One day workshop on nanomagnetism

October, 26 2015

Spintec, Grenoble, France

- 11H - 12H Teruo Ono, Kyoto University (Japan), *"Orbital Magnetism on the Dzyaloshinskii-Moriya Interaction"*

- 12 H - 13H Bert Koopmans, University of Eindhoven (The Netherlands), *"Optical spin transfer and field-free SOT switching"*

Lunch

- 14H30 - 15H30 Joerg Wunderlich, Hitachi Cambridge Laboratory (UK), *"Helicity dependent ballistic magnetic domain wall motion driven by ultra-short laser pulses"*

- 15H30 -16H30 Aurélien Manchon, King Abdullah University of Science and Technology, "*Spin-Orbit Torques: Old Materials, Novel Effects"*

Coffee break

- 16H50 - 17H30 Olivier Boulle, Spintec, Grenoble, France, "*Room temperature chiral magnetic skyrmion in ultrathin magnetic nanostructures"*

- 17H30 - 18H10 Maïr Chshiev, Spintec, Grenoble, France, "*Anatomy of spin-orbit phenomena at ferromagnet/nonmagnet interfaces: mechanisms of control of PMA and DMI"*

Orbital Magnetism on the Dzyaloshinskii-Moriya Interaction

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Chiral interaction between two atomic spins due to a strong spin-orbit coupling, which is known as the Dzyaloshinskii-Moriya interaction (DMI), has attracted intense interest. In particular, it has been demonstrated that the DMI at the interface between ferromagnetic (FM) and heavy nonmagnetic metals (HM) plays a major role for the formation of chiral spin textures, such as the skyrmion [1] and the homochiral Néel-type domain wall [2-4], which are attractive for the development of future information storage technology.
We show that orbital magnetism plays a crucial role in the emergence of the DMI. The temperature dependence of the DMI-induced effective field is quantified by magnetic domain-wall velocity measurements, while the temperature dependence of the spin and orbital magnetic moments in FM and HM layers is determined by x-ray magnetic circular dichroism measurements. We find no direct correlation between the increase of the DMI and the proximity-induced magnetic moment in a HM layer, which is contradictory to the results of a previous report [5], but is consistent with recent first-principle calculations [6]. Furthermore, we establish that the strength of the DMI is proportional to the ratio of the in-plane and out-of-plane orbital moments in a FM layer.
This work was partly supported by Grant-in-Aid for Scientific Research on Innovative Areas, Grant-in-Aid for Specially Promoted Research, and R & D Project for ICT Key Technology of MEXT.

[1] A. Fert *et al*., Nat. nanotech. **8**, 152 (2013).
[2] S. Emori *et al*., Nat. Mater. **12**, 611 (2013).
[3] K.-S. Ryu *et al*., Nat. Nanotechnol. **8**, 527 (2013).
[4] K. Ueda *et al*., Appl. Phys. Express **7**, 053006 (2014).
[5] K.-S. Ryu *et al*., Nat. Commun. **5**, 3910 (2014).
[6] H.Yang *et al*., Preprint at arXiv:1501.05511 (2015).

Biography

Teruo Ono received the B.S., M.S., and D.Sc. degrees from Kyoto University in 1991, 1993, and 1996, respectively. After a one year stay as a postdoctoral associate at Kyoto University, he moved to Keio University where he became an assistant professor. In 2000, he moved to Osaka University where he became a lecturer and an associate professor. Since 2004, he has been working at Kyoto University, where he is now a professor. He has published over 280 technical articles in peer-reviewed journals, including book chapters and review articles, and has given more than 90 invited presentations at international conferences. He served as conference co-chair of the 8th International Symposium on Metallic Multilayers (MML) in 2013, and on the program committees of various international conferences on magnetism and spintronics. He is a member of the IEEE Magnetics Society and is an editor of the Japanese Journal of Applied Physics.

