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IEEE Magnetics 2022 Distinguished Lecturer

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Exploring the Potentials of Spin-Orbitronics

The ever-increasing demand for information technology for power-efficient components has led to the search for alternative solutions to mainstream microelectronics. In this context, spintronics devices stand out as competitive candidates, especially for memory and logic applications. A promising route harvests unconventional transport properties arising from spin-orbit coupling in magnetic heterostructures lacking inversion symmetry.

In these systems, typically multilayers of transition-metal ferromagnets and heavy materials (e.g., W, Pt, Ta, Bi2Se3, and WTe2), interfacial spin-orbit coupling promotes a wealth of remarkable physical phenomena: the generation of spin-orbit torques, the interconversion between spin and charge currents, and the stabilization of topological magnetic skyrmions. These effects have gathered extraordinary interest and have led to remarkable experimental breakthroughs, including extremely fast magnetic reversal, terahertz emission, and current-driven skyrmion motion. The recent synthesis of novel classes of materials, including all-oxide heterostructures, noncollinear antiferromagnets, and van der Waals heterostructures, has profoundly enriched this vivid field of research by unlocking unforeseen forms of torques and magnetic interactions, thereby enhancing the functionalities of spin-orbitronic devices.

This lecture will provide a theoretical perspective of the advancement of the fascinating field of spin-orbitronics, focusing on two emblematic mechanisms: the spin-orbit torque and the Dzyaloshinskii-Moriya interaction. I will examine what theory and materials modeling can tell us about these two effects, and what future research directions they open. I will first introduce key concepts in spintronics, such as spin currents and spin-transfer torque, and show how spin-orbit coupling enables new physical effects of high interest for potential applications. I will present standard phenomenological descriptions of these two effects, spin-orbit torque and Dzyaloshinskii-Moriya interaction, determine the symmetry rules that govern them, and give a broad overview of the current state-of-the-art of the field from experimental and theoretical standpoints. Finally, I will explore how spin-orbitronics takes a completely new form in materials possessing low crystalline symmetries, such as Fe3GeTe2, CuPt/CoPt bilayers, and noncollinear antiferromagnets (e.g., Mn3Sn).

I hope this seminar will not only encourage electrical engineers to engage in this beguiling field of research and explore the device implications of this new technology but also reach out to scientists working in adjacent fields (terahertz science, for instance) who could bring inspiring new ideas to spintronics [1]–[5].

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- [3] E. Jué, C. K. Safeer, M. Drouard, A. Lopez, P. Balint, L. Buda-Prejbeanu, O. Boulle, S. Auffret, A. Schuhl, A. Manchon, I. M. Miron, and G. Gaudin, "Chiral damping of magnetic domain walls," Nature Mater., vol. 15, pp. 272-277, March 2016.
- [4] S. Laref, K.-W. Kim, and A. Manchon, "Elusive Dzyaloshinskii-Moriya interaction in monolayer Fe3GeTe2," Phys. Rev. B, vol. 102, 060402, August 2020.
- [5] L. Liu et al., "Symmetry-dependent field-free switching of perpendicular magnetization," Nat. Nanotech., vol. 16, pp. 277-282, January 2021.

Biography

Aurélien Manchon received the M.Eng. degree from the École Polytechnique, Palaiseau, France, in 2004, and the Ph.D. degree in physics from Université Joseph Fourier and Spintec Laboratory, Grenoble, France, in 2007.

He was a Post-Doctoral Fellow at the University of Missouri, Columbia, MO, USA, and the University of Arizona, Tucson, AZ, USA. He was an Assistant Professor from 2009 to 2015 and an Associate Professor from 2015 to 2019 of materials science and engineering at the King Abdullah University of Science and Technology, Thuwal, Saudi Arabia. He is a Professor of physics at the Interdisciplinary Center for Nanoscience of Marseille, Aix-Marseille University, Marseille, France. His research focuses on theoretical spintronics and aims at identifying novel mechanisms that can be used to operate low-power, ultrafast, spin-based devices. His research interests include spin-orbit coupled transport, chiral magnetism, antiferromagnets, and ultrafast dynamics.