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Non-linear, purely magnetic magnetization response to femtosecond structured laser pulses

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Since the pioneering work on ultrafast laser induced demagnetization [1], femtosecond (fs) laser pulses have attracted a lot of interest as a unique path to achieve sub-ps control of magnetic states. Most of the phenomena involved in these studies are related with non-linear effects of the electric field on the magnetization of the sample [2]. Nonetheless, the recent technological advances in the development of structured laser pulses have opened the possibility to study non-linear effects induced solely by the magnetic field. In particular, the use of azimuthally polarized ultrafast laser pulses. allows for the generation of Tesla-scale fs magnetic fields, isolated from the electric field [3]. Such novel isolation of the magnetic field poses the question of the effect of the magnetic field alone on this ultrashort and ultraintense scale.

In this contribution we show analytically and numerically that isolated circularly polarized magnetic fields promote a non-linear slow cumulative effect on the magnetization of a magnetic sample. Remarkably, such effect scales quadratically with the amplitude of the magnetic field. Our work shows that this effect can be understood as a drift field acting perpendicularly to the plane defined by the circular polarization state, evolving with the envelope of the laser pulse. This effect can be used to obtain purely precessional sub-ps switching with hundreds of Tesla on ferromagnets [4] or even to excite self-sustain oscillations in antiferromagnets with only several tens of Tesla. Our work introduces the possibility to perform ultrafast magnetization from non-linear magnetic effects in which undesirable effects that typically appear from the use intense electric fields, such as heating of the sample, can be avoided.

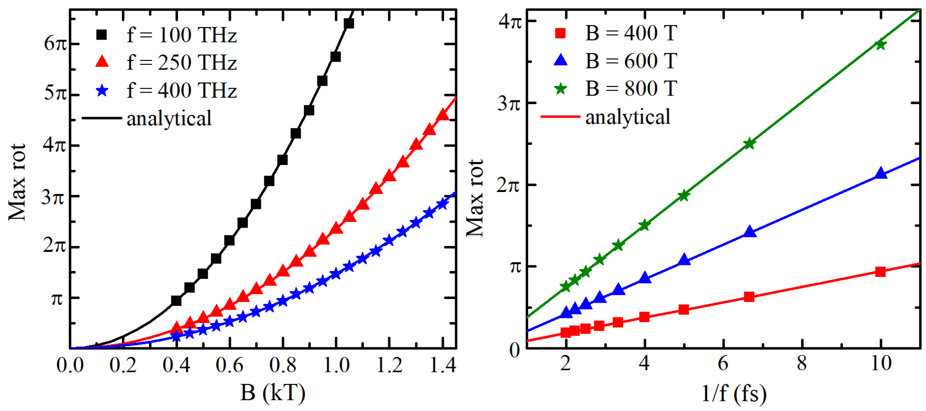

Figure 1. (a) Total rotation of a ferromagnetic sample after the application of a laser pulse of width $t_p = 750$ fs as a function of the magnetic field amplitude. (b) Total rotation of a ferromagnetic sample after the application of a laser pulse of width $t_p = 750$ fs as a function of main frequency.

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