Orbital mechnism for stabilization of higher-order magnetic skyrmions in strongly correlated layers

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We studied the formation of a special type of magnetic skyrmions – in which the azimuthal angle of magnetization (vorticity) $\phi = n\,\varphi$, where φ is the angle of polar coordinate system in the plane of the film and $|n| > 1$. Such structures are called higher-order magnetic skyrmions (HOMS) [1]. They are much less studied compared to the ordinary skyrmions because the Dzyaloshinskii–Moriya interaction does not stabilize such structures. The several models have been proposed in which HOMS arose due to frustrated exchange interaction [2, 3, 4]. However, such a mechanism requires a very fine selection of magnetic materials and lacks flexibility to change HOMS characteristics suitable for practical applications.

In the work [5], we propose a new mechanism for the formation of HOMS, based on the orbital effects of the inhomogeneous magnetic field. Due to wide experimental possibilities for the creation of various magnetic field profiles, it is clear that the proposed mechanism may be more promising when creating HOMS, compared with the mechanisms described above. From the magnetic point of view, the orbital effects of the magnetic field are responsible for emergence of the so-called scalar chiral interaction, which in the case of homogeneous field is proportional to the density of the topological charge of magnetic structure, and in the inhomogeneous fields can lead to new structures. At the same time, we noticed that in strongly correlated electron systems, the contribution from the scalar chiral interaction to the HOMS energy can be comparable to that of the Dzyaloshinsky-Moriya interaction for ordinary skyrmions. Taking into account the hierarchy of effective spin interactions, an analytical theory on the optimal sizes of HOMS is developed for axially symmetric magnetic fields of the form $h(r) \sim r^{\beta}$. The HOMS themselves could act as promising carriers of Majorana modes in superconductor / ferromagnet hybrids [6].

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