O 68: PhD Focus Session: Symposium on "Magnetism – A Potential Platform for Big Data?" (joint session MA/AKjDPG/O)

As the title of a recent nature editorial article "Big data needs a hardware revolution" points out, new technologies and hardware architectures are necessary in order to cope with the ever increasing amount of information. Google's AlphaGo's success apprised of the potential of parallel computing, yet energy efficiency is a major challenge. Hardware developers came up with mimicking the human brain as the most efficient processor, leading to the field of neuromorphic computing. An immense amount of research is deployed in different fields to screen for fast, low energy consuming and scalable solutions. This focus session is meant to give insight into the current state-of-the-art computing together with its challenges as an introduction. Two major approaches to implement new computation technologies using magnetism, namely, neuromorphic computing based on spintronics, and wave-based computing using magnonics will be presented. A fourth talk, covering the prevailing use of magnetic tape for Big Data storage will give insight into the magnetic backbone of the largest information repositories.

Organizers: Mauricio Bejarano and Tobias Hula (Helmholtz-Zentrum Dresden Rossendorf), Luis Flacke and Lukas Liensberger (Walther-Meissner Institute and TU Munich)

Time: Wednesday 15:00–17:15 Location: HSZ 04

Invited Talk O 68.1 Wed 15:00 HSZ 04
Data Storage and Processing in the Cognitive Era — •Giovanni Cherubini — IBM Research - Zurich

In this talk, I will present the emerging vision of cognitive data systems. A data system comprises physical devices that provide means to acquire, store and modify data for analytics and communications tasks, with the goal of obtaining high-value information. With the need to deal with exponentially growing amounts of data, however, the system size and complexity present major challenges for data storage and processing. In addition, with the approaching end of Moore's law, there is a dire need to significantly improve the efficiency of data systems in terms of cost and energy. To address these challenges, cognitive data systems will require novel learning algorithms and computing paradigms. The talk will be divided into two parts, focusing on data storage and processing aspects. First, I will present advanced technologies for big data storage systems, with focus on magnetic tape drives of future generations, targeting areal densities of several hundred gigabits per square inch on a flexible medium. Next, I will introduce in-memory computing techniques and devices that are well suited for novel computing systems, which are based on non-von Neumann architectures and aim at achieving the efficiency of the human brain.

Invited Talk O 68.2 Wed 15:30 HSZ 04
Brain-inspired approaches and ultrafast magnetism for Green ICT — •Theo Rasing — Radboud University, Institute for Molecules and Materials, Heijendaalseweg 135, 6525AJ Nijmegen, the Netherlands

The explosive growth of digital data use and storage has led to an enormous rise in global energy consumption of Information and Communication Technology (ICT), which already stands at 7% of the world electricity consumption. New ICT technologies, such as Artificial Intelligence push this exponentially increasing energy requirement even more, though the underlying hardware paradigm is utterly inefficient: tasks like pattern recognition can be performed by the human brain with only 20W, while conventional (super)computers require 10 MW. Therefore, the development of radically new physical principles that combine energy-efficiency with high speeds and high densities is crucial for a sustainable future. One of those is the use of non-thermodynamic routes that promises orders of magnitude faster and more energy efficient manipulation of bits. Another one is neuromorphic computing, that is inspired by the notion that our brain uses a million times less energy than a supercomputer while, at least for some tasks, it even outperforms the latter. In this talk, I will discuss the state of the art in ultrafast manipulation of magnetic bits and present some first results to implement brain-inspired computing concepts in magnetic materials that operate close to these ultimate limits.

15 min. break.

Invited Talk O 68.3 Wed 16:15 HSZ 04
How good are spin waves for data processing? — •Andrii Chumak — Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Over the last decade, spin waves and their quanta magnons attract attention as data carriers in novel types of data processing units instead of electrons. Among the advantages proposed by spin waves, one can name added value given by the phase of the wave, pronounced nonlinear phenomena, scalability down to nm sizes, GHz to THz frequency range as well as low-loss information transport [1].

Recently, significant progress in the miniaturization of magnonic elements down to 50 nm took place [2, 3]. Moreover, a spin-wave directional coupler was investigated numerically [4] and realized experimentally on the nano-scale [5]. This is a universal unit allowing for the processing of analog RF and binary-coded digital information and is suitable for novel unconventional computing. E.g., the first integrated magnonic circuit in the form of half-adder was studied numerically [6].

Finally, now we are able to determine the parameters of future magnonic devices. The benchmarking of magnonic circuits with respect to 7 nm CMOS will be presented in the talk.

[1] A.V. Chumak, et al., Nat. Phys. 11, 453 (2015). [2] Q. Wang, B. Heinz, et al., Phys. Rev. Lett. 122, 247202 (2019). [3] B. Heinz, et al., arXiv: 1910.08801 (2019). [4] Q. Wang, P. Pirro, et al., Sci. Adv. 4, e1701517 (2018). [5] Q. Wang, M. Kewenig, et al., arXiv: 1902.02855 (2019). [6] Q. Wang, R. Verba, et al., arXiv: 1905.12353 (2019).

Invited Talk O 68.4 Wed 16:45 HSZ 04
Unconventional computing with stochastic magnetic tunnel junctions — •Alice Mizrahi[1,2,3,4], Tifenn Hirtzlin[2], Matthew Daniels[3,4], Nicolas Locatelli[2], Akio Fukushima[5], Hit Kubota[5], Shinsi Yuasa[5], MD Stiles[4], Julie Grollier[1], and Damien Querlioz[2] — [1]Unité Mixte de Physique CNRS, Thales, Univ. Paris-Sud, Université Paris-Saclay, 91767 Palaiseau, France — [2]Centre de Nanosciences et de Nanotechnologies, Univ. Paris-Sud, CNRS, Université Paris-Saclay, 91405, Orsay, France — [3]Maryland NanoCenter, University of Maryland, College Park, Maryland 20742, USA — [4]National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA — [5]Spintronics Research Center, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, 305-8568, Japan

Magnetic tunnel junctions are bi-stable nanodevices which magnetic state can be both read and written electrically. Their high endurance, reliability and CMOS-compatibility have made them flagship devices for novel forms of computing. While they are mostly used as non-volatile binary memories, they can be made unstable and thus behave as stochastic oscillators. Here, we show how stochastic magnetic tunnel junctions are promising elements for low energy implementations of unconventional computing. An analogy can be drawn between stochastic magnetic tunnel junctions and stochastic spiking neurons. We apply neuroscience computing paradigm to these devices and demonstrate that they can be the building blocks of low energy artificial neural networks capable of on-chip learning.