Optic lens developed for Hard X-ray Nanoprobe beamline achieves 11-nm focus

February 24 2014, by Mona S. Rowe

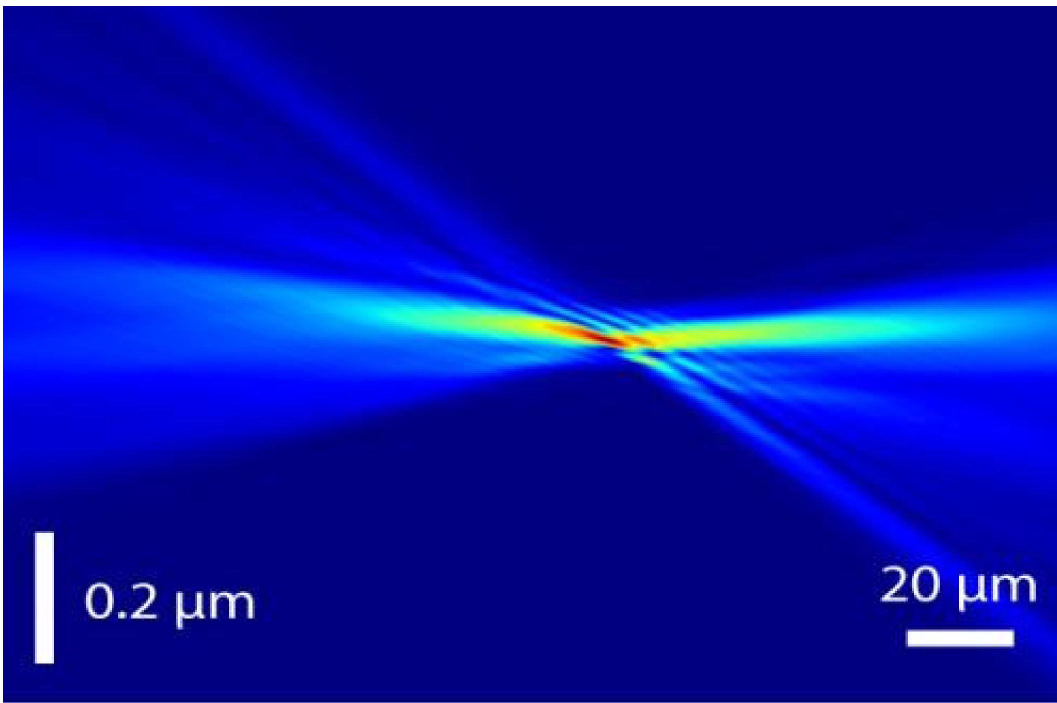

Image showing propagation of reconstructed wavefront, revealing the focusing performance of multilayer Laue lens developed for HXN Beamline at NSLS-II.

At the National Synchrotron Light Source II (NSLS-II), now under construction at Brookhaven National Laboratory, the Hard X-ray Nanoprobe beamline (HXN) will enable scientists to image structures at ever-smaller spatial scales. HXN's long-range goal is to achieve a resolution of 1 nanometer (nm), or a billionth of a meter, completely eliminating the long-standing resolution gap between x-ray and electron

microscopes. Hard x-rays exhibit excellent structural, elemental and chemical sensitivity and are particularly suited for in-situ studies that are challenging for electrons.

Brookhaven scientists, in collaboration with researchers from other institutions, have successfully focused 12 keV x-rays down to 11 nm using a novel x-ray optic called multilayer Laue lens (MLL). They published their results in Nature's *Scientific Reports*, December 2013.

The team was able to analyze their MLL's focusing performance to unprecedented details using a technique known as ptychography. "With ptychography, we can visualize how the x-rays are traveling from the lens to the focus and to an arbitrary point in the optical path. Therefore, we do not have to use conventional knife-edge scans to quantify lens aberrations," said Xiaojing Huang, the paper's first author. The ptychography analysis quantified the lens aberrations at a 0.3 wave period, very close to a quarter wave period. This represents a rigorous threshold value for "diffraction-limited" focusing.

The Brookhaven-fabricated MLL has a 43-micron aperture – the largest reported MLL size. It accepts substantially more x-rays than earlier MLLs and offers a significantly larger working distance, needed for in-situ experiments. It also contains an astonishing total of 6,510 layers, with thicknesses ranging from 4 to 21 nm.

Explained Nathalie Bouet, who is in charge of the MLL fabrication for NSLS-II, "The overall thickness accuracy for this MLL is insanely high – better than the size ratio of a penny to the height of the Empire State Building!"

"This is an important step toward our ultimate goal of achieving 1 nm," added coauthor Hanfei Yan.

Yong Chu, the paper's corresponding author and HXN group leader, stressed, "The HXN beamline is a highly complex instrument requiring expertise in many different areas. It is important to acknowledge the team effort by the committed collaborators at NSLS-II and at Argonne Lab's Advanced Photon Source." He also noted that the demonstrated MLL performance gives confidence to the team that HXN will deliver x-ray microscopy capabilities with an initial resolution of 10 nm, "encouraging news for the scientific community anticipating its completion."

More information: "11 nm hard X-ray focus from a large-aperture multilayer Laue lens." Xiaojing Huang, et al, *Scientific Reports* 3, Article number: 3562. DOI: 10.1038/srep03562

Provided by Brookhaven National Laboratory

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