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Capillary-based Soft X-ray Ptychography for Ultimate 4D Spectro-Microscopy with Versatile Sample Environment

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X-ray imaging techniques enabled a significant advancement in the understanding of the physics driving magnetic systems, thanks to the possibility of combining element selectivity, sensitivity to the magnetic and antiferromagnetic ordering, and high spatial and temporal resolutions. Looking forward to the upcoming (fourth) generation of synchrotrons, new frontiers in spectroscopy and microscopy are emerging, most notably the combination of multiple cutting-edge detection schemes in the same experiment. Examples of such "multimodal"experiments are time-resolved nano-tomography and spectro-imaging with simultaneous sensitivity to chemical heterogeneity and vector-spin orientation. Such experiments would not average over any dimension, providing unprecedented insights into real, imperfect functional materials and elucidating how a material's nanostructure generates functionality. As fourth-generation light sources also promise wavelength-limited spatial resolution, they are often referred to as "ultimate microscopes"(e.g., PETRA-IV). However, developing endstation instruments that realize this potential in practice remains an open challenge.

In this project we aim to create the first coherent, digital soft X-ray ptychography endstation with a highly versatile sample environment (temperature control down to 100 K, magnetic fields up to 1 T, 3D laminography, time-resolved imaging using GHz electrical and femtosecond optical excitation). To this end, we will employ capillary optics that extend the working distance compared to conventional zoneplates from sub-millimeter to several centimeters. The endstation is currently being built and will be located at the PETRA-III P04 beamline. Our scientific goal is to leverage this instrument to integrate chemical-spectroscopic and magnetic contrast with 3D resolution under uniform conditions and thereby examine the correlation between emergent textures and nanoscale material's defects, for example, in permanent magnets and skyrmion materials.

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