Optical and X-ray Measurement of Magnetization Dynamics Induced by Spin Currents

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Pure spin currents provide new opportunities for the construction of energy efficient electronic devices with novel functionality. In particular, spin currents are able to control the magnetization of ferromagnetic materials that are inherently bistable, and therefore ideally suited to memory and logic applications, or capable of sustained oscillation at microwave frequencies. However, present understanding of the propagation of spin currents and their interaction with ferromagnetic materials is based upon electrical transport measurements that provide only a spatially averaged signal, and which require additional electrical contacts and often elaborate nano-fabrication procedures. Furthermore, nanostructured magnetic elements possess a spatially inhomogeneous internal magnetic field and support a complicated precessional mode structure that may be very sensitive to the detailed structure of edge regions [1]. It will be shown that optical and x-ray probes may simplify the study of such processes. Firstly, time-resolved scanning Kerr microscopy (TRSKM) has been used to examine the effect of non-local spin transfer torque (NL-STT) within two-terminal current-perpendicular-to-plane non-local spin valves [2]. By comparing the form of the observed magnetization precession with a macrospin model, the strength of the NL-STT was quantified and found to be comparable to that achieved by direct injection of spin polarized current. In addition it was shown that the NL-STT can be detected through DC optical measurements of the component of magnetization perpendicular to the plane of the sample. Secondly, element-specific phase-resolved x-ray ferromagnetic resonance (FMR) has been used to study spin pumping within microscale spin valve structures [3]. The phase of precession of the fixed layer was recorded as FMR was induced in the free layer. The field dependence of the fixed layer phase contains a clear signature of spin transfer torque (STT) coupling due to spin pumping. It is shown that fitting the phase delay yields the spin mixing conductance, the quantity that controls all spin transfer phenomena. Furthermore, the STT coupling is destroyed by insertion of Ta into the middle of the Cu spacer layer. Finally, TRSKM has been used to image the magnetization dynamics excited in the continuous film NiFe free layer (FL) of a nano-contact spin-transfer vortex oscillator (NC-STVO). Injection locking was used to perform measurements at an exact multiple of the 80 MHz laser repetition rate. TR images of dynamics outside the area of the top contact at a frequency of 160 MHz show a response that results from a superposition of Oersted field excitation and vortex gyration, and which is highly relevant to the mutual phase-locking of arrays of NC-STVOs for higher power generation. In summary, optical and x-ray measurement techniques provide additional information about magnetization dynamics induced by spin currents, in some case removing the need for fabrication of nanoscale sample elements.

REFERENCES

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