Ultrafast Spin-transfer Driven Magnetization Reversal and Exciting Spin-Waves

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Spin-transfer is an interaction between iterant charge and magnetization that permits the excitation and rapid reversal of the magnetization using spin-currents. In this talk I will present an overview of some of our recent spin-transfer studies, focusing on pulse current experiments in spin-valves [1,2] and modeling of spin-transfer nano-oscillators (STNOs) [3]. Our experiments on spin-valves have been on nanopillars with perpendicularly magnetized free and reference layers separated by a non-magnetic spacer layer. This magnetic geometry is of interest because low quasistatic switching threshold currents (~100 μA) for have been achieved in nanomagnets that are thermally stable at room temperature (diameter=50 nm and U/kT>40). In addition, their strong uniaxial anisotropy makes them model systems for the study of spin-transfer driven magnetization dynamics. In the short time limit (pulses less than 10 ns in duration), we find that the pulse amplitude needed to reverse the magnetization is inversely proportional to the pulse duration, reflecting the conservation of angular momentum [1]. This also implies that there is an optimal pulse duration that minimizes the switching energy. We have also studied the switching probability as a function of pulse amplitude and duration, with pulse durations from 0.1 ns to seconds (over 9 orders of magnitude in pulse duration). Two physical regimes are clearly distinguished: a long pulse duration regime, in which reversal occurs by spin-transfer assisted thermal activation over an energy barrier, and a short time large pulse amplitude regime, in which the switching probability is determined by the spin angular momentum transported by the current pulse [2]. Finally, I will describe how arrays of STNOs can be used to produce anisotropic spin-wave patterns and interference that can be used for information processing [3]. The vast majority of experimental studies of the spin-transfer—like those described above—have been through electronic transport experiments and thus provide only indirect probes of the magnetization dynamics. There are therefore great opportunities for fundamental and more direct experimental studies of spin-transfer driven magnetization dynamics with x-ray techniques.

[1] D. Bedau, H. Liu, J-J. Bouzaglou, A. D. Kent, J. Z. Sun, J. A. Katine, E. E. Fullerton and S. Mangin, “Ultrafast Spin-Transfer Switching in Spin Valve Nanopillars with Perpendicular Anisotropy,” Applied Physics Letters 96, 022514 (2010).

[2] D. Bedau, H. Liu, J. Z. Sun, J. A. Katine, E. E. Fullerton, S. Mangin and A. D. Kent, “Spin-transfer pulse switching: From the dynamic to the thermally activated regime,” ArXiv:1009.5240

[3] F. Macia, A. D. Kent and F. Hoppensteadt, “Spin-wave interference patterns created by spin-torque nano-oscillators for memory and computation,” ArXiv:1009.4116