High-fluence x-ray focusing optics for high-resolution coherent diffractive imaging using X-ray free electron laser

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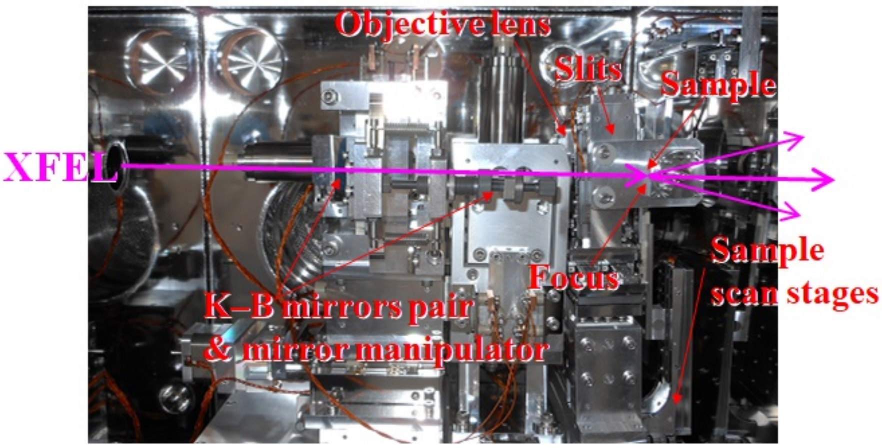
One of the key applications of using X-ray free electron laser (XFEL) is single-shot coherent diffractive imaging (CDI) of non-crystalline objects based on the "diffraction-before-destruction" scheme. Although a spatial resolution has been currently limited to ∼10 nm for biological particles, one can improve the resolution by increasing the fluence of XFEL to the samples.

In this presentation, we report our development on a high-resolution CDI system using a state-of-the-art X-ray focusing optics in the Kirkpatrick-Baez geometry. We fabricated multilayer mirrors operating at a photon energy of 4 keV with a substrate length of 80 mm, an incident angle of 25 mrad, and short focal lengths of 190 mm and 100 mm. This optical design with parameters of the SACLA light source leads to an extremely high fluence of 10^6 J/cm^2 (i.e. a peak power of 10^{20} W/cm^2) and a tight focus of 60 nm $\times$ 114 nm (full width at half maximum (FWHM)), while keeping a large spatial acceptance of more than 1 mm. We successfully suppressed figure errors of the mirror surfaces less than 1 nm (root-mean-square) by developing a special manufacturing process for the highly-curved surface. The CDI system consists of focusing mirrors, two sets of 4-blades slits, objective lens, and sample scan stages, as shown in the figure. An X-ray area detector is closely located to the sample with a distance of 320 mm, which can cover a high-spatial frequency corresponding to a nominal spatial resolution of 2 nm. We evaluated focusing performances of the mirrors at BL2 of SACLA, and achieved a focused beam size of around 100 nm (FWHM) at almost the same size as the designed value. We report the first result of the pilot experiment of single-shot CDI with achievement of single-nanometer resolutions.



High-resolution CDI system with tight-focusing mirrors