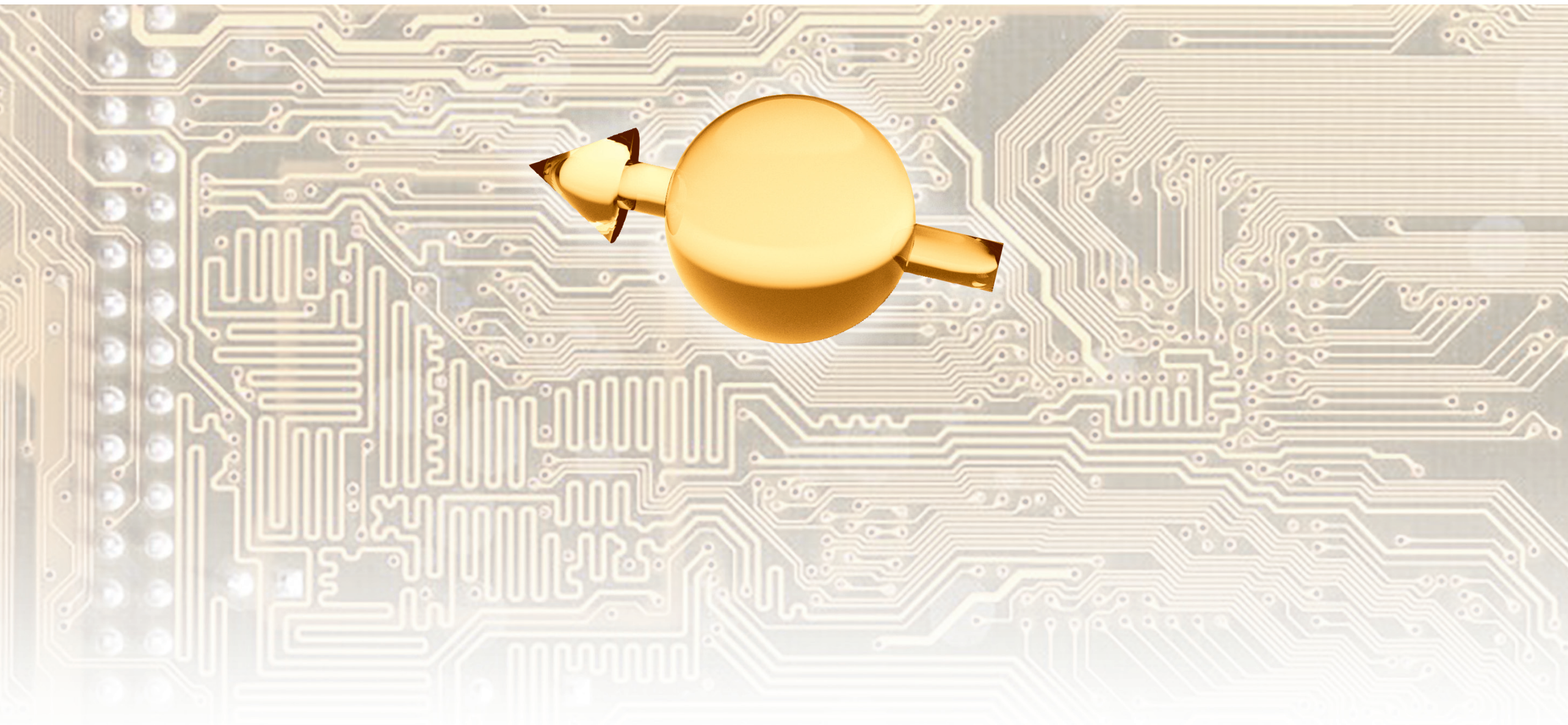
Grant-in-Aid for Scientific Research on Innovative Areas, MEXT, Japan

Nano-Spin Conversion Science

Research Highlights

Nano spin conversion



vol.2

December, 2016

Table of contents

Preface

Spintronics research emerged in the 1990s, has evolved throughout two decades, and still continues to grow. Japanese researchers have historically led this field, and the major participants in this innovative research area have made significant contributions in terms ofintriguing physical phenomena such as the spin Hall effect, inverse Faraday effect and spinSeebeck effect. Another outcome of spintronics research has been the concept of spin current,which has been established among the community of solid-state research. The concept of spincurrent has since been extended and is recognized as an angular momentum flow includingspin waves, circularly polarized light and mechanical vibration.

In this innovative research area, we focus on the itinerant and localized electron spins, phonons, and photons to explore and establish the principles of novel conversion mechanisms. Moreover, we aim to propose novel concepts and methods that are based on well-established physics, and finally to develop a spin conversion physics theory that can meet requests from industry. Ideally, we will present research outcomes that can contribute to building new paradigms for the development of practical devices and energy harvesting.

To maintain the future activity of this field, the education and securing of young talented researchers is considered to be an important and high priority. In addition to the securing ofhuman resources in Japan and improvement of research performance, the fostering of top-levelresearchers that will contribute to innovative progress will be promoted. From a long-termperspective, we consider that educating talented young researchers in this research area, notonly from Japan where we endure an aging society and science phobia, but also from overseas,and their promotion worldwide would offer a route to make Japan the world-leading country inthe fields of advanced basic science and technologies, which are related to this innovativeresearch area. Finally, I sincerely hope that this research area will create outcomes that will make significant contributions to society and will stimulate further growth.

大谷義近

Principal Investigator

Prof. YoshiChika Otani

Institute for Solid State Physics, The University of Tokyo

Efficient charge-to-spin current conversion in surface state of topological insulator

Kouta Kondou and YoshiChika Otani

K. Kondou, R. Yoshimi, A. Tsukazaki, Y. Fukuma, J. Matsuno, K. S. Takahashi, M. Kawasaki, Y. Tokura, and Y. Otani,
"Fermi-level-dependent charge-to-spin current conversion by Dirac surface states of topological insulators",
Nat. Phys. **12**, 1027 (2016). [http://dx.doi.org/10.1038/nphys3833]

Two-dimensional electronic systems with spin-bandsplitting, like the surface states of a topological insulator or Rashba interfaces, provide unique opportunities for spintronics applications. The spin-momentum locking in these surface states offers the possibility of highly efficient charge-to-spin current interconversion compared with the ordinary spin Hall effect in paramagnetic metals. To explain this phenomenon, the interfacial charge-to-spin conversion mechanism was proposed by Edelstein in 1990, and has recently been observed at aAg/Bi Rashba interface. For the further development of interfacial spin current devices, it is important to quantitatively evaluate the conversion efficiency between charge and spin current. In the present study, we investigated the charge-to-spincurrent conversion in the surface states of topological insulators. We prepared tri-layer films of topological insulator ($(Bi_{1-x}Sb_x)_2Te_3$: BST)/non-magnetic metal (Cu)/ferromagnetic-metal (NiFe) (Fig.1). A charge current flowing through the filminduces spin accumulation at the interface between the BST and Cu layers. By carrying out spin-torque ferromagnetic resonance measurements, we succeeded in determining the charge-to-spin current conversion coefficientfor the surface state of BST, whose Fermi level was varied by tuning x. We found that, except for two samples in the vicinity of the Dirac point, in bulk insulating conditions, the interface charge-to-spin current conversion coefficient via the Dirac surface state is large and nearly constant (Fig. 2).

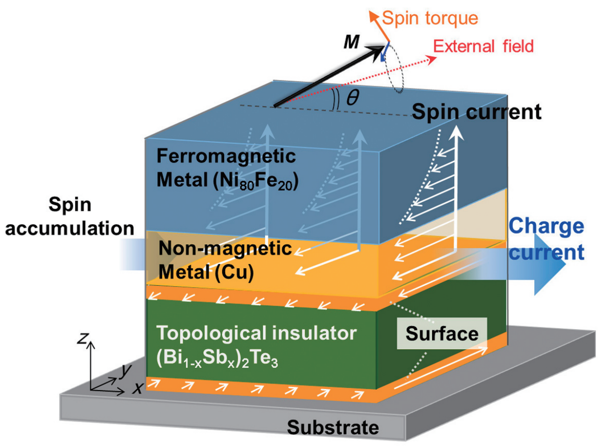


Fig. 1: Schematic illustration of the spin-torque ferromagnetic resonance device

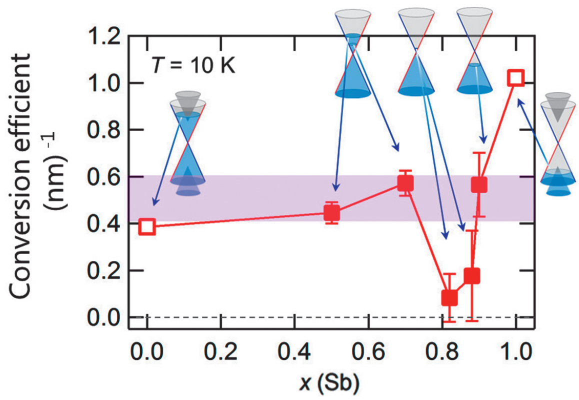
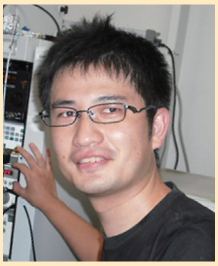
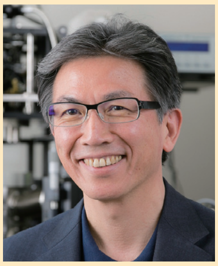


Fig. 2: Interfacial charge-to-spin current conversion coefficient



Kouta Kondou
Research Scientist at CEMS, RIKEN



YoshiChika Otani
Professor at ISSP, The University of Tokyo and Team Leader at CEMS, RIKEN

Group home page http://www.riken.jp/lab-www/nanomag/

Electric-field modulation of damping constant in a ferromagnetic semiconductor (Ga,Mn)As

Fumihiro Matsukura

L. Chen, F. Matsukura, and H. Ohno, "Electric-field modulation of damping constant in a ferromagnetic semiconductor (Ga,Mn)As", Phys. Rev. Lett. **106**, 222405(2015). [http://dx.doi.org/10.1103/115.057204]

The Gilbert damping constant α is a fundamental parameter that governs the magnetization dynamics in ferromagnets, and is critical for the performance of spintronics devices. Although many experimental studies have confirmed the material-dependent nature of α, neither details regarding the mechanism responsible for α nor external means to control it have been established. We evaluated α for a 4-nm-thick (Ga,Mn)As film under an applied electric field E from the linewidths of ferromagnetic resonance spectra, and found that α can be modulated by up to ~10% for a maximum E of $\pm$4 MV/cm. The value of α increases when the hole concentration p is decreased by E. To understand the mechanism of the modulation, we conducted transport and magnetization measurements under E. Because (Ga,Mn)As is in the vicinity of a metal-insulator transition and its ferromagnetism is carrier-induced, magnetic disorder exists in (Ga,Mn)As due to local fluctuationsin p. We adopt the ratio of the superparamagnetic moment to the total moment, M_{SP}/M_{tot}, as a measure of the degree of magnetic disorder, which increases with decreasing of p (squares in Fig. 1(a)), and find a clear correlation between M_{SP}/M_{tot} and α (squares in Fig. 1(b)). The correlation is also confirmed from (Ga,Mn)As films with a wide range of electrical conductivity, which is varied by post-growth annealing (triangles and circles in Fig. 1). The observation indicates that α is determined primarily by the magnetic disorder induced by carrier localization. These results are important for further understanding the microscopic origin of α, as well as for developing an efficient way to control the magnitude of α.

