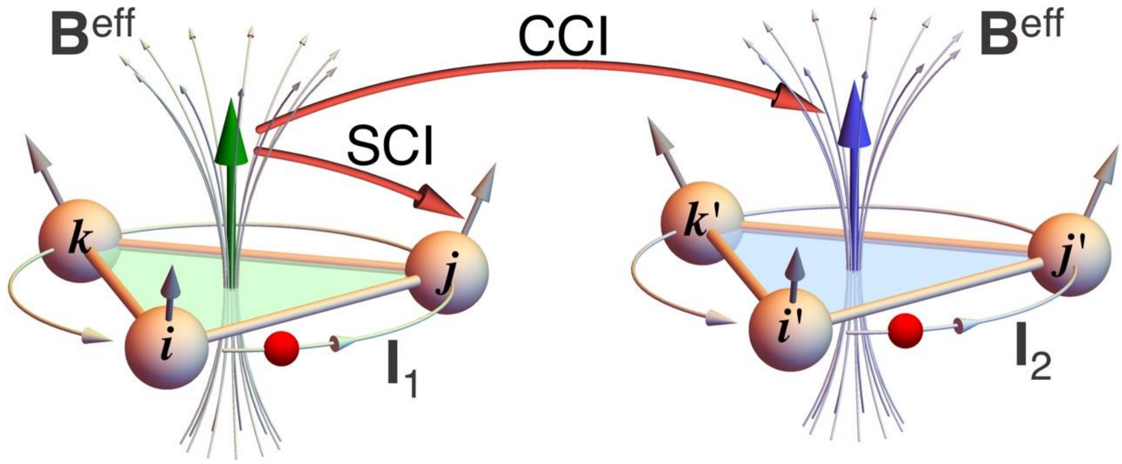

Figure 1: **Topological-chiral interactions.** In a magnet exhibiting a non-coplanar spin arrangement, the local scalar spin chirality between the triplets of spins, $\chi = \boldsymbol{S}_i \cdot [\boldsymbol{S}_j \times \boldsymbol{S}_k]$, can be interpreted as an effective magnetic field $\boldsymbol{B}^{eff}$ which gives rise to a so-called topological orbital moment (TOM, denoted by green and blue large arrows) generated by the orbital current of electrons hopping around the triangle, denoted as $\mathbf{I}_1$. The orbital currents $\mathbf{I}_2$ and $\mathbf{I}_2$, generated by different plaquettes of spins, can interact with each other, giving rise to the first type of topological-chiral interactions − the rotationally invariant chiral-chiral interaction (CCI). The second type of topological-chiral interactions − the spin-chiral interaction (SCI) − corresponds to the coupling between TOM and the local spins, mediated by the spin-orbit interaction.

[1] S. Mühlbauer, et al., *Skyrmion Lattice in a Chiral Magnet.* Science **323**, 915 (2009).

[2] A. Fert, et al., *Skyrmions on the track.* Nat. Nanotechnol. **8**, 152 (2013).

[3] G. Bourianoff, et al., *Potential implementation of reservoir computing models based on magnetic skyrmions.* AIP Advances **8**, 055602 (2018).

[4] I.E. Dzyaloshinskii, *Thermodynamic theory of "weak" ferromagnetism of antiferromagnetics.* J. Phys. Chem. Solids **4**, 241 (1958).

[5] T. Moriya, *New Mechanism of Anisotropic Superexchange Interaction.* Phys. Rev. Lett. **4**, 228 (1960).

[6] Y. Taguchi, et al., *Spin chirality, Berry phase, and anomalous Hall effect in a frustrated ferromagnet*. Science **291**, 2573 (2001).

Regular 14: Thursday 24th, 15:45-16:00

Photoinduced Rashba Spin-to-Charge Conversion via an Interfacial Unoccupied State

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At interfaces with inversion symmetry breaking, the Rashba effect couples the motion of the electrons to their spin; as a result, a spin charge interconversion mechanism can occur. These interconversion mechanisms commonly exploit Rashba spin splitting at the Fermi level by spin pumping or spin torque ferromagnetic resonance. Here, we report evidence of significant photoinduced spin-to-charge conversion via Rashba spin splitting in an unoccupied state above the Fermi level at the Cu(111)/α-Bi_2O_3 interface. We predict an average Rashba coefficient of 1.72×10^{-10} eV.m at 1.98 eV above the Fermi level, by a fully relativistic first principles analysis of the interfacial electronic structure with spin orbit interaction. We find agreement with our observation of helicity dependent photoinduced spin-to-charge conversion excited at 1.96 eV at room temperature, with a spin current generation of $J_s=10^6$ A/m^2. The present Letter shows evidence of efficient spin charge conversion exploiting Rashba spin splitting at excited states, harvesting light energy without magnetic materials or external magnetic fields.

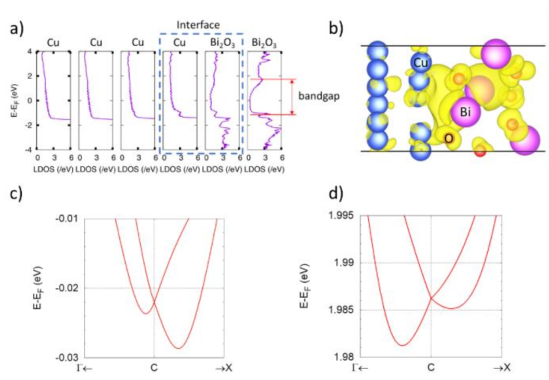

Figure 1: First-principles analysis of the Cu(111)/α-Bi_2O_3 interface

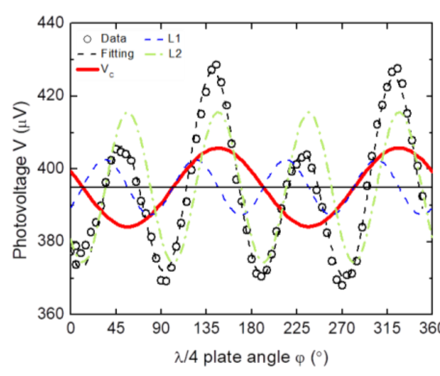

Figure 2: Helicity dependent photoinduced conversion

[1] J. Puebla et al. Phys. Rev. Lett. 122, 256401 (2019).

Invited 27: Thursday 24th, 16:30-17:00

Theory of Spin Transport and Torque in Non-Collinear Antiferromagnets

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Antiferromagnets have long remained an intriguing and exotic state of matter whose application has been restricted to interfacial exchange bias in spin-valves. A conceptual breakthrough was achieved ten years ago with the proposal that spin transfer torque could be used to electrically control the direction of the order parameter of AF spin valves [1], henceforth making these materials potential candidates for low energy spin devices [2]. The recent prediction and observation of current-induced switching of CuMnAs and Mn_2Au constitute a significant milestone towards the realization of antiferromagnetic memories [3]. In addition, recent theoretical and experimental progress has brought the attention on *non-collinear* antiferromagnets, which can display anomalous Hall effect under certain conditions [4].

In this presentation, I will explore the ability of non-collinear, but not necessarily coplanar, antiferromagnets for spintronics operation. In the first part, I will first introduce some basics concepts about spin and magnon transport in collinear antiferromagnets [5]. Then, I will discuss new results on the spin transport in non-collinear 3Q magnetic textures and show that their can promote (possibly quantum) anomalous Hall effect [6]. Afterwards, I will discuss the conditions under which collinear and non-collinear antiferromagnets can convey spin information through magnon currents or spin superfluidity. Finally, I will discuss the ability of such complex magnetic orders to support current-driven spin-orbit torque dynamics.

[1] A. S. Núñez et al., Phys. Rev. B 73, 214426 (2006).
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[3] Zelezny et al., Phys. Rev. Lett. 113, 157201 (2014); Wadley et al. Science 351, 587 (2016).
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[5] A. Manchon, J. Phys.: Cond. Matter. 29, 104002 (2017).
[6] P. Ndiaye et al., arXiv:1806.09114 (2018).

Invited 28: Thursday 24th, 17:00-17:30

Domain Walls dynamics in an Antiferromagnet

R. M. OTXOA[1,2], P. E. ROY[1], U. ATXITIA[6], R. RAMA[2,4], K. Y. GUSLIENKO[4,5], O. CHUBYKALO-FESENKO[7], J. WUNDERLICH[1,3]

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Magnetic domain wall dynamics in the layered antiferromagnet Mn_2Au, driven by field-like current-induced spin-orbit torques [1] is investigated by analytical theory and atomistic spin dynamics simulations. Our findings unveil the inertial character of the moving domain wall when the driving mechanism is of field-like torque type. Once the domain wall reaches velocities close to the maximum group velocity of the magnons, the natural response of the system is to nucleate a domain wall pair with trivial winding number preserving the overall topological charge. The impact of the new born domain wall pair is of great consequence onto the initially moving domain wall. We observe that, the system is able to sustain a moving domain wall at speeds higher than the maximum magnon group velocity revealing a supermagnonic regime of motion. We show that there is an emission of magnons which can be associated to the so-called spin-Cherenkov effect once the domain wall enters into the supermagnonic regime. Moreover, we propose to use the unique properties of moving antiferromagnetic domain walls; atomic scale confinement and ultrahigh velocity, to demonstrate that ultrafast antiferromagnetic domain wall motion produces giant spin-Peltier effect.

[1] J. Zelezny, H. Gao, K. Vyborny, J. Zemen, J. Masek, A.Manchon, J. Wunderlich, J. Sinova, and T. Jungwirth, Phys. Rev. Lett. 113, 157201 (2014).
[2] O. Gomonay, T. Jungwirth, and J. Sinova, Phys. Rev. Lett. 117, 017202 (2016).
[3] T. Shiino, S.-H. Oh, P. M. Haney, S.-W. Lee, G. Go, B.-G. Park, and K.-J. Lee, Physical review letters 117, 087203 (2016).

Invited 29: Thursday 24th, 17:30-18:00

Reservoir Computing with Random Magnetic Textures

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[1]Physics Department, Johannes Gutenberg University
[2]Intel Corp. (retired)

In this talk we will discuss how a random magnetic "fabric" composed of skyrmion clusters can be effectively employed to implement a computational technique known as *reservoir computing* [1]. This is achieved by leveraging the nonlinear resistive response of individual skyrmions to driving currents arising from the anisotropicmagneto-resistance effect (AMR). Time-varying current signals injected via contacts into the magnetic substrate are shown to be modulated by the fabric's AMR due to the current distribution following paths of least resistance as it traverses the geometry. By tracking resistances across multiple input/output contacts, we show how the instantaneous current distribution effectively carries temporally correlated information about the injected signal. This in turn allows us to numerically demonstrate simple pattern recognition.

We argue that the fundamental ingredients for such a device to work are threefold [2]: i) Concurrent probing of the magnetic state; ii) stable ground state; iii) nonlinear response to input forcing. Whereas this talk will only consider the use of skyrmion fabrics, the basic ingredients or reservoir computing will be argued to be general enough to spur the interest of the greater complex materials community to explore novel reservoir computing systems.

