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Possibility of Nanoscale Imaging of Ultrafast Magnetization Dynamics[1]

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Understanding the microscopic mechanisms driving the magnetization dynamics on the fs time scale is of essential importance for manipulating and controlling the macroscopic state in magnetic storage devices. The demagnetization in ferromagnetic films by an ultrashort laser excitation on a time scale of a few hundred fs raised controversies about the effective path to dissipate angular momentum to the lattice, see e.g. [1]. Even more intriguing is the demonstration of all-optical magnetization reversal in ferrimagnetic compounds using circularly polarized, fs laser pulses [2]. Until only recently, the field of "Femto-magnetism" has naturally been driven by all-optical pump-probe techniques. Femtosecond time-resolved X-ray magnetic circular dichroism spectroscopy has been utilized to unambiguously determine the ultrafast quenching of spin and orbital moments after ultrashort laser excitation [3]. While all-optical pump-probe techniques allow ultrafast excitations (pump) and the study of their evolution (probe) on the macroscopic scale by use of the magneto-optical Kerr or Faraday effect, little is known about the microscopic processes on nano- and sub-nanometer length scales because of the lack of real or momentum space resolution of optical techniques. By combining resonant coherent resonant magnetic scattering with the unique high peak-brightness, short pulse structure, and fully transverse coherence of the new x-ray free-electron lasers, the dynamics of magnetic fluctuations and magnetization relaxation processes can be studied on the nanometer scale with sub-picosecond time resolution. We demonstrate the possibility of nondestructive single shot imaging of the magnetization in Co/Pd multilayers at LCLS.

[1] Koopmans, B, et al., Nature materials 9, 259 (2010).
[2] Stanciu, C.D., et al., Phys. Rev. Lett. 99, 047601 (2007).
[3] Stamm, C., et al., Nature materials 6, 740 (2007).

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