INTERFERENCE OF ELECTRONS ON THE EDGE OF A THIN CHARGED FILM

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A new method is proposed for obtaining electron interference patterns.

It has been observed that the electric field on the edge of a charged film that is transparent to electrons can cause coherent splitting of an electron wave.

One of the methods of obtaining the interference pattern is shown in Fig. 1. The electric field produced in the system shown in Fig. 1a changes the front of the electron wave. The phase shift of the electron wave passing through such a field, disregarding the relativistic terms, is [1]

$$\Delta\phi = \frac{\pi}{\lambda U}\int_{-L/2}^{+L/2} V(x,y)\,dy,$$

where λ is the length of the electron wave, $V(x, y)$ the potential distribution near the film, U the accelerating voltage, and L the distance between the zero-potential surfaces. The integration is along the trajectories $x = \text{const}$. The x axis lies in the plane of the film perpendicular to its edge. The y axis is perpendicular to the plane of the film. Passage through the film produces an additional phase shift, equal to

$$\Delta\phi_f = \frac{\pi\Phi_0 d}{\lambda U},$$

where Φ_0 is the average internal potential of the film material and d is the film thickness. Figure 1b shows the character of the distribution of $\Delta\varphi_{tot} = \Delta\varphi + \Delta\varphi_f$ along the film, which duplicates the variation of the form of the wave front in the field of the system shown in Fig. 1a, is shown in Fig. 1b. In this case the interference pattern is produced against the background of the shadow image of the film boundary as a result of superposition of two coherent waves emerging from the sources S_1 and S_0 and passing outside the film as well as through the film. The distance Δ between the fringes of such an interference pattern is given by

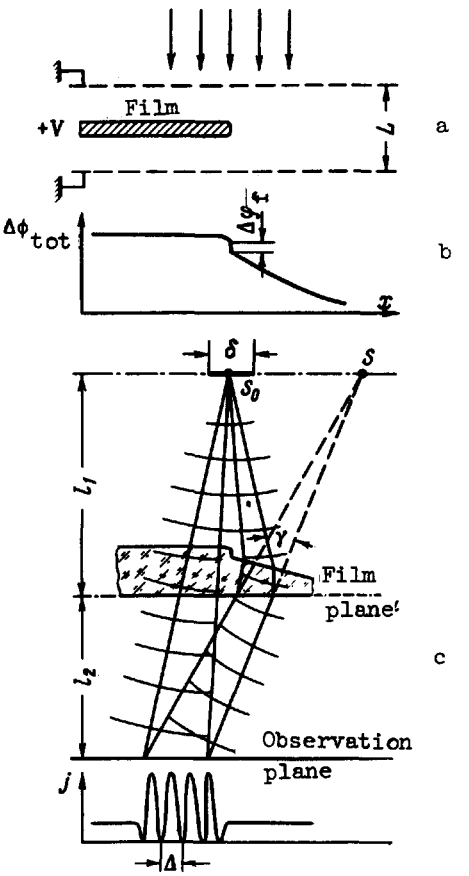

Fig. 1. Diagram showing the occurrence of electron interference on the edge of a positively charged film.

$$\Delta = \frac{\lambda(l_1 + l_2)}{l},$$

where l_1 and l_2 are the distances from the film to the plane of the sources and to the plane of observation, respectively, and γ is the deflection angle of the electrons moving through the space near the film.

The intensity is modulated in the region of electron-wave overlap (Fig. 1b) only if the coherence condition $\delta < \Delta l_1/l_2$ is satisfied, where δ is the dimension of the source. The presence of a sharply nonlinear region of variation of $\Delta\varphi$ near the edge of the film leads to the appearance of a third interfering beam. Owing to the smallness of this region (its size is of the order of the film thickness), the intensity of this beam is low and cannot change the periodicity and the total intensity of the two-beam interference pattern. The character of the phenomena under consideration depends little on the form of the zero equipotentials, therefore the scheme under consideration has a certain degree of generality.