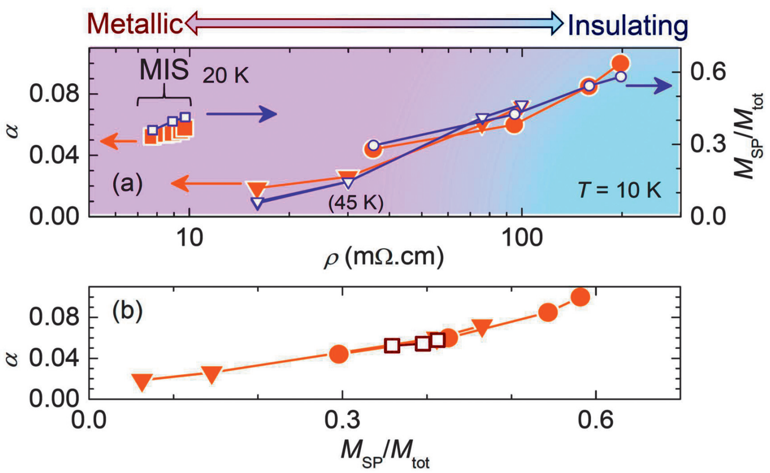


Fig. 1: (a) α and M_{SP}/M_{tot} as a function of ρ, and (b) α as a function of M_{SP}/M_{tot}. Squares correspond to (Ga,Mn)As films for which ρ was varied by varying E, and circles/triangles correspond to (Ga,Mn) films for which ρ was varied by varying the annealing condition.

Fumihiro Matsukura
Professor,
WPI-Advanced Institute for Materials Research, Center for Spintronics Integrated Systems, Center for Spintronics Research Network, Tohoku University

Group home page http://www.ohno.riec.tohoku.ac.jp/

Gate control over spin-charge conversion in graphene

Sergey Dushenko and Masashi Shiraishi

S. Dushenko, H. Ago, K. Kawahara, T. Tsuda, S. Kuwabata, T. Takenobu, T. Shinjo, Y. Ando, and M. Shiraishi,
Gate-Tunable Spin-Charge Conversion and the Role of Spin-Orbit Interaction in Graphene,
Phys. Rev. Lett. **116**, 166102 (2016). ［http://dx.doi.org/10.1103/PhysRevLett.116.166102］

Graphene—a single layer of sp^2 hybridized carbon atoms arranged in a honeycomb lattice—is 6 times thinner than the diameter of a human DNA helix and 300,000 times thinner than the diameter of human hair. Surprisingly, on this short distance, graphene is able to scatter electrons to opposite directions depending on their spin. Thus, graphene works as an extremely thin spin-to-charge converter, but how exactly this happens remains a big question.
In this study, we used coupling of microwaves to the magnetization under ferromagnetic resonance to inject spins into the graphene from anadjacent ferrimagnetic layer of yttrium iron garnet (YIG). The large band gap of YIG guaranteed that any electric signal generated in the system comes only from the graphene layer. We controlled the electric field at the YIG/graphene interface with anionic gel top gate. The drain current between Ti/Au pads at opposite edges of the sample confirmed application of the strong electric field and switching of the carrier type from holes to electrons in graphene. We showed that the efficiency of the spin-to-charge conversion in graphene is independent of the applied electric field, a previously missing piece of informationthat was necessary to determine the spin-to-charge conversion mechanism. While the inverse Rashba-Edelstein effect, which gives rise to spin-charge conversion through the Rashba spin-orbit interaction,is proportional to the out-of-plane electric field, the inverse spin-Hall effect is independent of it. From the gate voltage dependence of the generated charge current, we showed that spin-charge conversion is independent of the out-of-plane electric field, which indicates that it′s dominated by the inverse spin-Hall effect and not the inverse Rashba-Edelstein effect, as one may expect from a two-dimensional material like graphene. Our results also showed that graphene functionsas a stable spin-to-charge converter, while other electric properties can be tuned usingthe applied electric field, which is a promising feature for future magneto-electric devices.

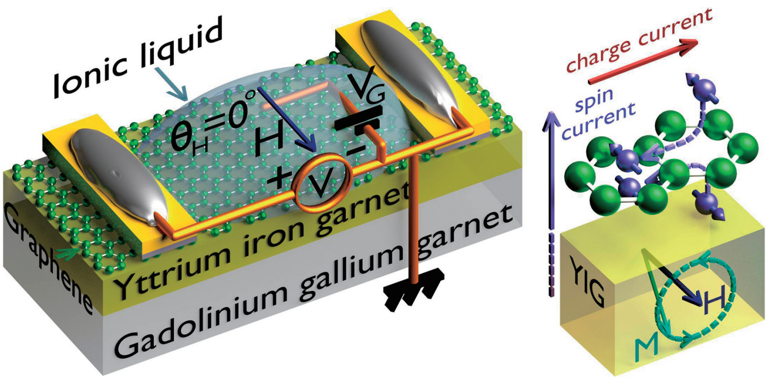
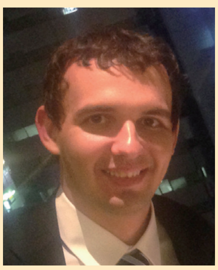


Fig. 1: (Left) Layout of the spin-charge conversion experiment in single-layer graphene. (Right) Under the ferromagnetic resonance pure spin current was transferred through the ferrimagnetic insulator/graphene interface and converted into an in-plane charge current.



Sergey Dushenko, Ph.D.
Japan Society for the Promotion of Science Postdoctoral Fellow,
Shiraishi Laboratory,
Kyoto University

Masashi Shiraishi
Professor, Ph.D.
Department of Electronic Science and Engineering, Kyoto University

Group home page http://cmp.kuee.kyoto-u.ac.jp/index_en.html

The Kondo effect is controlled by pure spin current

Takayuki Kurokawa, Tomoyasu Taniyama, and Kohei Hamaya

K. Hamaya,T. Kurokawa, S. Oki, S. Yamada, and T. Kanashima, and T. Taniyama, "Direct evidence for suppression of the Kondo effect due to pure spin current", Phys. Rev. B **94**, 140401(R) (2016). [http://journals.aps.org/prb/abstract/10.1103/PhysRevB.94.140401]

Using lateral spin-valve structures with highly spin-polarized Co_2FeSi (CFS) electrodes, we have studied the effect of a pure spin current on the Kondo singlet in a diluted magnetic alloy Cu(Fe), where the Kondo temperature (T_K) is 30 K. As can be seen in Fig. 1(a), the spin signals decrease with decreasing temperature starting from ~130 K, followed by a plateau corresponding to the low-temperature Fermi liquid regime below T_K. The reduction in spin signal below ~130 K indicates enhancement of the *s-d* spin-flip scattering between impurity spins and electron spins with decreasing temperature. On the other hand, the plateau below T_K indicates that the spin-flip scattering is nearly constant. When the generation of the pure spin current in Cu(Fe) is enhanced by increasing applied current from 1 to 5 mA, we find that the Kondo spin-flip scattering is markedly suppressed below ~130 K. This feature stands for the tunable Kondo effect due to pure spin current, as shown in Fig. 1(b).

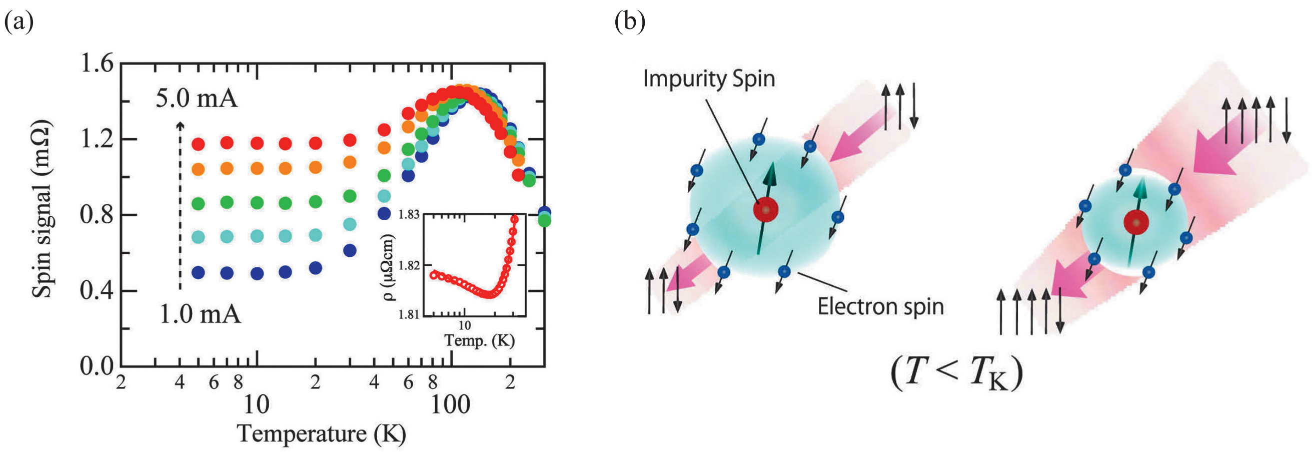


Fig. 1: (a) Control of the Kondo spin-flip scattering by pure spin current.
(b) Schematics of the Kondo effect under pure spin current injection below Kondo temperature (T_K).

Takayuki Kurokawa
Master's Course Student, Department of Systems Innovation
Graduate School of Engineering Science, Osaka University

Tomoyasu Taniyama
Associate Professor, Laboratory for Materials and Structures, Tokyo Institute of Technology

Kohei Hamaya
Professor, Department of Systems Innovation, Graduate School of Engineering Science, Osaka University

Group home page Hamaya group :http://www.semi.ee.es.osaka-u.ac.jp/hamayalab/ Taniyama group : http://www.msl.titech.ac.jp/~itohlab/index-E.html

Spin polarization in the vicinity of quantum point contact with spin-orbit interaction

Taketomo Nakamura and Shingo Katsumoto

Sunwoo Kim, Yoshiaki Hashimoto, Taketomo Nakamura, and Shingo Katsumoto, "Spin polarization in the vicinity of quantum point contact with spin-orbit interaction", Physical Review B **94**, 125307-1~125307-8, (2016).
［https://doi.org/10.1103/PhysRevB.94.125307 ］

The generation and detection of spin polarization without ferromagnetic materials is an interesting and challenging research in semiconductor spintronics. In the electric conduction through quantum point contacts (QPCs) under Rashba-type spin-orbit interaction (RSOI), plateaus at a half of the quantum conductance G_q (=2e^2/h, where e is the elementary charge and h is the Plank constant) have often been observed and attributed to spin-polarization albeit without sound evidence. We have developed a technique for measuring spin polarization in the vicinity of a QPCby utilizing a quantum dot (QD). The detection scheme is based on the Pauli exclusion principle, which prohibits two electrons with the same spin from tunneling into a single state in a QD (Fig. 1a). Spin-polarization in the electron source thus gives the difference in the rate for two-electron tunneling processes.

