October 1, 2018

Optics Group Strategy Document

Introduction

Achieving the mission of the APS requires high-quality x-ray optics (such as monochromators, mirrors, and focusing optics) to deliver x-ray beams to the samples and, in many cases (such as crystal analyzers), to collect the relevant signal from the experiments. Both the APS-U Feature beamlines and the existing APS beamlines will require a new generation of x-ray optics that will take advantage of the 100-fold increase in brightness, smaller source size, and increased coherence enabled by APS-U. This document describes the strategy of the APS Optics Group (OPT) to deliver state-of-the-art optics and integrated solutions, in synergy with the other X-ray Science Technologies (XST) support groups, to further the missions of the X-ray Science Division (XSD) and the APS.

Mission

The core mission of OPT is to develop and deliver innovative x-ray optics and optical systems and to provide related services to further the APS mission of enabling cutting-edge scientific research. In support of this mission, OPT

- Designs, fabricates, and characterizes x-ray optical elements, such as crystal monochromators and analyzers, single- and multi-layer optics, and nanofocusing optics;
- Operates and develops optics fabrication and characterization laboratories and instruments, including the crystal optics fabrication laboratory, the deposition laboratory, the optical metrology laboratory, and the 1-BM Optics Testing Beamline; and
- Conducts R&D to develop future-generation optical components as well as beamline optics and wavefront modeling and characterization tools.

XSD/XST/OPT Organization

Established in the mid-1990s after the commissioning of the APS, OPT has evolved to comprise the following main sections: 1) Crystal Optics; 2) Mirrors and Multilayer Optics and Metrology; 3) Beamline 1-BM for Optics and Detector Testing; and 4) Beamline Optics Simulation and Optimization.

Vision

The OPT's vision for the next 5 years and beyond is to be the world-leading expert and knowledge base on wavefront-preserving and nanofocusing x-ray optics R&D, with world-class capabilities, and to continue enabling research in a broad range of high-impact science and technology programs.

Strategy

The OPT performs R&D, design, fabrication, and delivery of cutting-edge optics and related services that are targeted to further the missions of XSD and the APS, and to support the APS-U. These activities are conducted in synergy with other XST support groups and in line with XST and XSD priorities. The OPT overall strategy is to focus its activities on the following two key areas:

- **High-performance nano-focusing optics** for current and future APS needs and

- **Wavefront-preserving optics**, including novel crystal optics, mirrors, and adaptive optics.

In developing these capabilities, the OPT group members will: 1) develop novel optics tools and techniques, including design, fabrication, optical and at-wavelength characterization, and simulation; 2) perform R&D, design, fabricate, and test optics either independently or in collaboration with beamline scientists or others as appropriate; and 3) collaborate with the XST staff and APS beamline scientists and resident users to ensure successful beamline optics implementation and integration.

Five-year Goals

The five-year goals in the above areas is as follows:

- Develop wavefront-preserving crystal and mirror optics, including related modeling/simulation tools and metrology.
- Develop focusing optics, such as zone plates and multilayer mirrors, with a stretch goal of 5 nm for the APS future Ptychoprobe.

Goals and Action Plan for FY 2019

Focusing Optics

- Develop a Diffractive Focusing Optics 5-year Strategy and Plan document (Q3-FY2019).
- Complete the Nanofocusing Optics project (i.e., stacked zone plates) for the APS-U Project by Q3-FY2019.

Thin-film Optics

- Optimize the MDS velocity profiling capability for laterally-graded multilayers. Produce high-quality multilayers requested by several beamlines (Q4-FY 2019).
- Test components and instrumentation for MDS *in situ* metrology (Q4-FY2019)

Wavefront-preserving Mirrors and *in situ* Wavefront Sensors

- Continue R&D on non-invasive wavefront sensors.

Zoom Optics (LDRD Project)

- Test 1-D mirror zoom optics, including *in situ* surface metrology and integrated feed-back control (Q4-2019).

Crystal Optics

- Upgrade the automated channel-cut polishing machine to 400 mm stage, to accommodate polishing of longer channel-cut crystals (Q4-FY2019).
- Develop a plan to upgrade the Topo Unit as an alternative tool to perform topography and high-resolution orienting of crystals and tuning of monochromators (Q4-2019).

Beamline Optics Simulation and Optimization

- Optimize the design of all APS-U Feature beamlines for CD2 (Q1-FY2019).
- Finalize the optics specification for all feature beamlines and for the beamlines selected for enhancements (Q2-FY2019).

- Continue to develop and maintain beamline optics design and simulation codes.

Optics Metrology

- Upgrade the APS Long Trace Profiler to <50 nrad resolution (Q4-FY2019).
- Conduct R&D to perform measurements with LTP of flatness and parallelism of inside surfaces of polished channel-cut crystals (Q4-FY2019).
- Begin implementing the Modular Deposition System in situ metrology.

1-BM Beamline

- Demonstrate a measurement for sub-100 nm focal spot (Q3-FY2019).
- Improve the stability of the beamline double crystal monochromator (Q4-FY2019).

Strengths Weaknesses, Opportunities, and Threats (SWOT) Analysis.

Strengths	Weaknesses
• Fast response to beamline optics needs and support requests. • Cost-effective and quick delivery of one-of-a- kind optical elements to APS beamlines and users. • Strong and versatile team with a wide range of expertise (unmatched in the U.S.) in optics fabrication, characterization, and theory. • Access to wide-ranging capabilities within the ANL complex.	• Obsolete crystal optics fabrication and characterization equipment limit performance and reduce productivity. • Dispersed and disjointed crystal fabrication labs hamper efficiency and impede workflow. • Lack of Central Shops equipment and expertise for advanced crystal machining results in lower productivity and efficiency and increased cost. • Reliance on matrix support system for critical activities leads to lack of project ownership, lack of continuity, and decreased success rate.
Opportunities	**Threats**
• Develop new generation x-ray optics and related expertise and tools. • Strengthen synergies with other XST groups and with beamline scientists in developing and implementing complex optical systems. • Increase scientific and publication output. • Become a world leader in nanofocusing and wavefront-preserving x-ray optics.	• Potential for shrinking budgets could impede progress and diminish quality of scientific output. • Reduced investments in staff could compromise readiness for next shift in x-ray optics technology and could prevent adequate support to APS-U Feature beamlines and APS beamline enhancements. • Moving to a “cost recovery” operating model will significantly diminish much-needed R&D. • Lack of reliable source of large-size, defect-free crystal materials, including diamond, quartz, sapphire, and SiC, could impede progress.