A high-temperature micromagnetic investigation of domain-wall dynamics based on the Inverse Faraday Effect

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The advent of the next-generation of memory and logic devices can potentially be stimulated by our understanding and ability to control domain wall (DW) dynamics at the nanoscale. [1, 2] At the other end, optical excitation holds the key to the fastest magnetisation processes observed so far. [3] Ultrashort circularly-polarised laser pumping in ferromagnets has been seen capable of inducing DW dynamics with the Inverse Faraday Effect (IFE) playing one of the most important roles.

The traditional method of modeling the IFE considers an additional effective field acting in the direction of the light propagation axis. [4] At the same time, ab-initio studies have described the effect in terms of an induced helicity-dependent magnetic moment or torque. [5, 6] To understand its role in driving DW dynamics, we make use of the high temperature micromagnetic formalism based on the Landau-Lifshitz-Bloch equation. [7] Considering a 180^0 Néel wall, we induce an initial magnetisation modulus gradient across the DW and explore the possibility to convert the subsequent longitudinal relaxation of the spins into a translational motion of the Néel wall in the absence of any additional field, torque or thermal gradient. We demonstrate that under the action of the IFE, the DW displaces to the region where the magnetisation length was reduced, similar to the action of the spin-Seebeck and Magnetic Circular Dichroism mechanisms. We compare this effect with the field and torque actuation methods and investigate the maximum displacement and acquired velocity of the DW as a function of the intrinsic damping (proportional to the spin-flip rate) and electron temperature.

We conclude the DW motion is qualitatively identical within the three IFE pictures, showcasing the final displacement is proportional to the electron temperature while an increase in intrinsic damping leads to an increase of the DW velocity without affecting the final displacement. We further show how in the presence of the Dzyaloshinskii-Moriya interaction, it is possible to augment the DW motion and achieve larger as well as faster DW displacements even under the application of one laser pulse.

References

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