[1] G. Bourianoff, D. Pinna, M. Sitte, K. Everschor-Sitte, AIP Advances 8 (5), 055602 (2018).
[2] D. Pinna, G. Bourianoff, K. Everschor-Sitte, arXiv:1811.12623 (2019).

Friday October 25th

9:00 – 9:30
Invited 30: *Light induced dynamics in the antiferromagnetic Mott insulator* La_2CuO_4.
Jure DEMSAR Mainz U., Germany
9:30 – 10:00
Invited 31: *Stripe domains in Fe based thin films: magnetic texture, magneto-transport and magnetic coupling*.
Julian MILANO Instituto Balseiro, CAB-CNEA, Bariloche, Argentina
10:15 – 10:30
Regular 15: *Application of Iron Oxide nanoparticles for biogas production*.
Maria QUINTANA UNI, Lima, Peru
10:30 – 10:45 Coffee Break
10:45 – 11:15
Invited 32: *Harnessing the spin orbit interaction at various interfaces for the interconversion between spin and charge currents*
Laurent VILA Spintec, France

11:15 – 11:45 Lunch

12:00 – 18:30 Social event: Tour to Maras/Moray
Departure 12:30 from conference venue.
For Maras & Moray, the participants must buy their tickets upon arrival.
You can buy the full tourist ticket which is valid for 10 days and can allow you to visit up to 16 different sites. Or you can buy the partial tourist ticket which is valid for two days and allow to visit 4 different places. If you have time, we'd like to suggest: Pisac, Ollantaytambo and Chinchero. And of course Cusco city.
Tickets can be bought at the entrance of Ollantaytambo fortress, 5 minutes walk from the workshop venue

Invited 30: Friday 25th, 9:00-9:30

Light induced dynamics in the antiferromagnetic Mott insulator La_2CuO_4

A. R. POKHAREL[1], M. BEYER[2], M. OBERGFELL[1], S. Y. AGUSTSSON[1], T. DONG[1], G. LOGVENOV[3], I. BOZOVIC[3], Z. LENARČIČ[4], P. PRELOVŠEK[4, 5] & J. DEMSAR[1]

[1]Instit1Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany
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We study transient phenomena in the Mott insulator La_2CuO_4, the parent compound of the La-based cuprate high temperature superconductor, following excitation across the 2 eV charge-transfer gap with femtosecond optical pulses. Experiments are performed over several orders of magnitude in excitation density, exceeding 0.1 absorbed photons/Cu, by tracking the time-evolution of the broadband complex dielectric function. The changes in the complex dielectric function reveal a pronounced renormalization of the CT gap, accompanied by the light-induced mid-gap absorption, resembling the evolution of optical properties by chemical doping. However, we demonstrate, that even at the highest excitation densities, where in the case of comparable chemical doping a robust metallic state is realized, photodoped carriers remain largely localized in the antiferromagnetic background, underscoring the underlying Mott physics. The rapid, picosecond relaxation dynamics at low to modest excitation densities is attributed to geminate recombination of holon-doublon pairs via multi-magnon emission. At high excitation densities the bimolecular relaxation kinetics takes over, suggesting dissociation of holon-doublon pairs, likely due to the partial melting of the AFM background.

Invited 31: Friday 25th, 9:30-10:00

Stripe domains in Fe based thin films: magnetic texture, magneto-transport and magnetic coupling

N. ÁLVAREZ[1], M. BARTUREN[1], S. BUSTINGORRY[1], A. BUTERA[1], E. DE BIASI[1], M. EDDRIEF[2], S. FLEWETT[3], D. GOIJMAN[1], J. GÓMEZ[1], M. GRANADA[1], C. HEPBURN[2], L. LOUNIS[2], M. MARANGOLO[2], F. OTT[3], B. PIANCIOLA[1], G. RAMÍREZ[1], M. SACCHI[2], M. VÁSQUEZ MANSILLA[1], J. MILANO[1]

[1]Instituto de Nanociencia y Nanotecnología, CNEA, Argentina.
[2]Sorbonne Université, CNRS, Institut des Nanosciences de Paris, France.
[3]Laboratoire Leon Brillouin, CEA, France.

In magnetic systems, domain and pattern formation have attracted much interest since its understanding can be crucial for many technological applications [1]. The competition between short range exchange interaction, which promotes homogeneous magnetic configurations at small length scales, and the unavoidable long-range dipolar interaction, which favors inhomogeneous configurations at large length scales, is primarily responsible for pattern formation. One of these particular patterns is formed by weak magnetic stripe domains. This particular behavior occurs due to the presence of a perpendicular-to-the-film magnetic anisotropy (PMA) that induces to magnetic moments to not keep the usual in-plane configuration imposed by magnetostatics. The parameter Q defined as $Q = 2K_{PMA}/\mu_0 M^2$, where K_{PMA} is the strength of the PMA and $\mu_0 M^2/2$ is the demagnetizing energy (E_{dem}) for a magnetic thin film, helps us to measure how far the system is from a fully in-plane magnetic configuration ($Q < 0$). If $Q > 1$, PMA overcomes E_{dem}, so the magnetization points perpendicular to the thin films. However, if $0 < Q < 1$, there exists an intermediate stage where PMA competes with E_{dem}. In this case, the film presents self organized stripe-shaped magnetic domains with a very complex magnetic structure along the sample. This periodically modulated arrangement across the sample present domains pointing in the three spatial directions: Some of those domains remain pointing along the direction of the saturating field (M_H), other one perpendicular to the film plane (M_{perp}) and the last one forming closures domains (M_{CD}) in order to reduce the stray magnetic field.

In this work, we present results concerning to several aspects to stripe domains: i) the determination of the magnetic domain structure; ii) magnetoresistant effects and iii) magnetic coupling. The systems involved in this study are thin films of FePt, permalloy and $Fe_{0.8}Ga_{0.2}$. The first two kind of films were grown by sputtering at INN, Argentina and the last one by molecular beam epitaxy, MBE, at INSP, France.

In order to study the stripe magnetic texture, we have performed circular dichroism in x-ray resonant magnetic scattering, CDXRMS, (at Circular Polarization beamline in synchrotron ELETTRA) in $Fe_{0.8}Ga_{0.2}$ thin films, and neutron polarized reflectometry experiments, PNR, (at PRISM beamline in Leon Brillouin Laboratory), in FePt thin films. The asymmetry of the first order magnetic bragg peaks observed in the rocking curve [Figure 1(a)] of CXMRS experiments, when both circular polarizations are used, shows explicitly the existence of closure domains, which is a fingerprint of the presence of the weak stripe pattern. On the other hand, PNR experiments allow us to determine the $M_{//}$ behavior as a function of the thin film depth when the stripes are set. PNR indicates that $M_{//}$ is reduced respect to the saturated state, reaching the lower value at the middle of the film [Figure 1(b)].

Magneto-transport properties of $Fe_{0.8}Ga_{0.2}$ films are studied. The anisotropic magnetoresistance, AMR, dominates the low field behavior, which is extremely dependent on the magnetic domain configuration [2]. At room temperature, the AMR shows two different behaviors depending on the measurement configuration, i.e., when the stripes are oriented along the electric current (parallel geometry) the resistivity increases with the applied field (positive AMR) [Figure 1(c)], while for the electronic current flowing perpendicular to the stripes (perpendicular geometry) AMR is negative [Figure 1(c)]. Moreover, when the temperature is decreased, the AMR changes in sign for the parallel geometry while AMR is nearly temperature independent in the perpendicular geometry. A simple model considering parallel and series conduction, plus the temperature dependence of anisotropic magnetoresistance and domains configuration, gives an insight of the phenomenology of these experimental results.

In order to study the effects of stripe domains on the magnetic coupling, we have grown FePt/permalloy bilayers [3], where both alloys present stripe domains. Magnetic force microscopy, MFM, images show that the bilayer stray field is a convolution arising from the stripe pattern of both layers. However, as it is shown in Figure 1(d), the stripe domains are not aligned along the same direction. We can observe wide stripes that correspond to the permalloy, and the thin ones that are canted with respect to the permalloy stripes. This effect can be attributed to the influence of the dipolar stray field of the permalloy layer on the stripe structure of the FePt film.

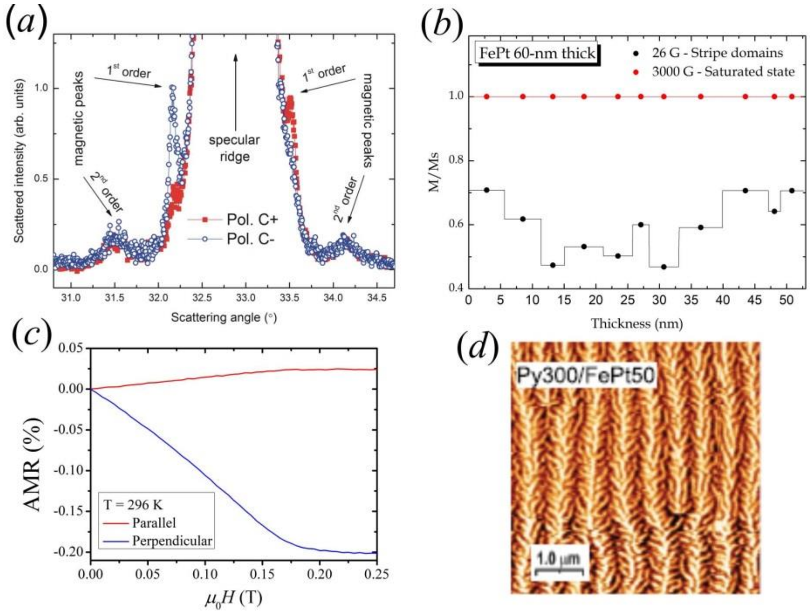

Figure 1: (a) CDXMRS rocking curve for $Fe_{0.8}Ga_{0.2}$ thin films. (b) $M_{//}$ profile from PNR measurements for FePt thin films at the stripe domain state and saturation. (c) AMR ratio (resistivity increases when positive) for $Fe_{0.8}Ga_{0.2}$ thin films. (d) MFM images for the FePt/permalloy bilayers.

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[2] Magnetotransport properties of $Fe_{0.8}Ga_{0.2}$ films with stripe domains. M. Granada et al., Phys. Rev. B 94, 184435 (2016).

[3] Magnetic coupling of stripe domains in FePt/$Ni_{80}Fe_{20}$ bilayers. N.R. Álvarez et al., J. Phys. D: Appl. Phys. 50 115001 (2017).

Regular 15: Friday 25th, 10:15-10:30

Application of Iron Oxide nanoparticles for biogas production

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Centro de desarrollo de Materiales Avanzados y Nanotecnologìa, Universidad Nacional de Ingenierìa

In the last few years nanomaterials applications are increasing, from medicine to electronics, energy is one of the most important. Biogas fulfills a double role, by generating cheap energy and giving an adequate use to organic waste [1]. However, production is often not very efficient, and we sought to improve it by using iron oxide nanoparticles [2].
In this work we will synthetize iron oxide nanoparticles and study the influence of their size, structure and morphology in the efficiency of biogas production. As well as the optimal conditions of operation for the biodigesters.
Iron oxide nanoparticles will be characterized by techniques such as XRay diffraction (XRD), Scanning Electronic Microscope (SEM), Dynamic Light Scattering (DLS) and Energy dispersive Xray Spectroscopy (EDS). The biodigesters were homemade and allow us to control the operating conditions for a complete study.

