Polarization control of emitted THz waves using spintronic emitters with anisotropic magnetic layers & birefringence characterization of Quartz

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The TeraHertz frequency band presents many potential applications in a wide variety of fields, from non-invasive control to spectroscopy. THz spintronic emitters, introduced by Kampfrath et al., offer a new approach to THz wave emission [1]. Exciting a 5d/3d non-magnetic (NM)/ferromagnetic (FM) multilayer by IR fs-pulses generates a spin-polarized current that upon diffusion in the NM metal undergoes strong spin-orbit coupling. The action of the inverse spin-Hall effect transforms the spin-current into a charge current dipole transversely oriented to the spin direction. The polarization state is intrinsically linked to the magnetization direction in the FM layer. Thus, the control of the THz polarization is possible with the rotation of magnetization. Up to now, it was done by rotating the applied magnetic field [2].

The use of a ferromagnetic layer with uni-axial anisotropy allows to coherently rotate the magnetization by varying the applied field ONLY along the hard axis between its saturation values (Fig1.(a)). We deposited a W(2nm)/ FeCo(0.5nm)/ $TbCo_2$(0.8nm)/ FeCo(0.5nm)/ Pt(2nm) emitter stack on a c-cut Sapphire substrate by RF sputtering in a LEYBOLD Z550 equipment. During the growth, a magnetic field

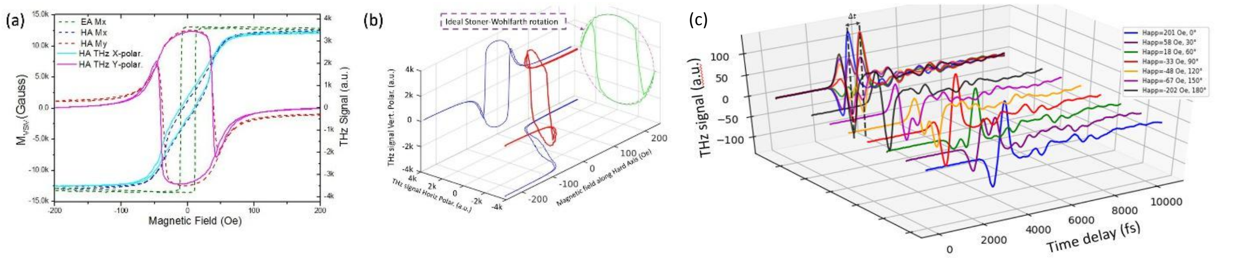

Fig. 1 (a) Comparison between VSM measured magnetic loops (dashed lines) and THz-TDS measurement (full lines) (b) 3D representation of the longitudinal and transversal components of the THz emission vs. magnetic field. (c) . Temporal traces of THz emission from a multilayer spintronic device with in-plane magnetic anisotropy through a quartz waveplate.

was applied in the plane of the substrate to induce the anisotropy. Fig1. (b) shows the Stoner-Wohlfrath-like rotation of the magnetization measured with a vectorial magnetometer, compared with the amplitude of the THz signal components, obtained with a Time Domain Spectroscopy setup. Varying the magnetic field along the magnetic hard axis direction, we demonstrate a full 360° rotation of the THz polarization.

As an application of the coherent rotation control, we determined the birefringence properties of a quartz half-wave plate in the THz band. Quartz is a well-known optically anisotropic material that presents two light propagation axes, the ordinary and extraordinary axes. With the polarization control of our emitters, the difference of refractive index between the two axes can be easily evaluated in the THz range thanks to our Time Domain Spectroscopy setup.

The temporal shift between the observed peaks gives the index difference: $\Delta n = \Delta t \times \frac{c}{d}$, with Δt the temporal shift, c the speed of light and d the thickness of the quartz crystal. With a $\Delta t = 480fs$, the resulting index differnce obtained is $\Delta n = 0.048$ between ordinary and extraordinary axis, which is consistent with values found in litterature [3].

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