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Phase Locking of Spin-Transfer Oscillators

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DC current flowing through a nanometer-scale lithographic contact made to a continuous spin-valve multilayer induces stable magnetic precession of the free layer at GHz frequencies. The resonance frequency of the spin-transfer oscillator (STO) is a function of both the applied current and external magnetic field, and the resonance has linewidths on the order of MHz. To study the properties of this resonance, and to determine the suitability of STOs for communications applications, we measured the response of these oscillators to variations in the magnetic field, electric current, and spin-wave environments. We studied phase locking effects induced by injecting ac currents, and by applying ac magnetic fields near the precession frequency of the device. In addition, we have fabricated two nanocontact devices in close proximity on the same magnetic film, and looked at the interactions between the two devices. In each case, when the impressed ac signal is sufficiently close to the STO frequency, the device will phase lock. For ac currents and fields, the device locks to the external signal via injection locking, a general property of nonlinear oscillators, taking on the frequency and phase characteristics of the source. For interacting nanocontacts, the devices modify each other's resonances, and lock together at frequency slightly different from the individual resonances. I will review these phase locking results, and discuss the variations of the locking with the excited mode of the oscillator. I will also present results on mutual locking of STOs, discuss the relative roles of dipolar fields and spin-wave interactions in the locking mechanism, and comment on the possible uses of phase controlled, coherent STOs.