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[2] Moller, H. ; Sommer, S. ; Ahring, B.: Methane productivity of manure, straw and solid fractions of manure. En: Biomass and Bioenergy 26 (2004),

Invited 32: Friday 25^{th}, 10:30-11:00

Harnessing the spin orbit interaction at various interfaces for the interconversion between spin and charge currents

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While classical spintronics has traditionally relied on ferromagnetic metals as spin generators and spin detectors, spin-orbitronics exploits the interplay between charge and spin currents enabled by the spin-orbit coupling (SOC) in non-magnetic systems [1]. Spin-charge interconversion can be obtained through Spin Hall Effect and Inverse Spin Hall Effect in heavy metals such as Pt or W. Yet a more efficient conversion can be obtained by exploiting the direct and inverse Edelstein effects at interfaces where broken inversion symmetry induces a Rashba SOC or at surfaces of topological insulators. The resulting spin currents can give access to the electrical control of magnetic and resistance states in spintronic nanostructures [2] and this type of conversion is at the heart of the recently proposed magneto-electric spin orbit device of Intel [3].

In this presentation we will first discuss the possible comparison between Spin Hall and Edelstein Rashba [4] conversion efficiencies and then present our recent results obtained on Rashba interfaces and on surfaces of topological insulators.

We will in particular focus on two class of systems showing record spin-to-charge conversion efficiencies. The first class is based on the 2DEG appearing at the interface between STO/LAO with high spin-charge conversion rate at low temperature [5]. Moreover, a gate voltage can tune the amplitude and even sign of the inverse Edelstein length (cf figure). We will show that this record value can be much enhanced by tuning carefully the heterostructure and be mapped to the band structure of STO. The second class relies on the surface of topological insulators, here at room temperature, where the inverse Edelstein length of alpha-Sn [6] or HgTe [7] of 2 nm are clearly exceeding that of Bi based TI's reported so far. Moreover the HgTe thickness dependence of the conversion efficiency reveals peculiar features (cf figure), much different from that of spin Hall effect, and points toward the importance of coupling/decoupling the top and bottom surfaces of the topological insulators.

Finally we will propose a simple nanodevice (cf figure), where spin-to charge and charge-to spin interconversions can be studied in heterostructures that are similar to the one used generally for spin orbit torque experiments [8]. This allows one to access to the interface resistance, as well as the influence of different material insertions or material combination on the conversion efficiency of the chosen heterostructures.

This work has been done in collaboration with CNRS/Thales, Néel Institute, Leti/Dopt, ESPCI, Institut J. Lamour and LPS labs in France and the Universities of Geneva (Switzerland) and Halle (Germany).

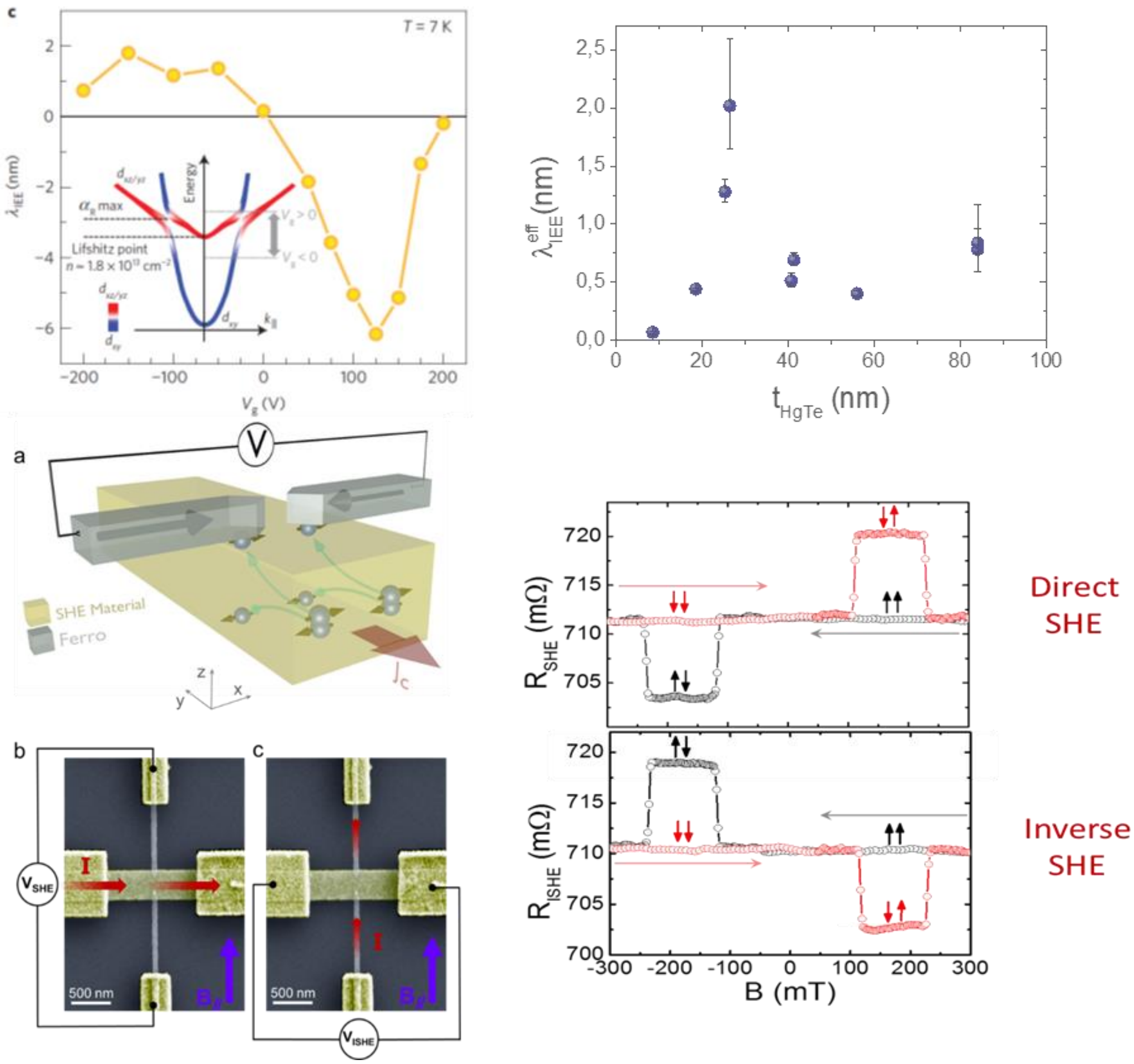

Figure: (top left) Inverse Edelstein length of the 2DEG measured at the interface of STO\LAO(2uc), and its modulation by a back gate voltage. (top right) Inverse Edelstein length measured at room temperature at the surface states of HgTe, as a function of the HgTe thickness. (bottom left) Schematics of the spin-charge interconversion device, and (bottom right) illustration of the Direct and Inverse SHE measurements..

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POSTERS

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Mingran XU — Institute for Solid State Physics, University of Tokyo, Japan

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Claudio GONZALEZ — Universidad Tecnica Federico Santa Maria, Valparaiso, Chile

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Junior Walder ALEGRE-SAENZ — Universidad Nacional de Ingeniería, Lima, Peru

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Boris DIVINSKIY University of Münster, Germany

P14. *Dipolar and anisotropic contributions to properly describe the magnetic properties of magnetic nanoparticles real systems*
Américo CUCHILLO Universidad de Atacama, Chile

P15. *Thermally activated magnetic relaxation in synthetic ferrimagnets: a transition-state-theory approach*
Heisember TARAZONA-CORONEL Universidad Nacional de San Marcos (UNMSM), Lima, Peru

P16. *Anomalous spin Hall effect in ferrimagnetic GdFeCo: unprecedented giant anomalous spin Hall angle*
David CÉSPEDES Universidad Nacional de Ingeniería (UNI), Lima, Peru

P17. *Thermal torque in double barrier tunnel junctions with magnetic insulators*
Christian ORTIZ-PAUYAC RIKEN, Japan

P1

Topological characterization of classical waves: The topological origin of magnetostatic surface spin waves

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Magnetostatic surface spin waves (a.k.a Damon-Eshbach mode) have long been known to have the largest decay lengths of all available modes and are robust against surface shapes and disorders [1,2]. Combined with their chiral and unidirectional propagation, these features remind one of topologically protected edge states of quantum Hall systems. We present a topological characterization of the dipolar spin wave Hamiltonian, which predicts, via the bulk-edge correspondence, the presence of robust surface spin wave modes without explicitly calculating eigenmodes of a system with boundaries [3].

While the characterization is based on the symmetry class CI of electronic topological band theory, it is reformulated for the particular dynamical structure of classical Hamiltonian systems in which symplectic, rather than unitary, structure plays an essential role. By suitably identifying the symplectic structure with the chiral symmetry of class CI, we show that the surface spin waves appear not in a gap of bulk frequency spectrum, consistent with the magnetostatic surface spin waves.

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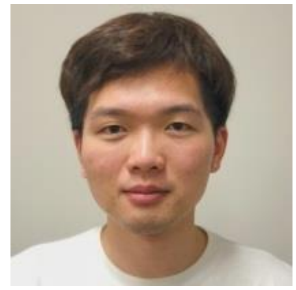
P2

Nonreciprocity of magnon phonon coupling driven by surface acoustic waves



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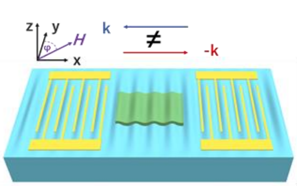
Nonreciprocity arises from the asymmetry of a system, which can give different transport properties of particles depending on the propagation direction. Starting from the invention of P-N diode, the nonreciprocal behavior has strongly influenced the electronic society. In digital circuits, high nonreciprocity suppresses the backscattering, enhancing transmission of information, improving the stability of the circuits. Further understanding of nonreciprocity is an essential building block for future electronic devices.

Our study focuses on the nonreciprocity in magnon phonon coupling driven by surface acoustic waves. In the presence of ferromagnetic materials, the mechanical oscillation of lattice can couple to the local magnetization, which, in the end, gives rise to the co-existing state of spin waves (SWs) and acoustic waves (AWs), known as magnetoelastic waves (MEWs). This unique state inherits merits from both SWs and AWs, presents long damping length, high propagating speed and the ability to deliver information.

a)



b)

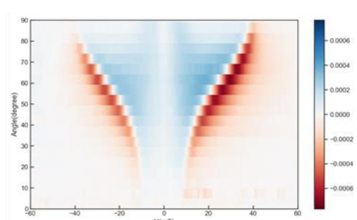


Figure: a) schematic of nonreciprocity of the wave propagation. b) the angular variation of the acoustic waves attenuation with respect to applied external magnetic field.

