

Magnetic Soft X-ray Microscopy: Imaging Spin Dynamics down to Fundamental Length and Time Scales

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Magnetism on the nanometer scale and its spin dynamics on a nanosecond (nsec) to femtosecond (fsec) time scale is currently a scientifically highly attractive topic. It addresses both fundamental magnetic length scales (e.g., magnetic exchange lengths in the sub-10-nanometer range) and fast time scales in the sub-nsec regime where precessional and relaxation phenomena, domain wall motion, and vortex dynamics occur. The picosecond (psec) time scale is the range of spin-orbit interaction, but ultimately the fundamental time scale in magnetism is given by the time required to transfer energy and momentum from the electronic into the spin system, which will occur on a fsec time scale.

There is also a strong technological interest in fundamental magnetization processes on the nanometer length and nsec time scale driven by current developments of future ultrahigh density magnetic data storage media and miniaturized magnetic sensor technologies. New technological concepts such as spintronics, where in addition to the charge the spin of the electron is considered, require precise control the electron spin on a nanoscale with psec timing. Logical elements for spintronics, non-volatile magnetic random access memories (MRAM) or three-dimensional magnetic data storage devices are just a few of the potential applications. New ideas are being investigated, trying to speed up magnetization reversal (e.g., by reversing the magnetization by spin currents) which are injected into nanoscale magnetic elements.

Progress in this area requires novel analytical capabilities and a direct visualization of the local and element specific magnetization is very appealing. Magnetic transmission soft x-ray microscopy is a powerful technique as it combines x-ray magnetic circular dichroism as huge and element specific magnetic contrast mechanism with high spatial and temporal resolution down to <10 nanometers [1, 2] and 70 psec, resp. Operating in a stroboscopic pump-probe mode, time resolved images of nanoscale magnetization phenomena can be observed with the temporal resolution only limited by the length of the probing x-ray pulses [3].

In this talk I will review recent achievements with time resolved magnetic soft x-ray microscopy with focus on current induced domain wall [4-6] and vortex dynamics in ferromagnetic elements [7-11].

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