Understanding and developing spin-based emitters for improved far-infrared radiation sources

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The ability to control the generation and the properties of terahertz (THz) radiation has the potential to facilitate a variety of technologically demanding applications, from improved medical diagnosis to detection of explosives and advanced security scanners [1]. To exploit this potential, broadband emitters are required that can emit far-infrared radiation over the full THz spectral region (1 - 10 THz). The recent demonstration of the emission of broadband mid- to far-infrared radiation (<1 – 30 THz) from ferromagnetic (FM)/non-magnetic (NM) heavy metal bilayers has opened up a range of possibilities for THz spin-based emitters [2,3], which potentially offer a cost-effective solution to this problem. In spin-based emitters, pulses of THz radiation with bandwidths of up to 30 THz [3,4] can be observed when a FM/NM bilayer is exposed to a femtosecond (fs) laser pulse. The THz pulses generated by spin-based emitters are polarized perpendicular to the magnetic moment of the FM layer, M, independent of the pump laser polarization [3]. Thus, polarization dependence on M offers a unique potential to directly tailor an arbitrary THz polarization profile by controlling the applied magnetic field pattern. One aspect of our research focuses on exploring this potential, where we have demonstrated a method to create arbitrary THz polarization profiles by exploiting the magnetic field-dependent emission process in sputter deposited Ni80Fe20 (2 nm)/Pt (2 nm) bilayers (Fig. 1) [5]. Applying a specific magnetic field pattern resulted in the generation of high-field THz radiation with either linear or quadrupole-like polarization (Fig. 2), which opens up possibilities for schemes such as rotatable polarization spectroscopy and efficient mode coupling in waveguides [6]. Material properties play a vital role in the generation of THz radiation, where previous works have studied a range of bilayer material combinations, thicknesses and annealing temperatures [3,4]. We therefore present our recent work investigating the role of the FM/NM interface on the amplitude and bandwidth of the THz radiation, to further understand the emission process.

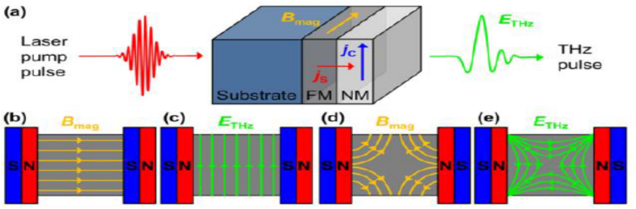
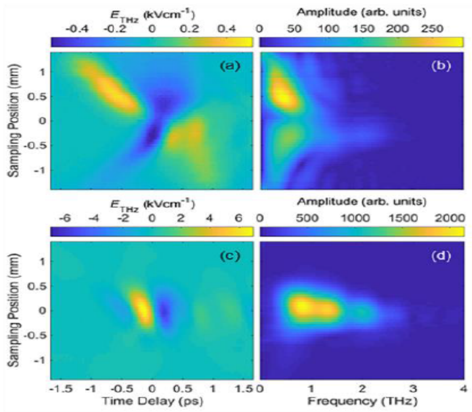


Fig. 1 (above): (a) A spin-polarized current (j_s) in FM layer converts to a transverse charge current (j_c) in NM layer, generating a THz pulse (B_{mag}). (b)-(e) Magnetic field lines and corresponding THz electric field lines (E_{THz}) for aligned and opposing polarity.

Fig. 2 (right): Longitudinal THz waveforms vs horizontal sampling position for spin-based emitter between magnets with (a) aligned and (c) opposing polarity. (b) and (d) Corresponding spectral amplitudes.



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