Direct determination of coherent electron source performances based on double biprism interferometry performed in splitting CBED configuration

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The spatial coherence of the electron beam is an important parameter for the performance of all forms of transmission electron microscopy (TEM) [1]. It must be optimized for advanced techniques, such as electron holography (EH), electron nanodiffraction and high-resolution electron microscopy (HREM). In a probe forming system, such as scanning TEM (STEM), the probe size and current define the important parameters [2]. Thanks to the advent of aberration correctors and the removal of spherical aberration, the probe parameters are mainly determined by the electron source properties. Both probe size and curret are included in the brightness definition of the source, which could be derived from the fundamental number of source brightness. But measuring the "practical brightness" of a complex electrons optics system is always very challenging and different definitions and methods can be found in the literature [3]. Further, the brightness is strongly influenced by the usual experimental setting of the electron source optics (as determined by the extraction voltage and the guns lens strength) and all intrinsic parameters of the gun (apex size, spherical aberration coefficient, etc.) .

The most straightforward way to determine the spatial coherence envelope of an electron beam is by using the interferometry methods. For instance it could be determined, in principle, using coherent CBED where the diffracted discs overlap and give rise to interference fringes. However, the visibility of interference fringes in such measurements also depends on the amount of inelastic scattering and the relative intensity of diffracted beams [4].

Using a split illumination for a convergent beam, the first author has demonstrated splitting CBED (SCBED) in the I2TEM microscope [5]. I2TEM is a Hitachi HF3300C TEM fitted with a 300kV cold FEG. This microscope has an electron biprism located above the three condensers illumination system, a multibrism set-up located between three intermediate lenses, a 4k X 4k camera and a Cs-corrector BCOR from CEOS. SCBED is achieved by combining the electron biprism located above the condenser system (called BPC) with a special setting of the three condensers lenses, which allows to separate the convergent beam into two parts and create two half-spots in the object/image plane. The convergent beam is finally recombined in a single CBED disk located in the back focal plane of the objective lens. Using a second electron biprism installed in the imaging system (called BPI), we are able to overlap the two sides of the SCBED disc and generate an interference pattern in the overlap area. Thanks to the double biprism configuration, the fringe spacing and the overlap area can be adjusted independently using BPC and BPI voltages respectively [6]. The visibility of the interference pattern as a function of the BPI voltage is then directly related to the spatial coherence envelope of the electron beam in the condenser aperture plane without any influence of other probe forming lenses or sample artefacts.

We will show how, using such a double biprism SCBED interferometry configuration combined with standard Fowler-Nordheim measurements, we were able to extract unambiguously the key electron source parameters of our 300keV CFEG. Indeed after determining the spatial coherence envelope, we have also extracted the amount of probe coherent current, usually used to determine the figure of merit of STEM systems [7], and finally retrieved the brightness.

This new method is therefore particularly well suited to determine the intrinsic performance of any electron source as well as dedicated illumination configuration used in advanced TEM and STEM applications.

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