Abstract Submitted
for the MAR16 Meeting of
The American Physical Society

Phase-sensitive inductive detection of ac currents due to spin-pumping/inverse spin Hall effect in unpatterned Permalloy/Pt bilayers THOMAS SILVA, NIST, HANS NEMBACH, University of Colorado, JUSTIN SHAW, NIST, ALEXY KARENOWSKA, Oxford University, MATHIAS WEILER, WMI — We present a new method to measure the ac inverse spin Hall effect at GHz frequencies. Unlike previous methods [1-3], our does not rely on any patterning or electrical contacts. We utilize phase-sensitive, broad-band, perpendicular-field ferromagnetic resonance to detect the ac current by the inverse spin Hall effect (iSHE) in Py/Pt bilayers. The iSHE component of the signal is non-linear in the excitation frequency; while the inductive FMR response scales linearly with frequency, the iSHE signal scales quadratically because the iSHE current itself is proportional to dm/dt. This differential gain affords us detection of previously unreported higher order contributions to the iSHE signal. We compare FMR measurements with a control samples that do not include the high spin-orbit layer, e.g. Pt. Data sets with and without Pt are normalized by the complex Polder susceptibility, which nullifies any effects due to differences in line-width and anisotropy. The complex ratio of the normalized inductive amplitudes is analyzed with a simple model that considers how the ac currents generated by the iSHE couple inductively back into the excitations waveguide. The linear iSHE signal agrees with previous reported values. The nonlinear iSHE signal is 3-4 orders of magnitude weaker, but is easily detected over the frequency range of 5-45 GHz. [1] M. Weiler, et al., PRL 113, 157204 (2014), [2] C. Hahn, et al., PRL 111, 217204 (2013) [3] D. Wei, et al., Nat. Comm. 5, (2014)

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Date submitted: 06 Nov 2015 Electronic form version 1.4