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Max-Planck-Institut für Intelligente Systeme
Max-Planck-Institut für Festkörperforschung
Fachbereich Physik, Universität Stuttgart

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Computational X-ray microscopy: making the perfect X-ray microscope

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Abstract

The limitations of X-ray optics are well known and analogous to the limitations faced by electron microscopy 50 years ago. Advances in electron imaging systems, primarily through correction of spherical and chromatic aberrations, have enabled sub-Å spatial resolution and revolutionized our ability to study the nano-scale world. A similar revolution is under way in the field of X-ray microscopy as we develop the experimental, theoretical and computational means of producing a complete description of coherent imaging systems from diffraction data. These methods not only allow for full quantification and removal of all optical aberrations but also for a noise-robust deconvolution of the illumination from the image at a resolution given by the wavelength. One such method under intensive development by researchers around the world is X-ray ptychography. This is a scanned probe method that reconstructs a scattering object and its illumination from coherent diffraction data. Within the first few years of development at the Advanced Light Source, Lawrence Berkeley National Laboratory, this method has already achieved the highest resolution X-ray images ever recorded in two, three and four dimensions. With the ability of X-rays to penetrate significantly more matter than electrons, their short wavelength and their sensitivity to chemical and magnetic states, the potential for X-ray ptychography to revolutionize how we see the nano-scale world cannot be overstated. In this lecture I will provide a historical perspective on the development of coherent X-ray imaging, the technical framework for how various methods work and a detailed account of a practical implementation at a scientific user facility within the US Department of Energy complex.