Single-shot magnetic Fourier transform holography at FERMI@Elettra.

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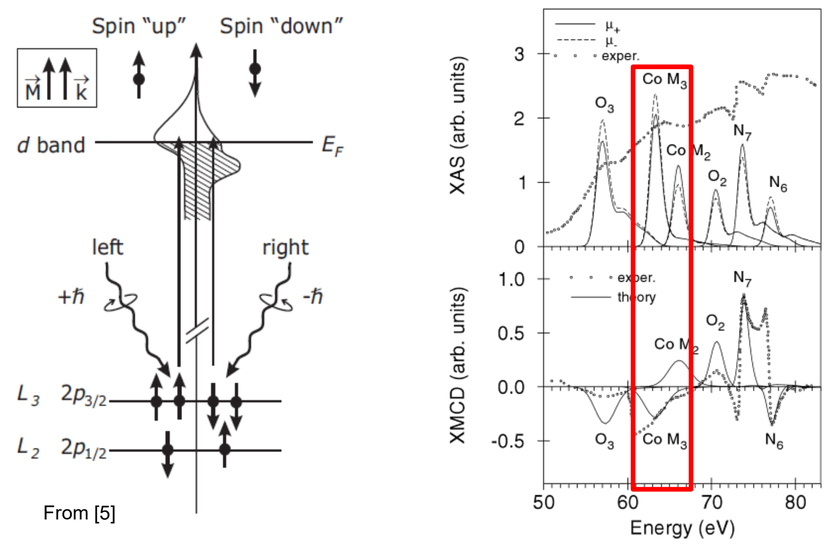
Aim: Following real-space demagnetization processes by means of stroboscopic single-shot imaging

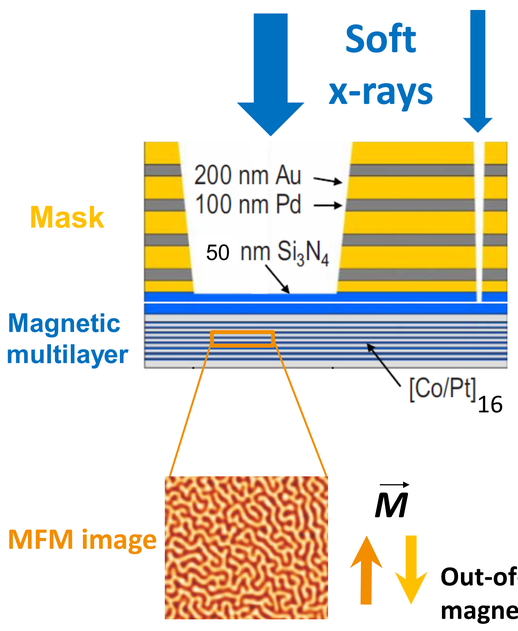
Understanding ultrafast de- and remagnetization processes on a nanometer length scale is essential to gain advance in utilizing new materials for spintronic devices. Since the first observation of 'ultrafast spin dynamics' in 1996 [1], the phenomenon of ultrafast demagnetization upon non-thermal optical excitation has been intensively studied. Beyond this, recent results from a optical pump–X-ray probe scattering experiment at the free-electron laser facility FLASH shows a spatial response of the magnetic system attributed to superdiffusive spin transport across the magnetic domain wall boundaries [2-4]. Our aim is to confirm these results in a stroboscopic resonant magnetic imaging experiment using holographic techniques.
In a 'proof-of-principle' experiment at the new FEL facility FERMI@Elettra we measured for the first time a single-shot magnetic hologram at the Co-M_3 edge by using Fourier transform holography (FTH). This result opens the door for time-resolved magnetic imaging experiments at FEL sources.

Magnetic contrast mechanism



➡ **XMCD effect**

Multilayer sample and FTH mask



The Au/Pd holographic mask is fabricated on a Si_3N_4 membrane and consists of an **object hole** (2.5 µm) and **5 reference holes** (~50 nm) which are drilled via FIB milling.

The **out-of-plane magnetized** Co/Pt mulilayer is deposited on a 50 nm thick Si_3N_4 membrane by ECR and DC magnetron sputtering and aligned ex-situ by an magnetic field to a metastable '**stripe domain**' state. **Average domain with is ~ 100 nm**.

The separate mask is attached directly to the magnetic mulitlayer.

Single-shot magnetic imaging at the Co-M_3 edge

We have successfully imaged the magnetic stripe domain structure of an Co/Pt multilayer system with out-of-plane easy axis of magnetization at the Co-M_3 edge using a single FEL shot generated by the new FERMI@Elettra facility in Trieste, Italy.

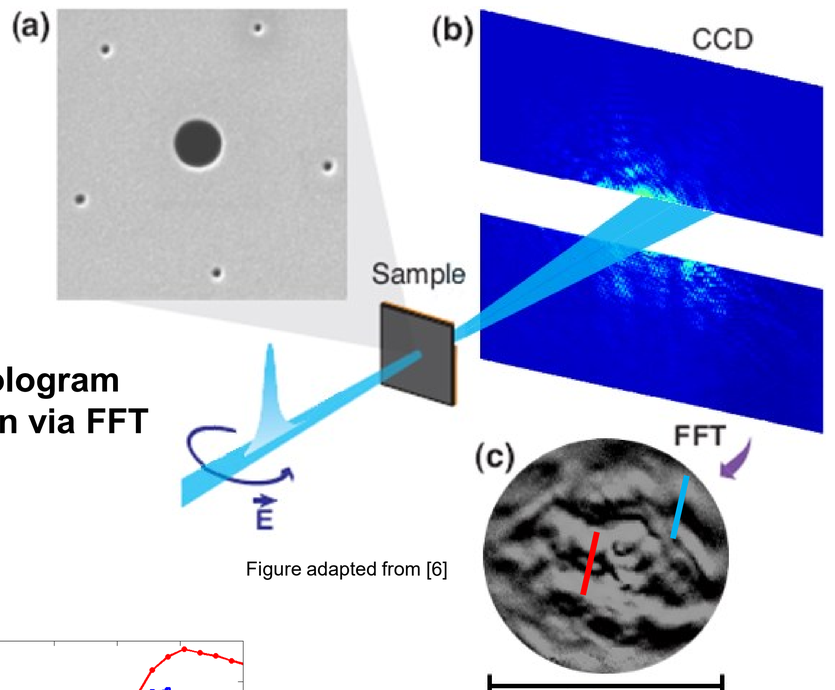
Imaging technique

➡ Diffraction-limited image resolution thru lensless Fourier transform holography (FTH)

Photon parameter

- ► Seeded HGHG FEL
- ► Energy 59 eV (λ = 20.8 nm, FEL-1)
- ► Circular polarization (APPLE-II type undulator)
- ► Pulse length <100 fs (FWHM)

Experimental setup (DeProI beamline)



(a) FTH mask
(b) Single-shot hologram
(c) Reconstruction via FFT

Figure adapted from [6]

Intensity profile

Single-shot magnetic imaging at the Co-M_3 edge is feasible and opens the gate for stroboscopic pump-probe imaging on the fs-timescale and with nanometer resolution.

References

[1] E. Beaurepaire, et al., Phys. Rev. Lett. **76**, 4250 (1996).
[2] B. Pfau, et al., Nature Comm., under review.
[3] C.Gutt, et al., Phys. Rev. B, **79** 212406 (2009).
[4] C. Gutt, et al., Phys. Rev. B **81**, 100401(R) (2010).
[5] C. Sorg, PhD thesis, FU Berlin (2005).
[6] T. Wang, et al., Phys. Rev. Lett. **108**, 267403 (2012).

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