Magneto-electric control of emission in spintronic terahertz emitters

Nicolas Tiercelin\textsuperscript{a*}, Geoffrey Lezier\textsuperscript{a}, Pierre Koleják\textsuperscript{a, b}, Jean-François Lampin\textsuperscript{a}, Yannick Dusch\textsuperscript{a}, Kamil Postava\textsuperscript{b} and Mathias Vanwolleghem\textsuperscript{a}

\textsuperscript{a}. Univ. Lille, CNRS, Centrale Lille, Univ. Polytechnique Hauts-de-France, UMR 8520 - IEMN - Institut d’Electronique de Microélectronique et de Nanotechnologie, F-59000 Lille, France

\textsuperscript{b}. Technical University of Ostrava, Nanotechnology Centre and IT4Innovations, Ostrava - Poruba, Czech Republic

* email : 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\cite{Seifert2016}. So far, such a control has only been achieved using an external magnetic field. We present here a scheme to achieve a voltage controlled coherent polarization rotation using a strain mediated magnetoelectric effect in spintronic emitters.

The considered emitter is a W(2nm)/ CoFe(0.5nm)/ TbCo\textsubscript{2}(0.8nm)/ CoFe(0.5nm)/ Pt(2nm) stack deposited by RF sputtering on a 300 \( \mu \)m 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/TbCo\textsubscript{2}/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. 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 and the E-field of the emitted terahertz pulse is measured by sampling the response of a phot-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 deducted 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 \cite{Tiercelin2011} which causes a coherent rotation of magnetization and thus of the emitted polarization.

\cite{Seifert2016} Seifert, T. et al. Nat. Photonics, 10(7), 483–488 (2016)
