What are spintronics based microwave components?

Spintronic materials based on metallic ferromagnets offer a new potential for integrated microwave components. Spintronic materials are magnetic heterostructures of nanometer thickness alternating metallic ferromagnetic and non-magnetic materials.

The **unique properties** of such spintronic materials derive from the spin polarized transport phenomena exploiting the spin degree of freedom. The control, via the magnetic configuration, of a current flowing through the heterostructure is a concept known as magneto-resistance (MR). It is commercially used since 1996 for read heads in all present day computers. The counterpart is the spin-transfer torque that permits to modify the magnetization via the application of a current flow.

Combining the **MR effect with the spin momentum transfer effect**, it is possible to drive the magnetization of one of the layers into large angle steady state oscillations and to create in this way a **nanoscale microwave oscillator** (called also spintronic nano-oscillator, STNO) that **emits microwave voltage signals in the range of 30 MHz to several tens of GHz** (see illustration in Fig. 1). The base frequency can be easily defined by the magnetic heterostructure composition and configuration. This provides a huge flexibility to device design. Tuning of the frequency around the base frequency can then be achieved via the injected DC current.

The **advantages** of such spintronic microwave oscillators are numerous: their small size (~100 nm), their radiation-hard property, their large frequency range to set the base frequency and up to 100% of tuning around the base frequency (below 10 GHz) and compatibility with CMOS technology (as demonstrated for MRAMs).

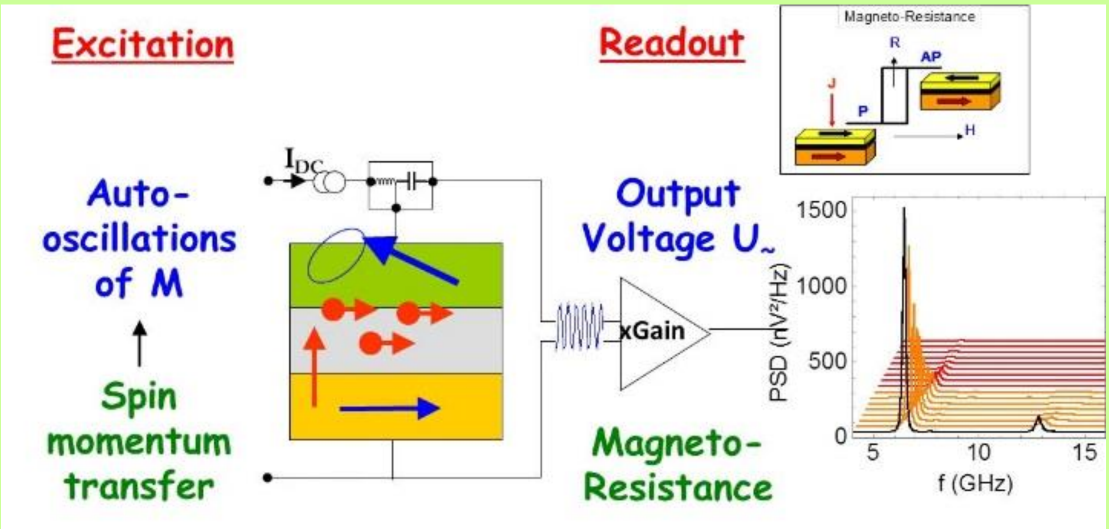

Fig. 1: Schematics of a spintronic microwave signal generator, showing to the left the spintronic heterostructure, into which a DC current is injected. Spin momentum transfer excites steady state magnetization oscillations that result in a microwave voltage signal due to the MR effect. The power spectra show the frequency shift of the microwave emission peak upon increasing current. The inset shows the MR effect.

Objectives of MOSAIC

The aim of MOSAIC has been to **demonstrate systems for broadband frequency generation** and **broadband simultaneous frequency detection** for use in telecommunication systems, **FSK based wireless communications** and **proximity sensing** for automation and control systems (ACS).

For this, **three different device classes were** considered that differ in their frequency range, their specific microwave performances or their RF operation**.**

The frequency tunable, **nanoscale microwave oscillator** can also be used as **a self-modulating mixer** by injecting simultaneously to the DC current (to generate the microwave signal) an rf signal (for modulation). Finally, they can also be used as **microwave signal rectifiers**, by injecting a microwave signal that produces a DC output voltage when the external and internal frequencies match.

Key results

The MOSAIC consortium was able to:

- Demonstrate PLL operation for vortex devices, with a phase noise reduction of more than 40 dB
- Demonstrate simultaneous microwave frequency detection with sensitivity of the order of tens of V/mW
- Test on an FSK based wireless emission and reception scheme in the 2-10 GHz range with up to 10 MHz data bit rate
- Realize high quality magnetic tunnel junction devices (low RA, high TMR)
- Demonstrate mutual synchronization and self-synchronization of STNOs

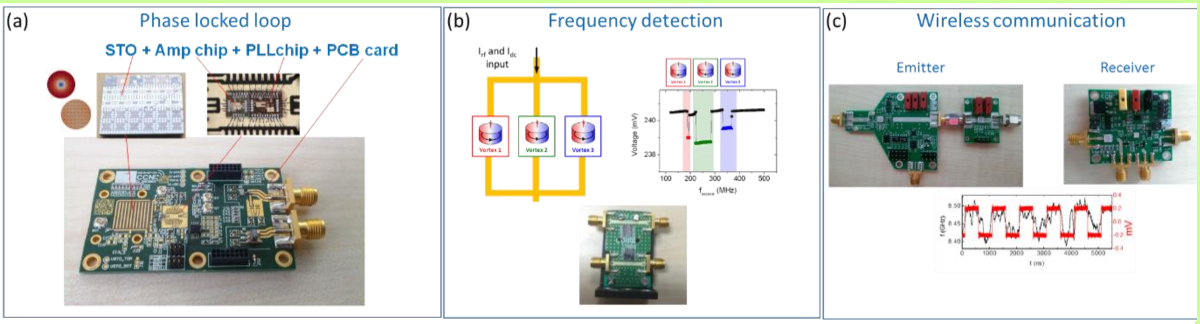

Fig. 2: Developed test systems: (a) PLL card including integrated PLL and amplifier chips, for homogeneous and vortex devices; (b) Example of simultaneous frequency detection using three different vortex STO devices, responding at different frequencies; (c) FSK based wireless communication with first test results for homogeneous devices.

If you want to learn more about the consortium activities, come and join the Enduser Meeting workshop in December 2016 (http://fp7-mosaic.eu/)

SEVENTH FRAMEWORK PROGRAMME