INVESTIGATIONS ON THE SKYRMIONIUM IN MAGNETIC NANOSTRUCTURES

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A growing interest has been expressed in the study of topological magnetic solitons as a likely candidate for future spintronics devices. Among these, skyrmions have become increasingly popular in the field of spintronics. Magnetic skyrmions are swirling magnetic spin configurations in few nm size ranges with topological number $Q = \pm 1$ and are stabilized by Dzyaloshinskii-Moriya interaction (DMI). The new interest in skyrmion is attributed to its captivating characteristics including its high stability, small size, and low current density requirement for propagation. Despite this, one major obstacle to their mobility is the Skyrmion Hall Effect (SkHE), which results in splitting or annihilation of skyrmion at the edge of the device. SkHE can be suppressed by a variety of means, but a spin texture with Q=0 topological charge lacks the effects of Magnus force, so it avoids the consequences of SkHE. Consequently, recent studies focus on nontopological solitons like antiferromagnetic skyrmion and skyrmionium. Thus, our study is mainly concerned with magnetic skyrmionium in ferromagnetic materials.

We demonstrate the generation of skyrmionium within a thin magnetic nanoring when Dzyaloshinskii-Moriya interaction (DMI) is present as well as an external magnetic field, by using micromagnetic simulation based on the Landau-Lifshitz-Gilbert equation.In this study, we investigated the possibility of creating other skyrmion states (kπ states) by varying the DMI strength and outer diameter of nanorings and reported the first appearance of 3π and 4π states in nanorings. Additionally, we demonstrate that the transition of the skyrmion state from kπ to (k-1)π occurs for a few millitesla (mT) magnetic fields in the out of plane configuration. Moreover, we have observed that by applying an in-plane spin-polarized current, skyrmionium degenerates into an isolated skyrmion and a pair of skyrmions.

We observed damped oscillation of skyrmionium after the current pulse is turned off. The respective oscillation frequencies are determined using Fast Fourier Transform. Additionally, parameter like current density, current pulse time, DMI constant, thickness of free layer and damping constant are varied to determine the eigenmode frequencies of skyrmionium. We observed that Skyrmionium oscillates coherently in a nanoring-shaped spin valve pillar, and the frequency is independent of the applied current density.

So far, skyrmionium nucleation, excitation and oscillation have been studied by applying an out-of-plane field. Therefore, we have applied the field along in-plane direction in a nanoring structure to study the effect of in-plane magnetic field and in-plane spin polarized current on skyrmionium.