# THz spintronics

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The Terahertz radiation is located between the infrared and microwave frequencies, a region of the electromagnetic spectrum known as the "terahertz gap". The latter refers to the absence of devices for the generation, modulation and the detection of THz frequencies. The technology for THz generation and manipulation is in its infancy and the need for the development of new devices and techniques large. Here, we present the recent advances in the novel field of THz spintronics where magnetic materials are utilized as THz sources.

We perform experiments using femtosecond laser pulses to trigger ultrafast spin and charge dynamics in magnetic bilayers composed of ferromagnetic (FM) /non-magnetic (NM) layers where the NM layer features a strong spin-orbit coupling. Such heterostructures are novel sources for the generation of THz radiation based on the spin-to-charge conversion in magnetic films [1-3]. The conversion mechanism of spin to charge currents and vice versa, is the spin Hall and the inverse spin Hall effect [3,4].

The key technological and scientific challenge of THz spintronic emitters is to increase their intensity and frequency bandwidth. In this presentation, it will be demonstrated the way to engineer both factors by taking into account the scattering lifetime and the interface transmission of spin polarized, non-equilibrium electrons. It will be resolved the role of the electron-defect scattering lifetime on the spectral shape and of the interface transmission on the THz amplitude and how this is linked to the structural properties of bilayer emitters. The enhanced performance of spintronic terahertz emitters based on bulk and interface defect density will be revealed (Fig. 1) [4]. Furthermore, the dependence of the emission on layer thicknesses, substrates and geometrical arrangement will be discussed. It will be shown that the spintronic THz emitters are as efficient operated at $\lambda$ = 400 and 1550 nm excitation wavelength as when excited with $\lambda$ = 800 nm. These results enable the construction of a roadmap [4] of the properties of the emitted as well as the detected THz-pulse shapes and spectra. The roadmap allows us to predict the temporal and spatial evolution of the spin current inside the metallic layers, to account for the generation and optical propagation of the THz wave, and to forecast the THz-pulse shapes and spectra by taking into account the electron scattering lifetime and the interfacial spin current transport.

The engineering of the THz emission is essential for future applications of spintronic emitters in THz technology in areas such as communication science and ultra-fast computing, biology, medical and pharmaceutical sciences, and non-destructive assessment.

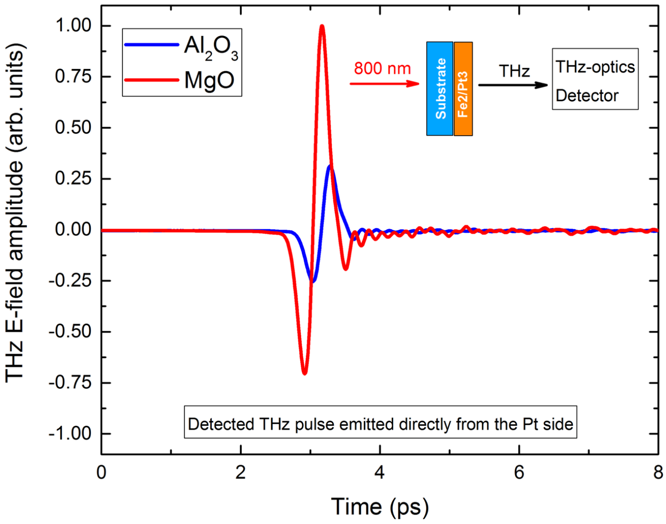


*Figure 1: Experimental THz-E-field amplitudes of the Fe (2 nm) / Pt (3 nm) bilayer emitters grown on MgO and $Al_2O_3$ substrates in the time domain. The sample grown on MgO exhibits singificantly larger THz-E-field amplitudę due to the decreased defect density that increases the electron-defect scattering lifetime. For longer elastic scattering lifetimes, the spin-polarized carriers contribute to a longer-lasting and stronger signal. The engineering of the lifetimes based on the growth modes of the bilayers paves the way for more efficient THz radiation sources.*

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