Cold ultrafast all-optical switching of magnetization

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In the last decade, a plethora of fundamental mechanisms for magnetization dynamics induced by laser pulses at ultrashort time scales has been actively discussed [1-4]. The main interest is not only in the excitation of spin precession but in the switching of magnetization between multiple stable states, as it opens up rich possibilities for non-volatile magnetic data storage technology. One of the most intriguing examples is the least-dissipative (cold) mechanisms of all-optical switching of magnetization with laser pulses.

Recently, we demonstrated the nonthermal all-optical photo-magnetic switching in Co-ions doped garnet films using a time-resolved magneto-optical spectroscopy and single-shot ultrafast imaging of magnetic domains [4]. The photo-magnetic effect is a general phenomenon in numerous dielectrics. However, by using ultrashort laser pulses and precisely tuning to optical resonances we vastly enhance the effective light-induced field amplitude [5]. The switching properties at the observed resonances are vastly different, related to the crystal site hosting the excited Co-ions. As these ions are the source of the strong magnetic anisotropy in a garnet, their excitation between the crystal filed split states results in a coherent and ultrafast manipulation of spin-orbital interaction. Moreover, another non-thermal mechanism of ultrafast magnetization switching was found in these garnets by resonant pumping of optical phonon modes [6].

Additionally, we demonstrated that with femtosecond pulses it is possible to write and rewrite magnetic bits with a frequency of up to 20 GHz, with the maximum repetition rate being defined by the frequency of ferromagnetic resonance in the field of photo-induced magnetic anisotropy [7]. Our results reveal the principles to be employed in achieving cold and ultrafast magnetic recording.

References:

[1] A. Kirilyuk, A.V. Kimel, and Th. Rasing, Rev. Mod. Phys. 82, 2731 (2010).
[2] C.D. Stanciu, et al. Phys. Rev. Lett. 99, 047601 (2007).
[3] C-H. Lambert, et al. Science 345, 1337 (2014).
[4] A. Stupakiewicz, et al. Nature 542, 71 (2017).
[5] A. Stupakiewicz, et al. Nat. Commun. 10, (2019).
[6] A. Stupakiewicz, et al. Nat. Phys. 17, 489 (2021).
[7] K. Szerenos, et al. Phys. Rev. Appl. 12, 044057 (2019).