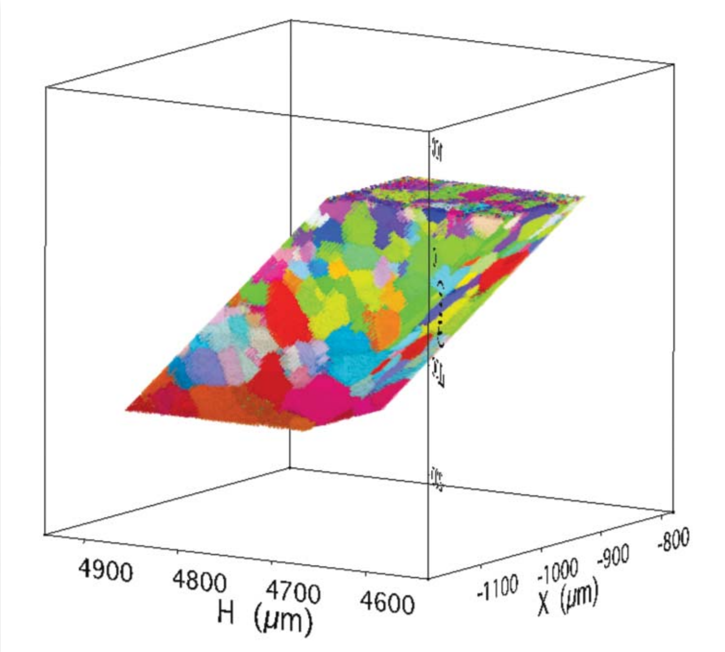
The Advanced Photon Source

High-Speed Microdiffraction at Beamline 34-ID-E

The microdiffraction station on X-ray Science Division beamline 34-ID-E at the Argonne National Laboratory Advanced Photon Source (APS) has been a world leader in utilizing sub-micron-sized x-ray beams for a wide range of diffraction problems in materials science and condensed matter physics since it was first built in 2001. With its small white (or monochromatic) beam size of only a few hundred nanometers and the ability to depth-resolve the scattering along an x-ray beam, it provides the ability to measure strain or orientation of all the volume elements in a three-dimensional (3-D) solid. This capability has been used as a source for probing the strain in deformed metals, the deformation around a nano-indent, structures in a diamond anvil cell, the strain at the base of a tin whisker, and identification of embedded phases, as well as the strain and orientation from many other small structures.



Orientations in a 3-D volume of aluminum. Each color represents a different orientation; the grains show themselves as volumes of constant color. The top is the only external surface, the height of the visible volume is 212 μm, and the base of the volume is 135 x 186 μm. The average rms orientation error for all of the measured points is than 0.01°. Image courtesy of John Budai, Oak Ridge National Laboratory.

Many of these studies require a 3-D volumetric measurement, which means scanning three spatial dimensions; this is inherently time consuming. So the utility of this technique has always been limited by the rate at which measurements could be made. With the acquisition of fast area detectors, the time for acquiring a single image dropped from 8 s to 0.1 s. This has made it practical to measure the scattering from volumes containing the order of half-a-million points.

Once the detector speed increased, it then became necessary to speed up all of the other parts of the data collection and processing. The first step was to change from a step-scan mode to a fly-scan mode where images are continuously acquired while the depth-resolving wire is scanned repeatedly over the same ~500-μm range. This removed all of the time lost stopping and starting the scanning motor for each image. The second step was to increase the data transfer rate and storage capacity. Operating at 10 images per second requires storing 80 MB/s continuously. For a one-day measurement this adds up to 6 TB of data. And the third step was to improve the analysis; if one is collecting terabytes of data per day, then one must be able to analyze terabytes of data per day. This required providing the data files with all of the information needed to process the data, the programs capable of processing the data, and a cluster capable of running everything.

One recent measurement of grain growth in an aluminum alloy is pictured in the figure, showing the result from a single annealing step. The data for this volume came from 7 TB of images collected in two days; this represents a 15-fold increase in data size and speed over non-fly scanning. Before this upgrade, measuring a volume of this size would have required one month of continuous measuring.

This advance was the result of a close collaboration between the APS and the Materials Science and Technology Division at Oak Ridge National Laboratory.

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Call for APS General-User Proposals

The Advanced Photon Source is open to experimenters who can benefit from the facility's high-brightness hard x-ray beams.

General-user proposals for beam time during Run 2014-1 are due by Friday, November 1, 2013.

Information on access to beam time at the APS is at http://www.aps.anl.gov/Users/apply_for_beamtime.html or contact Dr. Dennis Mills, DMM@aps.anl.gov, 630/252-5680.

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