ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ
СО АН СССР

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MEASUREMENTS OF THE PARAMETERS OF A SUPERVIDICON WITH PHOSPHOR SCREEN AS AN X-RAY IMAGING DETECTOR

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Together with a variety of researches on synchrotron radiation (SR) beams from electron-positron storage rings, the studies on X-ray topography, both fundamental and applied, are being carried out at the Novosibirsk Institute of Nuclear Physics. Conventional X-ray topographic imaging detectors - photoemulsions - have no competitors over spatial resolution but they have a low sensitivity and some disadvantages of phototreatment. Moreover, photoemulsions are not adequate to the studies of the dynamics of crystalline structures which have become really feasible just on the SR beams. At the INP, X-ray vidicons are being employed and CCD matrices are being prepared for use as X-ray topographic imaging detectors.

In an X-ray vidicon, an X-ray sensitive target is deposited on the inner surface of the entrance window which is made of 1-mm-thick carbonglass. The transmittance of such a window against the wavelength of X-rays is plotted in Fig. 1. It is obvious that the long-wave region, which is significant in obtaining the Borrmann images of the defects in crystals, is difficult to access for an X-ray vidicon of such a construction. At present there are X-ray luminophors with the X-rays-to--light conversion efficiency in tens percent. In addition to conventional light vidicons with 0.1 - 1 lx threshold of sensitivity, there are now home supervidicons with a diode-mosaic silicon target, electrostatic focusing in the electron image transfer section, magnetic focusing and beam deflection in the readout section, and with a fiber-optical window (decomposition of an image into 625 lines and 25 frames per second). Their threshold sensitivity reaches 10^{-3} lx. Deposition of X-ray luminophor on the fiber-optical entrance window of a supervidicon turns it into a highly-sensitive X-ray imaging detector. The device is light-shielded by thin black paper. The device is used in combination with a tv camera КТП-39, optical attachment ОП-22 and with tv monitors ВК-29 and ВК-23 (with photoattachment).

The parameters of the device have been measured by means of an apparatus shown in Fig. 2. For this purpose, the separated K-lines of various elements - the projections of the linear focus of an X-ray tube - were used; a grinded silicon crystal in the Bragg reflection (111) was used as the dispersing element. Utilization of a grinded crystal is due to the necessity of achieving a large flux density of photons at an insignificant relative widening of the images of the spaced apart X-ray lines because of large width of the reflection curve of the grinded crystal, since the projections of the focuses of X-ray tubes are equal, all the same, to 40-100μm in cross section. The absolute measurement of the flux density of the monoenergetic photons was carried out with a proportional soldering-off counter СРПО-16, previously calibrated with respect to the efficiency at various wavelengths (Fig. 4). The shape of the spectrum has been registered by means of photoplates of MP type intended for nuclear studies, with an emulsion thickness of 10 μm and with the same spatial resolution in the case of the development of exposured photoplates at room temperature. The photometering of the plates was performed (Fig. 5 illustrates the corresponding characteristic curve (/1/) for the K-lines of molybdenum; Ø is the flux of photons; H is the exposure dose; D is the photographic density of blackening) with a scanning slit of 10 μm.

To measure the spatial resolution of the tv device, the $K_{\alpha_{1,2}}$ -lines of molybdenum were taken on the photographic film Micrat-300 from the monitor screen (see the previously obtained, corresponding characteristic curve in Fig. 6). Because the measurement of dependence of the brightness of images on the monitor screen on the flux density of the photons in the peak of the line is too cumbersome with the use of photometering, this dependence was obtained for the K_{α_1} -line of molybdenum (Fig. 7) using the cutting-off light polarization attachment (a polarizer and mobile, with angular scale, analyzer) and neutral filters. The latter compensate the transparency of the analyzer and have the plateau within the 4000-6000 Å range, according to spectrophotometric data. The observation was performed with a mirror photocamera whose relative hole remained unchangeable. The brightness of image of the K_{α_1} -line of molybdenum against the flux density of the photons is plotted in Fig. 8; the comments concerning the particular parts of this dependence are given in this figure as well. In the present

