

Magneto-electric control of polarization in spintronic terahertz emitters

Nicolas Tiercelin¹, Geoffrey Lezier¹, Pierre Koleják^{1,2}, Jean-François Lampin¹, Yannick Dusch¹, Kamil Postava² and Mathias Vanwolleghem¹

¹Univ. Lille, CNRS, Centrale Lille, Univ. Polytechnique Hauts-de-France, UMR 8520 - IEMN - Institut d'Electronique de Microélectronique et de Nanotechnologie, F-59000 Lille, France

²Technical University of Ostrava, Nanotechnology Centre and IT4Innovations, Ostrava - Poruba, Czech Republic
Corresponding author: nicolas.tiercelin@iemn.fr

Polarization control of THz light is of paramount interest for the numerous applications offered in this frequency range. Recent developments in THz spintronic emitters allow for a very efficient broadband emission, and especially unique is their ability of THz polarization switching through magnetization control of the ferromagnetic layer[1]. So far, such a control has only been achieved using an external magnetic field. For the first time, we present here a scheme to achieve a voltage controlled coherent polarization rotation using a strain mediated magnetolectric effect in spintronic emitters.

The considered emitter is a W(2nm)/ CoFe(0.5nm)/ TbCo₂(0.8nm)/ CoFe(0.5nm)/ Pt(2nm) stack deposited by RF sputtering in a LEYBOLD Z550 equipment on a 300 μm thick <011> cut PMN-PT ferroelectric relaxor. During the growth, a magnetic field was applied in the plane of the substrate in order to induce a well-defined uni-axial anisotropy that allows for a stoner-wohlfarth coherent rotation of the magnetization in the ferromagnetic layer. The CoFe/TbCo₂/CoFe tri-layer acts as an exchange-coupled multilayer and the 5d metals Pt and W provide the ISHE with opposite signs for their spin-Hall angles.

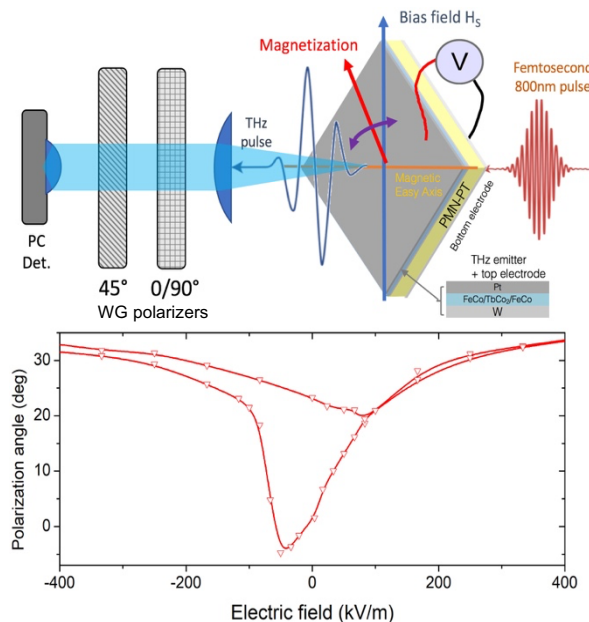


Fig. 1. Top: schematic representation of the magnetolectric spintronic emitter and characterization setup. Bottom: measured E-polarization angle with respect to the horizontal plane, as a function of the applied voltage on PMN-PT.

The THz emission was characterized on a customized existing terahertz time-domain spectroscopy (TDS) setup. The ISHE-mediated terahertz emission is generated by pumping the sample with femtosecond pulses from a Ti:sapphire laser oscillator (80MHz repetition rate, center wavelength 800nm and 100fs pulse duration). The E-field of the emitted terahertz pulse is measured by sampling the response of a photo-conductive Auston switch that is probed by a split-off fraction of the femtosecond infrared pulse by a delay line. In order to measure the horizontal and vertical components of the E-field and deduce the polarization angle, two wire-grid polarizers were inserted in the THz path, as seen on figure 1. Setting the delay line to obtain the maximum signal amplitude, E-field components were measured while cycling the applied voltage on the PMN-PT substrate. A static magnetic bias is also applied to the emitter. The deduced polarization angle is

shown on figure 1, which clearly shows its controlled rotation over a span of nearly 40 degrees. Thanks to the magnetostrictive properties of the ferromagnetic tri-layer, and upon voltage application, the substrate generated stress induces a large change in magnetic anisotropy [2]. This in turn causes a coherent rotation of magnetization and thus of the emitted polarization. The hysteresis behavior reflects the hysteresis of the ferroelectric relaxor response.

References:

- [1] Seifert, T. et al. Nature Photonics, 10(7), 483–488 (2016) <https://doi.org/10.1038/nphoton.2016.91>
[2] N. Tiercelin et al. Appl. Phys. Lett., 99, 192507 (2011) - [doi: 10.1063/1.3660259](https://doi.org/10.1063/1.3660259)