X-ray Intensity Interferometry using ΔE = 120 μeV Monochromatized Beam

Intensity interferometry developed by Hanbury-Brown and Twiss [1] is a powerful method to investigate the statistical properties of light (higher-order coherence). In particular, when it is applied to chaotic light, the spatial and temporal coherence (first-order coherence) can be determined with very fast time resolution, less than ns. These advantages have promoted interesting applications in various fields including astronomy, quantum optics, laser physics, and nuclear physics. Nowadays, application of the method to the X-ray region is of great importance both for diagnosing modern synchrotron light sources and for utilizing coherent X-rays. We report on our recent development of X-ray intensity interferometry and its application to characterizing the spatial coherence of synchrotron radiation [2].

We briefly present the principle. If one took a beam image *instantaneously* for chaotic light, one would observe a number of bright and dark spots in a *speckle* pattern. Such intensity distribution results from the interference of light, and the spatial coherence length can be determined simply by measuring the spot profiles. Because the actual profile varies quite rapidly (with a time scale of the temporal coherence time), the coincidence technique is useful for fast detection. Here the interference is simply observed as an enhancement of the coincidence rate. When the technique is applied to pulsed light such as synchrotron radiation, one can greatly improve the detecting time resolution as short as the incoming pulse width, which is 10 to 100 ps in our case [3].

Nevertheless, the extension of intensity interferometry to the X-ray region [4] has been difficult. The primary reason is that the temporal coherence time, which is inversely proportional to the energy bandwidth ΔE, is much shorter than the incident pulse width. This has obstructed the clear detection of the enhancement of the coincidence.

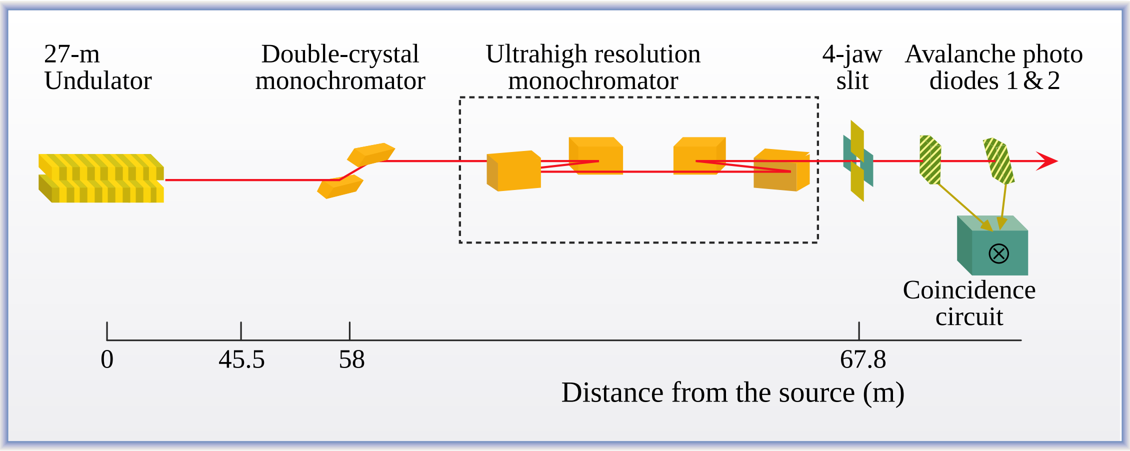

Fig. 1. Schematic view of the experimental setup. Undulator radiation was pre-monochromatized with the Si 111 double-crystal monochromator. The ultrahigh resolution monochromator was installed in the experimental hutch 1. The coincidence signals between outputs of two detectors were counted with changing aperture of the 4-jaw slit.

In addition, the brightness of the X-ray source was too low to obtain a good signal to noise ratio within a reasonable measurement time.

Recently, we achieved a significant improvement of energy resolution by developing an ultrahigh resolution monochromator: at 14.41 keV, 120-μeV bandwidth was realized using four-bounced asymmetric reflections [5]. The temporal coherence time is expected to reach ~ 40 % of the incident pulse width. With the monochromator the experiment was performed at beamline **BL19LXU** for the 27-m undulator [6], which is the brightest X-ray source. The setup is schematically shown in Fig. 1. The coincidence counts between two detectors were measured as a function of vertical slit width, as plotted in Fig. 2. The spatial coherence length was consequently determined to be 72.6 μm. A vertical source size of 12.8 μm was obtained from the value with van Cittert-Zernike's theorem. The source size almost agreed with that independently measured by the accelerator group. Furthermore, we characterized the coherence degradation in the transmitted beam through a filter and in the diffracted beam with diamond crystals [2].

To summarize, the combination of the narrowest bandwidth monochromator with the brightest X-ray source proved that X-ray intensity interferometry can be applied to the task of determining X-ray spatial coherence properties. This opens up new and broad opportunities to characterize beam qualities not only of the third-generation synchrotron sources but of the next generation ones.

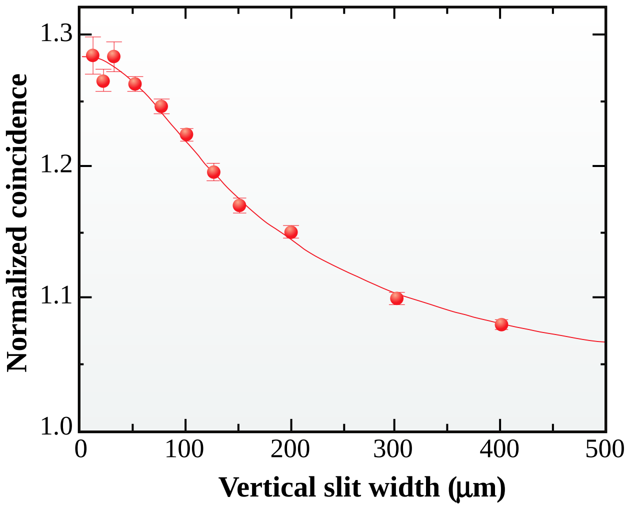

Fig. 2. Normalized coincidence as a function of the vertical slit width. The line shows a fit based on a Gaussian source profile.

Makina Yabashi

SPring-8 / JASRI

E-mail: yabashi@spring8.or.jp

References

[1] R. Hanbury-Brown and R. Q. Twiss, Nature (London) **177** (1956) 27.

[2] M. Yabashi, K. Tamasaku and T. Ishikawa, Phys. Rev. Lett. **87** (2001) 140801.

[3] E. Ikonen, Phys. Rev. Lett. **68** (1992) 2759.

[4] Y. Kunimune *et al.*, J. Synchrotron Rad. **4** (1997) 199; E. Gluskin *et al.*, *ibid.* **6** (1999) 1065.

[5] M. Yabashi, K. Tamasaku, S. Kikuta and T. Ishikawa, Rev. Sci. Instrum. **72** (2001) 4080.

[6] H. Kitamura *et al.*, Nucl. Instrum. Meth. Phys. Res. Sect. **A 467-468** (2001) 110; M. Yabashi *et al*, *ibid.* **467-468** (2001) 678; T. Hara *et al.*, Rev. Sci. Instrum. **73** (2002) 1125.