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Oscillatory dependence of current driven domain wall motion on current pulse length[1]

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The motion of domain walls (DW) in magnetic nanowires driven by spin torque from spin-polarized current is of considerable interest. Most previous work has considered the effect of dc or ∼microsecond long current pulses. Here, we show that the dynamics of DWs driven by nanosecond-long current pulses is unexpectedly complex. In particular, we show that the current driven motion of a DW, confined to a pinning site in a permalloy nanowire, exhibits an oscillatory dependence on the current pulse length with a period of just a few nanoseconds [1]. This behavior can be understood within a surprisingly straightforward one dimensional analytical model of the DW's motion. When a current pulse is applied, the DW's position oscillates within the pinning potential out of phase with the DW's out-of-plane magnetization, where the latter acts like the DW's momentum. Thus, the current driven motion of the DW is akin to a harmonic oscillator, whose frequency is determined by the "mass" of the DW and where the restoring force is related to the slope of the pinning potential. Remarkably, when the current pulse is turned off during phases of the DW motion when it has enough momentum, the amplitude of the oscillations can be amplified such that the DW exits the pinning potential well *after* the pulse is turned off. This oscillatory depinning occurs for currents smaller than the dc threshold current, and, moreover, the DW moves against the electron flow, opposite to the propagation direction above the dc threshold. These effects can be further amplified by using trains of current pulses whose lengths and separations are matched to the DW's oscillation period. In this way, we have demonstrated a five fold reduction in the threshold current required to move a DW out of a pinning site, making this effect potentially important for technological applications. [1] L. Thomas, M. Hayashi, X. Jiang, R. Moriya, C. Rettner and S.S.P. Parkin, Nature 443, 197 (2006).

[1]In collaboration with Masamitsu Hayashi, Rai Moriya, Charles Rettner, Xin Jiang, Bastiaan Bergman, Brian Hughes and Stuart Parkin