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CURRENT INDUCED VORTEX LATTICES IN NANOMAGNETS

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Influence of the spin-transfer torque on the vortex state magnetic nanodisk is studied numerically in the frame of Slonczewski-Berger mechanism [1, 2]. We consider the case of one-way directed current flow, current spin polarization and polarity of the magnetic vortex. The existence of a critical current j_c which separates two regimes: (i) deformed immobile vortex state, (ii) vortex-antivortex periodic structures, is shown and their stability for disturbances is proved.

We study influence of the spin-polarized electrical current on the magnetization dynamics of the disk-shaped magnetic nanodots of different sizes. The current flow was perpendicular to a disk plane. All considered disks had the same ground state – the vortex state [3]. The vortex state in a nanodisk can be described as following: $m=pf(r)$ and $\varphi=\chi\pm\pi/2$, where $m=m_z$ describes the magnetization component perpendicular to the disk plane and φ: $m_x+im_y=(1-m_z^2)^{1/2}e^{i\varphi}$ describes the magnetization distribution within the disk plane. Origin of the polar frame of reference (r, χ) coincides with the disk center and exponentially localized function f describes the vortex core profile. Vortex polarity $p=+1$ was the same in all simulations.

Using an open source micromagnetic simulator [4] we performed numerical experiments of two types (i) the spin current of the certain density is sharply applied to the vortex state nanodisk; (ii) the nanodisk is previously saturated to the uniform state by a strong external magnetic field which is applied perpendicularly to the disk plane, then the current of necessary density is switched on and the external field is adiabatically diminished down to zero. In two mentioned cases for currents $j<j_c$ the system relaxes to the stationary deformed vortex state. The deformation is radially symmetric and deals with in-plane magnetization component only, thus it can be described as following: $\varphi=\chi\pm\pi/2+\psi(r)$. Function $\psi(r)$ was studied numerically for different currents.

For the case $j_c<j<J_0$, where J_0 is the saturation current periodic vortex-antivortex structures appear. In the close vicinity of the saturation current J_0 the square vortex-antivortex lattice appears. The lattice is stable for disturbances and rotates as a whole around the disk center. The rotation frequency is much lower than the corresponding gyrofrequency and it depends on the applied current and disk sizes. With the current decreasing, the lattice oscillations is increasing and mobile lattice defects appears. Thus the short-range order only survives in the lattice and system demonstrates the fluid-like dynamics. For still smaller current the chaotic dynamics of vortex-antivortex gas appears. But for currents close to j_c the system of narrow current ranges exists were stable regular vortex-antivortex structures with symmetries C_2, C_3, C_4 appears. The ring-type structures which are the circularly closed cross-tie domain walls are also observed in this regime. It is worth noting that the periodic structures also appear in the no-damping case.

[1] J. C. Slonczewski, J. Magn. Magn. Mater. **159**, L1 (1996).
[2] L. Berger, Phys. Rev. B **54**, 9353 (1996).
[3] A. Kovalev, A. Kosevich, K. Maslov, JETP Lett., **30**, 296-299 (1979)
[4] OOMMF code of version 1.2a4, http://math.nist.gov/oommf/