case gadolinium oxysulphide (luminous in the green range of the spectrum) was used as an X-rays-to-light converter. Because the dynamic range of the tv device is clear from Fig. 8, only comments are given for the other luminophors (yttrium oxysulphide and КЛ3-3) and wavelengths: at Fig. 9, point 0 corresponds to the threshold of observation of the line, point S corresponds to the beginning of smearing ("overlighting") of the line, and point M corresponds to the beginning of merging of the α_1 and α_2 lines. Yttrium oxysulphide shines in the violet range and КЛ3-3 shines in the green-yellow range of the spectrum. It is natural that the supervidicon visualizes the images of the lines immediately: the estimated "spreading" of image equals about half a second during scanning of the vidicon and, apparently, is caused by the after-shining of luminophors.

Fig. 10 illustrates the spatial resolution of the tv device being tested; the standard is the spectrum of the K doublet of molybdenum on the photoplate; the thickness of the gadolinium oxysulphide layer was 71 μm in this case. In Fig. 11, it is shown that the increase of the thickness of luminophor layer (gadolinium oxysulphide) does not get worse substantially the spatial resolution. This is connected with very low light-transparency of luminophor powder: the light gets to the fiber-optic entrance window only from the thin layer of luminophor adjacent to it. The imperfect technology used in this case to deposit luminophor on the supervidicon entrance - airstream atomization of luminophor suspension in a solvent with sticking addition - makes it unavoidable the formation of thick (with very uneven relief) layers because of a great number of drops and, on the other hand, of "bald patchs". This results in a noticeable "grainness" of image and, the main thing, in the inefficient utilization of X-rays: in Fig. 9, given are not only the thicknesses of luminophor layers but also the measured transmissions of these layers (the supervidicon entrance and the "witness", which is intended for measuring the thickness and transmission of X-rays, were atomized simultaneously). The presented transmissions are of estimative nature. It is, however, seen that the threshold values for the flux density of the photons can be considerably decreased (points 0 in Fig. 9) if very fine luminophor powder (obtained after previous precipitation of large grains on the bottom of a vessel for preparation of suspension) is precipitated on the entrance window. Obvious is the following: the thickness of luminophor must not exceed the length of absorption of the light of roentgenoluminescence in it. In this case, not only the minimum values for the threshold flux densities of the photons can be achieved, but the spatial resolution, close to the cross size of the entrance window fibers, 10 μm, can be obtained reliably. In order to compare the sensitivity of a supervidicon with phosphor screen and that of X-ray vidicons, the following parameters were measured: threshold flux densities of the photons for non-commercial sample of the X-ray vidicon with a carbonglass entrance window, which is designed for defectoscopy of mobile objects and has an inertness of about 2 s and lateness time of about 0.5 s (Table 1); the times of writing down (storage times) of the prototype of an X-ray vidicon with controlled memory and carbonglass entrance window for operation with static objects (its spatial resolution is given in Ref. /1/) as a function of the flux density of the photons (Fig. 12).

It is clear that a supervidicon with luminophor screen extends the possibilities of televisualization of X-ray images, by moving both into the lower range of the threshold fluxes densities of the photons and into the longer-wave range of the X-ray spectrum.

Reference

/1/ O.P.Aleshko-Ozhevsky, V.P.Dycarev, V.A.Karpenko, T.M.Korolkova, N.S.Kuznetsov, V.E.Panchenko, X-ray topographic possibilities of a vidicon with controlled memory: its use on synchrotron radiation, Preprint 80-196, INF, Novosibirsk (1980).

Table 1

K - line	Mo β_1	Mo α_1	Cu β_1	Ni β_1	Cu α_1	Co β_1	Ni α_1	Fe β_1	Co α_1	Fe α_1	Cr β_1	Cr α_1
λ, Å	0.632	0.709	1.392	1.500	1.541	1.621	1.658	1.757	1.789	1.936	2.086	2.290
Phot.en., keV	19.605	17.476	8.904	8.263	8.046	7.648	7.477	7.057	6.929	6.403	5.945	5.414
Threshold flux dens. of phot., $cm^{-2} \cdot s^{-1}$	1.9x $x10^7$	1.4x $x10^7$	1.27x $x10^8$	4.7x $x10^7$	1.18x $x10^8$	7.0x $x10^7$	9.5x $x10^7$	1.03x $x10^8$	1.74x $x10^8$	2.40x $x10^8$	Not observ. at 9.3x $x10^7$	Not observ. at 4.71x $x10^8$

Fig.1.

