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Influence of the variable cross section on the domain wall dynamics in curved ferromagnetic nanostripes

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Curvilinear magnetism is an emerging field which connects low-dimensional magnetic architectures with their geometrical properties to describe resulting novel phenomena. Nanoscale curved magnetic stripes are a crucial building block in the race for high-density and ultrafast magnetic memory, and can substantially augment the performance of spintronic devices [1,2].

Here, we aim to theoretically and numerically study how changes in the cross-section area of the curved ferromagnetic nanostripe affect its magnetic structure. Namely, we show that tailoring of the gradient of the cross-section area can be used to control the motion of the domain wall. Although, the magnetic response of the curved nanostripe is already well-studied, in all previous studies cross section of the nanowire was assumed to be constant. Only recently, a new micromagnetic framework emerged that allows the exploration of the changes in the magnetization dynamics caused by the cross-section area gradient [3].

Here, we use the collective variable approach by adapting the q-Φ model to stripes with varying cross section. The description of the domain wall motion in ferromagnetic wires is investigated by considering the temporal evolution of the magnetization vector based on the Landau–Lifshitz–Gilbert equation. To derive the specific equations of motion for the collective variables, the Lagrange-Rayleight formalism is used, where the dependency on the spatial variation of the cross-section area is factored in both the Lagrangian and the dissipative function.

The resulting equations of the domain wall motion are studied for three specific geometries: a straight stripe, an arc of a circle and an Euler spiral. For the case of a straight stripe with absent curvature, we show that the domain wall velocity is mainly determined by the cross-section gradient. For the case of constant curvature, the asymptotic domain wall velocity is shown to have two components: the first component is identical to the speed of the domain wall in the straight wire, while the second one describes the coupling between the curvature and the cross-section gradient. For the case of the wire, whose curvature grows at a constant rate, the asymptotic domain wall velocity has two contributions. The first one is the same as the velocity in the straight wire, however, the second one differs from the previous case and is determined solely by the rate of curvature growth. All analytical predictions are wellconfirmed by the NMAG micromagnetic simulations [4].

The gradient of the cross-section area of the curved ferromagnetic nanostripe creates an internal driving force, which in turn induces the domain wall motion and can explain the recent experimental results [5]. We have shown how the dynamics of the domain wall motion can be modified through tailoring the cross-section area of the nanostripe. Although we showcased our approach only for three specific geometries, it is general and can be applied to a wide class of geometries.

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Primary authors: DMYTRO KARAKUTS (Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine); KOSTIANTYN V. YERSHOV (Leibniz-Institut für Festkörper- und Werkstoffforschung, IFW Dresden, 01171 Dresden, Germany); DENIS D. SHEKA (Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine)

Presenter: DMYTRO KARAKUTS (Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine)

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