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Single-Layer Spin-Orbit Torques in a Fully-Compensated Half-Metallic Ferrimagnet

There exists a gap in the electromagnetic spectrum between 0.3 - 30 THz in which semiconductor and optical technologies fail to generate and detect radiation using chip-sized elements. However, antiferromagnets (AFM) and compensated ferrimagnets (CFiM) have resonance frequencies in this range, making them a viable solution. AFMs and CFiMs cannot easily be manipulated by external fields due to their low net magnetization, but they can be excited via current-induced spin-transfer- (STT) or spin-orbit torques (SOT). SOT has been used as an effective means of magnetization switching in ferromagnet/heavy-metal (FM/HM) bilayers for several years. In this case, the spin Hall effect in the HM results in a diffusive spin current, perpendicular to the thin-film stack surface, which exerts a torque on the magnetic moments in the FM. In magnetically-ordered, noncentrosymmetric crystal structures, a single layer can perform the role of both the FM and the HM, allowing current-induced magnetization excitation via SOT. One such material is the half-metallic, fully compensated ferrimagnet Mn_2Ru_xGa (MRG) [1]. As a result of its crystal symmetry, the SOT-induced effective fields in an MRG single-layer can be described by the product of the current vector ($boldsymbolj$) and a 3×3 matrix ($boldsymbolH_{eff}$) with two parameters describing the field-like and damping-like parts (x_{fl} and x_{dl} respectively) [2]. Harmonic Hall voltage measurements are an effective method of evaluating current-induced torques in bilayers [3]. This method can also be utilised for single-layers, as is done here for an MRG thin-film to determine the anisotropy constants and the effective SOT fields. These experimental values in conjunction with theoretical modelling [4] predict that MRG will exhibit self-oscillations at a frequency of approximately 0.7 THz for a current density $j \approx 1 \times 10^7\, A\, cm^{-2}$, making it a promising candidate for filling the terahertz gap.

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[4] Troncoso, R. et al., https://arxiv.org/abs/1808.10182, (2018)

Primary authors: SMITH, Ross (Trinity College Dublin); RODE, Karsten (Trinity College Dublin); Mr LENNE, Simon; Dr LAU, Yong-Chang

Presenter: SMITH, Ross (Trinity College Dublin)