Optical spin transfer and field-free SOT switching

Bert Koopmans[1],
[1]Technische Universiteit Eindhoven, Einhoven, The Netherlands

Biography

Bert Koopmans (1963) graduated at the University of Groningen (1988), where he also obtained his PhD degree on optical second harmonic generation and fullerenes (1993). After a short stay as a postdoc at the Radboud University Nijmegen, he spent three years as a Humboldt Fellow at the Max-Planck Institute for Solid State Physics in Stuttgart, working on optics of semiconductor quantum structures. In 1997 he joined the Department of Applied Physics at the Eindhoven University of Technology, where since 2003 he is full-professor and Group leader of the Group Physics of Nanostructures (FNA). In 2004 he was awarded a NWO Vici Laureate on a program entitled "Spin Engineering in Molecular Devices". His current research interests encompass spintronics (including spin transfer and spin-orbit phenomena, domain wall devices and organic spintronics), nanomagnetism and ultrafast spin dynamics. As of 2014 he is in the management team of the Research Centre for Integrated NanoPhotonics, facilitated by a 20 M€ NWO Gravity grant, and where he initiates research on integrated spintronic-photonic memories. At present, he is coordinator of the center for NanoMaterials (cNM) and program director of the Program on Advanced NanoElectronic Devices within NanoNextNL, a national consortium for research on nanotechnology in The Netherlands. Moreover, he is a member of the board of NanoLabNL, a Dutch national facility providing an open-access infrastructure for R&D in nanotechnology, as well as the advisory board of NanoLab@TU/e.

Helicity dependent ballistic magnetic domain wall motion driven by ultra-short laser pulses[1]

[1]Joerg Wunderlich

Hitachi Cambridge Laboratory, Cambridge, United Kingdom

In my talk I will show that a magnetic domain wall in a perpendicular magnetic film of GaMnAsP propagates ballistically by its own inertia after being exposed by individual ~100fs circularly polarised light pulses. By exploiting the elastic property of a geometrically pinned domain wall we found that the magnetic domain wall still continues to move without excitation many order of magnitudes longer than the duration of the initial excitation. We show that the transfer of angular momentum from photons to the domain wall magnetization occurs at time-scales much faster than the precession time of the responding domain wall magnetisation.

Spin-Orbit Torques: Old Materials, Novel Effects

A. Manchon[1]

[1]King Abdullah University of Science and Technology (KAUST), Physical Science and Engineering Division, Thuwal 23955-6900, Saudi Arabia

Spin-orbit coupling has recently opened wide perspectives in the development of low-power consumption spin devices, by enabling the electrical control of the magnetic degree of freedom of single magnets. In this seminar, I will present a few new theoretical results that I believe can open interesting perspective in this field. I first will discuss our recent results on spin-orbit torque in antiferromagnets and show that spin Hall effect can in principle be used to control antiferromagnetic order parameter. In a second part, I will present our recent calculations on spin swapping torque in magnetic bilayers, showing that interfacial Rashba spin-orbit coupling is not necessary to obtain large field-like torques. Finally, I will introduce new ideas in the old topic of current-driven magnetic textures but emphasizing the role of emergent topological Hall effect in current-driven magnetic vortices and skyrmions.

Biography

Aurelien Manchon
Associate Professor, Material Science and Engineering
Physical Science and Engineering

Education
PhD Joseph Fourier University, France, 2007
MS Summa cum Laude, Orsay University, France, 2004
Engineering Diploma, École Polytechnique, France, 2004

Research Interests
Professor Manchon's interests include the interaction between spin-dependent electronic transport and magnetization in heterogeneous magnetic systems. He developed his research studying the manipulation of magnetization using a spin-polarized current, known as the spin torque effect. This field of investigation is of great importance for technological applications, such as Magnetic Random Access Memories and data storage.
He recently demonstrated that a spin torque effect exists in a single ferromagnetic layer, in the presence of spin-orbit coupling. The description of the magnetization dynamics at high temperature and large excitation regimes, as well as the conversion processes between spin and charge currents, have recently attracted his attention.
Finally, Manchon works on the recently discovered magnetoresistive effects in organic materials, which may provide promising results for sensor applications.

