

# Ultrafast reemergence of microscopic spin order in GdFeCo

Over the past decade, femtosecond optical laser pulses have fueled the discovery of ultrafast spin dynamics in magnetic materials that go beyond our equilibrium understanding of magnetism. Many of these phenomena are potentially suitable for future technological applications. For example, fs optical laser pulses can act as a stimulus to reverse the magnetization direction in ferrimagnetic GdFeCo, a phenomenon called all-optical switching [1]. However, much remains to be understood about these non-equilibrium spin dynamics, particularly how they manifest on nanometer lengthscales where magnetic order emerges. Further, our recent work on GdFeCo utilizing ultrafast x-ray diffraction showed that the non-equilibrium spin dynamics on the nanoscale can evolve very differently from the bulk [2]. Using the ultrabright and ultrafast x-ray pulses from the Linac Coherent Light Source (LCLS), we probed the fs magnetic response of GdFeCo with spatial resolution down to 10nm at both the Gd M5 (1190 eV) and Fe L3 (707 eV) absorption edges. Our results showed that GdFeCo displays nanoscale chemical and magnetic inhomogeneities that affect the spin dynamics. In particular, we observed Gd spin reversal in Gd-rich nanoregions within ~ 1 picosecond following optical excitation. These nanoregions of Gd 4f spin reversal result from a non-local flow of angular momentum originating from Fe 3d spins in surrounding areas. In addition, new time-resolved x-ray diffraction results from LCLS show that this nanoscale spin order not only persists against the disorder caused by the optical excitation, but that the reversed nucleated areas grow in size for the first 10ps. In this talk, I will discuss our recent work demonstrating the non-local flow of angular momentum with ultrafast x-ray diffraction measurements. I will then present our new results, which show the reemergence and growth of nanoscale spin order following optical excitation in GdFeCo.

[1] Stanciu, C. D. et al. All-Optical Magnetic Recording with Circularly Polarized Light. *Phys. Rev. Lett.* 99, 047601 (2007).

[2] Graves, C.E., Reid, A.H., et. al. Nanoscale spin reversal by non-local angular momentum transfer following ultrafast laser excitation in ferrimagnetic GdFeCo. *Nature Mater.* 12, 293 (2013).

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