Light Diffractograms of Electron Micrographs at Tilted Illumination †

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Light diffractograms of electron micrographs at tilted illumination have proved the compensation of chromatic aberration and the enhancement in resolution predicted by the theory.

Some time ago a new image reconstruction method in electron microscopy has been proposed, which is based on a series of micrographs taken with tilted illumination [1]. It has been shown, that this image reconstruction method is especially suited for the determination of the complex image function at high resolutions. Recent calculations have proved, that this method not only corrects for spherical aberration but also compensates the chromatic aberration [2, 3]. There is the difficulty for experimental work, that the asymmetric illumination causes a contamination of the aperture combined with asymmetric electrostatic charges. These difficulties can be removed, if a heated aperture [4] will be used. A thin aluminiumoxide foil ($d \sim 20$ Å) with small gold crystallites has been photographed in an Elmiskop 102 at different angles of illumination ($M_{el} = 520\,000$, $U = 125$ kV, $\Delta z \sim 2000$ Å). Two successive images have been taken under identical conditions in order to determine the limit of significance by the fringe method [5]. Some examples will be shown in the following Figures. Figure 1 ** shows the light diffractogram of a conventional micrograph with central illumination. If we tilt the illumination by an angle of $0.6 \cdot 10^{-2}$ rad the light diffractogram becomes asymmetric (Figure 2 a). The aperture has been shifted in these experiments, in order to bring the illumination point close to the aperture edge. Figure 2 b shows schematically the result. The achromatic circle can easily be seen in Figure 2 a. As the aperture opening is greater than the achromatic circle, significant Fourier coefficients will be transferred also outside of the achromatic circle. There is a considerable influence of the partial coherence ($\alpha_{ill} = 4 \cdot 10^{-4}$). As already predicted in [3] the partial coherence leads to an increase of the transfer function in the middle of the achromatic circle. Another example shows Figure 3. The tilting angle of illumination is $1.0 \cdot 10^{-2}$ rad. Again the region within the achromatic circle shows significant details, but the space frequencies in the outer regions of the light diffractogram become very small for other reasons ***. The space frequency limit in Fig. 2 is $d^* \sim 0.48$ Å^{-1}, in Fig. 3 $d^* \sim 0.55$ Å^{-1}. These limits would correspond to a coherent point resolution of 1.8 Å respectively 1.5 Å. The corresponding resolution in Fig. 1 is $d^* \sim 0.37$ Å^{-1}, $d_{coh} \sim 2.3$ Å. In contrast to electron diffractograms with tilted illumination (see [1], Fig. 9) the light diffractogram is centrosymmetric (for explanation see [1]).

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** Figures 1–3 on page 1934.

*** They can be seen in the original, but not in the reproduction.

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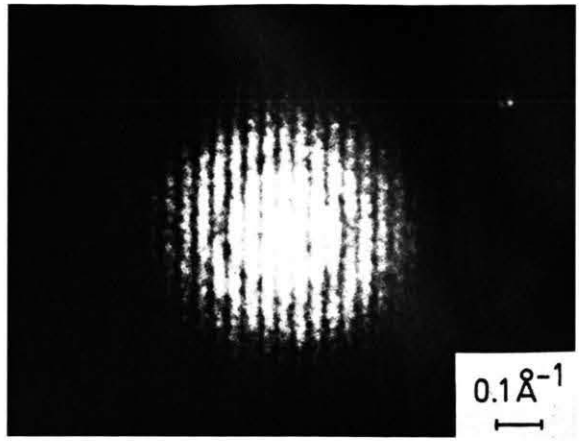
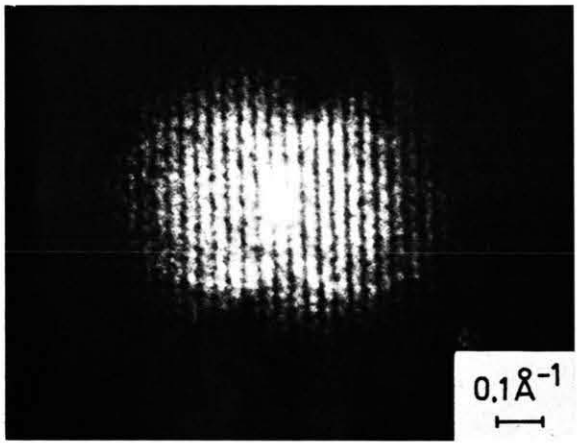
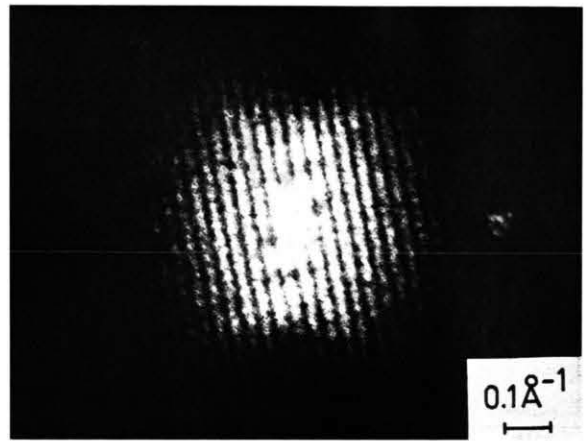


Fig. 1. Light diffractogram of a conventional micrograph.





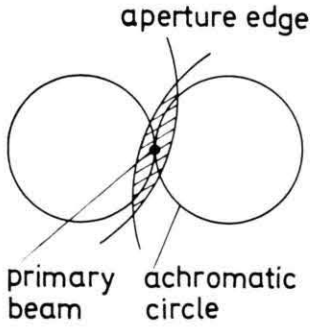


Fig. 2. Light diffractogram of a micrograph of the same specimen as in Fig. 1, taken at an illumination angle of $0.6 \cdot 10^{-2}$ rad. a) Light diffractogram, b) Schematic representation.

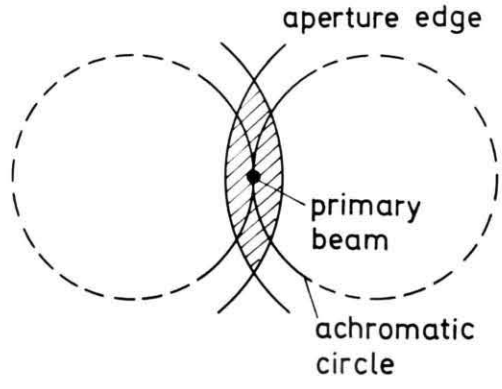


Fig. 3. Light diffractogram of a micrograph of the same specimen as in Fig. 1, taken at an illumination angle of $1.0 \cdot 10^{-2}$ rad. a) Light diffractogram, b) Schematic representation.