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Magnetic Skyrmions in Nanorings for Spintronics Applications

Dimitris Kechrakos‡
Physics Laboratory, Department of Education, School of Pedagogical and Technological Education (ASPETE), Athens, Greece

Vito Puliafito, Mario Carpentieri, Riccardo Tomasello†
Department of Electrical and Information Engineering, Technical University of Bari, 70125 Bari, Italy

Alejandro Riveros
Escuela de Ingeniería, Universidad Central de Chile, 8330601 Santiago, Chile

Jiahao Liu, Wanjun Jiang
State Key Laboratory of Low-Dimensional Quantum Physics and Department of Physics, Tsinghua University, Beijing 100084, China
Frontier Science Center for Quantum Information, Tsinghua University, Beijing 100084, China

Giovanni Finocchio*
Department of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, I-98166, Messina, Italy

email: ‡dkehrakos@aspete.gr ; † riccardo.tomasello@poliba.it ; *gfinocchio@unime.it

Abstract

The dynamical properties of skyrmions can be exploited to build spintronic devices with new functionalities. Skyrmion motion can be driven by external sources such as an electrical current and thermal gradients, or by material-based sources such as gradients in the perpendicular uniaxial anisotropy. Additionally, the use of circular skyrmion racetracks, such as nanorings, combine the sample size reduction with the feasibility of electrical pulse generation.

We will discuss three types of skyrmionic devices based on different driving forces of skyrmions in a nanoring geometry, namely: (1) a clock with tunable frequency that is biased with an electrical current having a radial spatial distribution, (2) an alternator, where the skyrmion circular motion driven by an engineered anisotropy gradient is converted into an electrical signal, and (3) an energy harvester, where the skyrmion motion driven by a thermal gradient is converted into an electrical signal, thus providing a heat recovery operation.

We study the skyrmion dynamics in the above model devices, using micromagnetic simulations and comparing with analytical resutls from Thiele's equation. We show how to precisely tune the frequency and amplitude of the output electrical signals by varying different control parameters of the device such as the material properties, the number of injected skyrmions and the geometry. Finally, we test the robustness of the proposed devices under realistic conditions including room temerature and internal material defects.