Ultrafast switching and domain wall dynamics in Mn_2Au by novel laser-induced torques

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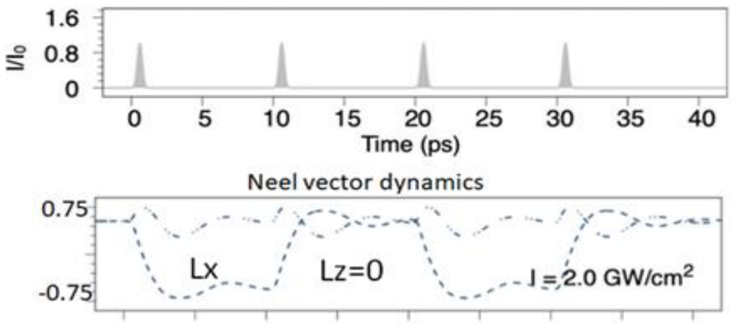
Finding ways to reliably activate antiferromagnetic (AFM) dynamics is of great interest for high-frequency spintronics. Most commonly this occurs by spin-orbit (SOT) torques generated by either current or THz radiation sources. Recently, classes of AFMs with special spin-group symmetries (such as Mn_2Au) have been shown to respond to current [1] or THz [2 [2] via intrinsic SOT, generating large interest in these materials. Despite of several theoretical predictions [3], reliable non-thermal switching has not been proved unambiguously. Thus, finding novel roots to control AFM order is of paramount.

Here we suggest a third option for direct Nèel vector control of AFMs: the induction of staggered fields using direct optical laser excitation. The prediction is based on ab-initio calculations of laser-induced torques (LOTs) in optical frequencies excluding references [4] By means of atomistic spin dynamics simulations, we predict AFM domain switching by using LOTs in Mn_2Au (Fig.1). The driving mechanism takes advantage of the sizeable exchange enhancement, characteristic of AFM dynamics, allowing for picosecond 90 and 180-degree precessional toggle switching of the Néel vector. The toggle switching is a result of special angular dependence of LOT as opposed to SOTs which would produce counter clock-wise circular switching with each laser pulse. Moreover, this special dependence largely prevents the over-shooting for LOT switching, characteristic to the SOT switching. We also demonstrate the opportunity for LOTs to produce deterministic, non-toggle switching by using a combination of laser pulses with different polarisations.

Interestingly, SOT can efficiently drive 180◦ AFM domain wall (DWs) but would change the shape of 90◦ DWs. Differently, LOT can efficiently drive 90◦ DWs without changing their shape but its spatial symmetry forbids the motion of 180◦ walls. In the steady-state regime, 90◦ DWs kinematics displays special relativity signatures accessed for low laser intensities. We also show the proliferation of DWs driven by LOT when approaching the magnonic limit. Our results are not unique to Mn_2Au. We believe that as the study and characterisation AFM responses to external stimuli continues, more materials of relevant symmetry should show LOTs features.

Fig. 1. Atomistic modelling of AFM dynamics in Mn_2Au under subsequent application of 4 laser pulses with 400 fs duration and <010> electric field polarisation. Results show toggle switching of the Néel vector rotating in-plane.



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