【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Engineering)

Title of Project : Development of zoom condenser system for X-ray free electron laser by high precision deformable reflective optics

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Research Project Number : 16H06358 Researcher Number : 10174575
Research Area : Mechanical engineering
Keyword : Precision machining, Shape metrology, X-ray optics

【Purpose and Background of the Research】

X-ray focusing optics is highly demanded both in 3rd-generation synchrotron radiation (SR) sources and X-ray free-electron lasers. We are studying X-ray mirror devices based on precision metrology and fabrication process developments, and have established nanofocusing optics for cutting-edge SR beamlines. In these optical systems, an advanced function to adaptively change the beam size enables multiple analysis in X-ray microscopy.

In this research, we aim to realize a zoom condenser system consisting of two-stage Kirkpatrick-Baez (KB) mirrors with four precision deformable mirrors, which can work under diffraction-limited condition. In addition we are planning to provide adaptive focusing optical system with single stage KB mirrors to a SPring-8 beamline within 3 years to clarify the future problems as a milestone.

【Research Methods】

We try to realize mirror fabrication process to satisfy the Rayleigh's criterion, in which optical path difference due to the shape error of the mirror is smaller than λ/4 (λ: employed X-ray wavelength). For the adaptive shape control, we employ piezoelectric actuators with appropriate drift reduction method. In parallel, we develop an at-wavelength wavefront determination method to perform in-situ wavefront correction to maintain the diffraction-limited performance at any beam size.

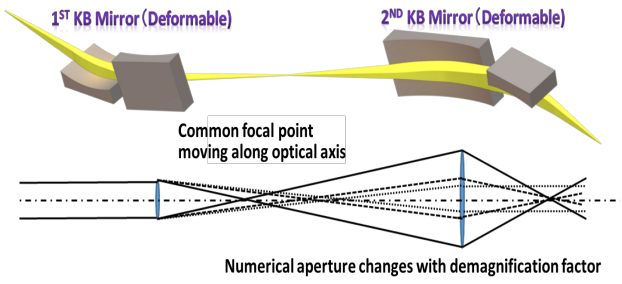

Fig. 1 Schematic drawing of zoom condenser system consisting of two-stage KB mirrors.

【Expected Research Achievements and Scientific Significance】

In coherent diffraction imaging which is one of the most important XFEL applications, the sizes of specimen and beam have significant relationship; beam size has to be nearly the same as the specimen size to maximize the photon density on it. So far, the specimen is selected mainly from the available beam size not from the scientific demand. The zoom condenser system can provide appropriate beam-size and can enhance the capability of XFEL.

Of course, the mirror figuring method plays significant roles for high precision manufacturing.

【Publications Relevant to the Project】

[1] S. Matsuyama, H. Nakamori, T. Goto, T. Kimura, K. P. Khakurel, Y. Kohmura, Y. Sano, M. Yabashi, T. Ishikawa, Y. Nishino K. Yamauchi, Nearly diffraction-limited X-ray focusing with variable-numerical-aperture focusing optical system based on four deformable mirrors, Scientific Reports 6, 24801 (2016)
[2] K. Yamauchi, M. Yabashi, H. Ohashi, T. Koyama, and T. Ishikawa, Nanofocusing of X-ray free-electron lasers by grazing-incidence reflective optics. Journal of Synchrotron Radiation, 22 (2015) 592-598
[3] H. Mimura, H. Yumoto, S. Matsuyama, T. Koyama, K. Tono, Y. Inubushi, T. Togashi, T. Sato, J. Kim, R. Fukui, Y. Sano, M. Yabashi, H. Ohashi, T. Ishikawa, and K. Yamauchi, Generation of 1020 W/cm2 Hard X-ray Laser Pulses with Two-Stage Reflective Focusing System, Nature Communications, 5 (2014) 3539

【Term of Project】 FY2016-2020

【Budget Allocation】 141,800 Thousand Yen

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