Reconstruction of Magnetic Domains from Coherent X-ray Scattering

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We have explored theoretically and numerically the reconstruction of magnetic domain patterns from coherent soft x-ray scattering for two different situations where we have used experimentally realistic parameters [1,2]: i) reflection from the surface of a rough, antiferromagnetically ordered sample, and ii) transmission through a ferromagnetically ordered multilayer thin film with the magnetization perpendicular to the multilayer plane. In the reflection geometry we have used experimental PEEM images of the antiferromagnetic domains to compute simulated magnetic scattering patterns (speckle) with varying amounts of noise added in the simulation. We have applied the concepts of error-reduction and hybrid input-output algorithms to reconstruct the shape of the antiferromagnetic domains. Using these methods we have been able to accurately retrieve the phase from the magnitude of the Fourier transform of the magnetic surface, by imposing appropriate constraints. In the reconstruction procedure, we first tune the x-ray energy slightly away from the resonant energy of the material to eliminate the magnetic contrast. Under these conditions the roughness of the sample may be reconstructed using conventional iterative methods. Then with the x-ray energy tuned to the resonant energy of the magnetic material, the scattered intensity (suitably over-sampled) can be used to reconstruct the magnetic pattern with the previously reconstructed roughness as a constraint. In the case of the multilayer sample in the transmission geometry, it is shown theoretically that the combined use of intensity measurements from both right and left circular polarization of the input beam allows for the roughness scattering to be separated from the magnetic scattering. This separation means that the reconstruction is more effective since the roughness and magnetization can be reconstructed independently. Iterative algorithms are developed for both cases and results are shown to be very successful with oversampling of the scattering patterns.

[1] S. Eisebitt et al., to be published
[2] L. Sorensen et al., private communication