

New lensless imaging technique opens door to nanoscale world

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Researchers at the Stanford Synchrotron Radiation Laboratory (SSRL) and the German laboratory Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung (BESSY) have crafted a technique to take X-ray images that reveal tiny variations and lightning-quick changes in materials a thousand times smaller than the thickness of a strand of hair. Their work merited the cover of the Dec. 16 issue of *Nature*. The technique - lensless X-ray holography - will be valuable for researchers working with the world's first X-ray [free electron laser](#), the Linac Coherent Light Source (LCLS), slated to begin experiments in 2009 at the Stanford Linear Accelerator Center (SLAC).

"We have demonstrated the first direct imaging technique that will work with LCLS, opening the door for taking pictures of ultra-fast changes in the collective behavior of ensembles of atoms and molecules," said SSRL physicist Jan Luning. He and BESSY colleague Stefan Eisebitt headed development of the technique.

"Our approach is simple and it can be applied to a wide variety of samples from thin films to small structures coming from material science, biology or chemistry," Luning said.

State-of-the-art light sources such as BESSY and SPEAR3 at SLAC achieve lensless imaging by filtering light so that the only remaining X-rays are "coherent"—that is, all the X-ray light waves are in phase with each other (each wave is peaking at the same time) and moving in the same direction like a marching band in step. Because it uses no lenses,

the technique has the potential to take direct images with 10 times better spatial resolution than can be achieved with current X-ray lenses and bring even finer details into view. Another advantage to the technique is it entails much simpler alignment and sample handling than do established X-ray microscopy methods.

Lensless imaging will be especially powerful at LCLS and other future X-ray free electron lasers being planned in Germany and other countries. X-ray free electron lasers will be 10 billion times brighter than today's brightest synchrotron sources. And because laser light is inherently coherent, X-ray filtering is unnecessary. In addition, LCLS X-ray pulses will be extremely short—lasting only femtoseconds, mere quadrillionths of a second.

This impressive combination of properties not only makes LCLS a revolutionary machine, it makes lensless imaging ideally suited for obtaining "single shot" images of rapid, intricate changes in nanometer-sized materials. Just one pulse of X-ray light, rather than billions of pulses, will be needed to capture a clear picture of the action at that moment in time.

Scientists could take a series of such images to create a "movie" of the changes, analogous to time-lapse photography for slow processes like a flower coming into bloom. This confers a brand new capability to study the nonrepeatable aspects of biological, physical and chemical processes occurring on dizzyingly fast time scales. A few areas of investigation include proteins attaching to each other step by step and polymer chains assembling into ordered clusters.

Holography is the key

The technique works by shining a coherent beam of X-ray light through two adjacent holes: one containing the sample to be studied, the other a

tiny "reference" hole. The scattered light from both holes overlays to form a single, holographic diffraction pattern. Holography not only maps the intensities of the light, as do normal diffraction patterns, it also encodes information about the phases of the light that is otherwise intrinsically lost.

"Without the phases, it's like trying to predict what happens next on a highway if you know where the cars are but not their speed," explained Luening. "You simply lack half of the important information. Holography elegantly encodes this other half in the measured intensities."

The information is decoded by applying a standard mathematical procedure known as Fourier transformation, yielding a complete image of the sample.

The demonstration experiment took place at BESSY in February 2004. The obtained image revealed the randomly organized "north" and "south" magnetic regions of a cobalt-platinum film to a spatial resolution of 50 nanometers (50 billionths of a meter).

Source: Stanford University

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