In our experiment, we pass Rayleigh-type surface acoustic wave through three independent ferromagnetic thin films (Permalloy, Nickle, CoFeB), triggering the MEWs. Unlike the general case, we observed strong asymmetry in the magnon phonon coupling depending on the wave direction (as depicted in fig. 1 a, b). We assign this nonreciprocal behavior to the collective effect of the Maekawa-Tachiki coupling **[1]**, chirality in Rayleigh type AWs and magnetic anisotropy.

Considering the potential of MEWs holds, the strong nonreciprocity observed in our experiment, may represent a step forward to improve the SWs based logic device, leading to the SWs diode and AWs diode.

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P3

Theory for spin torque in Weyl semimetal with magnetic textures

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The application of topological properties has attracted research interest to more efficiently manipulate magnetization. For instance, at the interface of the topological insulator and the ferromagnetic insulator, the electrical control of magnetic textures [1], magnetization switching induced by electric current [2], and spin-charge conversion [3] have been studied theoretically and experimentally. Recently, Weyl semimetals have been proposed as a new class of topological material characterized by gapless points in the bulk—the so-called Weyl nodes—. Close to the Weyl nodes, excitation can be described by a three-dimensional linear dispersion which is an analog of the Weyl fermion in high-energy physics. In particular, the Weyl semimetal realized by spontaneous ferromagnetism possesses both topological and magnetic properties, and thus may be a promising candidate for application to spintronics devices such as a race-track memory.

In this work, we theoretically study the spin-transfer torque and analyze the dynamics of the magnetic domain walls in magnetic Weyl semimetals. Owing to the strong spin-orbit coupling in Weyl semimetals, the spin-transfer torque can be significantly enhanced, because of which they can provide a more efficient means of controlling magnetic textures. We derive the analytical expression of the spin-transfer torque and find that the velocity of the domain wall is one order of magnitude greater than that of conventional ferromagnetic metals. Furthermore, due to the suppression of longitudinal conductivity in the thin domain-wall configuration, the dissipation due to Joule heating for the spin-transfer torque becomes much smaller than that in bulk metallic ferromagnets. Consequently, the fast-control of the domain wall can be achieved with smaller dissipation from Joule heating in the Weyl semimetals as required for application to low-energy-consumption spintronics devices.

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P4

Spintronics theory without spin current

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Linear response theory of spin-charge conversion effects in spintronics is presented in terms of correlation functions of physical observables, spin and electric current. Direct and inverse spin Hall effects and spin pumping effect are studied considering metallic systems with random spin-orbit interaction and spatially nonuniform Rashba interaction[1]. The theory is free from ambiguity associated with spin current, and provides a clear physical picture of the spin-charge conversion effects. In the present approach, the spin current transmission efficiency is essentially the nonuniform component of ferromagnetic susceptibility. Spin transport though an antiferromagnetic insulator is also studied (Fig. 1) [2]. Transport efficiency is calculated by evaluating correlation function of ferromagnetic component of antiferromagnet (susceptibility) in the magnon representation taking account of an auxiliary field imposing a constraint of a constant Néel vector. If time allows, a unified theoretical description of spintronics effects in terms of an effective gauge field for electron spin [3] is to be mentioned.
Support by KAKENHI from The Ministry of Education, Culture, Sports, Science and
Technology (MEXT), Japan is acknowledged.

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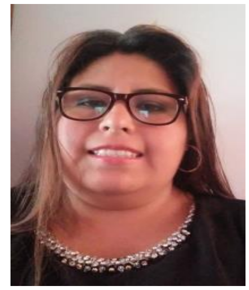
P5



Study of magnetic coupling in multilayers Fe/Ti/Fe

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In the last decades, the magnetic multilayers are studied with great interest both in the scientific and technological field for spintronics applications. In particular, the synthetic antiferromagnetic multilayers (SAF) have been widely studied due to their wide application in magnetic recording technology [1]. The SAF consist of two layers of ferromagnetic materials separated by a non-magnetic layer, whose properties are controlled by a bilinear coupling mechanism [2]. However, the biquadratic exchange coupling and the easy magnetic distribution of the axes in the interface are also relevant in some systems [3], but until now they cannot be completely understood. In the present work, we study the Fe / Ti / Fe multilayer system, grown on substrates of Si (111) varying the thickness of the magnetic and non-magnetic layers between 2 nm to 3.4 nm and 0.6 nm to 46 nm, respectively. After studying the magnetic response of the systems, we determine the optimal thicknesses for which the antiparallel coupling of the magnetic moments of the Fe layers is stronger, showing the hysteresis loops characteristic of this type of couplings [4]. The synthesis of these materials was carried out using the confocal magnetron sputtering technique; while the magnetic characterization was carried out with a vibrating sample magnetometer with measurements in the plane and as a function of temperature.

M. Z. Pinto. thanks to CONCYTEC for the financial support through the Doctoral Programs for Peruvian Universities (contract number Nº 218-2014-FONDECYT). J. Q.-M., V. A. P.-R., C.V.L. and M.Y. are grateful to CIENCIACTIVA (CONCYTEC) for partial financial support through its Excellence Center Program.

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P6

Magnetic properties in Fe/Ag magnetic multilayers

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Nowadays, magnetic multilayers separated by no magnetic spacer layer have been widely investigated in different research groups that show interesting theoretical and experimental works [1]. It is because, magnetic multilayers have different applications, and one of them is in the magneto resistive field. Their magnetic properties are strongly dependent of their structure and composition, it was determine by growth conditions using during fabrication [2].

In this context, Fe/Ag multilayers were prepared using magnetron sputtering technique on glass substrate. Different thickness as a buffer, no magnetic spacer layer (Ag) and layers number, were varied for verified how their magnetic properties change [3]. Physical properties of Fe/Ag multilayers depend on the surface and interface quality, for this reason atomic force microscopy (AFM) studies were made. The analysis of the hysteresis loop were performed using vibrating sample magnetometer applying a parallel and perpendicular field, furthermore for improve the magnetic analysis, magnetic measurements were made varying the temperature in a range of 50 – 300 K. In addition, studies of the crystal orientation related to the magnetic properties of this structure were made by X-ray diffraction.

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P7

Strain effect on the magnetism of $CaMnO_3$

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Bulk $CaMnO_3$ (CMO) has an orthorhombic crystalline structure and is weak ferromagnetic below T_N ≈120K [1]. This structure can be described, in the pseudocubic approximation, with a a_c≈3.73Å lattice parameter. Ab-initio calculations have recently shown that the magnetic behavior of CMO depends on surface conditions. In fact, Keshavarz et al [2] demonstrated that the Mn atoms at the surface and the sub-surface of the compound are very sensitive to structural changes, giving rise to ferromagnetic couplings. Additional experimental results made by Chandrasena et al [3] over a set of thin films of CMO, showed a substantial change of the valence state of Mn atoms due to the effect of strains between the substrate and the film.

With the aim of studying the effect of substrate-induced strains onto the magnetic behavior of CMO thin films we grew a series of samples by pulse laser deposition onto $SrTiO_3$(001) single-crystalline substrates. In order to examine the effect of strains on the magnetism of CMO, the film's thickness was varied from 3nm to 30nm.

Structural, magnetic and electric measurements were performed to characterize the sample's properties. The film's structure, analyzed by X-ray diffraction and transmission electron microscopy (TEM) measurements, reveals a strongly textured growth along the (00k) direction (see Fig.1) and remarkable substrate-induced strains effects on the lattice parameters of the compound. The mismatch between bulk CMO a_c≈3.73Å and SrTiO3 a_{STO}≈3.905Å lattice parameters is 4.8%. Due to the considerable mismatch, two main regions can be observed in the TEM images, with a significant variation of the lattice parameter of CMO. Near the interface both the in-plane (IP) and out-of-plane (OOP) parameters are larger than the bulk value and match the STO lattice parameters. 2nm away from the interface, the film's structure relaxes and the lattice parameters reduce to the bulk values. The magnetic properties of the films were found to be strongly dependent of their thickness, t. Magnetization loops, measured with a SQUID magnetometer and low temperature, reveal a strong enhancement of the saturation magnetization, Ms, for the thinner films. The Ms exhibits a sharp drop as the film´s thickness decreases to t~8nm, decreasing smoothly to a minimal value of 50emu/cm^3 at 30nm (see Fig. 2). The different magnetic behaviours observed in the $CaMnO_3$ thin films are discussed in terms of structural distortions and local composition variations within the layers.

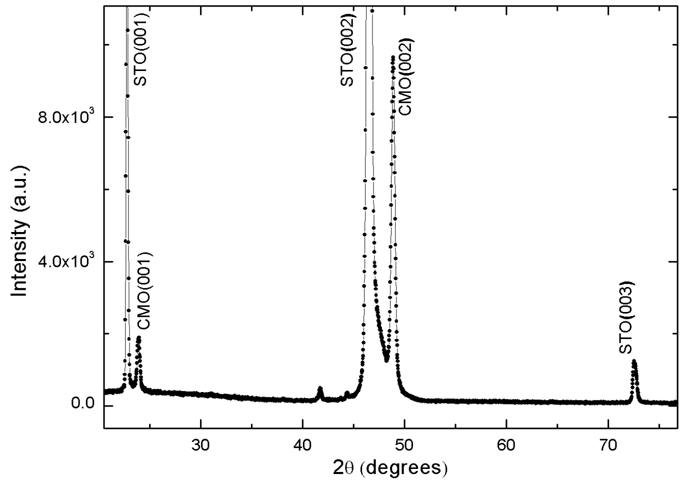

Figure 1: X-ray diffraction pattern of an CMO film of 30nmdeposited on STO(001) single-crystalline substrate.

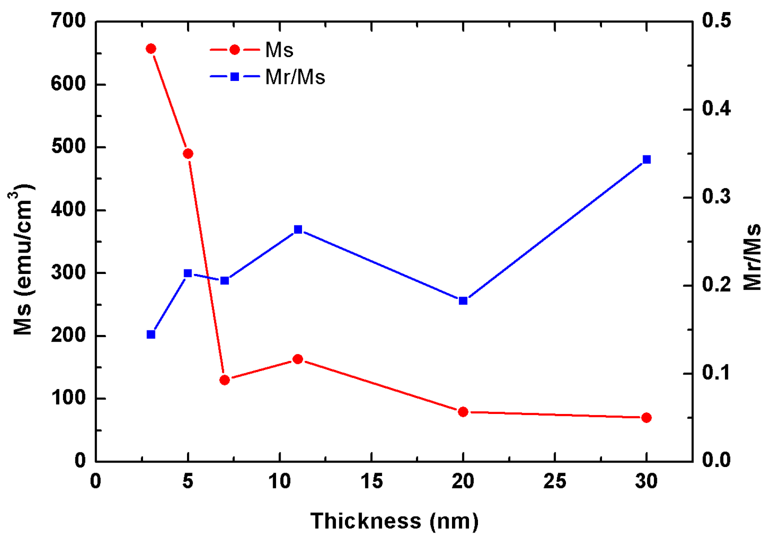

Figure 2: Variation of Ms (red dot) and normalize Mr (blue square) with films' thickness.

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P8

Tuning skyrmion Hall effect via engineering of spin-orbit interaction.

