

THE ADVANCED PHOTON SOURCE

A HARD X-RAY NON-INVASIVE WAVEFRONT SENSOR

Diffraction-limited storage rings deliver beam brightness and coherence orders of magnitude higher than existing third-generation synchrotron sources. These new characteristics will enable the exploration of new frontiers in science, especially with coherence-related techniques.

Critical to the advance of coherent x-ray scattering, imaging and microscopy is the ability to efficiently monitor, control and manipulate the beam wavefront to preserve the source property and to deliver the maximum coherent flux to the sample. Achieving these goals requires advanced optics and diagnostic tools, including wavefront sensors that, ideally, are non-invasive, and are possibly coupled with adaptive optics to compensate for optics imperfections such as thermo-mechanical distortions, fabrication errors, and misalignment.

Development of *in situ* wavefront sensors has become a hot topic, actively pursued by synchrotron and free-electron laser facilities worldwide. The first attempts to develop adaptive mirrors for synchrotron radiation were carried out more than two decades ago using optical sensors. While these schemes provide vital information about the mirror surface, they provide no information about the transmitted x-ray beam wavefront. As new sources with high coherent flux are becoming available, many at-wavelength metrology concepts in the hard x-ray regime have been explored.

One promising approach for wavefront sensing that has been developed by researchers from five laboratories could operate in a non-invasive or nearly non-invasive fashion.

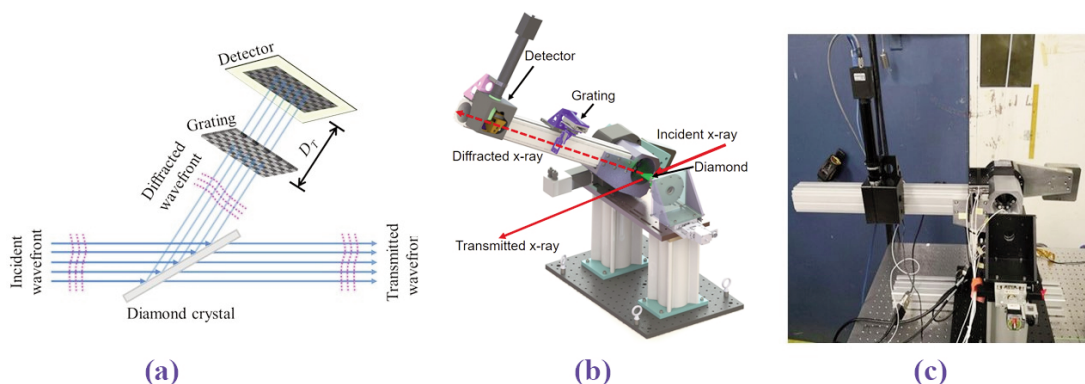


Fig. 1: (a) Concept of a hard x-ray wavefront sensor using a single-grating interferometer and a diamond-crystal beam splitter. (b) 3-D drawing of the prototype assembly. (c) A photo of the prototype assembly under test at the APS beamline 1-BM.

The concept consists (Fig. 1a&b) of a 2-D, single-shot, Talbot grating interferometer combined with a thin ($\sim 100\text{-}\mu\text{m}$ -thick) diamond single-crystal beam splitter set into the 111 Bragg diffraction. A prototype built to test the feasibility of such a sensor is shown in Fig. 1(c) [1]. The diamond crystal is mounted on a high-precision miniature goniometer and is inserted to diffract a fraction of the incident beam to a wavefront sensor mounted in the Bragg configuration.

The challenge is to ensure that the diamond crystal beam splitter transmits the experiment beam with minimal distortion, while the diffracted beam carries the signal. Tests carried out at the APS 1-BM beamline showed that the degradation in spatial coherence of the transmitted wavefront is less than 5% [2], while the relative phase error introduced by the crystal is very small, about $1/55$ th of the wavelength (1.55 \AA) at 8 keV, thus demonstrating that the proposed scheme could become a viable method to measure and monitor the beam wavefront while the experiment is ongoing, and possibly use the measured wavefront to generate a feedback signal to control or optimize the shape of an adaptive optical element.

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References

- [1] Kearney, S. P., et al., in Proceedings of the MEDSI 2018 Conference, 394–396 (2018). doi.org/10.18429/JACoW-MEDSI2018-THPH27
- [2] Grizolli, W., et al., Proc. SPIE, 10385 (2017). doi.org/10.1117/12.2274023

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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 2019-2 are due by Friday, March 1, 2019.

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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