24 November 2022

PhD position

Subject: "Optimization of rare-earth-based ferrimagnetic synthetic nanostructure towards nucleation and manipulation of skyrmions"

General information

Workplace: Institut Jean Lamour, University of Lorraine, Nancy, France + 12 months secondment at the Center for Quantum Phenomena, New York University
Type of contract: PhD contract funded by LUE (https://www.univ-lorraine.fr/lue/)
Contract period: 36 months
Expected date of employment: January 2023
Proportion of work: Full time
Desired level of education: Master's degree in physics, applied physics, material science or nanophysics.

Subject description

Magnetic skyrmions are topological spin textures. Since the experimental discovery of the Dzyaloshinskii–Moriya interaction (DMI) at the interfaces of thin film structure, they have been a center of interest for the nanomagnetism community. The interfacial DMI is an antisymmetric exchange interaction that establishes a preferred chirality for spin textures, making it a key ingredient for the formation of skyrmions in two-dimensional magnetic systems and nanoscale thin-film multilayers. Magnetic skyrmions are anticipated to be used as bits to store information in future memory and logic devices. To allow skyrmions-based nanodevices with dense integration and low energy cost, isolated skyrmions nucleated at room temperature which can be displaced and annihilated using current pulses and can be detected electrically are needed. Moreover, smaller skyrmion diameters (from the 100 nm to the 10 nm range) should be obtained together with reliable current-induced motion (faster velocities combined with further reduced depinning currents).

A problem with skyrmions in a ferromagnet layer is that because of strong magnetic dipolar interactions it is impossible to obtain ultra-small skyrmions and it is difficult to stabilize them. The dipolar interaction can also reduce the speed of those skyrmions. Furthermore, a consequence of the topology of ferromagnetic skyrmions on their dynamics is their deflection with respect to the direction of any driving force, known as the skyrmion Hall effect.

The goal of this project is to develop the study of skyrmions dynamics in perpendicular magnetization coupled anti-ferromagnetic (Synthetic Anti-Ferromagnetic or ferrimagnetic - SAF) multilayer structures. In antiferromagnets (ferrimagnet), two coupled equivalent magnetic subsystems align antiparallel to each other with no net (weak net) magnetic moment, which reduce the dipolar fields. These types of multilayers may enable small, easy to nucleate and fast skyrmions. Moreover, the skyrmion Hall effect is compensated in antiferromagnets and thus the cancellation of the transverse motion should allow efficient skyrmion motion along the driving force direction, which is crucial for most skyrmion-based applications. It has been shown using rare-earth transition metal ferrimagnets that skyrmions can be formed even in thick films [1] and that it is possible to tune Dzyaloshinskii-Moriya interactions in GdCo ferrimagnetic alloys [2,3]. Recently, we have shown a large self-production of spin current in rear-earth transition metal ferrimagnets thanks to the strong spin-orbit coupling in 5d bands of the rear-earth [4] that could be used to manipulate skyrmions. Moreover, we have shown skyrmions nucleation by fs laser pulses [5].

In this context the objectives of this project are: i) To grow synthetic antiferromagnets or synthetic ferrimagnets which allow the creation of skyrmions and to control and reduce the magnetic dipolar interaction, ii) To study the properties of skyrmions in these heterostructures, and iii) To study the dynamics of the skyrmions either induced by applied electrical current or fs laser pulses.

The selected PhD student will optimize nanostructure growth as well as optimize the system and approach to nucleate skyrmions and, depending on progress, show the manipulation of such skyrmions by electrical and/or optical means. She/he will work on an experimental setup for electronic transport characterization at the state of the art [2,3,4]. Moreover, she/he will use and develop new experimental setups, contribute to their improvement, participate in the interpretation of the results obtained and propose new experiments. This thesis is funded by Lorraine Université d'Excellence (LUE) program. The PhD will also conduct research for about 12 months in Prof. Kent's group in New York University with additional funding provided by sources from NYU for New York City accommodations. Prof. Kent is the Director of Center for Quantum Phenomena (CQP) at NYU. He is also Dr. Honoris Causa by Lorraine University.

References

[1] Woo *et al*., Nat. Comm. **9**, 959 (2018)
[2] Quessab, Kent, *et al*., Sci. Rep. **10**, 1 (2020)
[3] Quessab, Kent, *et al*. Adv. Science **8**, 210048 (2021)
[4] Cespedes-Berrocal, *et al.*, Adv. Mater. **33**, 2007047 (2021)
[5] Je *et al*., Nano Lett. **18**, 7362 (2018)

Keywords: spin current, ferrimagnet, antiferromagnet, spin-orbit torque, skyrmions.

Work context

The PhD student will work within the Spintronic and Nanomagnetism research group https://spin.ijl.cnrs.fr under the supervision of Dr. J. Carlos Rojas-Sánchez and within the Center for Quantum Phenomena under the supervision of Prof. Andy Kent from NYU https://as.nyu.edu/content/nyu-as/as/faculty/andrew-d-kent.html .

Skills

Knowledge of Solid State Physics, including magnetism and electronic transport properties is essential. Knowledge of English (oral and written) is important and knowledge of French would be an advantage. As an enthusiastic researcher you like team work, and have a flexible approach to collaborating between different laboratories. Taste in both experimental and theoretical work is of added interest. Knowledge of Landau Lifshitz Gilbert (LLG) equations and spin-orbit torques is an advantage too.

Constraints and risks

No major risk.

About Institut Jean Lamour

The Institute Jean Lamour (IJL) is a joint research unit (UMR 7198) of CNRS and *Université de Lorraine.* Focused on materials and processes, science and engineering, it covers: materials, metallurgy, plasmas, surfaces, nanomaterials and electronics. It has 183 researchers/lecturers, 91 engineers/technicians/administrative staff, 150 doctoral students and 25 post-doctoral fellows. Partnerships exist with 150 companies and our research groups collaborate with more than 30 countries throughout the world. Its exceptional instrumental platforms are spread over 4 sites; the main one is located on Artem campus in Nancy.

The project will be carried out within the SPIN team whose subjects range from the development of innovative materials for implementation in spin electronics devices, to the development of magnetic sensors and the fundamental study of physical phenomena related to magnetism.

Application

Application should be performed trough https://www.adum.fr/. A few candidates will be pre-selected for an interview as applications arrive. Also please email your application using the following subject: "NAME application for LUE PhD 2022 IJL+NYU" where NAME stands for your last name.
Applicants are invited to send a CV, recommendations letters and cover letter together with diploma copies to:

- J. Carlos Rojas-Sánchez (CNRS Researcher) : juan-carlos.rojas-sanchez@univ-lorraine.fr
- Andrew Kent (NYU CQP Director) andy.kent@nyu.edu