Topological energy release from collision of relativistic antiferromagnetic solitons

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Abstract

Most of the current multipurpose electronics devices function thanks to electrical energy that is previously stored and then delivered on the demand by the user [1]. However, due to the increasing dependence on numerous electronics devices, new effective methods for storing high energy density in a quickly manner are required [2]. In this work, we investigate storage, transport and later on release of energy embedded in magnetic topological soliton textures, such as antiferromagnetic domain walls (DW).

Some examples of magnetic topological solitons (MTS) are domain walls, vortices and skyrmions, which play a pivotal role for the development of spin-based applications like processing, sensing and storing information as well as radio-frequency and neuro-inspired devices because of their stability, compact size and energy efficient dynamics. These magnetic textures behave as pseudo-particles and therefore their energy is finite and localised in a limited region of the spin-space. Additionally, these textures can exist spontaneously due to the configurational energy. Furthermore, they can also be generated from the vacuum state and be regarded as an excited state of the magnetisation order parameter.

Recently, several numerical works have shown that out of a single MTS, a non-equilibrium number of magnetic textures can be generated offering a route to store the energy transferred to the magnetic material into the topological magnetic solitons leading to large amount of energy densities [3,4]. However, in spite of its potential for energy storage units, they are usually regarded as information carriers in most of the applications. Moreover, in antiferromagnets, the DW self-energy can be represented in a relativistic form as the dynamics are governed by the special theory of relativity [5], which implies that its self-energy increases significantly once it approaches the effective speed of light. Nevertheless, this self-energy cannot be extracted from the spin-space, since this would violate the overall topological number associated to the spin-space. In order to circumvent this issue, we force two domains walls with opposite topological charge to collide at relativistic speeds forcing them to release all the stored energy and transfer it to electron and phonon reservoirs [6]. Practical aspects such rate of charging the magnetic textures, transport of the energy and release/discharge time are discussed.

References

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Short Bio

Dr. Rubén M. Otxoa obtained his undergraduate studies in Theoretical Physics (Bach +5) in Complutense University of Madrid. He obtained a Marie Curie fellowship to carry out his PhD studies on magnetic vortices in Claude Chappert's group in Paris Sud XI, France. Afterwards, he carried a postdoc in the Cavendish Laboratories in Hitachi-Cambridge laboratory (HCL), UK, focusing on magnetisation dynamics both ferromagnet and antiferromagnet with a variety of excitation protocols. From 2015 onwards he became a permanent staff member in HCL and since 2018 he is visiting researcher of Donostia International Physic Center of San Sebastián, Spain.