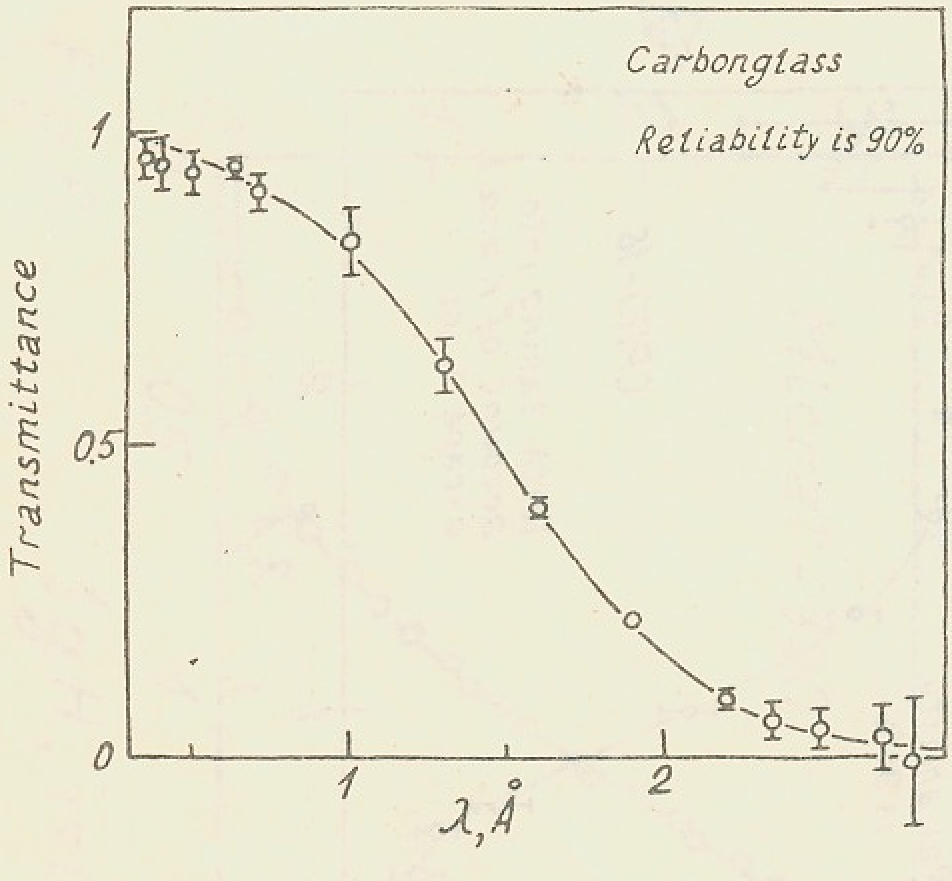


Fig.2.

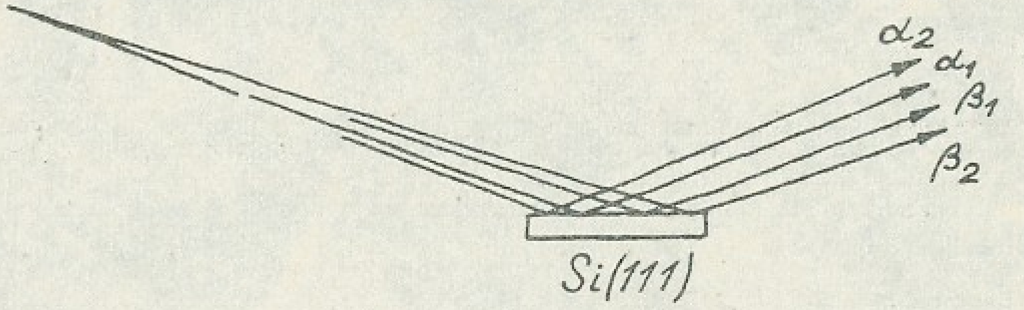


Fig.3.

