Simulation of Magnonic Properties of Three-Dimensional Nanoarchitectures

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Research in magnonics centers around the possibility of using magnons, the fundamental dynamic excitations of a magnetic system, to transfer and process information in nanoscale devices. The concept provides promising perspectives for low-energy, non-volatile data processing devices that could replace CMOS technology. After about twenty years since the first proposal of a spin-wave-based logic device [1], research in this domain has made significant progress in both experiment and theory [2].

An aspect of this topic that is particularly novel and promising concerns artificially prepared three-dimensional magnetic nanostructures and their high-frequency properties [3]. Due to tremendous improvement in nanoscale magnetic sample fabrication, it is now possible to generate arbitrarily shaped three-dimensional magnetic objects with nanometric feature size [4]. These artificial structures display a wide variety of magnetic properties, both in their magnetic structure and their high-frequency excitations in the GHz range, making them attractive candidates for applications in magnonic devices.

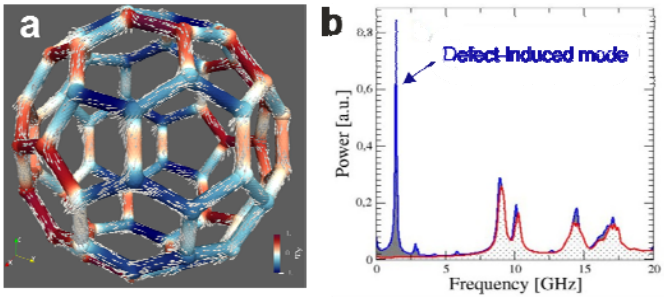

Fig 1: a) Micromagnetic simulation of the magnetization in a sub-micron sized artificial buckyball-type nanoarchitecture. b) The high-frequency magnetic oscillation spectrum changes with the magnetic structure. A characteristic peak develops if the magnetic structure contains a vertex with defect-type configuration [3].

Numerical simulation studies based on micromagnetic theory play a crucial role in understanding the magnetization dynamics on the nanoscale. The modeling of complex three-dimensional structures requires versatile numerical methods. We can reliably simulate such systems with our GPU-accelerated finite-element micromagnetic software [5].

This Ph.D. thesis aims to analyze the high-frequency magnetic oscillations and spin-wave propagation in various types of three-dimensional magnetic nano-architectures by using micromagnetic simulations and to study their variation upon changes in the geometry and their magnetic configuration. The software required to simulate the magnetization dynamics on the pico- and nanosecond scale in these samples is available in our team at the IPCMS.

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