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Quantum relativistic effects in heavy metals couple the spin and orbital motion of electrons via the spin-orbit interaction (SOI). The latter has been widely used in magnetic systems to provide a universal energy-efficient way to convert charge to spin currents and exploited together in broken inversion symmetric systems in combination with the chiral Dzyaloshinsky-Moriya interaction for the stabilization of novel classes of topological materials such as chiral domain walls and magnetic skyrmions. A magnetic skyrmion is particle-like, nanoscale, whirl spin texture exhibiting unique real-space topological characteristics, that makes it very promising information carrier for future non-volatile, energy-efficient, ultra-dense spintronic memory and logic devices. However, their integration in such applications is hampered by the undesirable so-called skyrmion Hall effect (SkHE) - a transverse motion to the direction of current flow. Therefore, to ensure robust electrical manipulation of magnetic skyrmions in spintronic applications, there is need to explore ways of overcoming this undesirable SkHE in nanostructures.
We demonstrate that the Magnus force acting on magnetic skyrmions can be efficiently tuned via modulation of the strength of spin-orbit interaction. We show that the SkHE, which is a direct consequence of the non-vanishing Magnus force on the magnetic structure can be suppressed in certain limits. Our calculations show that the emergent magnetic fields in the presence of spin-orbit coupling (SOC) renormalize the Lorentz force on itinerant electrons and thus influence its topological transport as illustrated in Figure 1. In particular, we show that for a Néel-type skyrmion and Bloch-type antiskyrmion, the SkHE can vanish by tuning appropriately the strength of Rashba and Dresselhaus SOCs, respectively. Our results open up alternative directions to explore in a bid to overcoming the parasitic and undesirable SkHE for spintronic applications.

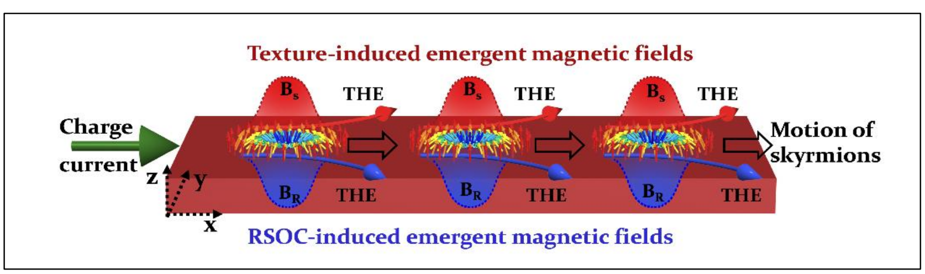

Figure 1: Schematic illustration of the current-driven motion of Néel-type skyrmions array in the presence of Rashba SOC. The texture induced emergent magnetic field $\mathbf{B}_s$ (red) and Rashba SOC induced emergent magnetic field $\mathbf{B}_R$ (blue) produces opposite topological Hall effect (THE) on traversing electrons.

P9

Tunable emergent phonons in magnetic skyrmion-like crystals distorted by coupled magnetoelastic fields

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Skyrmion crystals (SkX) are periodic alignment of magnetic skyrmions, i.e., a type of topologically protected spin textures. Compared with ordinary crystals, SkX and other skyrmion-like crystals can be drastically deformed under anisotropic effects [1] because they are composed of field patterns whose deformation does not cause any bond-breaking. This exotic ductility of SkX bring about great tunability of its collective excitations called emergent phonons, which are vital for magnonics application.
Here we systematically study the effect of anisotropic deformation on the emergent phonons of SkX and other skyrmion-like crystals such as Anti-SkX, where the anisotropic deformation can be induced by an intrinsic exchange-anisotropic, a tilted magnetic field [2], or a uniaxial mechanical distortion of the underlying materials. To process, we establish a systematic approach to determine the deformation of any emergent crystalline states[3], and then derives from it the basic equations of lattice dynamics for magnetic emergent crystals[4]. We show that all aspects of the emergent phonons, including their modes of vibration, spectrum, anisotropy of dispersion relation, etc., are thoroughly affected by the deformation, which shows great tunability. Our results show that skyrmion-like crystals are promising for magnonics applications with great tunability.

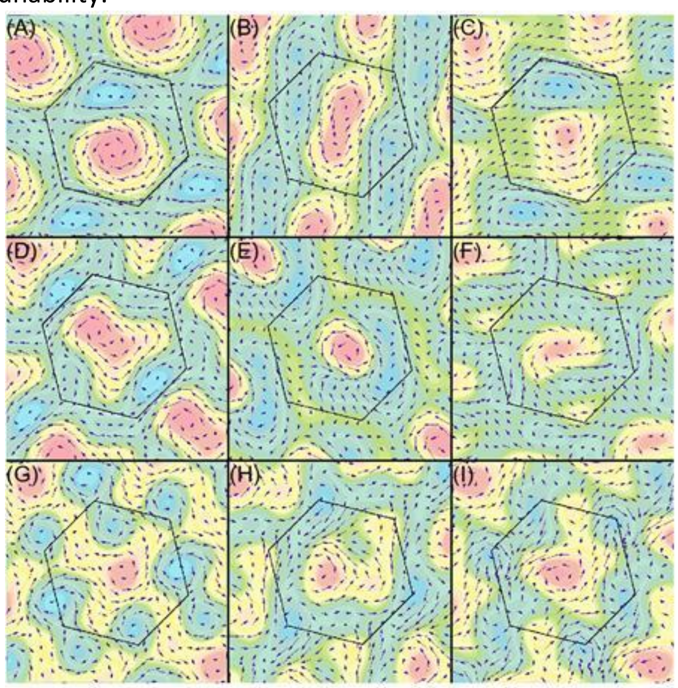

Figure 1: The first 9 orders of emergent phonon excitations of SkX at long wavelength when a tilted magnetic field with 45° tilting angle is appled

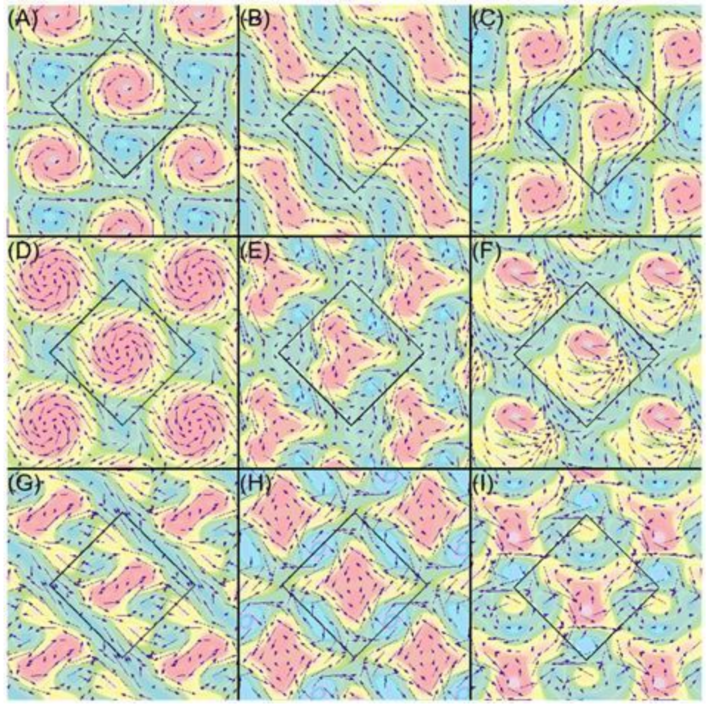

Figure 2: The first 9 orders of emergent phonon excitations of SkX at long wavelength when a negative exchange anisotropy is considered, which leads to a triangle-square structural transition.

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Magneto-optical detection of spin-orbit torques with oblique light incidence angle

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Experimental techniques for the accurate quantification of spin-orbit orbit torques (SOTs) are crucial for the progress of applied spintronics. Up to date, the detection of SOTs has been largely dominated by electrical methods, like Second Harmonic Generation [1] and Spin-Torque Ferromagnetic Resonance [2]. However, the interpretation of the data in these cases is difficult since requires the consideration of a variety of potential artifacts originated from magneto-transport, thermo-electric and spin-to-charge conversion effects. Magneto-optical detection of SOTs, on the other side, has arisen as an alternative strategy to solve the above mentioned problems, since it can probe the magnetization reorientation in a more direct way, naturally unaffected for these artifacts.

In this work we demonstrate the magneto-optical detection of the spin-current generated by the Spin Hall Effect in a Pt layer, injected into adjacent layer of NiFe (81% Ni and 19% Fe composition). The damping-like component of SOT acts as an effective field over NiFe magnetization. The quantification of magnetization tilting let us estimate the effective DL field and ultimately the spin hall angle of Pt, which resulted to be θ_{SH}=0.088 ± 0.006, falling inside the range of previously reported values.

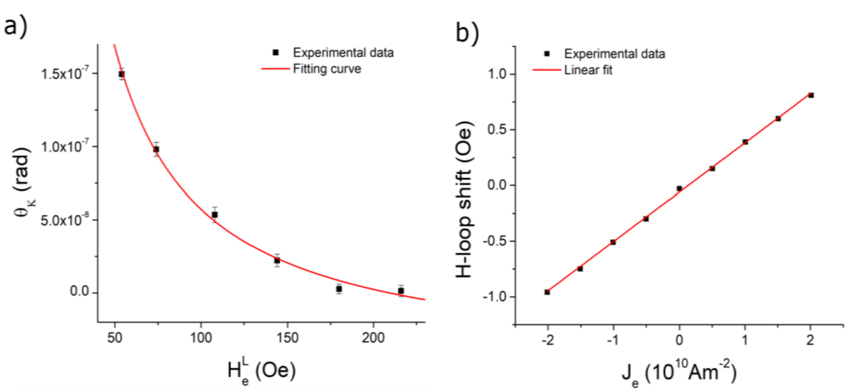

Figure 1: (a) Measured Kerr rotation (θ_K) vs magnitude of longitudinal magnetic field (H^L_e) in a NiFe(10nm)/Pt(7nm) bilayer stripe subjected to a current density Je= 2.5×10^{10}Am^{-2}, the fitting model is based on reference [3]. The fitting model is based on reference [5]. (b) Hysteresis loop shift vs current density for the same stripe.

Respect to previously published similar works [3,4], our method employs oblique incidence angle, which allow us also to quantify the in-plane component of the Oersted by hysteresis loop shift measurements, without modifying the optical set-up. This, in turn, was employed for correct calibration of the current density in Pt (J_e=2.5x10^{10} Am^{-2}), without additional assumptions for equivalent electrical circuit for the NiFe/Pt bilayer.