Our devices were fabricated on a two-dimensional electron system in an $In_{0.1}Ga_{0.9}As$ quantum well with a large RSOI. Two QPCs (t-QPC and d-QPC) and a QD were arranged as shown in Fig.1b. The tunneling rate from the t-QPC to the QD was measured via remote charge sensing by the d-QPC. The spin polarization P in the t-QPC was obtained from the above-mentioned difference in the tunneling rate. We found that P is high not only on the plateau of 0.5G$_q$ but also on that of 1.0G$_q$ (Fig.2b).The bias voltage dependence of P definitely differs on the 0.5 and 1.0 plateaus, as can be seen in Fig.2c, indicating different polarization mechanisms. As theoretically proposed, spin-dependent potentials around the QPC cause spin-filtering on the 0.5 plateau while a spin rotation by mixing of one-dimensional bands in the QPC through RSOI is the origin of high P on the 1.0 plateau.

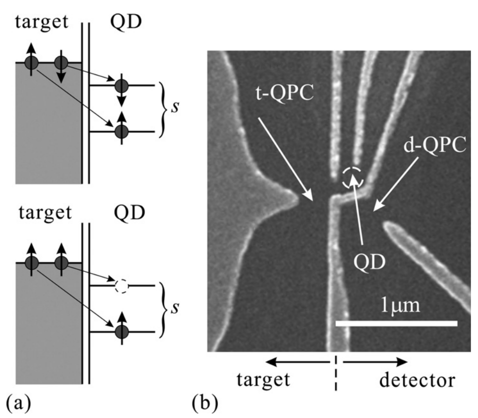


Fig. 1: (a) Schematic of the principle for detection of spin polarization. (b) An SEM image of our device.

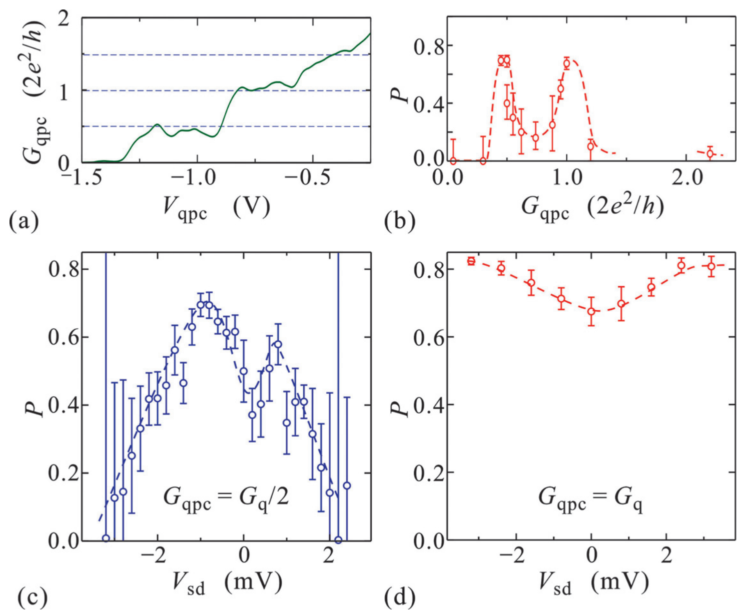


Fig. 2: (a) The conductance of a t-QPC. (b) Zero-bias spin polarization as a function of the t-QPC conductance. (c) and (d) represent the spin-polarization in the t-QPC on the 0.5 and 1.0 plateaus, respectively.

Taketomo Nakamura
Research Associate,
Institute for Solid State Physics,
The University of Tokyo.

Shingo Katsumoto
Professor,
Institute for Solid State Physics,
The University of Tokyo.

Group home page http://kats.issp.u-tokyo.ac.jp/index-en.html

Efficient spin injection into graphene from Heusler alloy

Rai Moriya

Takehiro Yamaguchi, Rai Moriya, Soichiro Oki, Shinya Yamada, Satoru Masubuchi, Kohei Hamaya, and Tomoki Machida
"Spin injection into multilayer graphene from highly spin-polarized Co_2FeSi Heusler alloy", Appl. Phys. Exp. **9**, 063006 (2016).
[http://dx.doi.org/10.7567/APEX.9.063006]

Efficient generation and detection of spin current in two-dimensional (2D) materials such as graphene, and transition metal dichalcogenides are milestones of our project. Previously, most studies have demonstrated that the electrical injection of highly spin-polarized carriers into 2D materialsis difficult, due to the lack of a fabrication method for generating a high-quality tunnel barrier and ferromagnetic materials on these materials. Here, we demonstrate electrical spin injection into multilayer graphene (MLG) in a lateral spin valve device from a highly spin-polarized Co_2FeSi (CFS) Huesler electrode. By employing an inverted device structure such that exfoliated MLG was transferred onto pre-patterned epitaxial CFS wires, junctions between single-crystalline CFS and MLG were fabricated. A non-local spin signal of 430 Ω was observed, which is the largest reported value of non-local magnetoresistance among graphene-based devices.

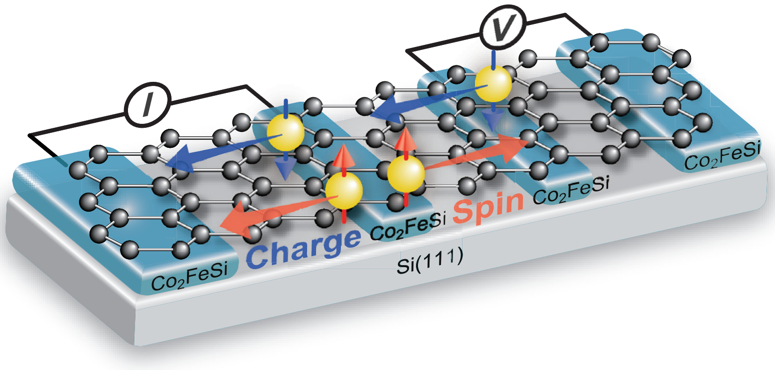


Fig. 1: Conceptual diagram of the efficient spin injection from Heusler alloy to graphene.

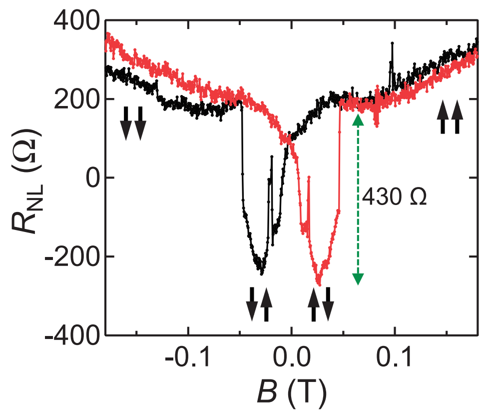


Fig. 2: Non-local magnetoresistance data measured at 1.6K. The directions of magnelization of CFS electrodes are indicated by arrows.

Rai Moriya
Assistant Professor
Institute of Industrial Science
The University of Tokyo

Group home page http://qhe.iis.u-tokyo.ac.jp/index_e.html#

A supercurrent with split Cooper pairs

Russell Stewart Deacon, Akira Oiwa, and Seigo Tarucha

R.S. Deacon, A. Oiwa, J. Sailer, S. Baba, Y. Kanai, K. Shibata, K. Hirakawa, and S. Tarucha, "Cooper pair splitting in parallel quantum dot Josephson junctions", Nature Communications. **6**, 7446 (2015). [http://dx.doi.org/10.1038/ncomms8446]

A fundamental element in quantum information technology is the Einstein-Podolsky-Rosen (EPR) pair, a pair of maximally entangled particles that can be shared between elements of a system to distribute entanglement and teleport states. Such EPR pairs are readily available in the field of quantum optics, where EPR sources have been used to demonstrate quantum teleportation. In the solid-state, however, the preparation of EPR pairs remains challenging, as strong interactions hinder the control and isolation of entangled electron pairs. An s-wave superconductor can be viewed as a natural reservoir of spin-entangled electron pairs (Cooper pairs) that form the superconducting ground state. Devices that can on-demand extract and separate a single Cooper pair, so-called Andreev entanglers, have long been proposed as a solid-state EPR pair source. In this field, the challenges have been to efficiently separate the Cooper pair and to demonstrate entanglement. Efficient separation of Cooper pairs can be realized using semiconductor quantum dots for which the on-site charging energy can prevent a current of Cooper pairs flowing through a single dot while still allowing a current of single particles. By placing two quantum dots in close proximity, Cooper pairs can separate and tunnel through both quantum dots with a high efficiency. We fabricate a Josephson junction formed from two self-assembled InAs quantum dots situated in parallel between nanogap superconducting aluminiumelectrodes (Fig. 1). A non-dissipative supercurrent can flow with the splitting of Cooper pairs from the source between the two quantum dots followed by recombination in the drain electrode (Fig. 2). As the Josephson current is immune to processes with disentangled electrons, the observation of enhanced junction switching currents with both quantum dots tuned on resonance confirms that the Cooper pair is split between two quantum dots.

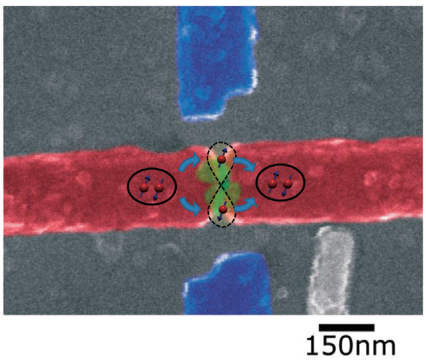


Fig. 1: Scanning electron microscope image of the device with two self-assembled quantum dots (green) contacted by aluminium electrodes (red) and electrically gated with side-gates (blue).

