Soft X-ray Magneto-Optics: probing magnetism by resonant scattering experiments

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Recent developments in x-ray sources (synchrotrons, linear free-electron lasers and high-harmonic generation sources) widened considerably the range of application of x-ray scattering techniques. Beyond flux and brilliance, major improvements concern polarization tuneability, degree of coherence and selectable time-structure, providing new methods for investigating the electronic and magnetic properties of solids. The soft x-ray range (50–2000 eV) is particularly suited for studying magneto-optical effects in laterally confined sub-micron sized objects, either artificially built or self-assembled.

Firstly, by tuning the photon energy at a core resonance, one provides the x-ray scattering technique with element selectivity. Secondly, resonant excitations make the optical constants sensitive to the local magnetization by introducing large off-diagonal elements in the dielectric tensor; x-ray magneto-optics effects are stronger when the core excitations produce dipolar transitions to a final state that directly involves the magnetic orbitals ($3d$ for the first row TM; $4f$ for RE), which implies that the most interesting resonances for studying magneto-optics effects $[(2,3)p \rightarrow 3d$ and $(3,4)d \rightarrow 4f]$ are all located in the soft x-ray region. Finally, the wavelengths corresponding to soft x-rays are very well suited for scattering studies of nanometer- to micrometer-sized magnetic structures.

We will present the results of recent soft x-ray resonant magnetic scattering experiments, with applications to the study of thin films, multilayers and arrays of dots. In particular, we will show how the combination of element selectivity, magnetic sensitivity and structural analysis can help disentangling and understanding the magnetic properties of complex systems. Lastly, recent coherent scattering experiments producing x-ray holographic imaging of magnetic domains will be reviewed.