The Advanced Photon Source

High-Speed and High-Resolution X-ray Imaging with the Velociprobe

Researchers from Argonne developed a new device for quickly acquiring high-resolution x-ray images over large sample areas. Dubbed the “Velociprobe” and installed at the APS, the new instrument is designed specifically for x-ray ptychography.

X-ray ptychography involves shining a coherent x-ray beam at many closely-spaced points on a sample, producing a collection of x-ray diffraction patterns. Computer algorithms then reconstruct the sample image from the recorded patterns.

Although the principles behind x-ray ptychography are well understood, scientists have invariably encountered difficulties when building practical instruments incorporating the technique. Even slight vibrations or thermal fluctuations can introduce errors in positioning the x-ray beam, which blurs the image. Another limitation involves how the x-ray beam is moved, or scanned, over the sample. X-ray ptychography instruments have traditionally used the step scan approach where one diffraction pattern is recorded and then the x-ray beam (or the sample itself) is moved a tiny amount.

The Velociprobe was engineered to address many of these limitations while also taking full advantage of the dramatically higher x-ray flux anticipated from the APS Upgrade. The basic design philosophy was to improve upon each aspect of earlier ptychographic instruments in order to achieve faster imaging at higher resolutions. The left side of Fig. 1 depicts the Velociprobe. Both the sample and the optics used to focus the x-ray beam are mounted near the top of the device. The incoming x-ray beam is indicated by the line of arrows.

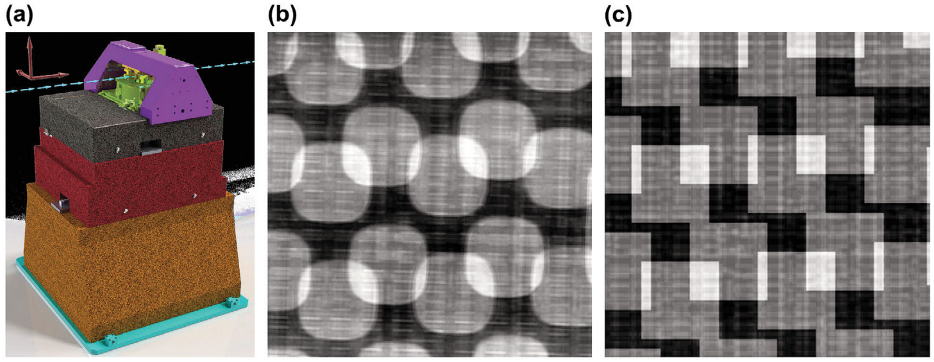

Fig. 1. Panel (a) highlights major components of the Velociprobe, which rests on a steel plate (cyan-colored component at bottom). Middle sections consist of precisely-shaped granite blocks that move relative to one another on a cushion of air. When air is removed, the blocks meet and form a highly stable platform. A gantry atop the Velociprobe holds its optical components and the sample. Cyan arrows indicate the x-ray path. Panel (b) is a high-resolution micrograph of an integrated circuit imaged by the Velociprobe in 1.2 sec. Individual square-shaped features are 720 nm across. Panel (c) simulates the expected features based on engineering diagrams.

In place of the intermittent step scan procedure, a fly-scan approach was adopted to continuously create diffraction patterns by directing the x-ray beam to follow a spiral or other pattern across the sample. Such continuous-scanning methods greatly reduce overall imaging time.

The Velociprobe demonstrated its imaging capabilities in a series of tests. Using the advanced fly-scan approach at the XSD 2-ID-D beamline at the APS, the Velociprobe produced a series of two-dimensional images from various samples. A gold test pattern was imaged at a spatial resolution of just under 9 nm. A fast scan was also used to quickly image an integrated circuit, as shown in Fig. 1 (middle panel). The entire scan required only 1.2 sec.

Further development of the Velociprobe is under way. While the images produced in this study were two-dimensional, an upgrade will permit high-resolution three-dimensional imaging.

— Philip Koth

See: Junjing Deng, et al.,, “The Velociprobe: an ultrafast X-ray nanoprobe for high-resolution ptychographic imaging,” Rev. Sci. Instrum. **90**, 083701 (2019). DOI: 10.1063/1.5103173

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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 2020-2 are due by Friday, February 28, 2020.

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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Advanced Photon Source
Bldg. 401/Rm A4113
Argonne National Laboratory
9700 S. Cass Ave.
Argonne, IL 60439 USA
aps.anl.gov
apsinfo@aps.anl.gov

U.S. Department of Energy Office of Science
science.energy.gov/

Argonne National Laboratory
anl.gov