Manipulation of magnetic skyrmions for neuromorphic computing

Context

Magnetic skyrmions are texture composed of spins that whirl closely to form a topologically stable, chiral structure (see Fig.1 (a-b)). Their size can be as small as a few nanometers. Skyrmions can also be manipulated by electric currents, which has led to novel concepts of non-volatile magnetic memories and logical devices where skyrmions in nanotracks encode the information. The nanometer size of skyrmions, combined with the low current density required to induce their motion, opens a path for devices that combine high storage density, high speed execution and low energy consumption. A first step toward application was made in Spintec with the first direct observation of magnetic skyrmions at room temperature in ultra-thin Pt/Co(1nm)/MgO multilayer nanostructures [1] and the demonstration of their fast (>100 m/s) manipulation using electrical currents [2].

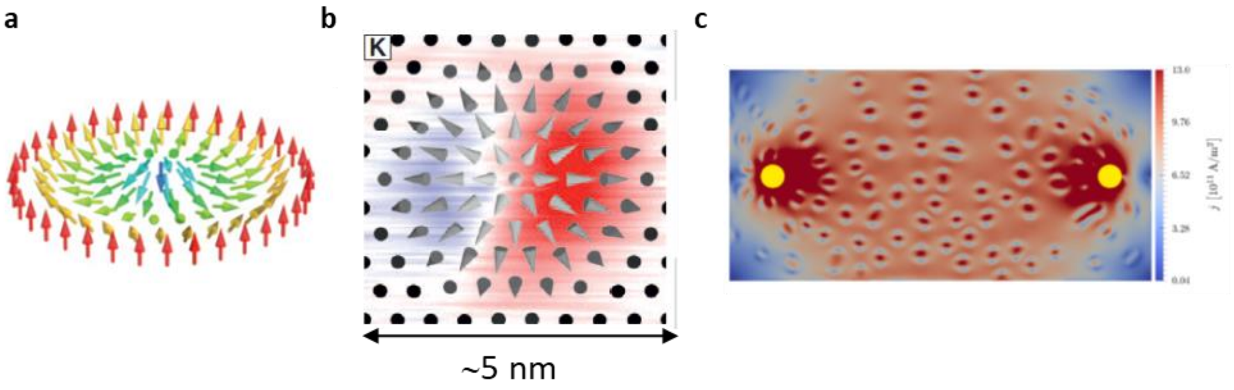

Figure 1a Schematic representation of the spin texture of a magnetic skyrmion b. Spin polarized scanning tunneling microscopy (SP-STM) of a magnetic skyrmion in FePd(2ML) on Ir(111) at 4.2 K [3]. c Proposal of skyrmion reservoir computing device: the current injected in the magnetic film at the position of the yellow dots, leads to oscillation of the skyrmion texture. The resulting changes in the device resistance can be used to recognize temporal pattern for speech recognition. [4]

Recently, unconventional computing schemes, such as neuromorphic or reservoir computing, have been proposed where skyrmions are used to solve standard complex machine learning problems (classification, prediction) with very low energy consumption [4]. The nanometer size of magnetic skyrmions and their non-volatility would allow gains of several orders of magnitude in computing speed and delay compared to current neuromorphic computing devices.

In this internship, we propose to demonstrate the potential of magnetic skyrmions for neuromorphic computing by showing the basic functionalities of logic devices based on the manipulation of magnetic skyrmions for non-conventional computing. The first step will be to fabricate neuromorphic devices based on the manipulation of skyrmions and demonstrate their basic functionalities. The final objective will be the demonstration of the resolution of standard learning problems, for instance voice recognition.

Work program & Skills acquired during internship

The internship will be based on all the methods and experimental techniques used for the development and characterization of spintronic devices: sputtering deposition of ultra-thin multilayers and the characterization of their magnetic properties by magnetometry methods, then nanofabrication of nanostructures by electron beam lithography and ion etching. The nanofabrication will be performed at the PTA nanofabrication platform located in the same building as the Spintec laboratory. The manipulation of the skyrmions in the nanostructures will then be characterized by Kerr effect optical magnetic microscopy (MOKE). The data will then be analyzed using neural network algorithms in order to achieve pattern recognition tasks.

Reference

[1] O. Boulle *et al.*, Nat Nano 11, 449 (2016).
[2] R. Juge *et al.*, Phys. Rev. Applied 12, 044007 (2019).
[3] N. Romming *et al.*, Science 341, 636 (2013).
[4] D. Pinna *et al.*, Phys. Rev. Applied 14, 054020 (2020).

http://www.spintec.fr/ 17 avenue des martyrs 38054 GRENOBLE cedex 9 Contact Olivier.boulle@cea.fr	Requested background: Master 2 Duration: 6 months Start period: beginning of 2023