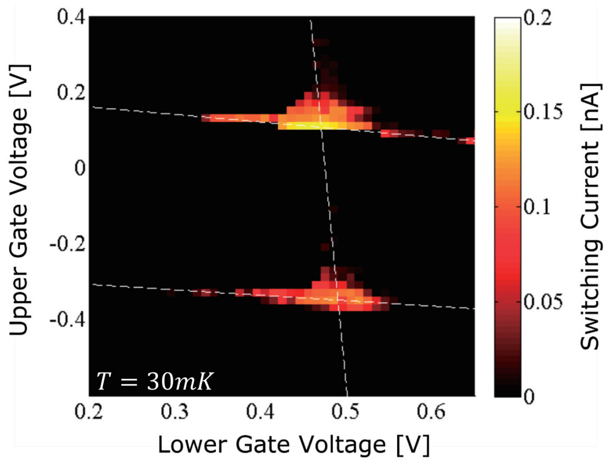


Fig. 2: Plot of the junction switching current as a function of gate voltages. Dashed lines indicate the position of charge state transitions for the two QDs. Enhanced switching current at the crossing points indicates a supercurrent due to Cooper pair splitting between the quantum dots.

Russell Stewart Deacon
Research Scientist,
Advanced Device Laboratory, RIKEN.

Akira Oiwa
Professor,
Department of Quantum System Electronics, the Institute of Scientific and Industrial Research, Osaka University

Seigo Tarucha
Professor,
Tokyo University
Department of Applied Physics
Team Leader at CEMS
RIKEN

Group home page http://www.riken.jp/lab-www/adv_device/en/index.html

Propagating magnon induced and detected by laser pulses in metallic magnets

Satoshi Iihama and Shigemi Mizukami

S. Iihama, Y. Sasaki, A. Sugihara, A. Kamimaki, Y. Ando, and S. Mizukami, "Quantification of a propagating spin-wave packet created by an ultrashort laser pulse in a thin film of a magnetic metal", Phys. Rev. B **94**, 020401(R) (2016).
[http://dx.doi.org/110.1103/PhysRevB.94.020401]

Coherent spin-wave generation by a focused ultrashort laser pulse has been demonstrated in magnetic insulators [Sato et al., Nat. Photo. 6, 662 (2012)]. Although a couple of studies in metals have also been reported eg., Au et al., Phys. Rev. Lett. 110, 097201 (2013), neither clear observation nor quantitative discussions have been reported for metallic films thus far. In this communication, we develop a laser-beam scanning space-time resolved magneto-optical Kerr microscopy method and use it to clearly demonstrate a laser-induced propagating coherent magnon in NiFe films [Fig. 1(a)]. The generated magnon wavepacket propagates from the laser spot up to a distance of 5 micron over 1.5 nsec [Figs. 1(b) and 1(c)], in good agreement with a theoretical simulation of a Damon-Eshbach surface wave induced by ultrafast demagnetization as a point source of the magnon.The technique developed here will enable us to further study light-magnon conversion in various metallic systems as well as develop optical applications in magnon spintronics.

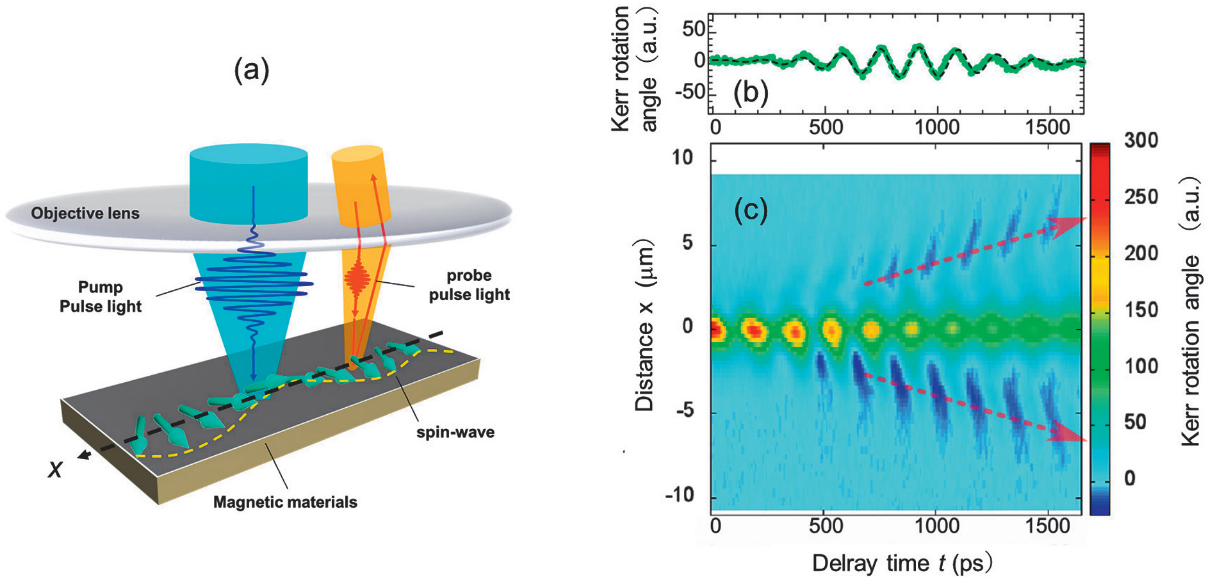


Fig. 1: (a) Schematic illustration of the experimental setup. (b) Magnonwave packet detected at x=-3.5 μm. (c) Spatio-temporal evolution of the magnon wavepacket. Broken lines denote propagation of the wavepacket.

Satoshi Iihama
Doctor's Course Student,
Department of Applied Physics,
Graduate School of Engineering,
Tohoku University.
Currently, JSPS Post Doctoral Fellow,
AIST.

Shigemi Mizukami
Professor,
WPI Advanced Institute for Materials Research, Tohoku University.

Group home page http://www.wpi-aimr.tohoku.ac.jp/mizukami_lab/

Selective Injection of Single Electron Spins into a Quantum Dot

Haruki Kiyama and Akira Oiwa

H. Kiyama, T. Nakajima, S. Teraoka, A. Oiwa, and S. Tarucha, "Spin-dependent current through a quantum dot from spin-polarized nonequilibrium quantum Hall edge channels", Phys. Rev. B **91**, 155302 (2015). [http://dx.doi.org/10.1103/PhysRevB.91.155302]

The injection of electron spins into gate-defined quantum dots (QDs) is useful for the preparation and detection of spins in spintronics and spin-based quantum information processing. So far, spin injection has been demonstrated using spin-filtering techniques;however, these techniques currently allow for the injection of ground-state (spin-up) but not excited-state spins (spin-down).

We demonstrate selective injection of both spin-up and spin-down single electrons into a QD by using spin-polarized nonequilibrium quantum Hall edge channels, which are generated by selective transmission of spin-resolved edge channels using a surface gate LC placed at a distance from the QD (Fig. 1). The spin polarization of the nonequilibrium edge channels, and thus that of electrons injected into the QD,is electrically switched by changing the bias voltages applied to two source Ohmic contacts S1 and S2. Figure 2 shows the spin polarization of electrons conducting through a spin-degenerate QD as a function of voltage applied to gate LC, V_{LC}, for spin-up and spin-down nonequilibrium edge channels. The spin polarization is opposite in sign between the two channels, demonstrating the electrically switchable injection of spin-up and -down single electrons into the QD.

This selective spin injection into QDs from edge channels will be useful in the preparation and detection of spin qubits in QDs. Furthermore, this technique may pave the way to connecting multiple local qubits in distant QDs via flying qubits in edge channels.

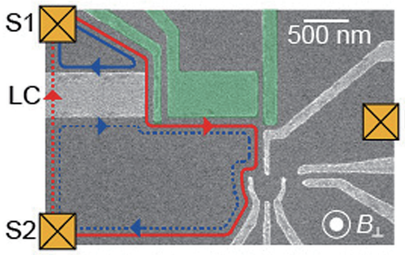


Fig. 1: Scanning electron micrograph of the device. Solid (dotted) red and blue lines show spin-up and spin-down edge channels in the lowest Landau level, respectively, biased at Ohmic contact S1 (S2).

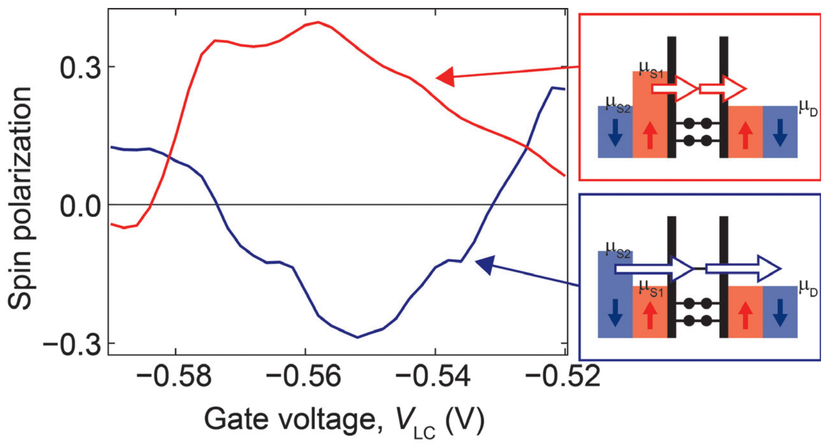
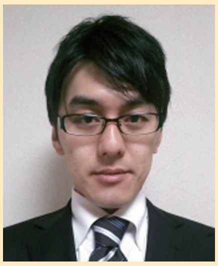


Fig. 2: Spin polarization at B = 1.5 T for spin-up (red) and spin-down (blue) nonequilibrium edge channels.



Haruki Kiyama
Assistant professor,
Department of Quantum System Electronics,
the Institute of Scientific and Industrial Research, Osaka University

Akira Oiwa
Professor,
Department of Quantum System Electronics, the Institute of Scientific and Industrial Research,
Osaka University

Group home page http://www.sanken.osaka-u.ac.jp/labs/qse/indexEN.html

Observation of Barnett effect in paramagnetic states

Masao Ono

M. Ono, H. Chudo, K. Hariii, S. Okayasu, M. Matsuo, J. Ieda, R. Takahashi, S. Maekawa,and E. Saitoh,
"Barnett effect in paramagnetic states", Phys. Rev. B **92**, 174424 (2015). [http://dx.doi.org/10.1103/PhysRevB.92.174424]

The Barnett effect, the magnetization of a magnetic body by rotation, was first reported in 1915 andunveiled the close relationship between rotation and magnetism[S. J. Barnett, "Magnetization by Rotation", Phys. Rev. **6**, 239-270 (1915)]. Despite its generality, the Barnett effect has not been experimentally demonstrated in a paramagnetic state, mainly due totechnical difficulties.After just over 100 years, we have finally succeeded in observing the effect in a paramagnetic state of gadolinium.

We developed a magnetic measurement setup comprising a high-speed rotation system and a fluxgate magnetometer for the measurement (Fig.1). Fig. 2 shows the rotational frequency dependence of the magnetization of the gadolinium sample at 300±0.5 K and that of a blank capsule. Using a dipole model, we estimated the magnetization of the rotating sample, M_Ω, from the stray field measured by the fluxgate magnetometer. We found that the magnetization is proportional to the rotational frequency and that its polarity changes with the rotation direction. For the blank capsule, no rotational frequency or directional dependence wereobserved. Thus, the magnetization arises from the rotating Gd sample.

