Magnetic vortex string gyrotropic dynamics in thick cylindrical nanodots

Kostyantyn Gusliyenko[1, 2]

[1] *Depto. Polímeros y Materiales Avanzados: Física, Química y Tecnología, Universidad del País Vasco, UPV/EHU, 20018 San Sebastián, Spain*

[2] *IKERBASQUE, the Basque Foundation for Science, 48009 Bilbao, Spain*

There is a longstanding interest in the topological spin textures in small ferromagnetic particles and thin films, such as magnetic vortices, skyrmions, and hopfions. The magnetic vortex is one of the simplest topologically nontrivial and stable spin textures in condensed matter physics. Since the vortex state of magnetization was discovered as the ground state of patterned soft magnetic dots, the dynamics of magnetic vortices attract considerable attention.

The nonuniform magnetic vortex gyrotropic oscillations along the cylindrical nanodot thickness were calculated [1]. A generalized Thiele equation was used for describing the vortex core motion including magnetostatic and exchange forces. The magnetostatic interaction was accounted for in a local form. This allowed reducing the Thiele equation of motion of the vortex core to the Schrödinger differential equation and analytically determining the spin eigenmode spatial profiles and eigenfrequencies using the Liouville–Green method for the high-frequency modes. The mapping of the Schrödinger equation to the Mathieu equation was used for description of the low-frequency gyrotropic mode. The lowest-frequency gyrotropic mode is transformed to the dot faces localized mode increasing the dot thickness. The vortex gyrotropic modes are described for a wide range of the dot thicknesses according to the concept of the turning points in the magnetostatic potential. This approach allows treating the vortex localized modes (turning points) and nonlocalized excitation modes within a unified picture [1].

The vortex gyrotropic modes calculated in Ref. [1] for thick circular cylinders are not specific to this nanodot shape. Similar magnetic vortex excitations should exist also for other nanodot shapes such as a dome shape or square/rectangular shape. The point is that the dot thickness should be large enough to allow 3D magnetization texture excitations. The inhomogeneous gyrotropic oscillations of the vortex core string can be considered as a step towards understanding the magnetic topological soliton dynamics increasing the system dimensionality from 2D to 3D.

References:

[1] K. Guslienko, Magnetism **2**, 239-250 (2022).

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