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Supporting information for article:

**Generation of an X-ray nanobeam of a free-electron laser using
reflective optics with speckle interferometry**

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Here, we explain the horizontal beam size. The final optimization of the KB mirror alignment was performed, and the maximized speckle patterns could be obtained, presenting practically perfect adjustments. However, while optimizing the various alignments of the KB mirror, the speckle size in the horizontal direction appeared to become slightly smaller than the achieved maximum size, owing to a slight temperature change around the mirrors. Figure 7(b) is the finally obtained speckle pattern after all the alignment adjustments based on the speckle shape.

Figure 1S (a) displays a typical speckle pattern obtained immediately after the horizontal incident angle adjustment, in which maximum speckles in the horizontal direction were recorded. The horizontal cross-section profiles of the autocorrelation function were compared to that of the speckles calculated based on the wavefront aberration measured simultaneously using a grating interferometer (see (b)). This graph reveals that the experimental and calculated profiles are in good agreement. In addition, the horizontal speckle size is approximately 2.5 times smaller than the vertical one, as depicted in Fig. 7. This is because the horizontal focusing system has a wavefront aberration of 0.893 rad in rms, whereas the vertical one has a wavefront aberration of 0.45 rad in rms. The guessed FWHM of the focused beam is 5.9 ± 1.4 nm in the horizontal direction.

Concurrently, Fig. 7(b) depicts a typical speckle pattern obtained immediately after the vertical incident angle adjustment and the astigmatism adjustment, in which maximum speckles in the vertical direction were recorded. For comparison, Figs. 1S(c) and (d) are presented, showing the horizontal autocorrelation functions before the adjustment (the identical state to Fig 7(c)) and those immediately after adjusting the astigmatism (an identical state to Fig. 7(d)).

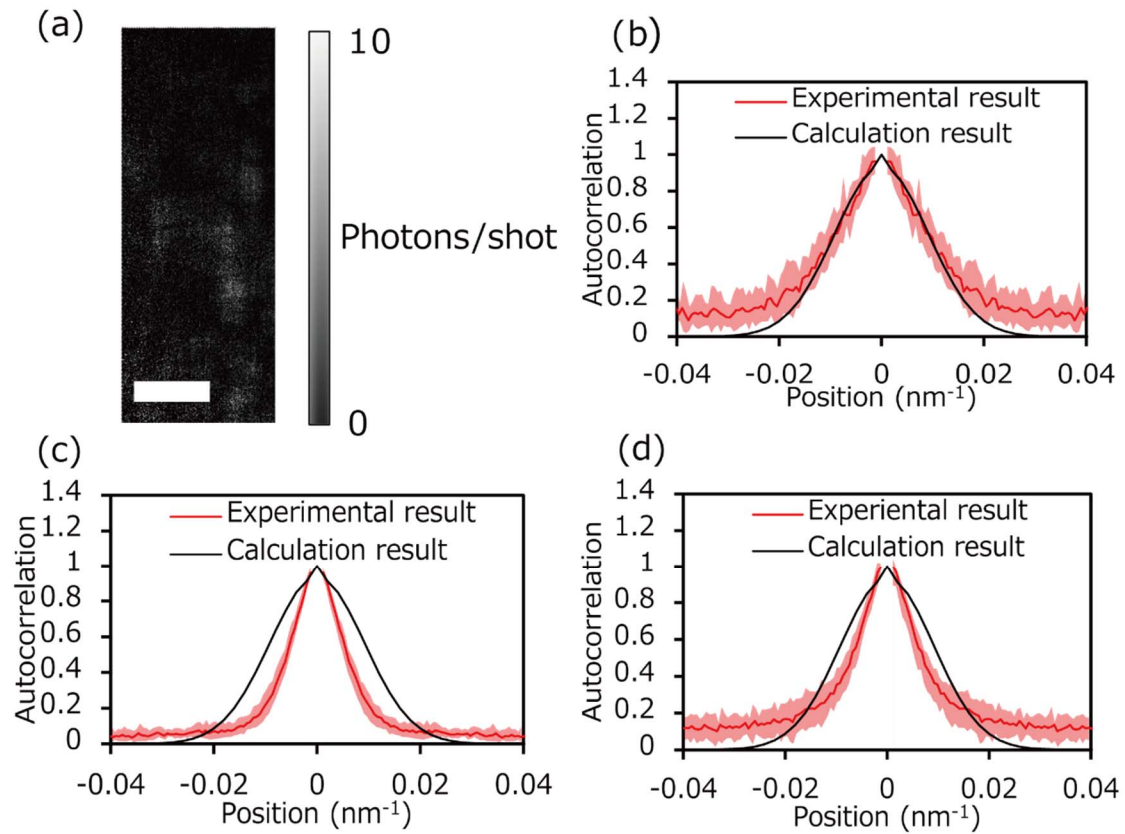


Figure S1 (a) Speckle intensity pattern obtained immediately after adjusting the horizontal incident angle. Scale bar: 0.06 nm^{-1} . Horizontal line profiles of the autocorrelation function (b) immediately after adjusting the horizontal incident angle, (c) before the adjustment (an identical state to Fig 7(c)), and (d) immediately after adjusting the astigmatism (an identical state to Fig. 7(d)). Red lines represent the experimental results averaged over (b) 12, (c) 10, and (d) 17 speckle patterns. The areas shaded in pink represent the standard deviation. Black lines represent the calculated results considering the measured wavefront aberration without introducing the misalignments.