The temperature and rotational frequency dependence of the observed magnetization were identified with paramagnetic susceptibility and the Barnett field emerging in the Gd sample, respectively. The Barnett field analysis shows the gyromagnetic ratio of Gdas −29 ± 5 GHz/T.

By improving the present apparatus, this mechanical method can be applied to estimate the gyromagnetic ratio in a variety of magnetic metals.This will open a new area of spintronics, in which the Barnett effect in paramagnetic states is the fundamental phenomenon.

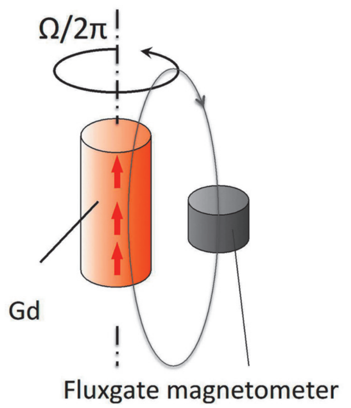


Figure 1: The experimental setup for observation of the Barnett

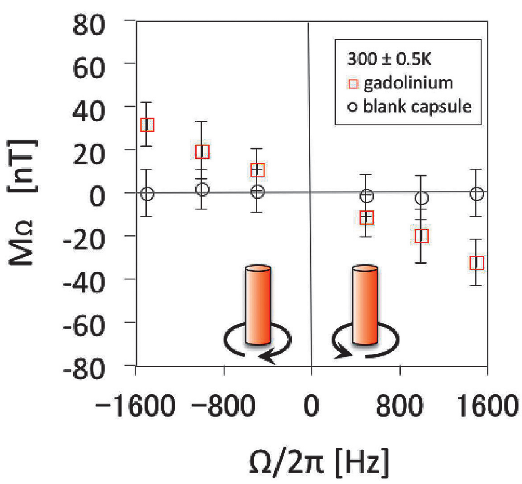


Figure 2: Rotational frequency dependence of the magnetization observed at 300±0.5K for the Gd sample and the blank capsule. Each data point is averaged over three measurements with the error bar in the standard deviation 1 σ including the rotational frequency fractionation.

Masao Ono
Senior Scientist,
Advanced Science Research Center,
Japan Atomic Energy Agency

Group home page http://asrc.jaea.go.jp/soshiki/gr/spinenergy/index-e.html

Magnon polarons in the spin Seebeck effect

Takashi Kikkawa, Gerrit E. W. Bauer, and Eiji Saitoh

T. Kikkawa, K. Shen, B. Flebus, R. A. Duine, K. Uchida, Z. Qiu, G. E. W. Bauer, and E. Saitoh, "Magnon polarons in the spin Seebeck effect", Phys. Rev. Lett. **117**, 207203 (2016). [http://dx.doi.org/10.1103/PhysRevLett.117.207203]

Magnon-phonon hybridized excitations, i.e., magnon polarons, are electrically detected by means of the spin Seebeck effect (SSE) in which a spin current is generated in a magnetic material by a temperature gradient. Since its discovery in 2008, the SSE has attracted increasing attention in the spin(calori)tronics community. It is well established for magnetic insulators with metallic contacts, at which a magnon flow is converted into a conduction-electron spin current by the interfacial exchange interaction and detected as a transverse electric voltage via the inverse spin Hall effect. Here, we report the observation of sharp features in the SSE induced by the strong magnon-phonon coupling at the band (anti-)crossings between the magnon and phonon dispersion curves in $Y_3Fe_5O_{12}$ (YIG) (Fig. 1). A high-resolution field scan shows saw-tooth peak structures in the magnetic field dependence of the SSE (Fig. 2). The SSE anomalies appear when the magnon and phonon dispersion curves touch, which maximizes the magnon-polaron phase space. The experimental results are well reproduced by solutions of a Boltzmann equation for the strongly coupled magnon-phonon systems. The sharp enhancement of the SSE can thereby be attributed to the spin current carried by magnon polarons exhibiting a longer propagation length than pure magnons. Our finding unveils an unknown role of phonons in spin(calori)tronics and demonstrates the power of the SSE to reveal spectroscopic information on the spin dynamics of magnetic insulators.

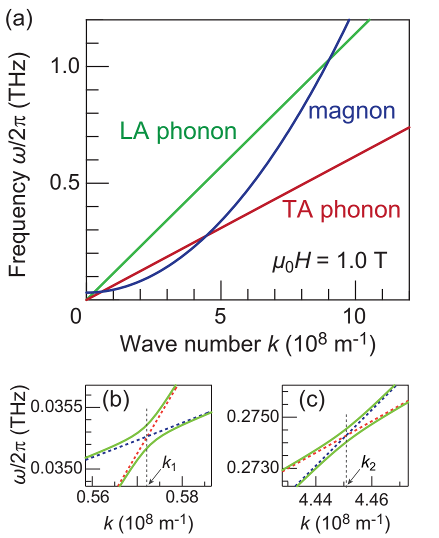


Fig. 1: (a) Magnon, TA-phonon, and LA-phonon dispersion relations for YIG. (b),(c) Magnon polarons at the (anti)crossings between the magnon and TA-phonon branches at (b) lower and (c) higher k values.

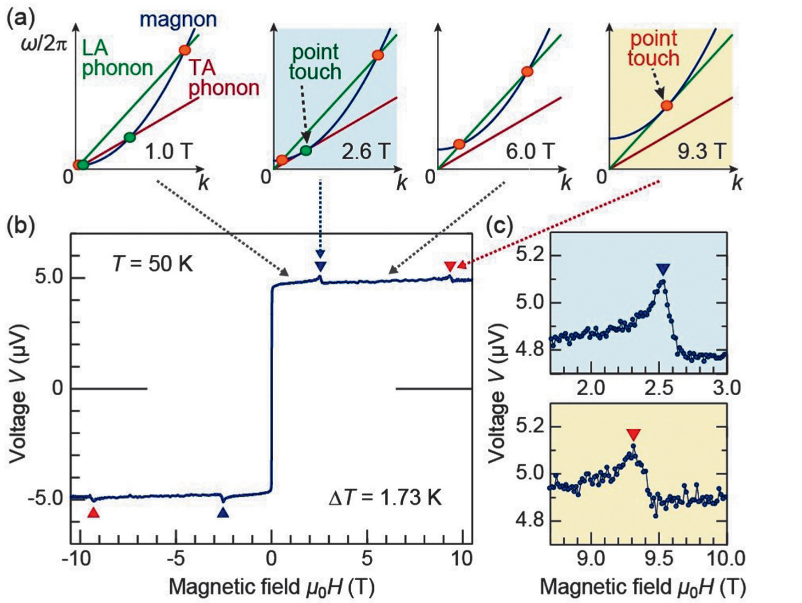


Fig. 2: (a) Magnon, TA-phonon, and LA-phonon dispersion relations for YIG at several magnetic field strengths (H). By increasing H, the magnon dispersion shifts toward high frequencies by the Zeeman energy. (b) H dependence of the SSE-induced voltage (V) in the Pt-film|YIG-film sample. (c) Magnified view of $V(H)$ around the peak fields.

Takashi Kikkawa
Ph.D. student,
Institute for Materials Research and WPI-AIMR,
Tohoku University

Gerrit E. W. Bauer
Professor,
Institute for Materials Research and WPI-AIMR, Tohoku University; Kavli Institute of NanoScience, Delft University of Technology

Eiji Saitoh
Professor,
Institute for Materials Research and WPI-AIMR, Tohoku University; Advanced Science Research Center, Japan Atomic Energy Agency; ERATO, Japan Science and Technology Agency

Group home page Saitoh group: http://saitoh.imr.tohoku.ac.jp/ Bauer group: http://www.bauer-lab.imr.tohoku.ac.jp/

Holographic dual approach to ferromagnets

Naoto Yokoi and Eiji Saitoh

Naoto Yokoi, Masafumi Ishihara, Koji Sato, and Eiji Saitoh, "Holographic realization of ferromagnets", Phys. Rev. D **93**, 026002 (2016). [https://doi.org/10.1103/PhysRevD.93.026002]

Discoveries of new phenomena in spintronics are guided by physical principles such as symmetry, reciprocity, and electric-magnetic duality. As a new guiding principle, we have proposed a dual approach to ferromagnetic systems based on holographic duality, which is a correspondence between a D-dimensional quantum many-body system and a (D+1)-dimensional gravitational theory. The holographic dual model to a 3-dimensional ferromagnetic system is a (4+1)-dimensional gravitational theory with an SU(2) gauge field and a triplet scalar field, which correspond to the spin current and magnetization, respectively. Thermal effects are represented by introducing black holes as background geometry in the dual gravitational theory. Our model provides a bridge between magnetic systems and gravitational theories, and methods and findings in general relativity and black hole physics can beutilized in the field of spintronics as novel guidelines.

A holographic dictionary between physical quantities in ferromagnets and dual gravitational theories was established, and the dictionary enables us to find the observables in magnetic systems by solving the equations of motion of the gauge and scalar field in a charged black hole background. As a first step, we obtained relevant thermodynamic quantities in ferromagnets, such as the magnetization, magnetic susceptibility, and free energy, from the equation of the scalar field Φ on the black hole. The dual model reproduces the critical behavior of the mean field theory near the Curie temperature. Furthermore, for low temperatures, we found the temperature dependence of magnetization consistent with the Bloch T^{3/2} law, which indicates the existenceof spin-wave excitations (magnons), and the resulting susceptibility and free energy exhibited signatures of conduction electrons. Our holographic approach, in principle, can further serve as a new tool to analyze dynamical phenomena involving both magnetization and spin transport.

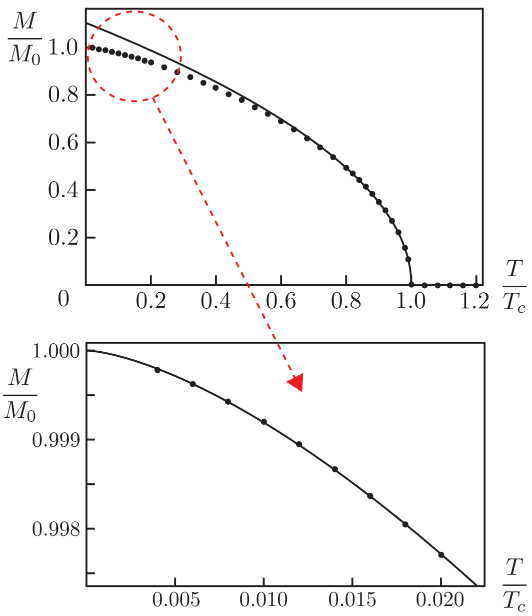


Figure 2: Top figure shows the temperature dependence of magnetization from holographic dual model (dots) and mean field result (solid line). Bottom figure shows the close-up of the results at low temperatures (dots) and the fitting with T3/2(solid line).

