

*Two colour imaging of ultrafast magnetisation dynamics*Clemens von Korff Schmising¹¹Max-Born-Institute Berlin, Berlin, Germany

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Many fundamental processes in magnetism take place on a nanometre length and sub-picosecond time scale. A prominent example of such phenomena in magnetism is ultrafast, spin-polarized transport of laser-excited hot electrons, which is now being recognized to play a crucial role for novel spintronic devices and for all-optical magnetic switching. Recent experimental examples include the demonstration of optical control of spin-polarized currents at ferromagnetic/heavy metal interfaces and nanoscale spin reversal in chemically heterogeneous magnetic sample systems driven by non-local transfer of angular momentum. In particular, for advanced information technologies with bit densities already exceeding 1 terabit per square inch with bit cell dimensions on the order of $15 \times 38 \text{ nm}^2$, it is of fundamental importance to understand and eventually control the mechanisms responsible for optically induced ultrafast spin dynamics on the nanoscale.

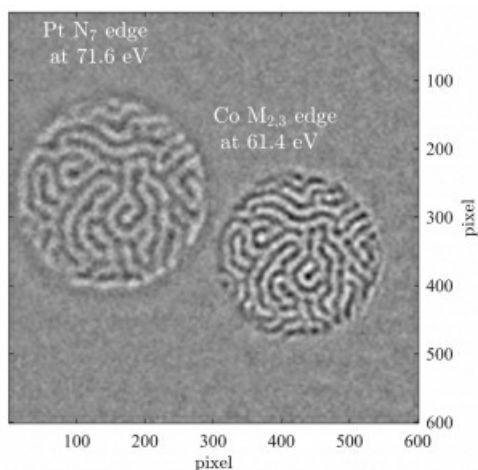
Free-electron-laser (FEL) radiation is the ideal tool to tackle these questions experimentally, allowing, for the first time, to access both the nanometre length and the femtosecond time scale in magnetization studies: FEL radiation combines an ultrashort pulse structure for an ultimate time resolution, tuneable wavelengths in the extreme ultraviolet to hard X-ray spectral range for element-selective magnetic spectroscopy, and a very bright and coherent photon flux for nanoscale imaging techniques. Additionally, new experimental schemes at FELs allow to generate two or- even multi-coloured pulses for spectroscopy of complex solid state systems where an optical excitation is followed by a coupled and ultrafast interaction between different constituent elements.

In this contribution we will discuss a series of recent experiments demonstrating spatially resolved studies of laser driven magnetization dynamics performed at the FEL facility FERMI, Trieste, Italy and at FLASH, DESY in Hamburg, Germany [1]. We present different approaches to confine the optical excitation to subwavelength spatial dimensions and demonstrate imaging of the subsequent nanoscale magnetization dynamics via Fourier transform holography. Finally we present the first experimental demonstration of simultaneous two colour imaging of a Co/Pt heterostructure, where a single diffraction pattern encodes the spatial information of the element specific magnetization stemming from the Co layer and the Co/Pt interface [2].

We argue that time-resolved, multi-colour and real-space spectroscopy at FEL and high harmonic radiation sources presents a novel and valuable tool to unravel ultrafast, non-equilibrium interactions within the electronic and spin structure of complex multicomponent and multiphase materials.

[1] C. von Korff Schmising, Phys. Rev. Lett., 112, 217203 (2014).

[2] F. Willems et al., Struct. Dyn., 4, 014301 (2017).



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