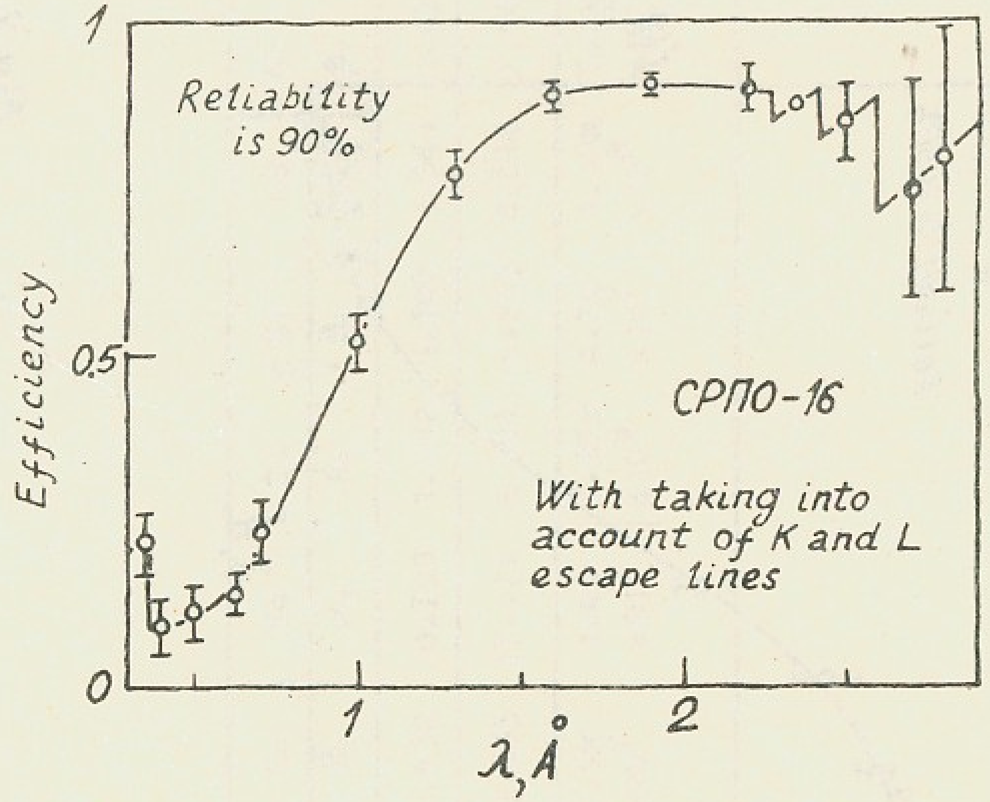


Fig.4.