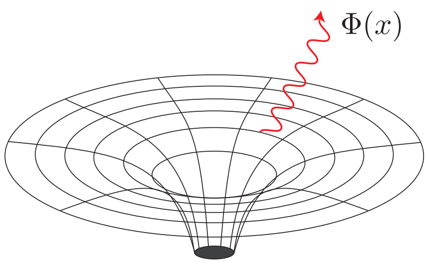


Figure 1: Schematic illustration of holographic dual ferromagnet.

Naoto Yokoi
Postdoctoral researcher,
Institute for Materials Research,
Tohoku University

Eiji Saitoh
Professor,
Advanced Institute for Materials Research and Institute for Materials Research,
Tohoku University; Advanced Science Research Center,
Japan Atomic Energy Agency; ERATO,
Japan Science and Technology Agency

Observation of spin hydrodynamic generation effect

Ryo Takahashi

R. Takahashi, M. Matsuo, M. Ono, K. Harii, H. Chudo, S. Okayasu, J. Ieda, S. Takahashi, S. Maekawa, and E. Saitoh, "Spin hydrodynamic generation", Nat. Phys. **12,** 52 (2016). [http://dx.doi.org/10.1038/nphys3526]

We have experimentally demonstrated spin hydrodynamic generation, the generation of spin current from fluid mechanical motion, in liquid-metal flows. This creates the first exciting point of contact between spintronics and fluid mechanics, which are two of the hottest areas of research but until now have been completely isolated from one another. Generating spin currents is one of the central issues in spintronics, and recent studies have utilized several interactions with electron spins for this purpose. Macroscopic mechanical rotation is a possible generator because of its direct interaction with electron spins, known as the Barnett effect. Despite its potential, little is known about mechanical spin-current generation because it requires a gradient of mechanical rotation, which is difficult to produce in rigid-body motion. However, this is easy in fluid motion due to the viscosity near the inner wall. Therefore, vorticity (local rotation in a flowing liquid) plays a crucial role in spin hydrodynamic generation. Vorticity is generated as the liquid flows through a channel, and the generation of spin currents due to macroscopic fluid motion along the direction of the vorticity gradient is expected. To detect this spin current, we measured the inverse spin Hall (ISH) voltage induced in two flowing liquid metals, Hg and $Ga_{62}In_{25}Sn_{13}$, which was expected along the flow direction [Fig. 1]. As shown in Fig. 2(a), clear voltage signals appear when the liquid metal is flowing. The reversal of polarity upon switching the flow direction is consistent with the ISH effect. We also found a unique scaling rule [Fig. 2(b)] for this phenomenon that is consistent with the current theory on spin hydrodynamic generation. The results demonstrated here have the potential to expand spintronics into branches of fluid mechanics such as micro/nano fluid engineering.

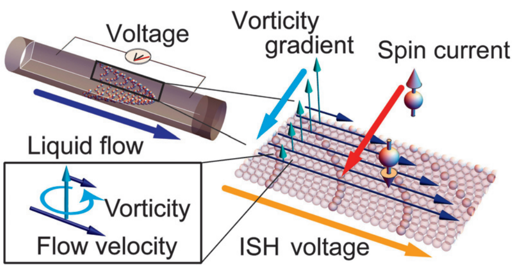


Fig. 1: Schematic diagram of spin hydrodynamic generation effect.

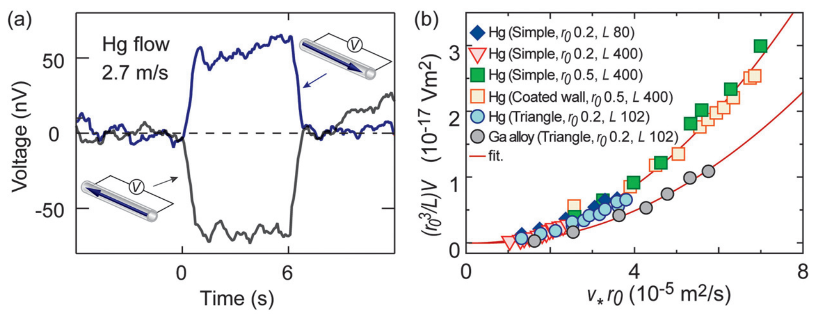


Fig. 2: ISH voltage as a result of fluid-mechanical spin-current generation. (a) Time evolution of the voltage for two flow directions. (b) Scaling behavior on the voltage signals due to spin hydrodynamic generation.

Ryo Takahashi
Postdoctoral Fellow,
Advanced Science Research Center,
Japan Atomic Energy Agency

Group home page http://asrc.jaea.go.jp/soshiki/gr/spinenergy/index-e.html

Observation of temperature-gradient-induced magnetization

Dazhi Hou

D. Hou, Z. Qiu, R. Iguchi, K. Sato, E. K. Vehstedt, K. Uchida, G. E.W. Bauer, and E. Saitoh,
"Observation of temperature-gradient induced magnetization", Nature Communications **7**, 12265 (2016).
[http://dx.doi.org/10.1038/NCOMMS12265]

WPI Advanced Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan.
Spin Quantum Rectification Project, ERATO, Japan Science and Technology Agency, Sendai 980-8577, Japan.
E-mail: dazhi.hou@imr.tohoku.ac.jp

We have reported the first experimental demonstration that gold, which had long been considered a non-magnetic metal, can in fact be magnetized by a heat flow driven by a temperature gradient (Fig. 1a). The experimental setup was quite simple, involving a bilayer comprising yttrium iron garnet (YIG), which is a magnetic insulator, and a thin film of gold (Fig. 1b). The YIG side and the gold side were maintained at different temperatures to drive a heat flow perpendicular to the bilayer. In addition, a magnetic field was applied parallel to the heat flow direction. The Hall voltage[*1] was measured in the gold film using an in-plane electric current, which exhibited a clear linear dependence on the applied temperature gradient. We interpreted this Hall voltage as evidence of induced magnetizationin the gold film due to the heat flow, and named this phenomenon the non-equilibrium anomalous Hall effect (nAHE). Using this technique, extremely small valuesof magnetization—the key to revealing as-yetunknown useful properties of matter—can be measured.

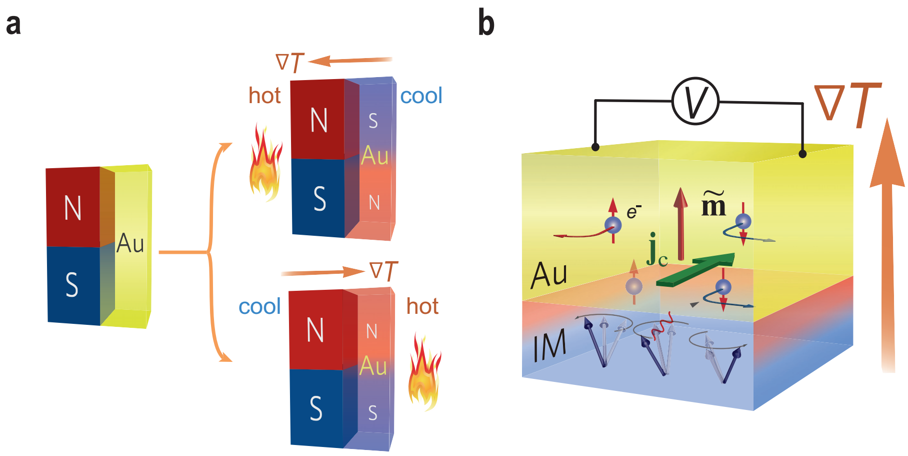


Figure 1: a. Concept of the non-equilibrium magnetization.
b. Illustration of experimental setup

Dr. Dazhi Hou
Research Associate,
WPI-AIMR,
Tohoku University

Group home page http://saitoh.imr.tohoku.ac.jp/

Emergent spinons carrying magnetic monopoles and artificial photons in frustrated pyrochlore quantum magnets

Shigeki Onoda

Yasuyuki Kato and Shigeki Onoda, "Numerical evidence of quantum melting of spin ice: quantum-to-classical crossover", Physical Review Letters **115**, 077202 (2015). [http://dx.doi.org/10.1103/PhysRevLett.115.077202]

Magnetic rare-earth pyrochlores called spin ice [1], e.g., $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$, host a spin-ice-rule interaction J, which makes two spins point inward toward the center of each tetrahedron and the other two spins point outward. This results in a residual entropy in the zero-temperature limit, as occurs in hexagonal water ice. Then, Due to this residual entropy, it costs a finite amount of energy to create positively or negatively "charged" hedgehog defects, such as "3-in, 1-out" or "1-in, 3-out" tetrahedral configurations, from the "2-in, 2-out" defect-free spin-ice vacuum. These charges are often referred to as spin-ice monopoles. When a nearest-neighbor pair of spins pointing "in" and "out" can exchange spin states, as happens in $Pr_2(Sn,Zr)_2O_7$ [2], $Yb_2Ti_2O_7$ [3], and $Tb_2Ti_2O_7$ [2,4], the monopoles exhibit quantum kinematics, and a flux associated with the monopole diamagnetic current is fixed. Thus, the monopoles behave as fractionalized deconfined bosonic quasiparticles that are prototypical spinons, as long as the energy gap in monopole excitations remains finite. This novel insulating state of the monopoles is referred to as a bosonic U(1) quantum spin liquid [5]. There exists a remarkable analogy to quantum electrodynamics (QED); monopoles take place of electric charges and artificial "photons" appear. Our study has provided compelling numerical evidence of the emergence of QED analogues with insulating monopole excitations and gapless artificial "photon" excitations at extremely low temperatures. This magnetic analogue of QED may lead to a magnetic analogue in electronics where "monopoles" take the place of electrons. How the effects of the magnetic field can be used to control monopoles and photons will be published elsewhere [6].

[1] S.T. Bramwell, M. J. P. Gingras, Science **294**, 1495 (2001).
[2] S. Onoda, Y. Tanaka, Phys. Rev. Lett. **105**, 047201 (2010); Phys. Rev. B **83**, 094411 (2011).
[3] L.-J. Chang, S. Onoda, Y. Su, et al., Nature Communications **3**:992 (2012).
[4] H. Takatsu, S. Onoda, S. Kittaka, et al., Phys. Rev. Lett. **116**, 2177201 (2016).
[5] M. Hermele, M. P. A. Fisher, L. Balents, Phys. Rev. B **69**, 064404 (2004).
[6] T. A. Bojesen, S. Onoda, unpublished.

