Dynamic magnetostriction for antiferromagnets

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As electronic devices grow smaller and smaller, their components get more sensitive to novel effects. One of these effects is what the engineering community identified and later named magnetostriction. Although it has been investigated quite extensively over the years, there still are many aspects which remain to be clarified. One example is the dynamical regime of this effect [1]. Indeed, what is generically investigated, is the equilibrium deformation of a magnetic isotropic solid in the linear regime which is encoded in the Lamé parameters under a constant external magnetic field. As one tries to probe the dynamical regime, a quantitative description is much harder.

Whatever the details, the dynamics of any such Magneto-Elastically coupled (ME-coupled) material can be cast in Hamiltonian form, from which the equations of motion (EOM) follow. From these EOMs, we then obtain the coupling between the tensor deformations and classical vector spins, as well as the corresponding constraints. We focus on how to solve the EOMs numerically using a symplectic integration scheme [2], thereby preserving the symmetries and consistently solving the constraints of the model. We apply this approach to the study of the magnetization (or more precisely the Néel order parameter) switching behavior under an external spin transfer torque (STT) for the case of the antiferromagnetic (AF) phase of NiO. As a useful check, we compare our results to a complementary Lagrangian approach, that we have also developed in recent work [3].

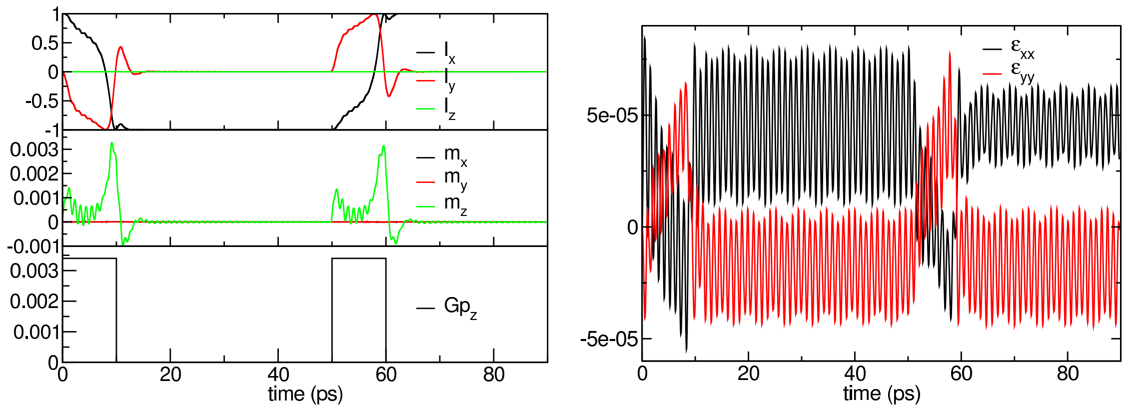

Figure 1: Magnetization switching for an AF under STT pulses : magnetization (left) and strain (right)

This example allows us to evaluate the influence of the coupling between the magnetic and the mechanical degrees of freedom on the switching behavior of the Néel order parameter. Since in an AF, the net magnetization is – close to – 0, identifying relations between the deformations and the magnetization can be done much more easily, since background magnetic effects are absent, far below the spin flop transition field. This would be a great new testing ground for experimental investigation techniques on magnetic AF materials, which are notorious for displaying a broad spectrum of behavior, that challenge traditional approaches [4]. We show, in particular, how new kinds of symmetries, that either mix commuting and anticommuting degrees of freedom, or extend Hamiltonian mechanics to phase spaces of odd dimension (known under the name of Nambu mechanics), can provide insight into the constraints that are useful into controlling such materials [5].

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[3] T. Nussle, P. Thibaudeau, S. Nicolis. 2019. JMMM 469: 633-37.
[4] S. Baierl, et al. 2016. Phys. Rev. Lett. 117, 197201.
[5] T. Nussle, P. Thibaudeau, S. Nicolis, arXiv:1907.01857.