

SRN Article from the workshop:
“Advanced X-Ray Optics Metrology for Nano-focusing and Coherence Preservation”
Kenneth Goldberg and Valeriy Yashchuk, *Lawrence Berkeley National Laboratory*

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What is the point of developing new high-brightness light sources if beamline optics won't be available to realize the goals of nano-focusing and coherence preservation? That was one of the central questions raised during a workshop at the 2007 Advanced Light Source Users' Meeting. Titled, “Advanced X-Ray Optics Metrology for Nano-focusing and Coherence Preservation,” the workshop was organized by **Kenneth Goldberg** and **Valeriy Yashchuk** (both of Lawrence Berkeley National Laboratory, LBNL), and it brought together industry representatives and researchers from Japan, Europe, and the US to discuss the state of the art and to outline the optics requirements of new light sources. Many of the presentations are viewable on the workshop website <http://goldberg.lbl.gov/MetrologyWorkshop07/>.

Many speakers shared the same view of one of the most significant challenges facing the development of new high-brightness third and fourth generation x-ray, soft x-ray, and EUV light sources: these sources place extremely high demands on the surface quality of beamline optics. In many cases, the 1–2-nm surface error specs that define the outer bounds of “diffraction-limited” quality are beyond the reach of leading facilities and optics vendors. To focus light to 50-nm focal spots, or smaller, from reflective optics and to preserve the high coherent flux that new sources make possible, the optical surface quality and alignment tolerances must be measured in nano-meters and nano-radians. Without a significant, well-supported research effort, including the development of new metrology techniques for use both on and off the beamline, these goals will likely not be met. The scant attention this issue has garnered is evident in the stretched budgets and limited manpower currently dedicated to metrology. With many of the world's leading groups represented at the workshop, it became clear that Japan and Europe are several steps ahead of the US in this critical area.

But the situation isn't all dire: several leading groups are blazing a trail forward, and the recognition of this issue is increasing. The workshop featured eleven invited talks whose presenters came from Japan, Europe, and the US.

Showing how to build support for this research, **Howard Padmore** (LBNL) presented a strategy based on recent successful efforts to establish a new program in advanced detectors within the US Department of Energy (DOE).

The gap between the current state of the art and new beamline optics requirements was one of the main issues raised by **Peter Takacs** (BNL). Along with several other speakers, Takacs showed that for x-ray wavelengths, a mirror figure error of 0.5-nm RMS decreases the Strehl ratio noticeably, a 1.0-nm error reduces it to half, and a 2.0-nm error can destroy focusing entirely. Takacs then placed this field in context with a very interesting historical overview, going back to the seminal work of Mori in Japan (1965),

through the EUV Lithography programs of the 80s and 90s, to the current efforts in Japan and Europe.

SLAC's **John Arthur** contributed a review of the generation mechanisms of synchrotron and free-electron laser light, and explained design aspects of Stanford's LCLS.

Kazuto Yamauchi (Osaka University) described his team's world-leading efforts in hard x-ray nano-focusing. They have demonstrated excellent correspondence between externally measured surface figure errors and x-ray focusing performance using a lateral and longitudinal scanning slit and a phase-retrieval algorithm.

Several speakers also addressed advanced instrumentation, and scientific motivations behind the drive toward high coherence and nano-focusing.

Frank Siewert (BESSY) described what it has taken to achieve 0.05 μrad accuracy in his group's state of the art Nanometer Optic component measuring Machine (NOM), recently used in cross-correlation experiments with numerous other slope measuring instruments worldwide and in collaborative work on the Nanometer Optics Components program in Europe.

Applications of visible-light Shack-Hartmann wavefront sensing to two-dimensional LTP measurements both on and off the beamline were shown by **François Polack** (SOLEIL). Polack also described the MARX project at SOLEIL which is creating active mirror elements and at-wavelength testing for micro and nano-focusing.

Tetsuya Ishikawa (SPring-8) described the development of advanced optical systems for synchrotron and free-electron lasers including a Hambury-Brown Twiss interferometer for coherence measurements. He also showed the importance of using beryllium windows of exceptional quality to avoid coherent speckle artifacts downstream.

Ali Khounsary (APS) showed advanced mirror polishing and K-B bending that allowed his group to achieve 100-nm focusing. He reminded the audience that reaching 0.1–0.2 μrad surface quality requires measurement accuracy levels that are higher still. Khounsary revealed plans for a hard x-ray Laue lens geometry that may reach 16-nm focal spot size.

The instrumentation requirements for several Fermi @ Elettra FEL endstations were discussed by **Daniele Cocco** (ELETTRA). In order to meet the stringent mirror shape requirements of these microscopy and scattering beamlines, his group is developing active K-B mirrors with multiple piezoelectric actuators to control the mid and low spatial frequency figure.

Yi-De Chuang (LBNL) described many applications in the science of complex materials that can be greatly advanced with 1 meV energy resolution and tightly focused beams. High-temperature superconductivity, colossal magnetoresistance, gigantic thermal power, and anomalous magneto-optical properties are just a few of the topics that will be studied by the new *MERLIN* beamline under development at the ALS.

Finally, **Regina Soufli** (LLNL) described optical requirements for both hard and soft x-ray mirrors in the LCLS, where power levels will be orders of orders of magnitude higher than third-generation synchrotron sources. Consequently the melting temperatures of the coating materials must be carefully considered. Coupled with the reflectivity requirements, four candidate coating materials have emerged: Si, SiC, B₄C, and Be. Soufli showed the results of extensive surface characterization of vendor sample mirrors, with two vendors now having the potential to meet the LCLS specs.

A lively discussion lead by **Goldberg** and **Yashchuk** continued long after the formal talks. What was clear to all is that despite the unavoidable fact that sub-2.0-nm RMS quality is required for these new sources to reach their design potential, there is no substantive plan within the US to create or support the development of these mirrors. Without improved LTP accuracy and a state of the art at-wavelength on-beamline testing capability, the creation of these mirrors, as Takacs wryly noted, is an issue being left to *magic*. With or without supernatural intervention, *InSync*'s **Jim Metz** notably offered to fabricate optics to any of the specifications that were discussed, *provided that metrology becomes available*. This begs a twist on the old adage (attributed to LLNL's Norm Brown): "If you can't measure it, I can make it."

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