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Femtosecond control and dynamics of magnetism at the nanoscale

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The idea to change magnetic properties of media with the help of light has long intrigued people. This research direction became especially appealing after the development of femtosecond laser sources which are able to generate sub-100 fs laser pulses. These pulses are among the shortest stimuli in contemporary experimental physics. Such a development has naturally raised the question about feasibility of ultrafast optical control of magnetism and triggered the field of ultrafast magnetism [1]. The action of electric field of light on electronic dipoles, being the largest perturbation in physics of light-matter interaction, conserves the spin of electron. Nevertheless, an effective optical control and detection of antiferromagnetism become possible due to spin-orbit [2] and exchange interactions [3,4]. Here we review the fundamentals and recent progress in the areas of femtosecond magneto-optics and opto-magnetism. A special attention will be paid to optical control of magnetism in magnetic nanostructures [5], opto-magnetic recording with subwavelength spatial resolution [6] and generation of femtosecond nanomagnons [7]. [1] A. Kirilyuk, A. V. Kimel, Th. Rasing, Ultrafast optical manipulation of magnetic order, *Review of Modern Physics* 82 2731-2784 (2010). [2] A. V. Kimel, A. Kirilyuk, P. A. Usachev, R. V. Pisarev, A. M. Balbashov, R. V. Pisarev, and Th. Rasing, Ultrafast non-thermal control of magnetization by instantaneous photomagnetic pulses, *Nature* 435 655 (2005). [3] R. Mikhaylovskiy, E. A. Secchi, J. Mentink, M. Eckstein, A. Wu, R. Pisarev, V. Kruglyak, M. Katsnelson, Th. Rasing, and A. V. Kimel, Ultrafast optical modification of exchange interactions in iron oxides, *Nature Communications* 6, 8190 (2015). [4] R. R. Subkhangulov, A. B. Henriques, P. H. O. Rappl, E. Abramof, Th. Rasing, A. V. Kimel, All-optical manipulation and probing of the d-f exchange interaction in EuTe, *Scientific Reports* 4, 4368 (2014). [5] L. le Guyader, M. Savoini, S. El Moussaoui, M. Buzzi, A. Tsukamoto, A. Itoh, A. Kirilyuk, T. Rasing, A. V. Kimel & F. Nolting, “Nanoscale sub-100 picosecond all-optical magnetization switching in GdFeCo microstructures”, *Nature Communications* 6, 5839 (2015). [6] R. R. Subkhangulov, A. B. Henriques, P. H. O. Rappl, E. Abramof, Th. Rasing, A. V. Kimel, All-optical manipulation and probing of the d-f exchange interaction in EuTe, *Scientific Reports* 4, 4368 (2014). [7] D. Bossini, S. Dal Conte, Y. Hashimoto, A. Secchi, R. V. Pisarev, Th. Rasing, G. Cerullo, and A. V. Kimel, Macrospin dynamics in antiferromagnets triggered by sub-20 femtosecond injection of nanomagnons, *Nature Communications* 7, 10645 (2016).