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P11

Study of cobalt nanomagnetic patterns for the stabilization of magnetic skyrmions

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Magnetic skyrmions are small quasiparticles which can be created in thin ferromagnetic films and patterned magnetic nanostrcutures and is associated principally to the influence of the Dzyaloshinskii-Moriya (DMI) interaction. The stability of magnetic skyrmions depend largely on its topological properties and is characterized by a topological load and helicity. Magnetic skyrmions are suitable for applications in storage and logical technologies such as spintronics and skyrmionic [1-3]. In this work we study the effect of the cutting angle from the center to the border of a cobalt nanodisc of 2 nm thick and 128 nm of diameter, on the stability of magnetic skyrmion. We started from a vortex-like skyrmion (VL) located 32 nm below the center of the disc, except for a cutting angle of 0° wich is located at the center of the disc. The figure shows the anisotropy constant versus the DMI constant for cutting angles of 0°, 15°, 120°, and 180°. It is found that by increasing the cutting angle from 0° to 120⁰, the area for stable skyrmions decreases, however at 180° the area for stable skyrmions increases strongly. Since the shape anisotropy in the disc is changing with the cutting angle, we can explain the stability of the magnetic skyrmions in function of the variation of the demagnetizing energy.

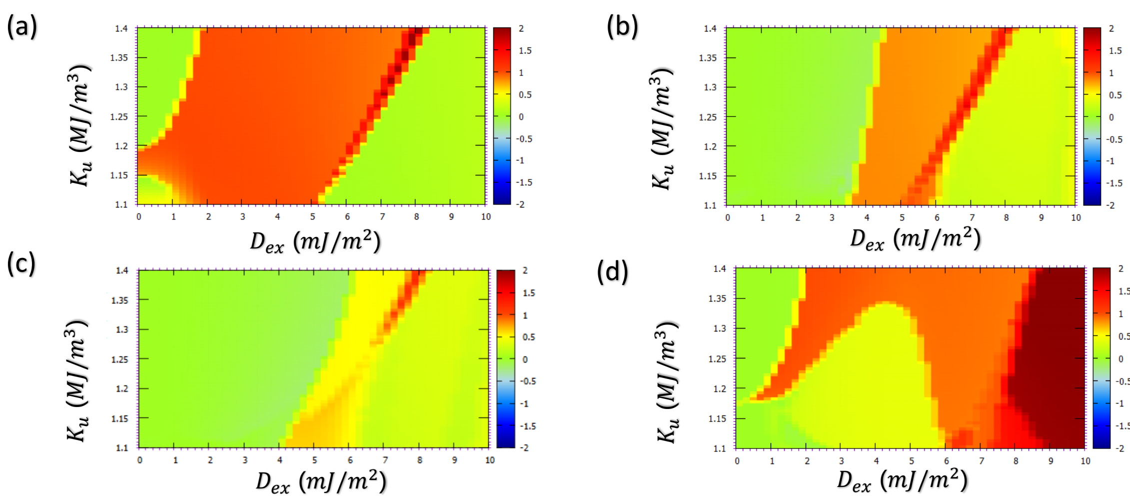

Figure: Skyrmion number phase diagrams with a skyrmion VL initial state of 128 nm in diameter for 0° (a), 15° (b), 120° (c), and 180° (d).

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Study of semicircular cobalt disks for the stabilization of magnetic skyrmions

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Simulations of the magnetic properties for semicircular cobalt disks have been carried out by using MuMax^3[1], an open-source GPU-accelerated micromagnetic simulation program. Magnetic skyrmions are whirl-like magnetic quasiparticles on the sub-micrometer scale. Each skyrmion is characterized by a topological charge S_k which imposes an energy barrier that protects a skyrmion from annihilating to the ferromagnetic ground state. Semicircular magnetic elements of cobalt were set to one of these three magnetization states prior to each simulation: vortex-like (VL), hedgehog (HG) or uniform perpendicular magnetization. Slightly different shapes, at their width, semicircular shape (SS) and elongated semicircular shape (ESS) were put in contrast (figure 1). Skyrmions phase diagrams were performed from both geometries. The stability of the magnetic skyrmions is studied by varying the perpendicular magnetic anisotropy (PMA) and the Dzyaloshinskii-Moriya-interaction (DMI). Skyrmion numbers, corresponding to the topological charge, are calculated in all final states and confirm the occurrence of isolated, stable, axially symmetric skyrmions for several combinations of DMI and anisotropy constant (figure 2).

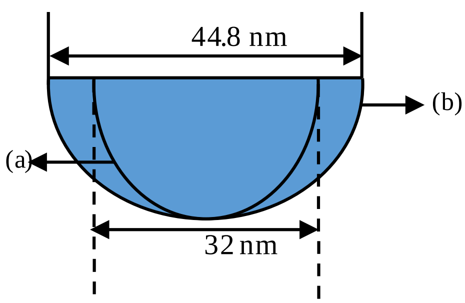

Figure 1. Geometric representation of the micromagnetic pattern where (a) is the 32 nm half-disk (SS) and (b) is the 40% elongated half-disk on its longest axis (ESS).

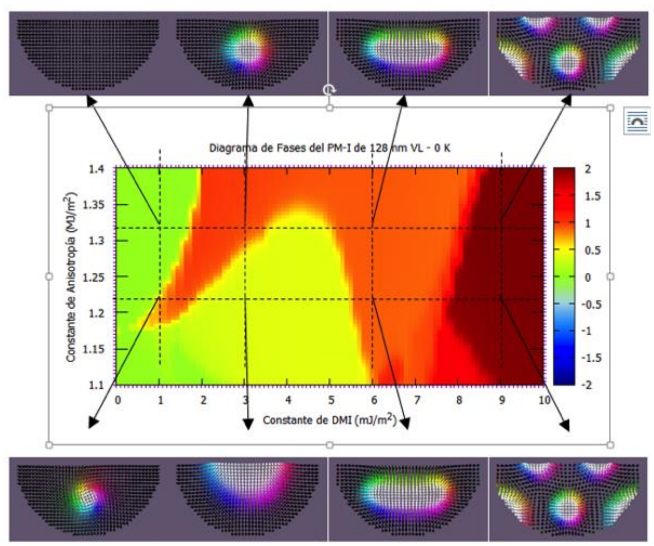

Figure 2. Evolution of the magnetization of the SS of 128 nm in diameter, with initial magnetization VL, for the values of $K_u = 1.2\ and\ 1.3\ MJ/m^3$, and $D_{ex} = 2, 4, 6\ and\ 9\ mJ/m^2$.

P13

Magnons driven by the spin-orbit torque

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Recent theoretical studies suggest that spin orbit-torque (SOT) can drive the magnon gas into a quasi-equilibrium state described by the Bose-Einstein statistics with non-zero chemical potential, suggesting the possibility of electrically-driven Bose-Einstein condensation (BEC) of magnons [1]. Variations of the chemical potential of the magnon gas were recently detected in measurements of spin relaxation rates of a nitrogen-vacancy center in diamond coupled to spin waves in a magnetic insulator [2]. However, there was no direct experimental evidence that the magnon gas driven by SOT forms a quasi-equilibrium distribution, and the dependence of the effective thermodynamic characteristics has not been established.

Here, we study the effects of SOT on the magnon distribution in Permalloy (Py) over a broad spectral range, by utilizing the micro-focus Brillouin light scattering (BLS) spectroscopy. Pure spin current is injected into Py due to the spin-Hall effect in the adjacent Pt layer. The BLS spectra, reflecting the current-dependent spectral density of magnons, allow us to analyze the spectral magnon population function and determine the thermodynamic characteristics of the magnon gas. Our analysis clearly indicates that the magnon distribution can be described by the Bose-Einstein statistics expected for the quasi-equilibrium state. We determine the current-dependent chemical potential and the effective temperature of the magnon gas, and show that, for one polarization of the spin current, the effective temperature of the magnon gas becomes significantly reduced, while the chemical potential stays almost constant (Figure 1a). In contrast, for the opposite polarization, the effective temperature remains nearly unaffected, while the chemical potential linearly increases with current, until it closely approaches the lowest-energy magnon state (Figure 1b), indicating the possibility of spin current-driven Bose-Einstein condensation [3].

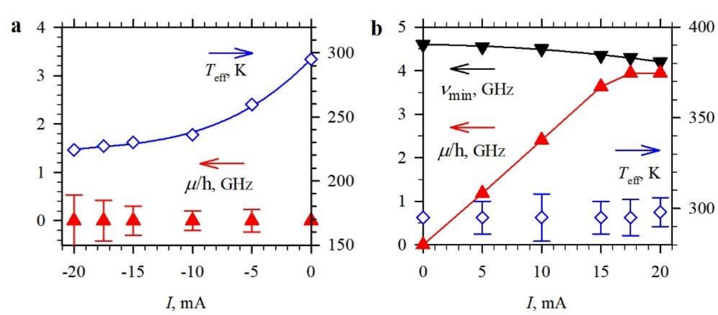

Figure 1: Current dependences of the chemical potential in the frequency units (point-up triangles) and of the effective temperature (diamonds) of the magnon gas for I<0 (a) and I>0 (b). Point-down triangles in (b) show the frequency of the lowest-energy magnon state.

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P14

Dipolar and anisotropic contributions to properly describe the magnetic properties of magnetic nanoparticles real systems

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The magnetic properties of a real system of magnetite nanoparticles with controlled interparticle distances via a silica shell are modeled by the modification of existing theoretical models that describe ideal non-interacting superparamagnetic systems. In this work, the variation of the blocking temperature as a function of the interparticle separation is explained through a phenomenological model where the interaction is taken into account through a dipolar field that modifies the intrinsic anisotropy field of the system. Moreover, it is observed that the field-dependent magnetization of the studied samples does not fulfill the universal scaling law of superparamagnetic systems, in which the magnetization is well described by the classic Langevin model, even for the less interacting samples. However, when the actual temperature of the system is modified by a temperature factor comprised by two terms that account for dipolar and anisotropy contributions, the magnetization curves satisfactorily comply with the scaling law. The results suggest that the interaction increases the anisotropy barrier and the developed approach allows to distinguish the effect of this contribution from the anisotropic contribution on the magnetic properties studied in this system.

P15

Thermally activated magnetic relaxation in synthetic ferrimagnets: a transition-state-theory approach

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As the size of magnetic nanosystems decreases, the thermal fluctuation phenomenon becomes very crucial to determine the magnetic properties of these kind of systems. This phenomenon plays a key role in information storage because it can promote transitions between different magnetic states, thereby causing loss of information. In this sense, synthetic ferrimagnets, which are very attractive for spintronics devices, are an example of such systems, where relaxation between different stable magnetic states are thermally activated.

Synthetic ferrimagnets consist, in general, of two thin ferromagnetic layers with strong perpendicular anisotropy, that are antiferromagnetically exchange-coupled by a nonmagnetic spacer. In this kind of systems it is possible to find out four stable magnetic states [1] which correspond to minima in its energy landscape. The stability of these states depends on several factors such as external applied magnetic field, magnetic anisotropy, and temperature. In general, these states can make a transition from one state to another promoted by thermal fluctuations. The study of these transitions is a very challenging issue that cannot be tackled by traditional micromagnetic methods due to the sizes and timescales involved in such phenomena. Thus, we choose the transition-state-theory as an alternative method to study this phenomenon because it allows to work with timescales of the same order of magnitude as those corresponding to the experiments. Furthermore, this method uses energy barriers, obtained from the energy landscape, to calculate the temporal evolution of the probabilities in each state. In this work the transition-state-theory is developed for two magnetic moments (each ferromagnetic layer represented by a macroscopic magnetization) in which we have defined the potential energy surface as a function of the magnetization orientations in polar coordinates θ_1 and θ_2, as it is shown in figure 1(a). The potential energy surface (PES) represents all possible configurations in which there are four minima (see figure 1(b)), such that the energy barrier between those minima was obtained with a numerical procedure we have implemented following the nudged elastic band method (NEB) [3].

