Towards a topology-based compact neuromorphic component

Marie-Blandine Martin[1]
Tristan da Câmara Santa Clara Gomes[1], Yanis Sassi[1], Sachin Krishnia[1], Dedalo Sanz-Hernandez[1], Tanvi Bhatnagar-Schöffmann[2], Dafiné Ravelosona[2], Damien Querlioz[2], Liza Herrera-Diez[2], Bruno Dlubak[1], Pierre Seneor[1], Vincent Cros[1], Julie Grollier[1], Nicolas Reyren[1]

[1]Laboratoire Albert Fert, CNRS, Thales, Université Paris-Saclay, 1 Avenue Augustin Fresnel, 91120 Palaiseau, France
[2]Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Saclay, 91120 Palaiseau, France

Marie-blandine.martin@cnrs-thales.fr

Thanks to their original properties, magnetic skyrmions have many promising applications, from sensors through data storage to non-conventional computing [1-3]. Among the main advantages of magnetic skyrmions are their sub-micronic size, their particle-like behavior, their stability and non-volatility at room temperature and the low energy requirement for their motion. It has been shown, most often separately, that magnetic skyrmions can be experimentally nucleated [4-7], moved [4,7], annihilated [6] and detected electrically using Anomalous Hall effect [8] in metallic multilayers.
In this talk, we will propose a neuromorphic device design using full-electrical manipulation and detection of skyrmions to perform basic operations required for neuromorphic computing [9]. Indeed, the operating principle of an artificial neuromorphic component is to work by performing a simple operation: it multiplies various input signals with corresponding synaptic weights and sums them up [10]. Mathematically, this can be represented as $y = \Sigma(w_i x_i)$, where x_i are the inputs and w_i are the synaptic weights. All the building blocks necessary to achieve the demonstration of a weighted sum of skyrmions will be presented, from the nucleation and motion of a controlled number of magnetic skyrmions in multilayer tracks using electrical current pulse parameters to the electrical detection of a sum of skyrmions through anomalous hall effect.
The demonstrated skyrmion-based neuromorphic device paves the way to skyrmionic low-energy devices contributing to a global reduction of the environmental impact of AI applications.

References

[1] Fert, A., Reyren, N. and Cros, V. Nat Rev Mater 2 (2017) 17031
[2] Bourianoff G. et al, AIP Adv. 8 (2018) 055602
[3] Fert, A., Reyren, N. and Cros, V. Nat Rev Mater 2 (2017) 17031,
[4] Bourianoff G. et al, AIP Adv. 8 (2018) 055602
[5] K.M. Song et al, Nature Electronics 3.3 (2020) 148
[6] Legrand, W. et al. Nano Lett. 17 (2017) 2703
[7] Hrabec, A. et al. Nat. Commun. 8 (2017) 15765
[8] Woo, S. et al., Nat. Electron. 1(2018) 288
[9] Da Camara Santa Clara Gomes, T et al arXiv preprint arXiv:2310.16909
[10] Grollier, J et al Nat. Electron. 3 (2020) 360