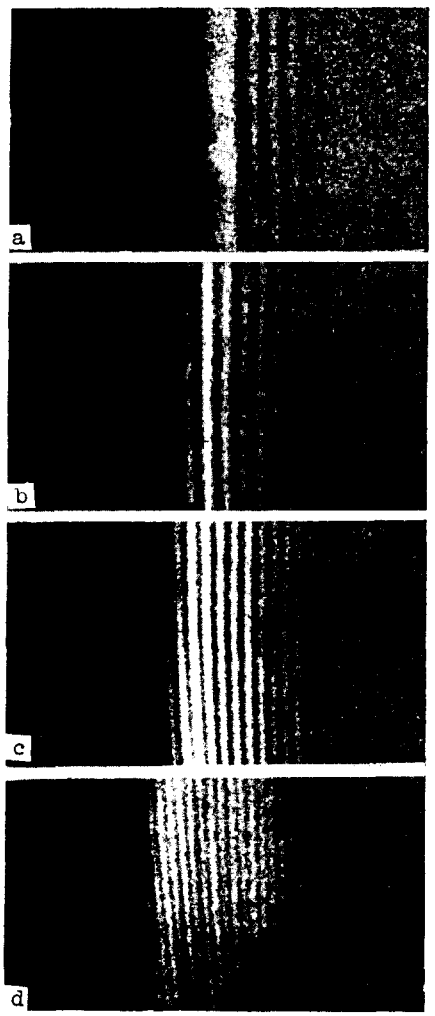

Fig. 2. Shadow image of the edge of a thin film at film potentials 0 (a), +8 (b), +16 (c), and +24 (d). Accelerating voltage 75 kV. Total magnification 4000.

We observed the interference with an electron interference microscope based on the UEMV-100 electron microscope [2]. We investigated carbon films 300 - 500 Å thick, obtained by sputtering in high vacuum on freshly cleaved mica. The scheme shown in Fig. 1a constituted in practice an aggregate of three superimposed microgrids spaced a distance on the order of 100 μ apart. The investigated film was deposited on the central microgrid, to which a potential ±(0 - 100) V was applied. The entire setup was placed between the objective and intermediate lenses of the electron microscope. A shadow image of the film, magnified 650×, was produced on the end screen. Figure 2 shows the interference patterns of the edge of the film, produced when a positive potential is applied to the film.* With increasing potential, the distance between the interference maxima decreases and the interference zone increases. Just as in the case of the interference of electrons with a biprism [3], Fresnel diffraction causes modulation of the intensity of the interference maxima. The high contrast of the interference lines $((j_{max} - j_{min})/(j_{max} + j_{min}) = 0.4)$ is evidence that the coherence of the electron wave is maintained on passing through a thin film.

Thus, the method proposed by us allows us to obtain electron interference images with adjustable character-

istics.

The principal analogy between the method of obtaining electron interference images of the edges of the films and the method of obtaining holograms in light optics makes it possible to use these phenomena in electron holography.

The authors consider it their pleasant duty to thank Academician I. M. Frank for interest in the work.

[1] V. Glazer, Osnovy elektronnoi optiki (Fundamentals of Electron Optics), Gostekhizdat, M. 1957.
[2] I. F. Anaskin, I. G. Stoyanova, and A. F. Chyapas, Izv. AN SSSR ser. fiz. 30, No. 5 (1966).
[3] G. Mollenstedt and H. Duker, Z. Physik 145, 377 (1956).

* Coherent splitting of an electron wave can also be produced by the fields of the electrostatic charges created in a conducting or semiconducting film bombarded with electrons. In this case the film must be placed in the object plane of the objective lens of the microscope, and the interference image of the film edge is observed by suitable defocusing. We observed in such a system distinct interference patterns of the edges of thin collodion films.

VARIATION OF THE EMISSION WAVELENGTH OF A PARAMETRIC LIGHT GENERATOR BY MEANS OF AN EXTERNAL ELECTRIC FIELD

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Besides the existing methods for tuning the emission wavelength of a parametric light generator (PLG), namely mechanical rotation of the crystal in the resonator [1] and change of the crystal temperature [2], the electrooptical method is of definite interest.

The gist of the electrooptical method is that the output frequency of the PLG ($\Delta\omega$) is varied by applying an external electric field to vary the refractive index (Δn) of a KDP (or KH_2PO_4) crystal: $\Delta\omega \sim \Delta n \sim r_{63}E$, where r_{63} is the linear electrooptical coefficient, equal to 10^{-7} cgs esu at T = 300°K. Calculations performed for a KDP crystal [3] have shown that at room temperature even relatively strong fields (100 kV/cm) do not produce a noticeable effect. An appreciable change in the PLG frequency can be obtained in the region of the ferroelectric transition (the Curie temperature of the KDP crystal is T_c = 123°K). In this region, the electrooptical effect increases sharply and reaches 10^{-4} cgs esu units at the Curie point itself [4]. The results of calculations for a pumping wavelength $\lambda_p = 0.53\ \mu$ (the second harmonic of a neodymium laser) and for an "eoe" type of synchronism are shown in Fig. 1, from which it follows that when an external electric field is applied to the KDP crystal the tuning curves shift in accordance with the magnitude and sign of the field. Thus, smooth tuning of the PLG frequency is possible at a fixed crystal direction, defined by an angle θ. To verify this possibility, we performed an experiment with the setup shown schematically in Fig. 2. A polarized beam from a Q-switched (rotating prism) Nd^{3+} glass laser passed through an amplifier and struck a KDP doubler crystal (ℓ = 3 cm), in which it excited a second-harmonic wave serving as a pump for the PLG. An additional plate was placed in the laser cavity at the Brewster angle to produce more complete polarization. A liquid