Hence, the theoretical model provides an understanding of the phenomena observed in Co/Ir/Co synthetic ferrimagnet systems [2], at least qualitatively, giving a good agreement with the experimental results. This agreement suggests evidences that the nonmonotonic behavior observed in this synthetic ferrimagnets could be a very general feature of any synthetic ferromagnet.

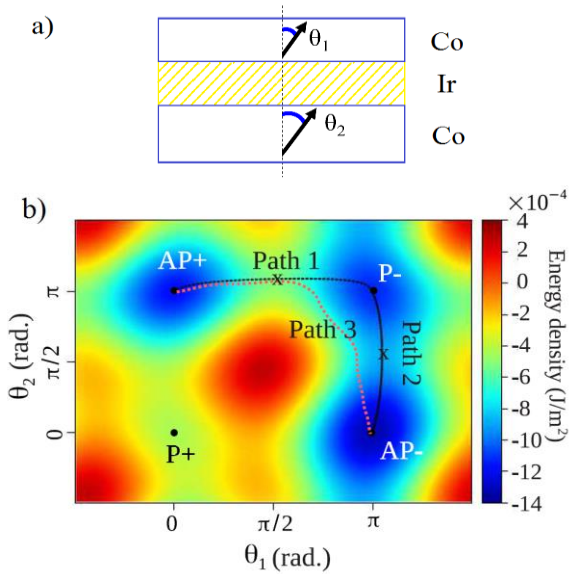

Figure 1: (a) magnetization representation of the two ferromagnetic layers in Co/Ir/Co synthetic ferromagnet. (b) density plot of the potential energy surface where can be seen four minima: AP+ (antiparallel configuration with net magnetization upwards), P- (both downward), AP- (antiparallel configuration with net magnetization downward), AP+ (both upward).

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P16

Giant Spin Anomalous Hall effect and self-induced torques on ferrimagnetic GdFeCo

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The basic operations in spintronics are the creation of spin currents from charge currents and the detection of spin currents by transforming them into charge currents. In other words, conversion between charge and spin currents. Such spin-charge conversions can be obtained by mechanisms based on spin-orbit coupling (SOC), namely the spin Hall effect (SHE) and its reciprocal, the inverse spin hall effect (ISHE) [1,2] in heavy metals and, as well, the Edelstein effect (EE) and its reciprocal called Inverse Edelstein effect (IEE) in two-dimensional systems such as Rashba or topological interface states [3,4]. SOC effects similar to the SHE can also be obtained in ferromagnetic metals: in addition to the well-known Anomalous Hall Effect (AHE), they present the so-called Spin Anomalous Hall Effect (SAHE) [5,6]. According to recent publications, the SAHE can coexist with a SHE of standard symmetry [7]. Up to now, the SOC effects in ferromagnetic metals have been poorly documented. However, as shown by the experiments we present, they can be very efficient for spin-charge conversions.

Here we report the determination of the charge-spin conversion by the SOC, mainly SAHE, in GdFeCo ferrimagnetic thin films. To do so we have deposited //GdFeCo(10 nm)/Cu(6 nm)/NiFe(4 nm)/Al (3 nm) on oxide thermalized silicon, Si-SiO_2, by magnetron sputtering. Then the samples were patterned by standard optical lithography (Fig.1a). The conversion of a dc charge current in GdFeCo into a spin current injected into NiFe was experimentally determined by the so called spin-orbit or spin transfer ferromagnetic resonance (ST-FMR) technique. In this experiment, we inject a radiofrequency current at a given frequency and power between the GSG (grounded-signal-grounded) electrodes as shown in Fig. 1(a). The dc voltage is picked up through a bias-T. An external in-plane field is swept and applied at 45 degrees of the slab. When the resonance condition is reached we can observe a typical ST-FMR scan which has and symmetric and antisymmetric Lorentz-type contributions. We have performed broadband frequency dependency between 2 and 25 GHz. We could observe the resonance condition of both layers, NiFe and GdFeCo (Fig. 1(b). The results shown that the equilibrium position of the GdFeCo magnetization, M_{GdFeCo}, is out-of-the plane but with an in-plane field above 0.17 T M_{GdFeCo} lies in the plane. This was also corroborated by SQUID magnetometry.

More important, we have applied an additional dc current to study the evolution of the linewidth of the NiFe resonance line which is induced by the dc current in GdFeCo and the resulting dc spin current created by SOC effects (SAHE + SHE) in GdFeCo and injected into NiFe. This so-called damping modulation technique allows a reliable determination of the charge-spin current conversion of the layer under evaluation, GdFeCo in this case. A result of such experiment is shown in the Figure 2. Following similar analysis for this technique [6], we have just found out an unprecedented large effective value of spin

Anomalous Hall angle of about 0.9 for GdFeCo which is much larger than the one reported for NiFe [7] and CoFeB [6]. From the symmetry of the FMR lines, the predominant effect comes from SAHE. The very large value that we find for the *effective* SAHE angle includes both, bulk SAHE and contribution from an additional spin accumulation by Rashba magnetic interfaces [8].
We have also studied the self-induced torques using the fisrt and second harmonic technique in Hall crosses [9]. We applied a given current parallel (perpendicular) to the in-plane magnetic field and we measure V_{1w} and V_{2w} of the Hall voltage to determine damping-like, DL (field-like, FL) torque. We use the low magnetic fiedl limit [9] to calculate the effective fields, H_{DL} and H_{FL}.

D. Céspedes-Berrocal acknowledges Nanomagnetism and Spintronic team at Instiuto Jean Lamour for its 2018 internshipscholarship and "LUE Graduated" program internship 2019 from "Lorraine Université de Excelence" LUE reference ANR-151DEX-04-LUE. JC Rojas-Sánchez thanks Region Grand Est and Feder for its support in "Projet Chercheur d'Avenir"

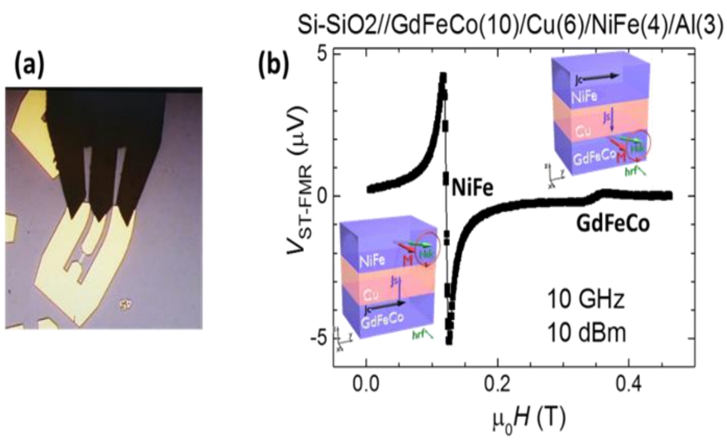

Figure 1: (a) picture of a device with the GSG contacts to perform the experiment. (b) ST-FMR scan acquisition at zero dc current, 10 GHz and input power of 10 dBm. We can observe the FMR line corresponding to NiFe at 0.121 T, and the one corresponding to GdFeCo magnetic precession at 0.346 T.

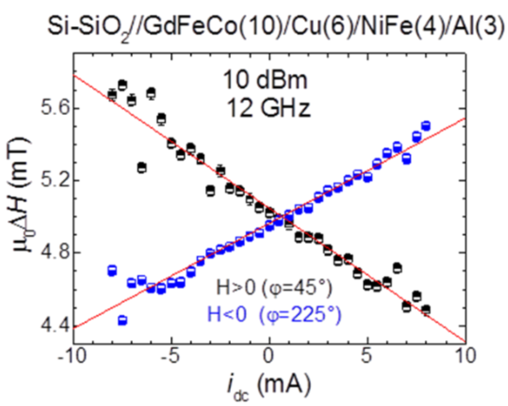

Figure 2: NiFe FMR linewidth as a function of the dc bias current for two opposite field directions.

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P17

Thermal torque in double barrier tunnel junctions with magnetic insulators

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The thermal spin torque induced by the spin dependent Seebeck effect [1] in double barrier tunnel junctions is derived considering free electron and tight binding calculations. We show that in systems comprising ferromagnetic electrodes and non-magnetic barriers the in-plane component of the thermal spin torque is the dominant term, whereas in junctions comprising non-magnetic electrodes and ferromagnetic barriers the dominant term is the out-of-plane. Moreover, larger torque amplitudes are obtained in the second system as a result of spin filtering effect; consequently, double barrier tunnel junctions in the presence of magnetic insulators offer an enhanced thermal spin torque mechanism for reliable applications. We propose that taking advantage of quantum resonant tunneling through resonance states below the Fermi level in these structures can be a route towards achieving larger spin torque efficiencies compared to the voltage induced case. Furthermore, we identify the parameters needed to tune efficiently these resonant states.

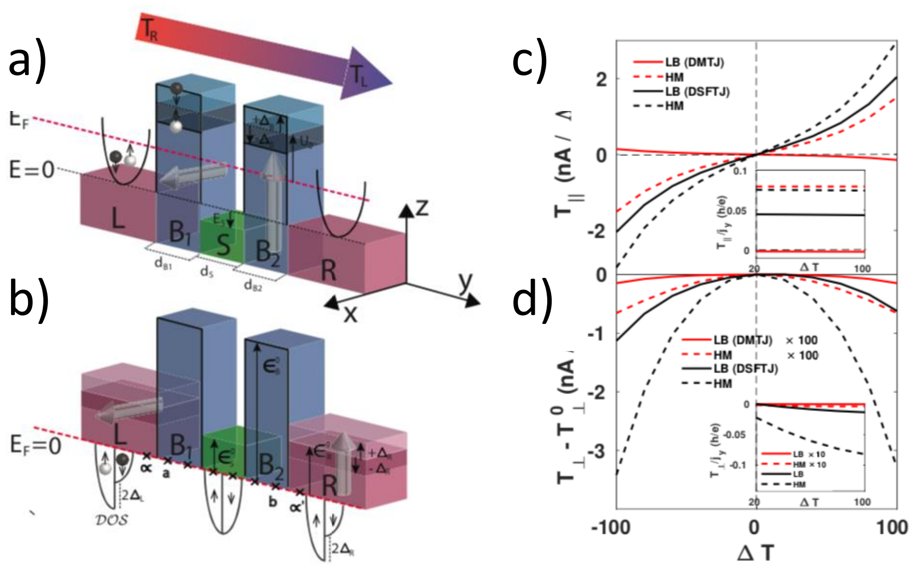

Figure 1: (left) a) Double barrier junction with magnetic insulating barriers and normal metal electrodes (DSFTJ). b) Double barrier junction with ferromagnetic electrodes and non-magnetic insulating barriers (DMTJ). (right) c) in-plane torque and d) out-of-plane torque for 2 types of regimes, low band filling (LB) and half metallic (HM). The exchange splitting in LB is 0.5 eV and in HM is 1.5 eV. Other parameters are similar in both systems.

