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Abstract

Full Text

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PHYSICS

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RECORDING SOFT X-RAY RADIATION USING ELECTRON-OPTICAL CONVERTERS

(Presented by Academician A. P. Aleksandrov on 26 VIII 1968)

Electron-optical converters (EOCs) are sensitive to the optical part of the spectrum of electromagnetic radiation. A converter screen, used to match the spectrum of the recorded radiation to the region of spectral sensitivity of the EOC photocathode, may be located either outside or inside the EOC bulb. In the case of soft X-ray radiation, difficulties arise with both solutions. When the screen-converter is placed inside the bulb in optical contact with the photocathode, part of the X-ray quanta is absorbed by the entrance window. Because of these losses, when the number of recorded quanta is small, the role of statistical fluctuations increases, and the quality of the resulting image may deteriorate. The fabrication of an entrance window transparent to soft X-ray radiation encounters technological difficulties. Therefore, it becomes necessary to increase the exposure in order to record the minimally required number of quanta.

Fig. 1. Schematic of recording, by means of an EOC, the diffraction of X-rays. 1 –demountable X-ray tube with a copper anode (voltage 24 kV, current 0.8 mA); 2 –nickel filter (65 μ); 3 –collimator of the primary beam made of lead glass (length 20 mm, diameter ~0.2 mm); 4 –specimen under study; 5 –primary-beam trap; 6 –screen-converter made of CdS-2 phosphor (20 mg/cm^2); 7 –four-cascade EOC (voltage 50 kV) with focusing magnetic coils; 8 –Zenit-E camera with a Helios-40 lens (1:1.5/85). The distance from the specimen to the screen-converter was 20 mm. When photographing on RF-3 film, the image scale was reduced by a factor of two.

Fig. 2. Debye patterns of a paraffin sample

Figure 2: Fig. 2. Debye patterns of a paraffin sample

Fig. 3

Figure 3: Fig. 3

The use of photographic objectives to transfer the optical image from an external screen-converter in practice leads to large light losses. For radiation with a wavelength on the order of 1 Å and less, as calculation shows, each quantum, producing hundreds of photons in the screen-converter,

Fig. 2. Debye patterns of a paraffin sample (thickness 0.28 mm). The photographs were obtained using an electron-optical converter with exposure times: **a** –17 sec; **b** –3 min; **c** –40 min; **d** –obtained by direct recording on RM-5-1 X-ray film (sensitivity according to GOST $S_{g=1.0} = 80$ reciprocal roentgens under the recommended processing conditions), which was placed in the plane of the converter screen; exposure time 10 h.

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is recorded by the EOC. Therefore, with sufficiently large amplification by the EOC, an increase in exposure is not required. However, owing to the deterioration of the signal-to-noise ratio, the possibilities for long exposures are reduced, since the image is masked by the EOC' s own noise. The known solution of image transfer using fiber optics has not yet become widespread.

Fig. 3. Transmission of exposed films as a function of the distance R from the axis of the primary beam. The exposures are the same as in Fig. 2. The measurements were made on an MF-4 microphotometer with slit dimensions, reduced to the plane of the converter screen, 0.07×0.15 mm^2. The transmission of unexposed regions was taken as 100%.

To reduce light losses, an EOC was developed with a thin (35–40 μ) mica input window. On its inner side a photocathode is formed, and on the outside a converter screen is applied. Each of the four amplification stages consists of a combination of a phosphor layer with a semitransparent photocathode. (The design of the new EOC was developed under the direction of one of the authors, M. M. Butslov.) Different specimens of the EOC had their own resolution of 10–20 lines/mm over a field 40 mm in diameter. In combination with the converter screen, a resolution no worse than 5 lines/mm was achieved.

The layout of the setup in which the EOC is used is clear from Fig. 1. Figure 2 gives diffraction patterns at different exposures. To obtain approximately identical blackening at different exposure times, the photographic lens was stopped down. With the aperture fully open and with exposures of seconds, traces of individual quanta were obtained on the photographic film. For comparison, a diffraction pattern recorded directly on x-ray film is also presented. Figure 3 shows plots of the transmission of the exposed films.

As can be seen from the photographs and the plots, with increasing exposure, i.e., with an increase in the number of recorded x-ray quanta, the graininess of the image decreases, and the image quality approaches that obtained on x-ray film. However, the exposures still remain at ···

many times smaller than for X-ray film. Depending on the requirements imposed on image quality, a gain of 10–100 times or more can be obtained. It should be borne in mind, however, that as the resolution of the recording device is increased, the gain in exposure will decrease. Some discrepancy in the transmission curves may be explained by the nonmonochromaticity of the X-ray radiation and by the different spectral sensitivity of the methods being compared.

For the selected exposure times, the intrinsic noise of the electro-optical converter was practically not recorded, and it was possible to record diffraction patterns at least several times weaker. Thus, the possibility has been experimentally demonstrated of reducing exposure manyfold under conditions requiring many-hour exposures of X-ray films, which previously could not be achieved.

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