Stony Brook University
The Graduate School

Doctoral Defense Announcement

Abstract

Hard X-ray Phase Contrast Microscopy – Techniques and Applications

By

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In 1918, Einstein provided the first description of the nature of the refractive index for x-rays, showing that phase contrast effects are significant. A century later, most x-ray microscopy and nearly all medical imaging remains based on absorption contrast, even though phase contrast offers orders of magnitude improvements in contrast and reduced radiation exposure at multi-keV x-ray energies.

The work presented is concerned with developing practical and quantitative methods of phase contrast for x-ray microscopy. A theoretical framework for imaging in phase contrast is put forward; this is used to obtain quantitative images in a scanning microscope using a segmented detector, and to correct for artifacts in a commercial phase contrast x-ray nano-tomography system. The principle of reciprocity between scanning and full-field microscopes is then used to arrive at a novel solution: Zernike contrast in a scanning microscope. These approaches are compared on a theoretical and experimental basis in direct connection with applications using multi-keV x-ray microscopes at the Advanced Photon Source at Argonne National Laboratory.

Phase contrast provides the best means to image mass and ultrastructure of light elements that mainly constitute biological matter, while stimulated x-ray fluorescence provides high sensitivity for studies of the distribution of heavier trace elements, such as metals. These approaches are combined in a complementary way to yield quantitative maps of elemental concentration from 2D images, with elements placed in their ultrastructural context. The combination of x-ray fluorescence and phase contrast poses an ideal match for routine, high-resolution tomographic imaging of biological samples in the future. The presented techniques and demonstration experiments will help pave the way for this development.

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