Using magnetic domain walls as nanometric waveguides for spin-waves

Magnetic domain walls are micromagnetic objects with nanometric lateral dimensions, which separate regions of a magnetic medium with magnetization vectors oriented in different (often opposite) directions and where the direction of the magnetization rotates progressively. They can be created, moved, shaped and erased almost at will. Spin-waves, on the other hand, are collective excitations, which take the form of propagating disturbances in the magnetic ordering. They are considered as possible candidates for processing information and realizing reprogrammable logic operations in so-called magnonic circuits, the design of which will ultimately require to guide spin-waves along curved and modifiable paths. Recent studies [1,2] have shown that magnetic domain walls can act as efficient waveguide and force spin-waves to take sharp turns. The fundamental reason for this is that magnetic domain walls host special spin-wave modes, which are strongly localized sidewise but free to propagate in the direction parallel to the wall. These bound spin-wave modes are lying in the frequency gap of the usual extended spin-wave modes and can then be excited independently [Fig. 1].

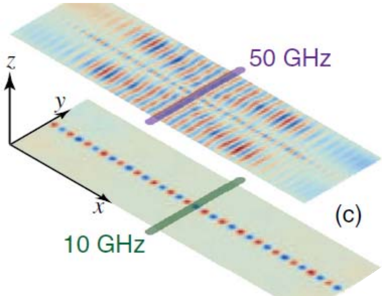
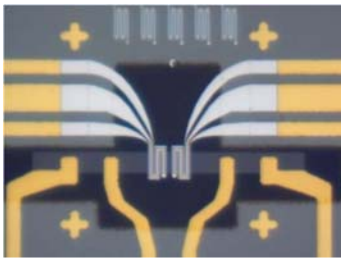
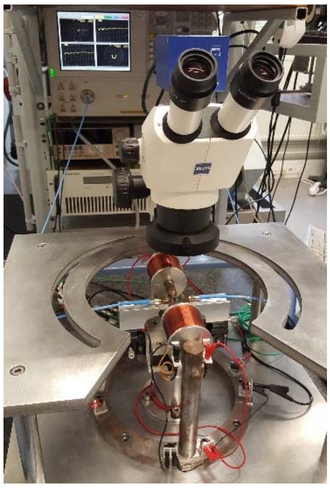


Fig. 1: Excitation of spin-waves by a localized ac magnetic field. At low frequency, spin-waves are confined in the domain wall sitting in the center of the medium, whereas at higher frequency, spin-waves are excited both in the wall and in the adjacent domains. Taken from Ref. 1.

Fig. 2 (right): Microwave magnetic probe station of IPCMS.

Fig. 3 (below): Electron microscopy image of a typical PSWS device (the field view is 120 µm wide).





The goal of the proposed internship is to study such domain-wall channelized spin-wave (DWCSW) modes using the Propagating Spin-Wave Spectroscopy (PSWS) technique[3] developed at IPCMS. Two types of magnetic domain walls will be considered namely Néel walls in in-plane magnetized single crystal Fe films and Bloch walls in out-of-plane magnetized Co-based films and multilayers. The central task of the work will consist in carrying out microwave electrical measurements using a dedicated probe station equipped with a vector-network analyzer [Fig. 2]. Yet, the work will also involve participations in other tasks, prior to the measurements and afterwards: i) Characterization of the studied magnetic domain structures using imaging techniques (magneto-optical Kerr and magnetic force microscopies); ii) Fabrication of PSWS devices [Fig. 3] comprising microwave antennas by lithography techniques in the STnano clean room facility; iii) Micromagnetic numerical simulations for interpreting the measured data.

The detection of a propagating DWCSW mode by means of an electrical method, such as PSWS, is a prerequisite to the use of domain walls in magnonic circuits but it currently remains a challenge. The applicant should therefore possess a strong motivation, in addition to good experimental skills.

[1] P. Garcia-Sanchez *et al*., Phys. Rev. Lett. **114**, 247206 (2015).
[2] K. Wagner *et al*., Nature Nanotech. **11**, 432 (2016).
[3] V. Vlaminck and M. Bailleul, Science **322**, 410 (2008); Phys. Rev. B **81**, 014425 (2010).

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