PyMag - macrospin modeling tool for spintronics applications

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Fabrication and characterization of spintronics devices such as sensors, spin torque oscillators or spin diode detectors require many advanced cleanroom and experimental techniques [1]. However, the use of dedicated simulation tools may vastly reduce this effort. Here, we present a tool for computer design, simulation and optimization of spintronic devices and magnetic multilayer structures. Magnetization trajectories of a simulated element are computed using the macrospin model by numerical integration of the Landau–Lifshitz–Gilbert (LLG) equation, taking into account the ferromagnetic properties of component layers and couplings between them. In contrast to the existing microspin modelling frameworks [2,3] macrospin model combines high speed of operation with sufficient reproduction of physical phenomena behind. Python-based Graphical-User-Interface (GUI) allows for convenient management of the simulations and their comparison against the experimental data. Fast computational backend in C++ [4] is provided along with the GUI and may be used as a standalone application. PyMag provides an easy way for simulating magnetization dynamics in two different modes which correspond to the following experimental techniques: spin diode (SD) ferromagnetic resonance (FMR) and pulse induced magnetization magnetometry (PIMM-FMR). In SD-FMR mode, magnetization is excited by radio-frequency (RF) sinusoidal current, which generates oscillating resistance due to the magnetoresistance (anisotropic, spin Hall, giant magnetoresistance), giving rise to a DC voltage across the element. In the PIMM mode, PyMag computes the Fast Fourier Transform (FFT) from the magnetization oscillations excited by a short pulse of the magnetic field. The user may view the results as maps where the amplitudes of the oscillations are plotted as a function of frequency, and magnitude or angle of the magnetic field. Likewise, the magnetization-field (M-H) and resistance-field (R-H) loops are calculated as a function of magnetic field magnitude or angle, given a magnetisation vector converged to the steady-state.

References:

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[3] OOMMF User's Guide, Version 1.0 M.J. Donahue and D.G. Porter Interagency Report NISTIR 6376, National Institute of Standards and Technology, Gaithersburg, MD (Sept 1999)
[4] https://github.com/LemurPwned/spinpy/

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