

# THE INFLUENCE OF THE INCOHERENT COMPONENT OF ELECTRON SCATTERING ON THE VISIBILITY OF THE INTERFERENCE PATTERN

I. G. STOYANOVA, I. F. ANASKIN

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**Abstract**

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**PHYSICS**

**I. G. STOYANOVA, I. F. ANASKIN**

**THE INFLUENCE OF THE INCOHERENT COMPONENT OF ELECTRON SCATTERING ON THE VISIBILITY OF THE INTERFERENCE PATTERN**

*(Presented by Academician A. A. Lebedev on 6 VI 1966)*

In the present work the influence of the incoherent component of electron scattering on the quality of the interference pattern obtained with the aid of an electrostatic Fresnel biprism is considered <sup>(1,2)</sup>.

To estimate the quality of an electron interference pattern, the concept of visibility  $K$ , proposed in light optics by Michelson, is used:

$$K = (A_{\max}^2 - A_{\min}^2) / (A_{\max}^2 + A_{\min}^2), \quad (1)$$

where  $A_{\max}^2$  and  $A_{\min}^2$  are the intensities at the maxima and minima of the interference pattern, respectively. In two-beam interference of waves with equal amplitudes, the visibility  $K$  is a measure of the mutual coherence of the interfering beams <sup>(3)</sup>.

The intensity distribution in a two-beam interference pattern has the form

$$A^2 = 2B_0 + 2B_1 \cos \left( \frac{2\pi}{\lambda} d\beta \right). \quad (2)$$

Here

$$B_0 = \int_{-\infty}^{+\infty} f(x_{\text{src}}) dx_{\text{src}}$$

is the background intensity outside the interference zone, where  $f(x_{\text{src}})$  is the background intensity of an elementary wave emitted from the point  $x_{\text{src}}$  of an extended source;

$$2B_1 = 2 \int_{-\infty}^{+\infty} f(x_{\text{src}}) \cos\left(\frac{2\pi}{\lambda} x_{\text{src}} \cdot 2u\right) dx_{\text{src}}$$

is the amplitude of the intensity oscillations in the interference zone;  $\lambda$  is the electron wavelength;  $2u$  is the angle at which the two interfering beams go from the source;  $d$  is the distance between the apparent sources formed during operation of the biprism, and  $\beta$  is the angle between the direction of propagation of the interfering waves and the optical axis.

**Fig. 1.** Estimating the influence of an object on the visibility of an interference pattern.  $S$  –electron source,  $O$  –object,  $F$  –biprism filament,  $\alpha$  –electron scattering angle,  $c$  –distance from the object to the source

Expression (2) does not take into account Fresnel diffraction by the filament, which modulates the interference pattern; however, in the present case this is inessential.

From expressions (1) and (2) it follows that

$$K = B_1/B_0. \quad (3)$$

This equation describes the quality of the interference pattern determined by the parameters of the interference instrument.

When objects to be studied are placed in the electron interferometer (Fig. 1), the visibility of the interference pattern deteriorates (Fig. 2) because the object placed in the path of the interferometer beams changes the mutual coherence of the interfering beams. In this case the virtual source, the distribution of elementary waves in which is similar to the distribution of waves scattered by the object, represents, as it were, a combination of two sources, formed respectively by coherently and incoherently scattered electrons. Coherently scattered electrons do not change the mutual coherence of the interfering beams. Consequently, the visibility of the interference pattern formed by the coherent source, despite the increase in its size, does not change and is equal to the visibility of the interference pattern in the case when there is no object in the path of the beams ( $\hat{3}$ ). Incoherently scattered electrons form a second source, differing from the first in spatial and temporal coherence. Consequently, because of the increase in size, such a source can produce only an interference pattern with sharply reduced visibility. Thus, for example, with a half-width of the angular distribution of inelastically scattered electrons  $a = 1 \cdot 10^{-3}$  rad ( $\hat{4}$ ) and a distance from the object to the source  $c = 100$  mm, the effective width of the source formed will be  $\delta = c \cdot 2a = 0.2$  mm. With such source dimensions, no interference pattern arises. In this case the intensity from the incoherent component is superposed on the interference pattern as a background.

