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Magnetic order excitation by magnetic fields from sub-picosecond structured laser pulses

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The manipulation of magnetic properties can be exploited in a wide range of applications, such as detectors, actuators, memories, etc. Ultrafast, yet efficient, ways of manipulating magnetic textures could widen even more the use of magnetically ordered systems. The pioneering work on ultrafast laser induced demagnetization in Ni [1], demonstrated that ultrafast laser sources can promote femtosecond (fs) ferromagnetic switching, opening the door to a large number of theoretical and experimental studies on femtomagnetism. Recent technological advances in structured laser sources are opening the door to novel magnetic manipulation schemes. In particular, it has been recently proposed that Tesla-scale fs magnetic fields, isolated from the electric field, can be obtained through the use of ultrafast azimuthally polarized laser beams [2]. Such configuration offers the opportunity to perform pure magnetic interactions with an intense fs B field.

In the present work [3] we show that non-linear magnetic field effects driven by structured laser pulses provide a way to manipulate the magnetic order of ferro- and antiferromagnetic materials. We introduce a novel ferromagnetic switching scheme on sub-ps time-scales by purely magnetic precession of the magnetization with field amplitudes of hundreds of Tesla. We provide an analytical expression that relates the magnetic field amplitude, frequency and pulse duration to achieve switching. Interestingly, lower magnetic fields are enough to excite self-oscillations in AFM materials even after the laser pulse. In this case, the effect can be enhanced or inhibited by the application of a train of laser pulses by properly choosing the polarization and time delay between the pulses. In this sense, it could be possible to construct an artificial neuron excited by this mechanism. The isolation of the magnetic field avoids the heating due to the electric field which may drive stochastic processes or even damage the sample. Our work opens a promising scenario for the manipulation of magnetic states on fs time scales through the use of structured laser beams.

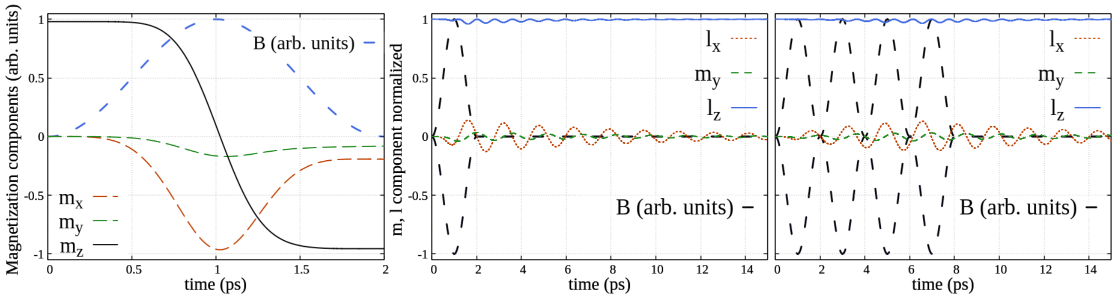

Figure 1. (a) Ferromagnetic switching due to a laser pulse with amplitude $B = 400\,\mathrm{T}$, main frequency $f = 100\,\mathrm{THz}$ and pulse width $t_p = 750\,\mathrm{fs}$. (b) Antiferromagnetic oscillations after a laser pulse with amplitude $B = 200\,\mathrm{T}$, main frequency $f = 125\,\mathrm{THz}$ and pulse width $t_p = 637.5\,\mathrm{fs}$. (c) Antiferromagnetic oscillations after four laser pulses with amplitude $B = 120\,\mathrm{T}$, main frequency $f = 125\,\mathrm{THz}$ and pulse width $t_p = 637.5\,\mathrm{fs}$. The amplitude of the oscillations is the same as in (b).

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