Precise measurements of spatial coherence in electron beams using Airy diffraction patterns

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Partial coherence of electron beams imposes limitations in various imaging/diffraction methods in transmission electron microscopes (TEMs), such as off-axis electron holography, high-resolution TEM/STEM, and electron diffractive imaging. Therefore, quantitative estimations of the beam coherence are one of the important issues for the correct interpretation and enhanced quality of the experimental data gathered using these interference methods. Although the spatial coherence can be measured from the visibility of the interference fringes formed by an electron biprism, considering that the majority of TEMs are not equipped with biprisms, developing other methods is important from a practical viewpoint. In the present study, we have developed a method to precisely measure spatial coherence in electron beams based on analysis of the Airy diffraction pattern of a selector aperture [1]. The method does not require an electron biprism and can be implemented in existing analytical TEMs equipped with a post-column energy filter.

Figure 1(a) shows a small-angle scattering pattern from a circular selector aperture (Airy diffraction pattern), which was precisely recorded at an extended camera length utilizing the additional magnification in a post-column energy filter (Gatan: GIF Quantum). The elongation of the main peak is owing to 2-fold astigmatism of the lens system. As shown in Fig. 1(b), the experimental pattern is well reproduced by a calculation considering various parameters such as geometric/chromatic aberrations of the lens system and the point-spread function of the diffraction blurring. Analyzing the point spread functions depending on the beam diameters, components that are attributed to the partial spatial coherence were successfully separated from the point-spread functions. As the result, a linear relationship between the spatial coherence length and beam diameter was revealed as shown in Fig. 1(c).

In addition to the coherence measurements, this method has a remarkable feature that is the ability to simultaneously determine diffraction blurring and lens aberrations. As an example of effective applications, remarkable improvements in phase imaging by electron diffractive imaging [2] after the corrections based on the fitting results are also explained.

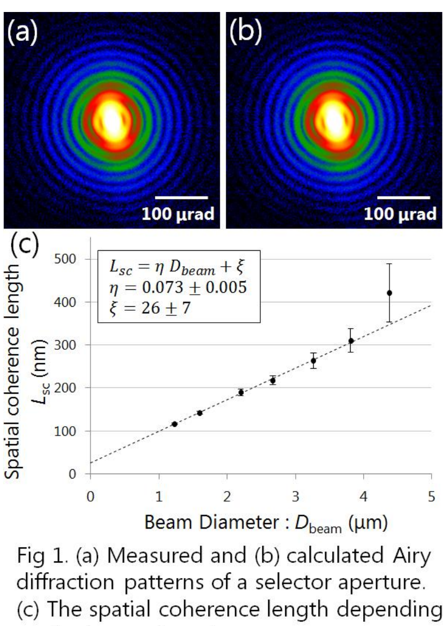

Fig 1. (a) Measured and (b) calculated Airy diffraction patterns of a selector aperture. (c) The spatial coherence length depending on the beam diameter.

References:
[1] Jun Yamasaki, et al., Microscopy 67, 1-10 (2018).
[2] Jun Yamasaki, et al., Appl. Phys. Lett., 101, 234105 (2012).