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Micromagnetics simulation of mode jump driven by high d.c. spin-polarized current in vortex nano-oscillator

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The angular momentum carried by the spin-polarized current exerts a torque on the magnetic moment inducing steady or damped oscillations in the magnetic state of the system. The magnetic vortex state in confined magnetic structures is one of the ideal magnetic states for the spin-polarized current manipulation of the magnetic state by the electric current [1]. The mode transition of vortex oscillation was observed under high current; [2] however the detail of excitation phenomena is not understood yet. Here, we present micromagnetic simulation results of vortex dynamics in permalloy free layer with perpendicular polarizer. The simulations are performed for circular dots with fixed size of 120 nm. The magnetization dynamics is investigated by OOMMF micromagnetic simulation tool for solving the LLG equation with including spin-transfer-torque term [3]. After the equilibrium state is reached in static simulations the resulting spin state is used for dynamic simulations by applying spin polarized d.c. current to obtain magnetization precession and spatial distributions of excited spin states of dot. To obtain sufficient high resolution frequency spectrum, the simulations were performed with low damping (α=0.001) parameter and each state of the magnetization is stored at every 1 ps and total simulation time was 50 ns. Figure 1 shows the excited low frequency mode (vortex state) and high frequency mode (quasi single domain state (C-state)) at low and relatively high current value. In the low current values, vortex core performs spiral motion under the applied current until it is expelled from the edge of dot (core up) and then it enters with switched polarity (core down). After the switching, the vortex core gets damped at the center of the dot due to spin torque acts like damping effect on the gyroscopic motion of the core. Micromagnetic simulations indicate that the two distinct magnetization dynamics governed by the spin-torque driven reversal. The first one is vortex core gyration and expulsion in free magnetic layer. The second case is formation of single domain state favored by the Oersted field from the current which resulting the higher oscillation mode in the observed spectra.

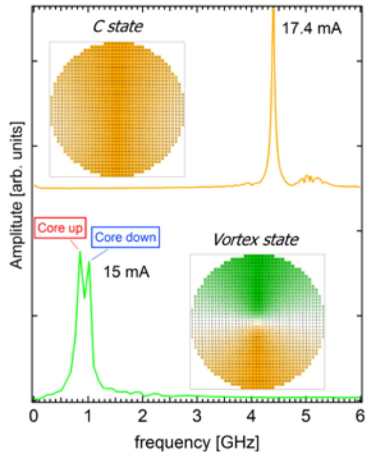

Fig.1 Frequency spectrum including corresponding magnetization mode images of a circular dot with a diameter of 120 nm.

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