Modeling of magneto-thermo dynamics

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Magnetization and temperature dynamics are two coupled reciprocal phenomena. In principle, any magnetization change is accompanied by temperature changes, and the fundamental question of practical interest is how to minimize/maximize the effect, depending on the desired application. For example, for magnetic heating applications such as magnetic hyperthermia cancer treatment, the temperature release should be maximized. Here we present the self-consistent micromagnetic model which allows to calculate dynamics of the heat release during the magnetization dynamics. The model shows that the heat release occurs at the same timescale as the magnetization dynamics and can be large in the case of ultrafast magnetization dynamics. As a first example, we will present the possibility to disentangle the dynamics local temperature increase in the case of interacting magnetic nanoparticles [1].

Furthermore, the possibility to move magnetic textures by thermal gradient is well known as a spin-Seebeck effect for domain walls. Less known is the opposite effect- i.e. domain wall motion produces heat in the system. We will show that the ultrafast domain wall motion could be accompanied by a temperature release, known as the spin-Peltier effect for domain wall [2]. In this case the released temperature is proportional to the ratio of domain wall velocity/width. Here we consider the antiferromagnetic Mn_2Au material, where ultra-high velocities (up to 40 km/s) are predicted when the domain wall is moved under current by spin-orbit torque. Importantly, when the domain wall velocities are high, its width decreases due to relativistic effects. We estimate that the domain wall motion in this material can be accompanied by a localized ultrafast heat pulse as strong as 0.1K, much higher than for coherent magnetization switching of magnetic nanoparticles. The energy release is especially efficient under inelastic collision of domain walls with the opposite topological charge [3].

Our final example will consider ultrafast motion of the Bloch point domain wall in cylindrical magnetic nanowires of high magnetization where the velocities up to 10 km/s can be achieved under applied field [4]. In this case also large local temperature increase is expected.

References

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