**Fig. 2.** Microphotograms of interference patterns obtained without an object ( $a$ ) and with an object ( $b$ ). The interference patterns were obtained using an

Fig. 2. Microphotograms of interference patterns obtained without an object (a) and with an object (b). The interference patterns were obtained using an electrostatic Fresnel biprism installed in a UEMV-100 electron microscope at 75 kV. The object was a Formvar film about  $\sim 200 \text{ \AA}$  thick.

Figure 1: Fig. 2. Microphotograms of interference patterns obtained without an object (a) and with an object (b). The interference patterns were obtained using an electrostatic Fresnel biprism installed in a UEMV-100 electron microscope at 75 kV. The object was a Formvar film about  $\sim 200 \text{ \AA}$  thick.

electrostatic Fresnel biprism installed in a UEMV-100 electron microscope at 75 kV. The object was a Formvar film about  $\sim 200 \text{ \AA}$  thick.

When an object is introduced into the path of the interferometer beams, the intensity distribution in the interference pattern takes the form

$$A^2 = 2B_0 + 2B_1 \cos \psi; \quad (2a)$$

here  $\psi = \frac{2\pi}{\lambda} d\beta$ .

From the physical meaning of  $B_0$  and  $B_1$  it follows that the ratio

$$B_1 / B_0 = m \quad (4)$$

expresses the fraction of electrons that have passed through the limiting diaphragms of the interference instrument.

On the basis of the above reasoning, the interference pattern in the presence of an object in the interferometer may be regarded as a superposition of interference patterns from a virtual coherent and a virtual incoherent source. Equation (2a) splits into two equations. The first,

$$A^2 = 2B_0 + 2B_1 \cos \psi \quad (5)$$

describes the interference pattern from the virtual coherent source; moreover, as already stated, the visibility of this pattern  $K = B_1 / B_0$  is equal to the visibility of the interference pattern obtained without an object,  $K = B_1 / B_0$ . The second equation,

$$A^2 = 2B_0 + 2B_1 \cos \psi \quad (6)$$

describes the interference pattern from an imaginary coherent source. The visibility of this pattern is equal to  $K_{nk} = B_{1nk} / B_{0nk}$ .

According to the estimate of the width of the imaginary incoherent source,  $K_{\text{nk}}$  is close to zero. From (5), (6), and (2a) it follows that the ratios

$$R_{\text{kog}} = \frac{B_{0\text{kog}}}{B_{0\text{ob}}}, \quad (7)$$

$$R_{\text{nk}} = \frac{B_{0\text{nk}}}{B_{0\text{ob}}} \quad (8)$$

represent, respectively, the coherent and incoherent parts of the electron beam that has passed through the object and the limiting diaphragms. From the condition  $K_{\text{kog}} = K$ , and from (4) and (7), it follows that

$$B_{1\text{kog}} = R_{\text{kog}} m B_1. \quad (9)$$

According to (5), (6), and (2a),  $B_{1\text{ob}} = B_{1\text{kog}} + B_{1\text{nk}}$ , and

$$K_{\text{ob}} = B_{1\text{kog}}/B_{0\text{ob}} + B_{1\text{nk}}/B_{0\text{ob}}. \quad (10)$$

From (4), (7), (8), (9), and (10) we obtain

$$K_{\text{ob}} = R_{\text{kog}} m B_1 / m B_0 + R_{\text{nk}} B_{1\text{nk}} / B_{0\text{nk}} = R_{\text{kog}} K + R_{\text{nk}} K_{\text{nk}}. \quad (11)$$

Since  $K_{\text{nk}} \approx 0$ , then

$$K_{\text{ob}} = R_{\text{kog}} K. \quad (12)$$

From (7), (8), and (12),

$$K_{\text{ob}} = K - R_{\text{nk}} K. \quad (13)$$

This equation takes into account the influence of the incoherent component of electron scattering in the object on the visibility of the interference pattern.

The equations derived can be used to separate the coherent and incoherent components in a beam of electrons that has passed through an electron-microscopic object. To do this it is only necessary to measure the visibility of the patterns obtained in an interference instrument without the object (Fig. 2a) and with the object (Fig. 2b). The estimate we made showed that, for a Formvar film of thickness  $\sim 200 \text{ \AA}$ , the coherent and incoherent parts of the electron scattering are, respectively, 84 and 16%.

Institute of Biological Physics  
Academy of Sciences of the USSR

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*Note: Figure translations are in progress. See original paper for figures.*

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