Room temperature chiral magnetic skyrmion in ultrathin magnetic nanostructures

Olivier Boulle[1]
[1]Spintec, CEA/CNRS/Université Grenoble Alpes, Grenoble, 38057, France

Magnetic skyrmions are nanometer scale whirling spin configurations that were predicted in the 80's [1] but were observed only recently. Their small size, topological protection and the fact they can be moved by very small current densities has opened a new paradigm to manipulate magnetization at the nanoscale. This has led to novel concepts of memory and logic devices where skyrmions are the information carriers. A key feature of this spin structure is its chirality, which is at the origin of its topological protection. To date, chiral magnetic skyrmions have been demonstrated only in B20 bulk materials, such as MnSi, FexCo1-xSi or FeGe, and at the surface of ultrathin magnetic films. However, these observations were carried out in the presence of a large external magnetic field and at low temperature which prevents any application to devices. Furthermore, these materials were deposited using slow epitaxial deposition techniques, while faster sputtering deposition techniques are needed for industrial applications. Here we report on the experimental observation of stable magnetic skyrmions at room temperature without applied magnetic field in a Pt/Co/MgO sputtered ultrathin magnetic nanostructure. We used photoemission electron microscopy combined with X-ray magnetic circular dichroism (XMCD-PEEM) to demonstrate its chiral Néel internal structure. The skyrmions have been observed in sub-micrometer dots or wires and their sizes are typically of the order of 120 nm. Spin wave spectroscopy measurements confirm the presence of a large Dzyaloshinskii Moryia interaction in our thin films (D=2 mJ/m2), which explains the observed chiral order. Our experimental observations are well reproduced by micromagnetic simulations and numerical modelling. This allows the identification of the physical mechanisms governing the size and stability of the skyrmions, which are keys for the design of devices based on the manipulation of skyrmions.

Biography
Olivier Boulle did his Phd in the Unité mixte CNRS/Thalès in Palaiseau, France on spin transfer oscillators under the supervision of V. Cros and A. Fert. He then carried out his post-doctoral research at the University of Konstanz with M. Kläui on spin transfer effect in magnetic domain walls and vortices. Since 2010, he is a CNRS staff researcher in Spintec, where he is working on spin transfer and spin orbit torque effects in magnetic domain walls and nanomagnets, SOT-MRAM non-volatile magnetic memories and magnetic skyrmions.

Anatomy of spin-orbit phenomena at ferromagnet/nonmagnet interfaces: mechanisms of control of PMA and DMI

Maïr Chshiev[1],
[1]Spintec, CEA/CNRS/Université Grenoble Alpes, Grenoble, 38057, France

In this talk we elucidate the main features and microscopic mechanisms of both PMA and DMI in FM/NM, FM/I, FM/NM/I, NM1/FM/NM2 bilayer and trilayer structures. The thickness dependencies as well as the impact of interfacial mixing on DMI and PMA values in these interfaces will be discussed. The E-field control possibilities will be explored as well. All these results help clarifying underlying mechanisms of these spin orbit phenomena should help optimizing material combinations for skyrmion- and DW-based storage devices as well as SOT- and STT-MRAM memories.

Biography

M. Chshiev is a theoretical physicist specializing on theory of spintronic phenomena in magnetic nanostructures and electronic structure of materials for spintronics. He is the theory group leader at SPINTEC, one of the world leading labs in the field of spintronics. His background comprises both condensed matter theory and computational material science approaches including ab-initio, tight binding, free electron and diffusive approaches. His works are published in leading scientific journals (Nature Phys., Phys. Rev. Lett. etc.) and he delivered numerous invited and contributed talks worldwide. In particular, he has made important contributions to the understanding of the spin transfer torque (STT) in MTJs and clarified the nature of its voltage dependences which is of crucial importance for creating spintronic applications such as STT-MRAM memories and spin torque nano-oscillators. Among the topics he has been working on are spin-orbit based spintronic phenomena such as perpendicular magnetic anisotropy (PMA), interlayer exchange coupling (IEC), and spin Hall effect (SHE), Dzyaloshinskii-Moriya Interaction (DMI).