New record set for smallest X-ray nano-spot

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An award-winning device developed at the U.S. Department of Energy's Argonne National Laboratory has set a world's record for tiny spot size with a hard X-ray beam.

The device is called a Multilayer Laue Lens. The wafer from which the device was made won a 2005 R&D 100 award, given to the world's top 100 scientific and technological innovations. The enhancements to the device have now increased its ability to focus the X-rays with an energy level of 19.5 keV to 30 nanometers. For comparison, the period at the end of this sentence is approximately one million nanometers in diameter.

The lens – just like the lens of a camera – allows precise focusing of the X-ray light.Using the lens, researchers will be able to visualize three-dimensional electronic circuit boards to find circuit errors, or map impurities in biological or environmental samples at the nanometer scale. They can also analyze samples inside high-pressure or high-temperature cells, since hard X-rays, unlike soft X-rays, are able to penetrate container walls.

Other examples of uses of the new lens include development of smaller, better-performing and more reliable computers and telecommunications equipment; improving materials for energy efficient lighting, motors, fuel cells and solar energy production; production of lighter, sturdier, safer transportation vehicles through advanced materials with tailored properties; imaging cell division and tumor growth, providing a new mechanism for the early detection of cancer; and faster, more sensitive detection of hazards in local and global environments.

The researchers developed the record-setting lens by depositing 728 layers of material, one layer at a time, on a silicon substrate wafer. The thickness of the layer stack, when completed, was 12.4 microns. The wafer is then sectioned into bars that are used to make the lenses for the X-ray.

The work is published in the last edition of *Physical Review Letters*.

“The accomplishment here is two-fold,” said lead author Hyon Chol Kang. “The first is to grow that many layers without peeling, and, second, to cut and polish a bar without damaging the lens. We're continuing the development, and calculations for an idealized structure indicate that a focus of one nanometer is not prohibited by any known physics. The great challenge will be to grow the idealized structure.”

The optical design is akin to a linear Fresnel lens conventionally made by photolithography, but with the crucial difference that the diffraction structure is formed from many individually sputtered layers. High quality sputtered layers can be grown with thicknesses of 1 nm, and it is this control which makes the multilayer lens possible.

The new device is being used at the Advanced Photon Source at Argonne, which produces the most brilliant X-rays in the Western Hemisphere. It will also be particularly useful as the Center for Nanoscale Materials at Argonne becomes operational later this year.

Researchers Al Macrander, Chian Liu and Raymond Conley, all part of the Advanced Photon Source Experimental Facilities Division optics fabrication and metrology group, developed the lens wafers which won the 2005 R&D 100 award. They are joined by Stefan Vogt, also of the Experimental Facilities Division; Kang and Brian Stephenson of the

Materials Science Division at Argonne, and Jorg Maser of the Accelerator Systems Division at Argonne. The work is especially meaningful for Maser, who predicted the theoretical ability of an X-ray lens to focus at this small size in his doctoral dissertation in 1994.

Source: Argonne National Laboratory