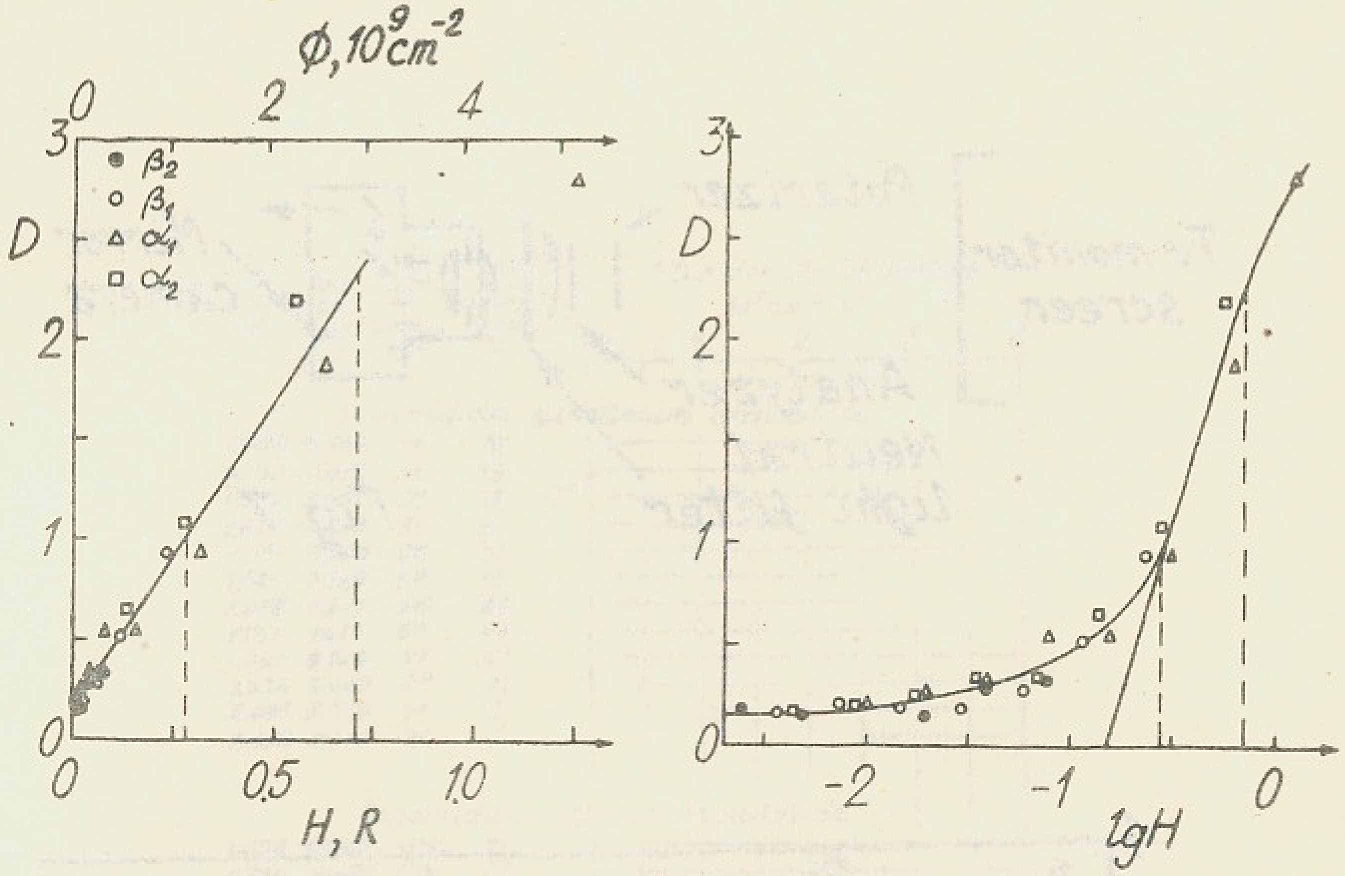


Fig.5.