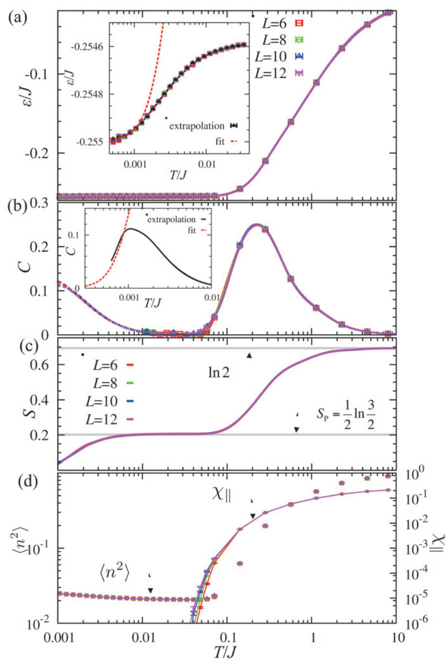


Fig.1: Quantum Monte Carlo results for the temperature (T)-dependent (a) energy ε, (b) specific heat C, (c) entropy S, and (d) charge compressibility $\chi_{\|}$ (right vertical axis). The specific heat peak at higher T arises from a release of entropy from a monopole vacuum, as indicated by the rapid decay of $\chi_{\|}$, while the peak at lower T originates mainly from artificial photons, as revealed in Fig.2.

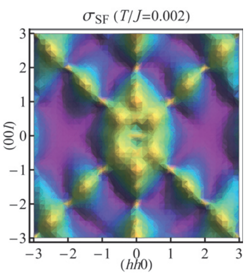


Fig. 2: Low-temperature profile of the polarized neutron-scattering cross-section, matching a pattern created by an artificial photon propagator

Shigeki Onoda
Senior Research Scientist,
Condensed Matter Theory Laboratory;
Quantum Matter Theory Research Team, RIKEN Center for Emergent Matter Science

Group home page http://www.riken.jp/lab-www/cond-mat-theory/onoda/index.html

All-electrical control of spin-spiral domain wall propagation

Koji Sato and Oleg A. Tretiakov

K. Sato and O. A. Tretiakov, "Electrically controlled pinning of Dzyaloshinskii-Moriya domain walls", Appl. Phys. Lett.**108**, 122403 (2016). [http://dx.doi.org/10.1063/1.4944664]

Controlling magnetic domain wall textures is crucial for successful applications of spintronic memory, logic, and sensor nanodevices. Spin currents and local magnetic fields are typically used to manipulate domain walls. However, employing a spin-polarized charge current suffers from Joule heating, and it is difficult to make scalable systems with magnetic fields. It is thus essential to seek out less dissipative and more scalable methods of controlling domain walls for the further development ofdomain-wall based devices such as race-track memories, where controlling the position of a domain wall is important. Mechanical notches have conventionally been used to fix domain wall positions, but the lack of mobility of the pinning site and difficulty in fabrication are the potential drawbacks of this approach. Therefore, it is more desirable to achieve easily adjustable domain wall pinning, especially by all-electrical means.

Thus, we theoretically proposed an approach to control the pinning of a domain wall in a thin ferromagnetic nanowire by an external electric field (see Fig. 1). We considered a nanowire with an easy-axis anisotropy along the wire, an exchange interaction, and a Dzyaloshinskii-Moriya interaction (DMI), where transverse domain walls can be formed when the anisotropy is sufficiently strong. Due to the DMI, the domain wall exhibits a spin-spiral structure whose pitch is determined by the DMI strength. This domain wall has a non-vanishing transverse magnetization, which can be efficiently pinned in the vicinity of a pinning ferromagnet (see Fig. 1).

Applying an electric field modifies the DMI strength, which in turn alters the magnitude of the transverse domain-wall magnetization. Consequently, the pinning strength arising from the interaction between the domain wall and the pinning magnet can be changed. Hence, this proposal provides a way to control the pinning strength of domain walls by all-electrical means via manipulation ofthe DMI strength. Furthermore, we found that the minimal current needed to drive the domain walls can be reduced usingthis method, which maybe beneficial for low-power spintronic applications.

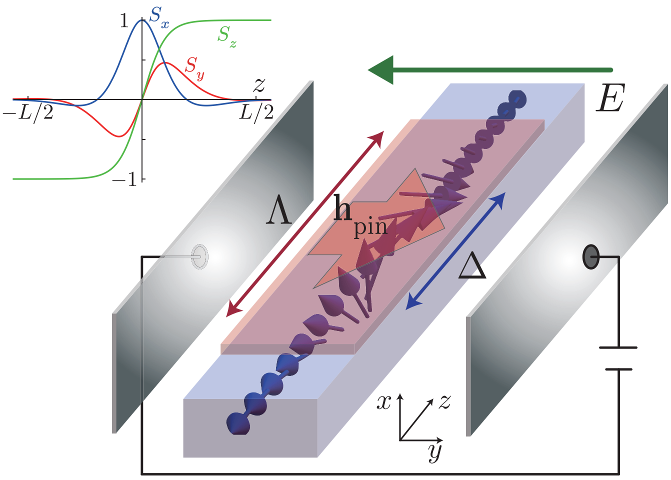


Fig. 1: The setup for a ferromagnetic nanowire with a domain wall in proximity to a strong single-domain ferromagnet under electrostatic gating.

Koji Sato
Assistant Professor,
Institute for Materials Research,
Tohoku University

Oleg A. Tretiakov
Assistant Professor,
Institute for Materials Research,
Tohoku University

Group home page https://sites.google.com/site/tretiakov/

Fermi-point semimetal and Z_2 topological insulator in Pyrochlore Iridates

Fumiyuki Ishii and Shigeki Onoda

F. Ishii, Y.P. Mizuta, T. Kato, T. Ozaki, H. Weng, and S. Onoda, "First-principles study on cubic Pyrochlore Iridates $Y_2Ir_2O_7$ and Pr_2Ir_2O", J. Phys. Soc. Jpn. **84**, 073703 (2015). [http://dx.doi.org/10.7566/JPSJ.84.073703]

Pyrochloreiridates $A_2Ir_2O_7$, (A = Y, rare-earth elements)have attracted great interest for experimental observations of a chiral spin-liquid state below 1.4 K, possible underscreened Kondo effects around 20 K for A=Pr, and insulator-semimetal transitions for A=Nd, Sm, Eu, Gd, Tb, Dy, Ho and Y. In addition, they are candidate materials for hosting nontrivial topological electronic structures with and without electron correlation, due to the strong spin-orbit interaction of Ir 5d electrons compared to the bandwidth and the Coulomb interaction. We have performed extensive fully relativistic LSDA and LSDA+Uelectronic structure calculations on $Y_2Ir_2O_7$ and on $La_2Ir_2O_7$ with crystal parameters the experimentally observed crystal parameter for $Pr_2Ir_2O_7$. With increasing on-site Coulomb repulsion U, asuccessivetransition from a paramagnetic semimetal to an all-in, all-out topologically non-trivial antiferromagnetic (AF) semimetal, and then to an all-in, all-out topologically trivial Mott insulator occurs (Fig.1). A choice of U=1.3eV is consistent with experiments on a narrow-gap AF insulator for $Y_2Ir_2O_7$ and on a paramagnetic semimetal close to an onset of the AF order for $Pr_2Ir_2O_7$. In the case of U=0 for $Pr_2Ir_2O_7$, we demonstrate that decreasing the trigonal compression of IrO_6 octahedra, as is typicallyachieved by changing the A-site elements, drives successive transitions through Fermi-point semimetals of an electron and a hole quadratic bands, to a cubic Z_2 topological band insulator (Fig. 2).

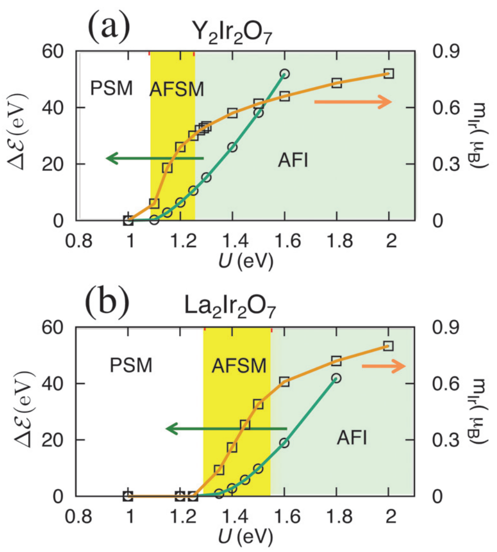


Fig. 1: Phase diagrams of (a) $Y_2Ir_2O_7$ and (b) $Pr_2Ir_2O_7$ as functions of U, obtained with the experimentally observed crystal parameters. The left axis is the total energy difference ΔE between paramagnetic semimetal (PSM) and AF semimetal (AFSM) or insulator (AFI), and the right axis is the magnitude mIr of the ordered local magnetic moment per Ir site.

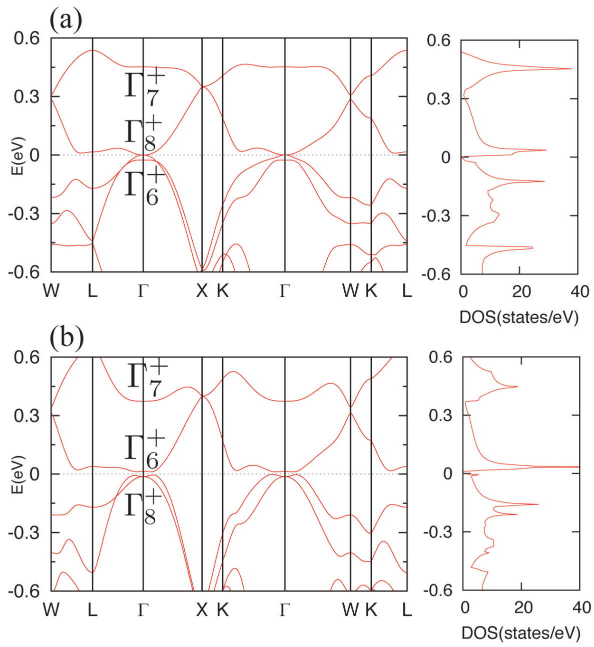


Fig. 2: Electronic band dispersions (left) and densities of states (right) of (a)paramagnetic Fermi-point semimetal phase and (b) Z_2 topological band insulator phase.

Fumiyuki Ishii
Associate Professor,
Faculty of Mathematics and Physics,
Kanazawa University

Shigeki Onoda
Senior Research Scientist,
RIKEN Center for Emergent Mater
Science

Group home page http://f-ishii.w3.kanazawa-u.ac.jp/en/

Current-induced orbital and spin magnetizations in chiral crystals

Taiki Yoda, Takehito Yokoyama, and Shuichi Murakami

T. Yoda, T. Yokoyama, and S. Murakami, "Current-induced Orbital and Spin Magnetizations in Crystals with Helical Structure", Scientific Reports **5**, 12024 (2015). ［http://dx.doi.org/10.1038/srep12024］

Various interconversion phenomena exist between current and electron spins. Such phenomena, such as the spin Hall effect and the Edelstein effect (current-induced spin magnetization), require spin-orbit coupling; however, spin-orbit coupling also gives rise to spin relaxation, which is unfavorable for measurements and applications.

