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Ultrafast Spin Dynamics

# Modeling of spin-lattice dynamics

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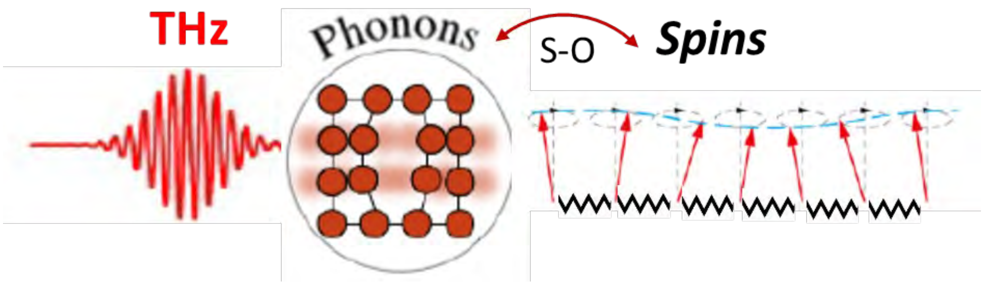
The main equation governing the dynamics of magnetic systems is the Landau-Lifshitz-Gilbert equation for the precession of spin. The damping term in this approach assumes a separation of timescales, i.e. the bath (electrons or phonons) are assumed in the (quasi-) equilibrium. Recent experiments of ultrafast magnetization dynamics on femto or pico- seconds are conducted in the situations where this assumption is questionable. Particularly, it has ben demonstrated that excitation of spin systems can lead to strong excitation of non-equilibrium phonon waves [1]. Conversely, specific phonon modes can excite the spin system [2] and even reverse the magnetization [3]. Thus, it is necessary to consider the coupled dynamics or spin and lattice without the assumption that phonons are in the equilibrium.

In this work I will present our recent model based on the classical coupled dynamics of spin and phonons [4], see illustration in the Figure. Unlike many similar models used in the literature, our model works equally well in the canonical and micro-canonical ensembles and produces a reliable angular momentum transfer from spins to lattice and vice versus. The model also allows the evaluation of the temperature dependence of the macroscopic damping parameter in insulators, giving experimentally reasonable values. Next we demonstrate that the magnetization switching is possible when the magnetic system is excited by THz phonon modes with very specific frequencies. The underlying mechanism is the quasi-precessional switching by angular momentum transfer from the phonon to the spin system which leads to strong effective fields in the spin system of the magneto-elastic origin. Importantly, this process can be considered "cold" since the energy from the phonon system is efficiently transferred to the spin precession with a completely negligible increase of the spin temperature.




**References:**

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[2] T. Kampfrath, et al Nature Photonics 5, 31 (2011).
[3] A. Stupakiewicz, et al Nat. Phys. 17, 489 (2021).
[4] M.Strungaru et al Phys. Rev. B 103, 024429 (2021)