Magnetic field-induced textures and phase transitions in antiferromagnetic spin chains: geometry-induced effects

Yelyzaveta A. Borysenko[1, 2, 3], Denis D. Sheka[1], Kostiantyn V. Yershov[3, 4], Jürgen Fassbender[2], Jeroen van den Brink[3, 5], Denys Makarov[2] and Oleksandr V. Pylypovskyi[2, 6]

[1]*Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine*
[2]*Helmholtz-Zentrum Dresden-Rossendorf e.V., 01328 Dresden, Germany*
[3]*Institute for Theoretical Solid State Physics, Leibniz IFW, 01069 Dresden, Germany*
[4]*Bogolyubov Institute for Theoretical Physics of NAS of Ukraine, 03143 Kyiv, Ukraine*
[5]*Technische Universität Dresden, 01069 Dresden, Germany*
[6]*Kyiv Academic University, 03142 Kyiv, Ukraine*
E-mail: y.borysenko@ifw-dresden.de

Easy axis antiferromagnets (AFMs) are robust against external magnetic fields of a moderate strength. Spin reorientation transitions in strong fields can provide an insight into more subtle properties of antiferromagnetic materials, which are often hidden by their high ground state symmetry. In curved intrinsically achiral AFM spin chains geometrical bends and twists provide helimagnetic responses, characterized as effective anisotropic and Dzyaloshinskii–Moriya-like (DMI) interactions [1].

Here, we address theoretically effects of curvature in achiral anisotropic ring-shaped AFM spin chains with even number of spins exposed to strong magnetic fields using the methodology of curvilinear magnetism. We identify the geometry-governed helimagnetic phase transition enabled in the spin-flop phase, which separates locally homogeneous (vortex) and periodic (onion) AFM textures [2, 3]. The curvature-induced Dzyaloshinskii–Moriya interaction results in the spin-flop transition being of the first- or second-order depending on the ring curvature. Spatial inhomogeneity of the Néel vector in the spin-flop phase generates the weakly ferromagnetic response in the plane perpendicular to the applied magnetic field [3]. In AFM spin chains possesing torsion, e.g. helices, these effects are enhanced by the inhomogeneity of local texture in the ground state. Our work provides further insights in the physics of curvilinear AFMs in static magnetic fields and guides prospective experimental studies of geometrical effects in the spin-chain nanomagnets.

References

[1] O. V. Pylypovskyi, D. Y. Kononenko, K. V. Yershov, U. K. Rößler, A. V. Tomilo, J. Fassbender, J. van den Brink, D. Makarov, and D. D. Sheka, Nano Lett. **20**, 8157 (2020)

[2] O. V. Pylypovskyi, Y. A. Borysenko, J. Fassbender, D. D. Sheka, and D. Makarov, App. Phys. Lett. **118**, 182405 (2021)

[3] Yelyzaveta A. Borysenko, Denis D. Sheka, Jürgen Fassbender, Jeroen van den Brink, Denys Makarov, and Oleksandr V. Pylypovskyi, Phys. Rev. B **106**, 174426 (2022)