Nanometer Imaging with a High Brightness Source

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The future high brightness synchrotron sources will permit development of x-ray imaging techniques with sub-10 nm resolution and unprecedented capabilities, including 3D tomography for imaging biological specimens and studying crack initiation and propagation in materials science, spectromicroscopy for chemical state mapping of soil and environmental samples, and microdiffraction for mapping of crystallography phases and textures. As in the optical spectrum, the development of suitable lenses with the required optical property is of critical importance to realize these capabilities.

Zone plate lens has demonstrated 20-nm resolution, which is the highest spatial resolution achieved over the whole electromagnetic spectrum. The inherent high fabrication accuracy by advanced lithography technology means that it has a high degree of the source coherence preservation, as manifested by its diffraction limited focusing demonstrated by many researchers at high spatial resolution. Fabricating high-resolution zone plates for multikeV x-rays is very challenging because it requires producing precise nanometer scale structures with a high aspect ration (defined as thickness/feature-size). The challenge increases with x-ray energy because the aspect ratio required for maintaining a reasonable focusing efficiency increases with x-ray energy. Currently, Xradia is producing some of the best performing x-ray zone plates for multikeV x-rays. With a focusing efficiency exceeding 10% for 3-10 keV x-rays, Xradia's zone plate has an outermost zone width of 50-nm. This zone plate has a spatial resolution of 60-nm using its first order diffraction and 20-nm with a reduced efficiency using its third order diffraction. In principle, there is no fundamental limit to the resolution of a zone plate and the practical limitation is the fabrication of precise and accurate nanostructures with extreme high aspect ratio. While the challenge is substantial to develop zone plates with improving spatial resolution, the available resources are limited for research labs as well as companies like Xradia.

We will discuss some exciting possibilities of some synchrotron-based x-ray imaging techniques, including high spatial resolution sub-10 nm resolution and spectromicroscopy capable of chemical state mapping and elemental specific imaging at high spatial resolution. We will also present the development of zone plate lenses for coherent hard x-ray applications.

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