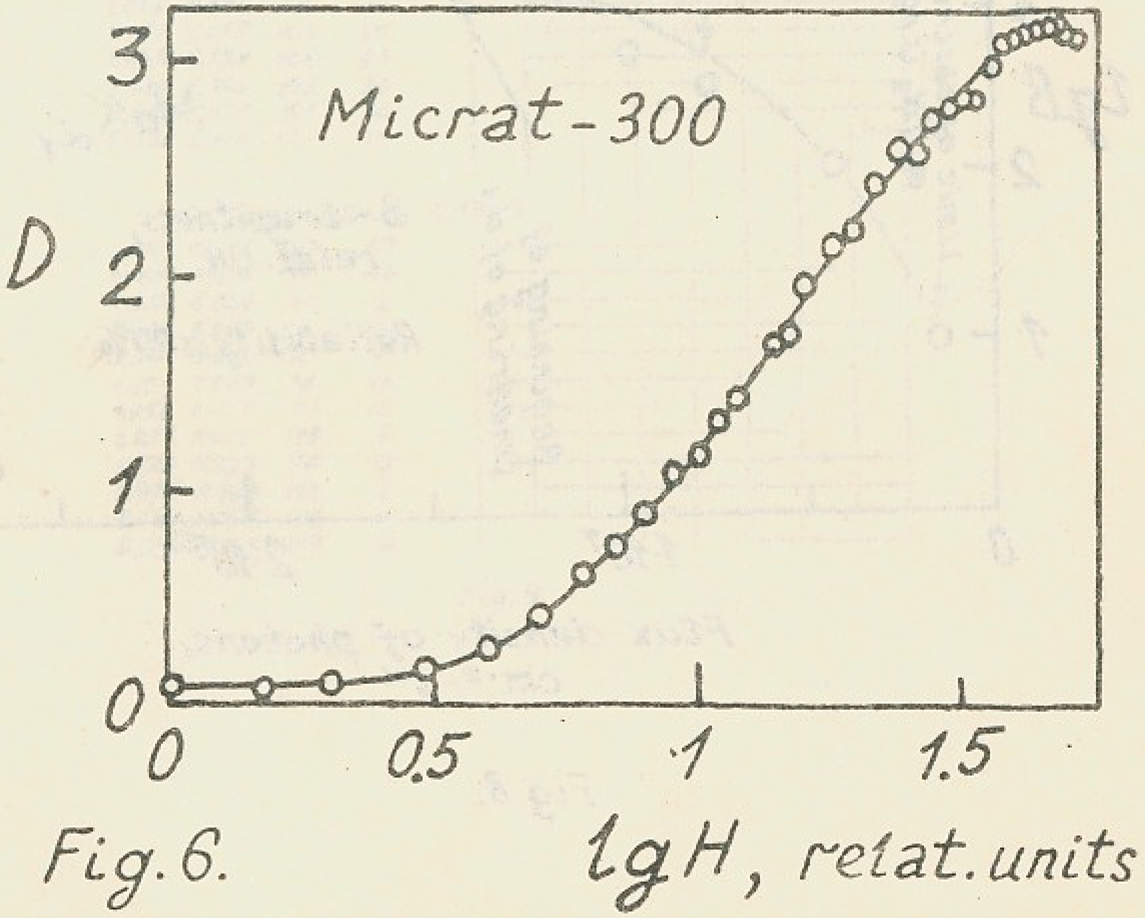


Fig.6.

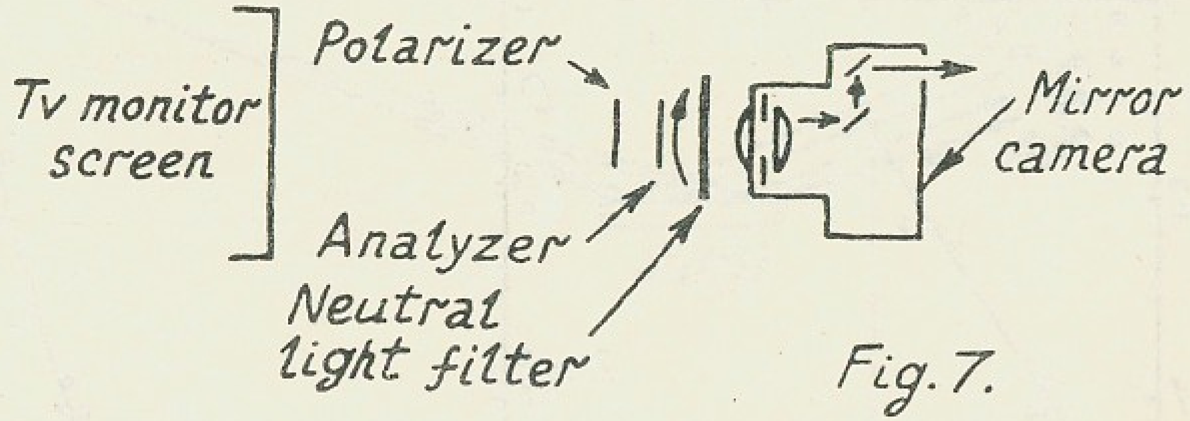


Fig. 7.

