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Development of adaptive X-ray microscopy based on ultraprecise deformable mirrors

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Hard X-ray microscopy is very promising for nondestructive and high-spatial-resolution observation of the internal structure of a sample. However, the spatial resolution of microscopes remains unsatisfactory owing to the fabrication error in the objective lens. This problem is becoming more serious, especially as the spatial resolution decreases.

To overcome the problem and achieve ultrahigh resolution, we proposed and developed a monolithic deformable mirror based on a lithium niobite single crystal (LNDM) and a novel adaptive imaging system based on LNDM, which enables high-precision, high-stability, and high-spatial-frequency-controlled deformation (Fig. 1) [1]. Unlike lead zirconate titanate (PZT), which is often used for deformable mirrors, the surface of the single-crystal piezoelectric material can be atomically smoothed by superpolishing; thus, it can function as an actuator and a reflective surface for X-rays. This enables a simple structure consisting only of an LN substrate and electrodes, which would contribute to improving deformation accuracy. In addition, because single-crystal LN is a single-domain piezoelectric material, it can be expected to deform with high precision without hysteresis or drift.

A prototype LNDM was designed and fabricated. An X-ray interferometer confirmed that wavefront compensation using the LNDM could be performed with a shape accuracy of 0.67 nm under high stability (0.17 nm over 7 h) and hysteresis-free deformation control (Fig. 1 right). An adaptive X-ray microscope based on advanced Kirkpatrick-Baez mirror optics including the LNDM demonstrated that the wavefront aberration caused by mirror fabrication error was successfully corrected, resulting in an improvement in X-ray image quality (Fig. 2) [1].

[1] T. Inoue and S. Matsuyama et al., Monolithic deformable mirror based on lithium niobate single crystal for high-resolution X-ray adaptive microscopy, Optica, accepted.

Fig. 1 Developed monolithic deformable mirror (left) and result of shape correction (right).

Fig. 2 X-ray images obtained using the adaptive X-ray microscope before and after the shape correction.

I plan to submit also conference proceedings

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