Stage N° : 10

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Title:
Spin waves manipulation and detection in conventional materials

Keywords:
Spintronics, Spin waves, spin orbit coupling, magnetization dynamics, ferromagnetic resonance

Summary
The miniaturization of CMOS devices becomes increasingly difficult due to fundamental limitations and the increase of leakage currents responsible for increased power consumption and over-heating. Large research efforts are devoted to find alternative concepts that allow for increased data-density at low power consumption as compared to conventional semiconductor approaches.
Spin waves have been identified as a potential technology that can complement and outperform CMOS in complex logic applications, profiting from the fact that these waves enable wave computing on the nano-scale.
The practical application of spin waves, however, requires the demonstration of scalable, CMOS compatible spin-wave detection schemes in material systems compatible with standard spintronics as well as semiconductor circuitry.
This internship will focus on the manipulation and detection of spin waves, based on spin orbit coupling phenomena (e.g. the inverse spin Hall effect and the spin orbit torques). It will involve nanofabrication of devices using clean room facilities and RF measurements of magnetization dynamics.

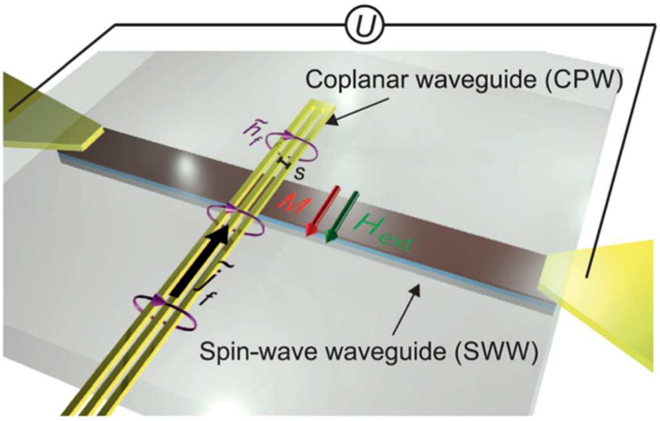
Details of subject
The miniaturization of CMOS devices becomes increasingly difficult due to fundamental limitations and the increase of leakage currents responsible for devices large consumption and over-heating. Large research efforts are devoted to find alternative concepts that allow for a larger data-density and lower power consumption than conventional semiconductor approaches.
Spin waves have been identified as a potential technology that can complement and outperform CMOS in complex logic applications, profiting from the fact that these waves enable wave computing on the nano-scale.
Magnonics explores the physics of spin waves and magnons as well as their use in information transport and processing: proof of concept of a magnon transistor, a spin-wave multiplexer, … Nevertheless, their large sizes and the unconventional materials used prevent their direct integration in CMOS circuits.
The use of these spin waves in practical applications requires demonstrating that they can be generated, manipulated and detected by scalable nanoscale devices made of standard spin electronics materials and compatible with CMOS technology.
The spin orbit coupling provides a new "family" of interesting effects for the manipulation and detection of these spin waves. The inverse spin Hall effect (iSHE), for example, would allow local electrical detection of propagating spin waves while the spin orbit torques would allow their local manipulation.
The internship will focus on these two aspects. The experimental work will take place at Spintec, pioneer in the study of these phenomena. The spin orbit torques influence will be studied in the case of an overall and uniform excitation of the magnetic material (ferromagnetic resonance) and in the case of propagating spin waves. The detection will be done using the iSHE by optimizing the devices materials and geometry.

The samples, whose sensitive elements will be around the hundred nanometer, will require nanofabrication in clean room. They will be studied by RF measurements of magnetization dynamics under the action of a DC current.
The student will be introduced to the concepts of spintronics (spin polarized transport, spin orbit torques, spin Hall effect), the concept of magnetization dynamics under spin current and high frequency measurement techniques.

Requested skills
Master 2 solid state physics / Condensed matter physics / Material science

Possibility to follow with a PhD Yes/No
Yes

Figure



Schematic of an investigated sample: an asymmetric magnetic stack is patterned into a spin-wave waveguide (SWW) with two leads (yellow) to measure the DC voltage (spin wave detection). An insulating Al_2O_3 separates the SWW from a nanometric, shorted coplanar wave guide (CPW) that acts as a spin-wave excitation source.