Measurement of TEM – Parameters for Electron Holography

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In order to apply electron holography in transmission electron microscope (TEM) with Möllenstedt-biprism [1], the experimental optical setup (fig. 1) has to be optimized [2]. To achieve this, the free lens control facility of TEM is used for adjusting the objective and diffraction lens. The most important holographic parameters to be controlled – i.e. hologram width, fringe spacing, contrast of interference fringes and coherent electron dose in hologram - are all influenced more or less directly by the imaging parameters of the two mentioned lenses. Consequently, to get high-quality holograms, accurate measurement of the optical parameters of objective and diffraction lens is necessary.

A measurement method based on the thin lens approximation of the optical system is proposed, taking into account that some of the geometrical parameters are directly accessible. This is the case with the distance a between the focal plane of the objective lens and the selected area (SA) diaphragm, and with the distance l between the objective and the diffraction lens; furthermore, an arbitrary shift Δs of the object along the optical axis, introduced by means of the z-control of the specimen holder, is known.

The parameters to be determined are mainly the focal lengths of the objective and diffraction lens, f_O and f_D, the distances of the object s_0 and of the images given by the objective lens s'_0, and the diffraction lens s'_D. In the usual case of the biprism mounted in the SA plane with a distance to objective lens of $s'_{BP} = f_O + a$, the distance b between biprism and image plane of the objective lens (Fig. 1) is to be determined for every new setting [3].

The procedure consists of the following:
1. SA – standard: object in eucentric height yields magnification MSA
2. object shifted with a freely chosen (well-known) distance Δs followed by refocusing:
   a. objective lens (final focal length f_{Oa}) at constant diffraction lens $\Delta f_D = 0$ yielding magnification MO
   b. diffraction lens (final focal length f_{Db}) at constant objective lens $\Delta f_O = 0$ yielding magnification MD

The normalized values MO/MSA and MD/MSA are inserted into the two respective imaging equations. The solutions of the (nonlinear) system of equations deliver the focal lengths f_O and f_D of the two lenses in SA-mode, as well as f_{Oa} and f_{Db} in 2a- and 2b-mode. Furthermore, the object distance s_0 to objective lens at eucentric height results. Subsequently, the imaging equations also deliver the image distances s'_0 and s'_D. This allows the distance $b = s'_0|_M - s'_0|_{SA}$ to be determined, where $s'_0|_M$ is the image distance to the objective lens for electron holographic settings.

The shift of the principal planes of the lenses due to different lens excitations is supposed to be negligible, but could be considered, if necessary, by incorporating it in l.

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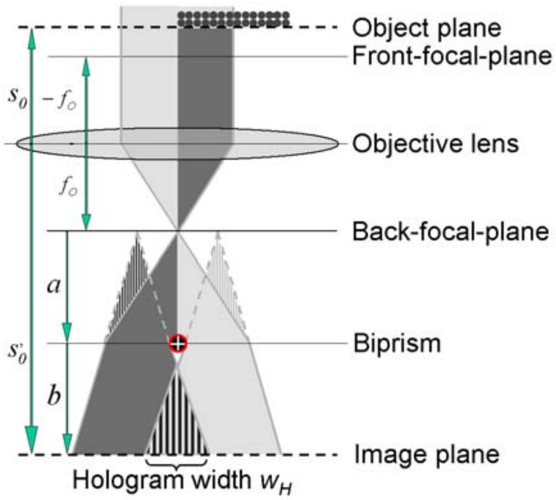

Figure 1. Setup for off-axis electron holography in conventional TEM

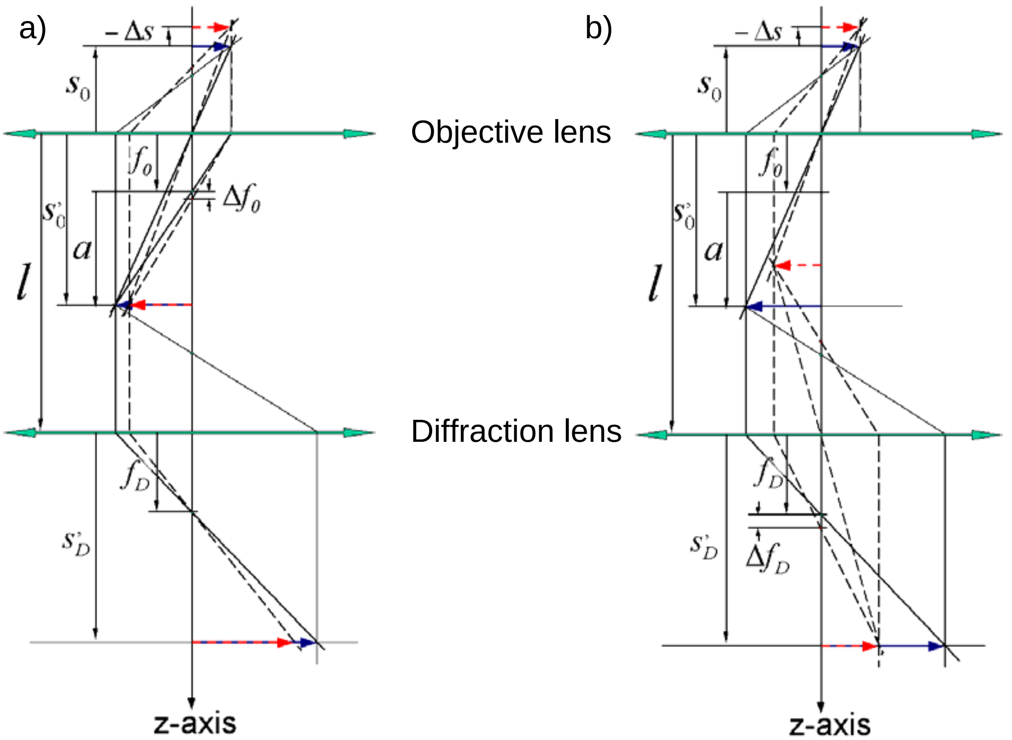

Figure 2. Optical ray path for standard SA-imaging mode (continuous line) and for refocused system at object shift Δs (dashed line) using: a) the objective lens $f_{Oa} = f_O + \Delta f_O$ ($\Delta f_O > 0, \Delta f_D = 0$) and b) the diffraction lens $f_{Db} = f_D + \Delta f_D$ ($\Delta f_O = 0, \Delta f_D > 0$).

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