A Path Towards Nanofocusing of X-rays: Multilayer Laue Lenses

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Research Thrust Area

The possibility of imaging at near-atomic resolution using short-wavelength x-rays has been a dream ever since the nature of x-rays was first understood nearly 100 years ago. Although hard x-rays can in principle be focused to spot sizes on the order of their wavelength (0.1 nm), this limit has never been approached because of the difficulty in fabricating the optics – indeed, it has not even been clear what type of optics will work.

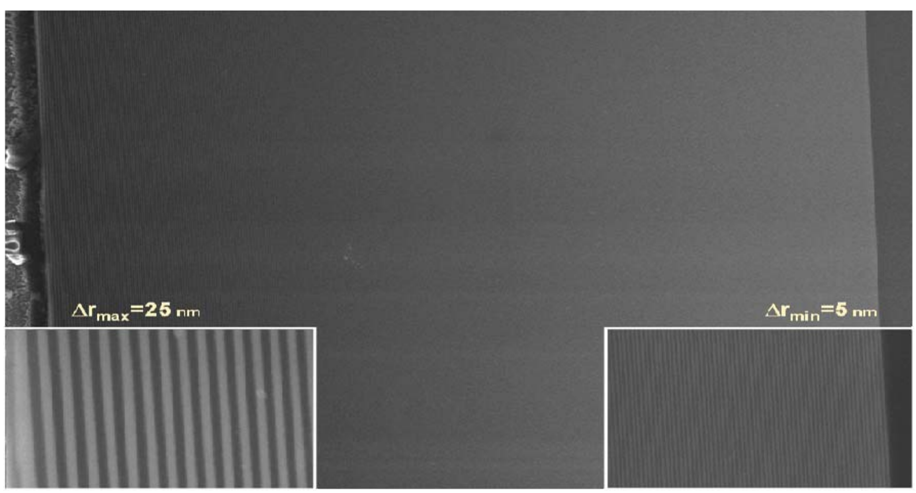

Fig. 1. Multilayer Laue Lens Structure. A total of 1588 layers have been deposited, with inner layer spacing of 25 nm and outer layer spacing of 5 nm. The structure has been thinned to a thickness of 16 μm, optimized for focusing x-rays with a photon energy of 20 keV

Research Achievement

Multilayer Laue Lenses[1] are diffractive x-ray optics with the capability to focus x-rays to focal spots of well below 10 nm. MLL's are fabricated by coating a flat substrate with alternating layers of nanometer thickness, with d-spacing varying to allow focusing of diffracted x-rays into a single spot. The approach allows deposition of the smallest layers first, thereby reducing the effect buildup of errors has on the focusing properties. Thin cross sections of the multilayer are made following deposition. Such an individual MLL section allows focusing of x-rays in transmission (Laue) diffraction geometry. Crossing two such linear zone plate sections will allow 2-dimensional focusing.

We have shown theoretically that a resolution of 5 nm should be achievable using the non-optimized geometry we are currently fabricating, and that approaching 1 nm with an optimized geometry is feasible. We have experimentally demonstrated a line focus with a width of 16 nm at photon energies of 20 keV and 30 keV[2], with diffraction efficiencies of 30% and above 15%, respectively.

Future Work

We have designed a MLL Microscope that is capable of two-dimensional focusing of x-rays. We will also design optimized MLL structures capable of focusing below 5 nm. We plan to demonstrate a two-dimensional x-ray focus using the existing structures, proceed to 2D focusing with optimized structures, and apply the hard x-ray nanobeams to problems in materials science and nanoscience.

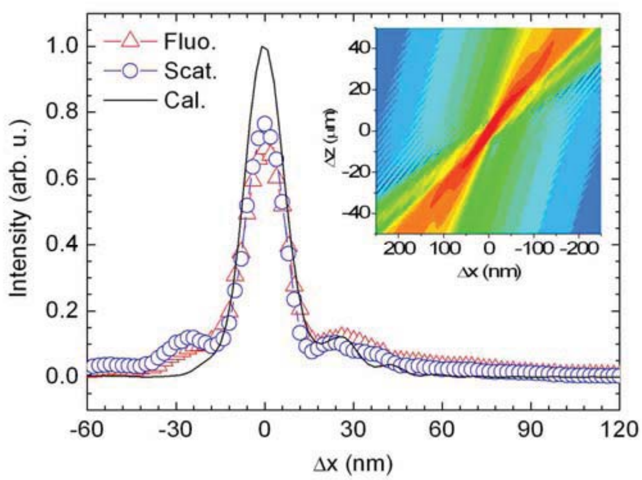

Fig. 2. Focusing of 20 keV X-rays. A line focus of 16 nm has been demonstrated.

Publications

[1] H.C. Kang, J. Maser, G.B. Stephenson, C. Liu, R. Conley, A.T. Macrander, S. Vogt, Phys. Rev. Lett. **96**, March, 127401-1-127401-4 (2006).

[2] Hyon Chol Kang, Hanfei Yan, Robert P. Winarski, Martin V. Holt, Jörg Maser, Chian Liu, Ray Conley, Stefan Vogt, Albert T. Macrander, G.Brian Stephenson, "Focusing of hard x-rays to 16 nanometers with a multilayer Laue lens," Appl. Phys. Lett. **92**, 221114-1-221114-3 (2008).