[1] A. Slachter, F. L. Bakker, J. P. Adam, and B. J. van Wees, Nature Phys. **6**, 879 (2010).

List of participants SPIN PERU 2019

INVITED SPEAKERS

1. Can Onur AVCI ETH Zürich, Switzerland
"Chiral magnetism, current-driven domain walls and thermal spin drag in magnetic insulators with perpendicular anisotropy"

2. Gerrit BAUER Tohoku U., Japan
"Spintronics with magnetic insulators"

3. Olivier BOULLE Spintec, France
"Manipulation of magnetic skyrmions in ultrathin films by current and light"

4. Mair CHSHIEV Spintec, France
"Theory for spin torque in Weyl semimetal with magnetic textures"

5. Vincent CROS UMPhi CNRS-Thales, France
"Antiferromagnetic spin spiral and magnetic skyrmions in synthetic antiferromagnetic multilayers"

6. Jure DEMSAR Mainz U., Germany
"Light induced dynamics in the antiferromagnetic Mott insulator La2CuO4"

7. Samik DUTTAGUPTA CSIS, Tohoku University, Japan
"Spin Hall Magnetoresistance in antiferromagnet/nonmagnet metallic structures"

8. Giovanni FINOCCHIO Messina U., Italy
"New directions for microwave and THz detectors based on spintronic diodes"

9. Eric FULLERTON UCSD, USA
"Chiral magnetism and skyrmion nucleation in Pt/Co/Ni based thin-film heterostructures"

10. Markus GARST U. of Karlsruhe, Germany
"Solitary wave excitations of skyrmion strings in chiral magnets"

11. Andrew KENT NYU, USA
"Spin-transfer switching and magnetic interactions in perpendicular magnetic tunnel junctions nanopillars"

12. Mathias KLÄUI Mainz U., Germany (tutorial 2)
"Topological Spin Dynamics in ferro- and antiferromagnets"

13. Olivier KLEIN Spintec, France
"Long range coupling of magnetic bi-layers by coherent phonons"

14. Kyung-Jin LEE Korea U., South Korea
"Magnetization dynamics and spin transport in antiferromagnetically coupled ferrimagnets"

15. Andrey LEONOV Hiroshima U., Japan
"Clusters with mutually orthogonal skyrmion tubes: theoretical prediction and real-space observation"

16. Alan MACDONALD UT, Austin, USA
"Spin-Orbit Torques from a Microscopic Point of View"

17. Aurelien MANCHON KAUST, Saudi Arabia
"Theory of Spin Transport and Torque in Non-Collinear Antiferromagnets"

18. Julian MILANO Instituto Balseiro, CAB-CNEA, Bariloche, Argentina
"Stripe domains in Fe based thin films: magnetic texture, magneto-transport and magnetic coupling"

19. Mihai MIRON Spintec, France
"Interplay of chiral energy and chiral dissipation in domain wall dynamics"

20. Takahiro MORIYAMA U. of Kyoto, Japan
"Spintronic operations with antiferromagnets"

21. Shuichi MURAKAMI TIT, Japan
"Theory of generation and conversion of phonon angular momenta"
22. Ruben OTXOA Hitachi Cambridge Laboratory, UK
"Domain Walls dynamics in an Antiferromagnet"
23. Daniele PINNA Mainz U., Germany
"Reservoir Computing with Random Magnetic Textures"
24. Juan Carlos ROJAS-SÁNCHEZ U. Lorraine -CNRS, France
"Ferrimagnetic spintronic: From thermal contribution to the spin-orbit torque to different and efficient sources of spin currents"
25. Andrei SLAVIN Oakland University, Rochester, Michigan, USA
"Spectrum analysis using vortex-state spin-torque nano-oscillators"
26. Igor SOLOVYEV NIMS, Japan
"Electric polarization induced by skyrmionic order in GaV4S8: from first-principles calculations to microscopic models"
27. Laura STEREN CNEA, Argentina
"Surface and interfaces of transition metal oxides"
28. So TAKEI CUNY, USA
"Spin transport in an electrically-driven magnon gas near Bose-Einstein condensation: a Hartree-Fock-Keldysh theory"
29. Yaroslav TSERKOVNYAK UCLA, USA (tutorial 1)
"From quantum spintronics to topological hydrodynamics in insulators"
30. Oleg TRETIAKOV U. of New South Wales, Australia
"Antiferromagnetic Spintronics with (Anti)Skyrmions and Bimerons »
31. Laurent VILA Spintec, France
"Harnessing the spin orbit interaction at various interfaces for the interconversion between spin and charge currents"
32. Kang L. WANG UCLA, USA
"Spin-Orbit Torque in Ferri- and Antiferromagnetism"
33. Xiangrong WANG HKUST, Hong Kong
"Current-driving skyrmion motion in inhomogeneous films"
34. Jiang XIAO Fudan University, China
"Level attraction via dissipative coupling"

ORAL CONTRIBUTED

1. Benedetta FLEBUS University of California, Los Angeles (UCLA)
"Probing magnetic phenomena using Nitrogen Vacancy (NV) Center in Diamond"
2. Jorge A. OTALORA-ARIAS Universidad Católica del Norte, Antofagasta Chile
"Spin waves in magnetic nanotubes"
3. Amilcar BEDOYA-PINTO Max Planck of Microstructure Physics, Halle, Germany
"Spin torque ferromagnetic resonance in Weyl Semimetal/ferromagnet heterostructures"
4. Shin MIYAHARA Fukuoka University, Japan
"Electro active magnetic excitation in frustrated magnets"
5. Koichi OYANAGI Institute for Materials Research, Tohoku University, Japan
"Long-range spin transport in paramagnetic insulators"
6. Camilo ULLOA Utrecht University, Netherlands

"Nonlocal spin transport as a probe of viscous magnon fluids"

7. Lorenzo BALDRATI Johannes Gutenberg Universität-Mainz, Germany

"Manipulating and transporting spins in antiferromagnetic insulators/heavy metal bilayers"

8. Maria QUINTANA UNI, Lima, Peru

"Application of Iron Oxide nanoparticles for biogas production"

9. Yuta YAMANE RIKEN, Japan

"Dynamics of noncollinear antiferromagnetic domain walls driven by spin current injection"

10. Rodolfo GALLARDO Universidad Técnica Federico Santa María, Valparaíso, Chile.

"Spin waves in thin films and magnonic crystals with Dzyaloshinskii-Moriya interactions"

11. Dmitry YUDIN Uppsala University, Uppsala, Sweden

"A microscopic theory of Gilbert dampings and spin-orbit torques in antiferromagnets"

12. Anastasiia PERVISHKO Uppsala University, Uppsala, Sweden

"Gilbert damping in low-dimensional magnetic systems: microscopic approach"

13. Sergey STRELTSOV URAN, Russia

"Orbital-selective behavior and suppression of the double exchange in 4d and 4d transition metal oxides"

14. Sergii GRYTSIUK Peter Grümberg Institute, Germany

"Topological-chiral magnetic interactions driven by emergent orbital magnetism"

15. Jorge PUEBLA Center for Emergent Matter Science, RIKEN, Japan

"Photoinduced Rashba Spin-to-Charge Conversion via an Interfacial Unoccupied State"

Posters

P1. Kei YAMAMOTO Advanced Science Research Center, Japan Atomic Energy Agency

"Topological characterization of classical waves: The topological origin of magnetostatic surface spin waves"

P2. Mingran XU Institute for Solid State Physics, University of Tokyo, Japan

"Nonreciprocity of magnon phonon coupling driven by surface acoustic waves"

P3. Daichi KUREBAYASHI Center for Emergent Matter Science, RIKEN, Japan

"Theory for spin torque in Weyl semimetal with magnetic textures"

P4. Gen TATARA RIKEN, Japan

"Spintronics theory without spin current"

P5. Milida PINTO-VERGARA Universidad Nacional de San Marcos, Lima, Peru

"Study of magnetic coupling in multilayers Fe/Ti/Fe"

P6. Melissa YACTATO-YARANGA Universidad Nacional de San Marcos, Lima, Peru

"Magnetic properties in Fe/Ag magnetic multilayers"

P7. Agustin LOPEZ-PEDROSO CNEA/CONICET, Argentina

"Strain effect on the magnetism of CaMnO3"

P8. Collins AKOSA Spin Physics Theory Research Team, CEMS, RIKEN

"Tuning skyrmion Hall effect via engineering of spin-orbit interaction"

P9. Yangfan HU Sun Yat-wen University, China

"Tunable emergent phonons in magnetic skyrmion-like crystals distorted by coupled magnetoelastic fields"

P10. Claudio GONZALEZ Universidad Tecnica Federico Santa Maria, Valparaiso, Chile
"Magneto-optical detection of spin-orbit torques with oblique light incidence angle"
P11. Felix Alexander GALLEGOS Universidad Nacional de Ingeniería, Lima, Peru
"Study of cobalt nanomagnetic patterns for the stabilization of magnetic skyrmions"
P12. Junior Walder ALEGRE-SAENZ Universidad Nacional de Ingeniería, Lima, Peru
"Study of semicircular cobalt disks for the stabilization of magnetic skyrmions"
P13. Boris DIVINSKIY University of Münster, Germany
"Magnons driven by the spin-orbit torque"
P14. Américo CUCHILLO Universidad de Atacama, Chile
"Dipolar and anisotropic contributions to properly describe the magnetic properties of magnetic nanoparticles real systems"
P15. Heisember TARAZONA-CORONEL Universidad Nacional de San Marcos, Lima, Peru
"Thermally activated magnetic relaxation in synthetic ferrimagnets: a transition-state-theory approach"
P16. David CÉSPEDES Universidad Nacional de Ingeniería, Lima, Peru
"Giant Spin Anomalous Hall effect and self-induced torques on ferrimagnetic GdFeCo"
P17. Christian ORTIZ-PAUYAC RIKEN, Japan
"Thermal torque in double barrier tunnel junctions with magnetic insulators"

Others attending

1. Xixiang ZHANG KAUST, Saudi Arabia
2. Juan José TORRES-VEGA CITBM - Universidad Nacional de San Marcos, Lima, Perú
3. Braulio Rafael PUJADA Universidad Nacional de San Marcos, Lima, Peru
4. Karina Silvana GUTIERREZ-VALVERDE Universidad Nacional de Piura, Piura, Peru
5. José Ignacio COSTILLA-PINEDO Universidad Nacional de San Marcos, Lima, Peru

Poster winners:

1 Mingran XU
Institute for Solid State Physics, University of Tokyo, Japan
"Nonreciprocity of magnon phonon coupling driven by surface acoustic waves"

2. Daichi KUREBAYASHI
Center for Emergent Matter Science, RIKEN, Japan
"Theory for spin torque in Weyl semimetal with magnetic textures"

3. Heisember TARAZONA-CORONEL
Universidad Nacional de San Marcos, Lima, Peru
"Thermally activated magnetic relaxation in synthetic ferrimagnets: a transition-state-theory approach"