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Ultrafast Magnetism of Multi-component Ferromagnets and Ferrimagnets on the Time Scale of the Exchange Interaction

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Revealing the ultimate speed limit at which magnetic order can be controlled, is a fundamental challenge of modern magnetism having far reaching implications for the magnetic recording industry [1]. Exchange interaction is the strongest force in magnetism, being ultimately responsible for ferromagnetic or antiferromagnetic spin order. How do spins react after being optically excited on a timescale of or even faster than the exchange interaction? Here, we demonstrate that femtosecond (fs) measurements of ferrimagnetic and ferromagnetic alloys using X-ray magnetic circular dichroism provide revolutionary new insights into the problem of ultrafast magnetism on timescales pertinent to the exchange interaction. In particular, we show that upon fs optical excitation the ultrafast spin reversal of GdFeCo - a material with antiferromagnetic coupling of spins - occurs via a transient ferromagnetic state [2]. The latter emerges due to different dynamics of the Gd and Fe magnetic moments: Gd switches within 1.5 ps while it takes only 300 fs for Fe. Thus, by using a single fs laser pulse one can force the spin system to evolve via an energetically unfavorable way and temporarily switch from an antiferromagnetic to a ferromagnetic type of ordering. In order to understand whether the observation of this temporarily decoupled and element-specific dynamics is a general phenomenon or just something strictly related to the case of ferrimagnetic GdFeCo, we have investigated the demagnetization of the archetypal ferromagnetic NiFe alloys. Essentially, we observe the same distinct magnetization dynamics of the constituent magnetic moments: Ni demagnetizes within $\sim$300 fs being much faster than the demagnetization of Fe of $\sim$800 fs. This distinct demagnetization behavior leads to an apparent decoupling of the Fe and Ni magnetic moments on a few hundreds of fs time scale, despite the strong exchange interaction of 260meV ($\sim$16 fs) that couples them. These observations supported by atomistic simulations, present a novel concept of manipulating magnetic order on different classes of magnetic materials on timescales of the exchange interaction [3].

[1] A. Kirilyuk, A.V. Kimel and Th. Rasing, *Rev. Mod. Phys.* **82**, 2731 (2010).
[2] I. Radu *et al.*, *Nature* **472**, 205 (2011).
[3] I. Radu *et al.*, *submitted* (2011).