Control and Manipulation of a Magnetic Skyrmionium in Nanostructures

Univ. of Hong Kong 1, Nanjing Univ. 2, Central South Univ. 3, Shinshu Univ. 4, Beihang Univ. 5, Univ. of Tokyo 6, Xichao Zhang 1, 2, *, Jing Xia 1, 2, *, Yan Zhou 1, 2, Daowei Wang 3, Xiaoxi Liu 4, Weisheng Zhao 5, Motohiko Ezawa 6

E-mail: xichaozhang@gmail.com

Magnetic skyrmionium is a non-topological soliton with a doughnut-like spin texture in magnetic thin film, which can be phenomenologically viewed as a coalition of a magnetic skyrmion and a magnetic anti-skyrmion. Due to its zero topological number, that is, \( Q = 0 \), the skyrmionium has distinctive characteristics as compared to its topological skyrmion counterpart with \( Q = \pm 1 \). In this work, we systematically study the generation, manipulation and motion of a skyrmionium in nanostructures in the presence of a magnetic field or a spin current [1]. We demonstrate the degeneration of a skyrmionium with \( Q = 0 \) into a skyrmion with \( Q = +1 \) or \( Q = -1 \) triggered by a magnetic field pulse in a nanodisk. We show the transformation of a skyrmionium with \( Q = 0 \) into two skyrmions with \( Q = +1 \) in a nanotrack. In addition, we investigate the motion dynamics of a skyrmionium as well as a bilayer-skyrmionium compared to that of a skyrmion. The velocity of a skyrmionium driven by vertical current can be faster than that of a skyrmion at a reasonable driving current density. The results have technological implications in the emerging field of skyrmionics.

Figure 1. (a) Illustrations of a magnetic skyrmionium, which can be seen as composed of a skyrmion and an anti-skyrmion. (b) The out-of-plane magnetization component \( m_z(x) \) along the diameter of the skyrmionium as a function of the external perpendicular magnetic field \( H_z \). (c) Velocities of the skyrmion \( \left(v_{Sk}\right) \), skyrmionium \( \left(v_{Skium}\right) \), and bilayer-skyrmionium \( \left(v_{Bi-Skium}\right) \) driven by perpendicular-to-plane (CPP) and in-plane (CIP) spin-polarized current as functions of the driving current density \( j \).

Reference

* These two authors contributed equally to this work.