In the present paper, we theoretically show that orbital and spin magnetization is induced by a charge current in chiral crystals. We consider a model of a three-dimensional crystal with neither mirror symmetry nor inversion symmetry. As shown in the Figure, the model is built on a three-dimensional crystal consisting of helical one-dimensional chains with interchain hopping, and one can define a helical axis. Such a crystal can be regarded as an analog of a classical solenoid. In a classical solenoid, a current induces a magnetic field whose orientation depends on the handedness of the solenoid. Analogously, one can expect that a current in the chiral crystal will induce orbital magnetization, depending on its handedness.

Our calculations show that when the current flows along the helical axis, the orbital magnetization is induced either parallel or antiparallel to the current, depending on its handedness. In addition, the current gives rise to an off-equilibrium electron distribution, leading to spin magnetization due to the (spin) Edelstein effect. The current-induced orbital magnetization can be regarded as an orbital version of the Edelstein effect, but, in contrast to many other spin-conversion phenomena, it does not require spin-orbit interaction. There are various materials having chiral crystal structures, such as tellurium (Te) and selenium (Se), and it would be interesting in the future to design and observe this orbital Edelstein effect in various chiral crystals. Because this effect is different from conventional pathways of interconversion between current and magnetization, it will provide us with a new building block for spintronics applications.

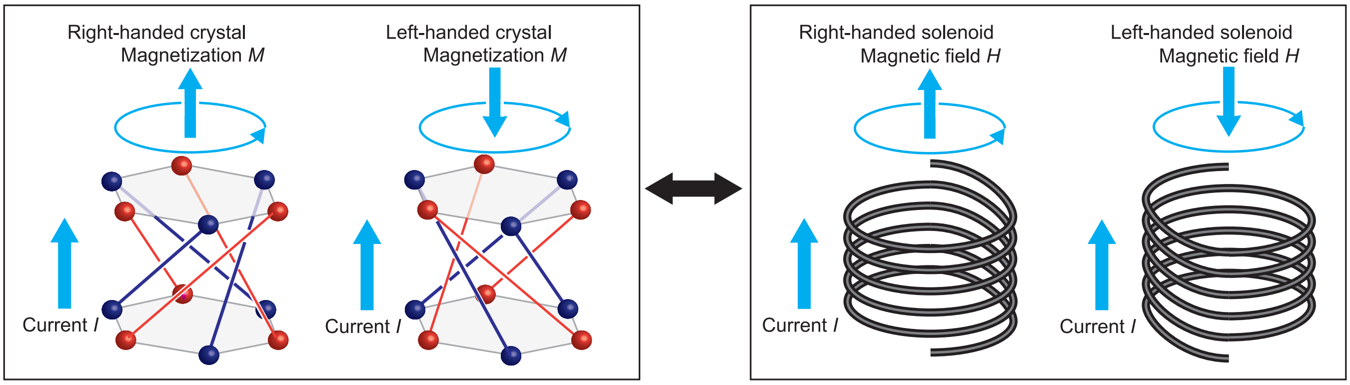
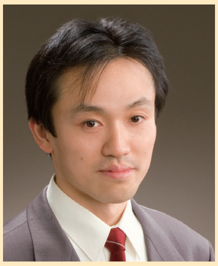


Figure caption: (Left) Lattice of the chiral model used in the calculation. There are two kinds of crystal structure: left-handed and right-handed crystals. (Right) Left-handed and right-handed solenoids, which are analogous to the helical crystals.

Taiki Yoda
Ph.D. student,
Department of Physics,
Tokyo Institute of Technology

Takehito Yokoyama
Assistant Professor,
Department of Physics,
Tokyo Institute of Technology



Shuichi Murakami
Professor,
Department of Physics,
Tokyo Institute of Technology Professor,
Materials Research Center for Element Strategy, TokyoInstitute of Technology

Group home page http://www.stat.phys.titech.ac.jp/murakami/

Meetings and Events

● Event Reports

9th International Conference on Physics and Applications of Spin-Related Phenomena in Solids (PASPS9)

The aim of PASPS9 was to discuss the basic physics of spin-related phenomena in spintronics materials, including semiconductors, metals, and insulators, and their applications to spintronics devices and quantum information technologies. Three plenary speakers and ten invited speakers were respectively selected among the distinguished and young and energetic researchers in attendance. They all gave excellent talks about their high-quality research. An additional thirty-oneyoung researchers and students were selected to be general speakers, and their talks covered broad topics in the field ofspintronics. At the poster sessions, 11 "Young Researcher Best Poster Awards" were given to young researchers, including students, to encourage the youngerscientists in the field. The total number of participants was 237 people, including 67 people from overseas.
PASPS9 successfully overviewed the state-of-the-art research in spintronics and promoted the exchange of information among the researchers in this field. At the end of the conference, it was announced that the next PASPS will be held in Linz, Austria in 2018.

International Workshop on Nano-spin Conversion Science & Quantum Spin Dynamics 2016

The International Workshop on Nano-spin Conversion Science &Quantum Spin Dynamics was held from October 12 to 15, 2016 at Takeda Hall, University of Tokyo. This workshop was co-sponsored by Nano-spin Conversion Science and the RIKEN Center for Emergent Matter Science (CEMS). Twenty-five invited speakers involved in innovative areas of research and 13 speakers from CEMS, RIKEN, gave excellent talks on state-of-the-art research in spintronics, quantum technologies, and topological phenomena. A total of 202 people participated in the workshop, and exchanged ideas and gained friendships. The workshop was truly successful and demonstrated the future prospects of these research fields.

Organization of Nano Spin Conversion Science

Steering Committee

Principle Investigator YoshiChika Otani Institute for Solid State Physics, The University of Tokyo, Professor
Co-Investigator Eiji Saitoh Advanced Institute for Materials Research, Tohoku University, Professor, Tohoku University, Professor
Co-Investigator Masashi Shiraishi Graduate School of Engineering and Faculty of Engineering, Kyoto University, Professor
Co-Investigator Shuichi Murakami Graduate School of Science and Engineering ,Tokyo Institute of Physics, Professor
Co-Investigator Akira Oiwa The Institute of Scientific and Industrial Research, Osaka University, Professor
Co-Investigator Koki Takanashi Institute for Materials Research, Tohoku University, Director
Co-Investigator Sadamichi Maekawa Advanced Science Research Center, Japan Atomic Energy Agency, Director General

Research group A01：Magnetic Spin Conversion

Principal Investigator YoshiChika Otani Institute for Solid State Physics, The University of Tokyo, Professor
Co-Investigator Takashi Kimura Faculty of Science, Kyushu University, Professor
Co-Investigator Fumihiro Matsukura Advanced Institute for Materials Research, Tohoku University, Professor
Co-Investigator Ron Jansen Spintronics Research Center, National Institute of Advanced Industrial Science and Technology, Invited Senior Researcher
Co-Investigator Yasuhiro Niimi Graduate School of Science, Osaka University, Associate Professor
Co-Investigator Teruo Ono Institute for Chemical Research, Kyoto University, Professor

Selected Projects

Principal Investigator Tomoyasu Taniyama Materials & Structures Laboratory, Tokyo Institute of Technology, Associate Professor
Principal Investigator Shinji Miwa Graduate School of Engineering Science, Osaka University, Assistant Professor
Principal Investigator Toshu An School of Materials Science, Japan Advanced Institute of Science and Technology, Associate Professor

Research group A02：Electric Spin Conversion

Principal Investigator Masashi Shiraishi Graduate School of Engineering and Faculty of Engineering, Kyoto University, Professor
Co-Investigator Kohei Hamaya Graduate School of Engineering Science, Osaka University, Professor
Co-Investigator Shingo Katsumoto Institute for Solid State Physics, University of Tokyo, Professor
Co-Investigator Hidekazu Saito Spintronics Research Center, National Institute of Advanced Industrial Science and Technology, Semiconductor Spintronics Team Leader
Co-Investigator Shik Shin Institute for Solid State Physics, University of Tokyo, Professor

Selected Projects

Principal Investigator Rai Moriya Institute of Industrial Science, University of Tokyo, Assistant Professor
Principal Investigator Shinobu Ohya Department of Electrical Engineering and Information Systems, The University of Tokyo, Associate Professor

Research group A03：Optical Spin Conversion

Principal Investigator Akira Oiwa The Institute of Scientific and Industrial Research, Osaka University, Professor
Co-Investigator Arata Tsukamoto Department of Electronic Engineering, Nihon University, Professor
Co-Investigator Shigemi Mizukami WPI Advanced Institute for Materials Research, Tohoku University, Professor
Co-Investigator Kazuya Ando Department of Applied Physics and Physico-Informatics, Keio University, Associate Professor
Co-investigator Takuya Sato Department of Physics, Kyushu University, Associate Professor

Selected Projects

Principal Investigator Sadashige Matsuo Department of Applied Physics, The University of Tokyo, Assistant Professor
Principal Investigator Osamu Sato Institute for Materials Chemistry and Engineering, Kyushu University, Professor

Research group A04：Thermodynamic Spin Conversion

Principal Investigator Eiji Saitoh Advanced Institute for Materials Research, Tohoku University, Professor, Tohoku University, Professor
Co-Investigator Masao Ono Advanced Science Reserch Center, Japan Atomic Energy Agency, Senior Scientist
Co-Investigator Koki Takanashi Institute for Materials Research, Tohoku University, Director

Selected Projects

Principal Investigator Atsushi Hatakeyama Department of Applied Physics, Tokyo University of Agriculture and Technology, Associate Professor
Principal Investigator Yukio Nozaki Department of Physics, Keio University, Professor

Research Group A05：Functional Design of Spin Conversion

Principal Investigator Shuichi Murakami Graduate School of Science and Engineering ,Tokyo Institute of Physics, Professor
Co-Investigator Sadamichi Maekawa Advanced Science Research Center, Japan Atomic Energy Agency, Director General
Co-Investigator Gen Tatara RIKEN Center for Emergent Matter Science, Team Leader
Co-Investigator Naoto Nagaosa Department of Applied Physics, The University of Tokyo, Professor/ RIKEN Center for Emergent Matter Science, Deputy Center Director
Co-Investigator Gerrit E. W. Bauer Institute for Materials Research, Tohoku University, Professor

Selected Projects

Principal Investigator Oleg A. Tretiakov Institute for Materials Research, Tohoku University, Assistant Professor
Principal Investigator Fumiyuki Ishii Faculty of Mathematics and Physics, Kanazawa University, Associate Professor
Principal Investigator Shin Miyahara Faculty of Science Department of Applied Physics, Fukuoka University, Associate Professor
Principal Investigator Shigeki Onoda RIKEN Center for Emergent Matter Science, Senior Research Scientist