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Theory of spin torque resonance for magnetic insulators

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The spin Hall effect (SHE) refers to a spin current induced in the transverse direction by a charge current through a nonmagnetic material with spin-orbit interaction. The efficiency of the SHE is measured by the spin Hall angle defined by the ratio, $\theta_{SH} = J_s/J_c$, where J_s is the transverse spin current density induced by a charge current density J_c. Recent experiments[1,2] demonstrate ferromagnetic resonance in bilayer thin films made from metallic ferromagnets (FM) and nonmagnetic metals (N) with spin-orbit interaction, which is excited by a resonant spin transfer torque generated via the SHE by an AC current bias over the sample (ST-FMR). The resonance is detected by a DC voltage created by down-conversion due to the anisotropic magnetoresistance (AMR) in the FM, i.e. the spin torque diode effect.[3] A complication for all-metal systems is the current that flows through the ferromagnet which makes an accurate modelling difficult. This complication can be avoided by working with insulating magnets such as yttrium iron garnet (YIG) and employ the spin Hall magnetoresistance (SMR)[4] instead of the AMR in the system sketched in Fig. 1. We present the computed magnetization dynamics and DC voltage as a function of frequency in bilayer thin films of YIG|N with N being Pt[1] and Ta.[2] Experimental confirmation of this effect would yield important additional information on the spin-transfer torque-induced magnetization dynamics in YIG as discovered by Kajiwara *et al.*.[5]

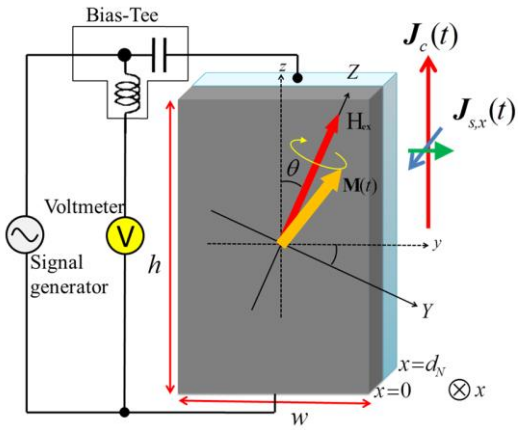

Fig.1: Schematic of the device with layer thickness Pt(6 nm)|YIG(4 nm).

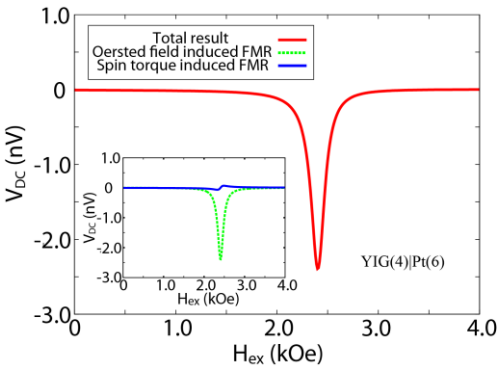

Fig.2: Calculated DC voltage V_{DC} in the YIG|Pt bilayer at f_a = 9GHz as a function of external magnetic field for a current density $J_c = 10^{10}$ A/m^2 for F(N) layer length h=3 nm and $\theta = 45^{\circ}$.

References

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