X-rays as probes for time-resolved magnetic imaging

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About 125 years after their discovery in 1895 by Wilhelm Konrad Röntgen, x-rays have become an indispensable tool for magnetism research. Here I will focus on utilizing soft x-rays for advanced time-resolved magnetic microscopy, offering element-specific imaging at a unique spatio-temporal resolution of appx. 10 nm and 10 ps, respectively.
In that respect, the investigation of spin-wave phenomena, also referred to as *magnonics*, plays an important role in present magnetism research [1] [Fig. 1]. By means of time-resolved scanning transmission x-ray microscopy (TR-STXM), we could demonstrate that ferromagnetic spin textures in metallic systems can be used as nanoscale spin-wave emitters and wave guides. In particular, topological spin vortex cores prove to act as efficient and tunable generators for sub-100 nm waves [2,3] [Fig. 2(a,b)], while domain walls can be utilized as quasi one-dimensional channels for spin-wave propagation and routing [4] [Fig. 2(c)].
Besides x-ray magnetic circular dichroism (XMCD) as a contrast mechanism for ferromagnetic orientation, also x-ray magnetic linear dichroism (XMLD) - sensitive to antiferromagnetic order - can be employed for time-resolved imaging.

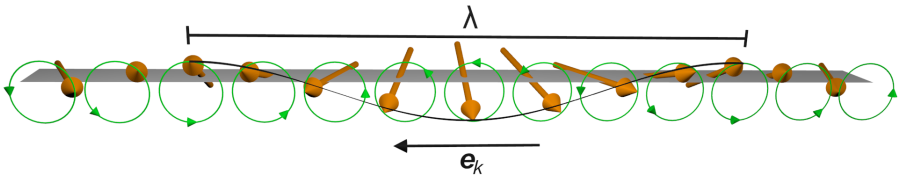

Figure 1: Schematics of a propagating spin wave [3].

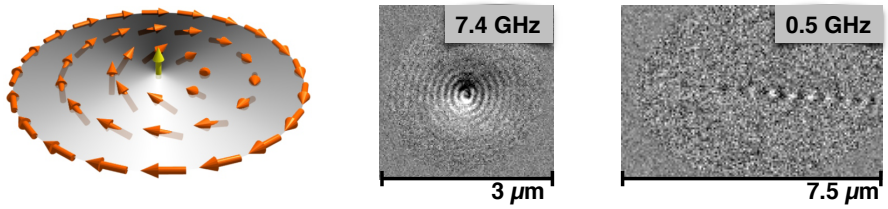

Figure 2: (a) Schematics of a spin vortex. (b) Spin-wave emission from a vortex core.
(c) Domain wall as 1D spin-wave channel as measured by STXM

[1] A. V. Chumak *et al.*, Nat. Phys. **11** 453 (2015).
[2] S. Wintz *et al.,* Nat. Nanotech. **11** 948 (2016).
[3] G. Dieterle *et al.,* Phys. Rev. Lett. **122** 117202 (2019).
[4] V. Sluka *et al.,* Nat. Nanotech. **14** 328 (2019).

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