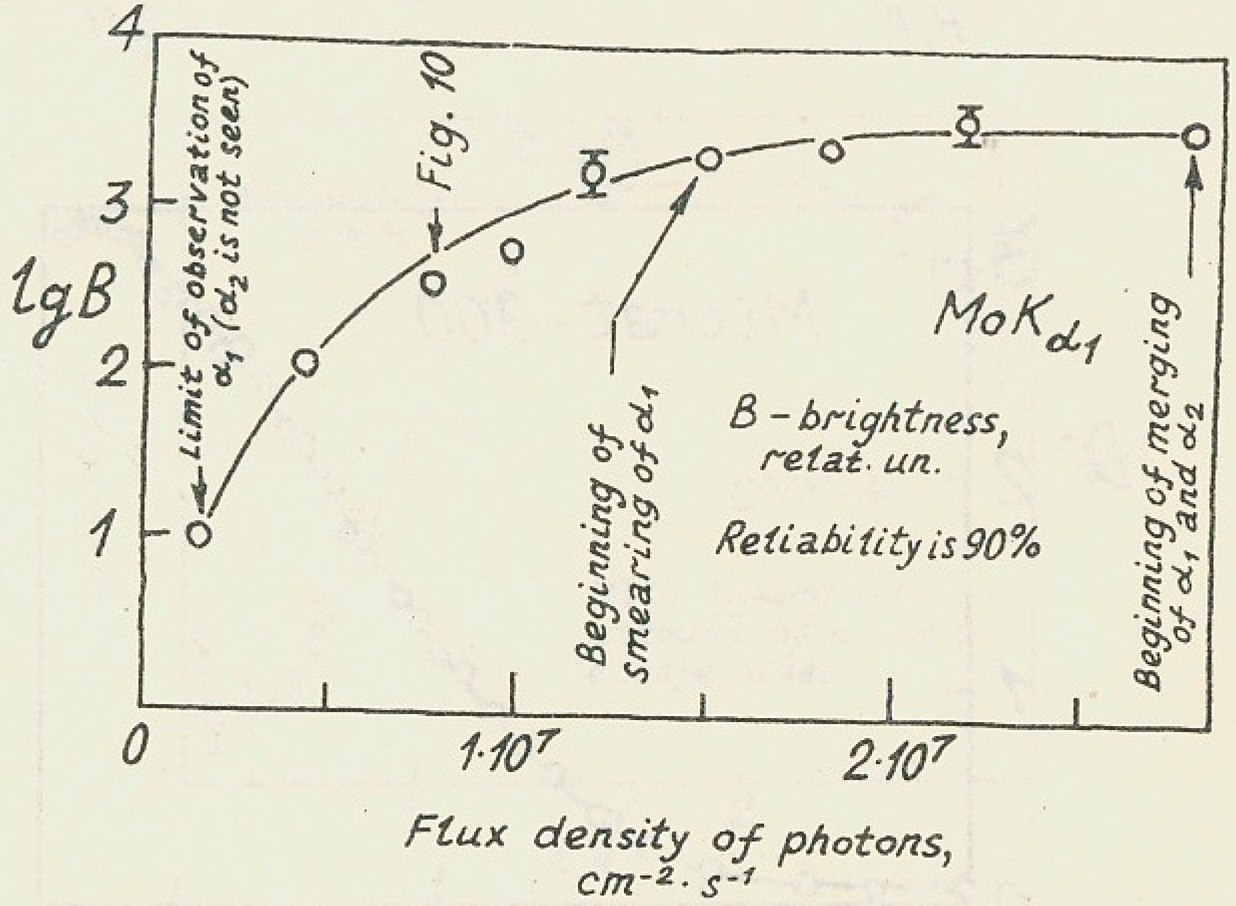
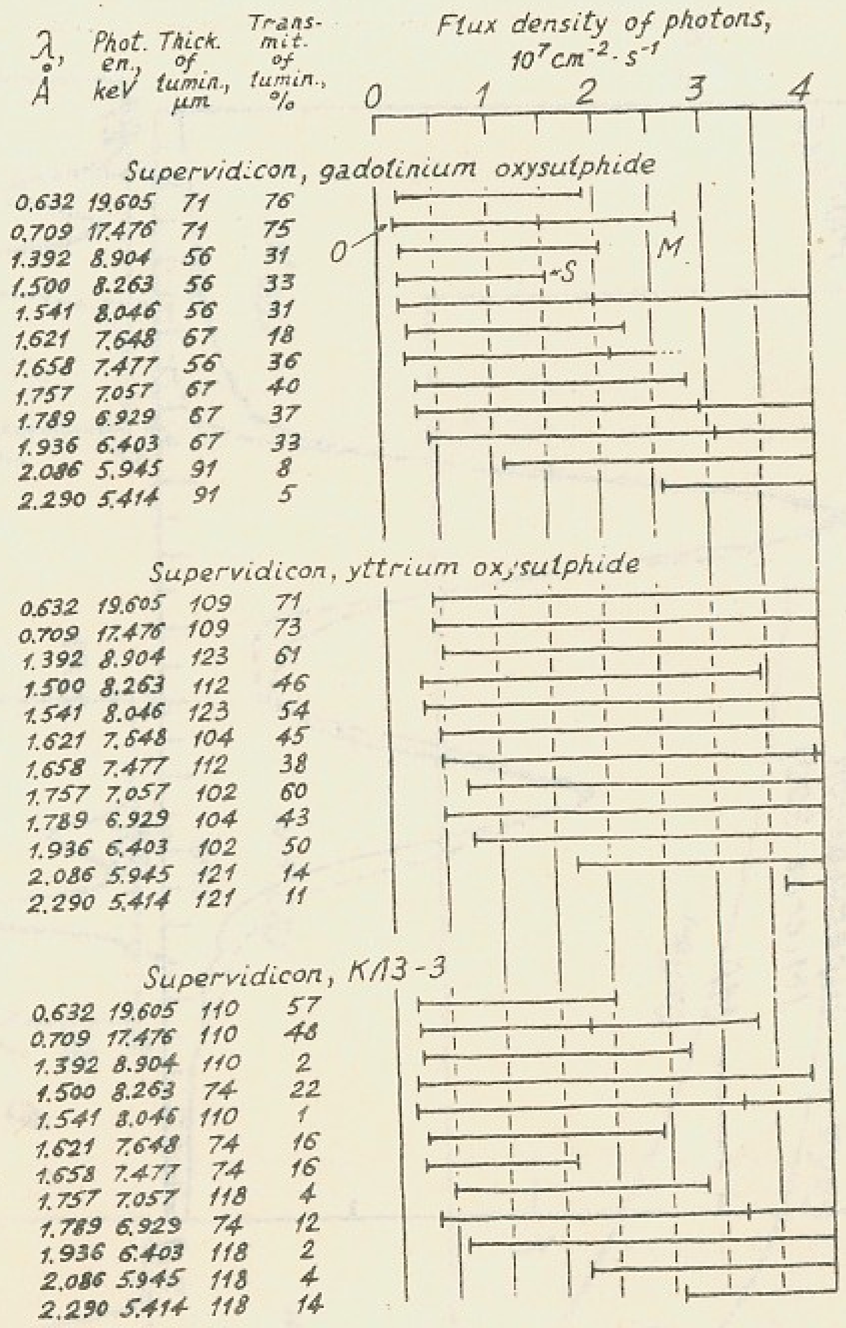


Fig. 8.



Supervidicon, gadolinium oxysulphide

λ, Å	Phot. en., keV	Thick. of lumin., µm	Trans-mit. of lumin., %
0,632	19,605	71	76
0,709	17.476	71	75
1.392	8,904	56	31
1,500	8.263	56	33
1.541	8,046	56	31
1,621	7,648	67	18
1,658	7.477	56	36
1,757	7,057	67	40
1.789	6.929	67	37
1.936	6.403	67	33
2.086	5,945	91	8
2.290	5.414	91	5

Supervidicon, yttrium oxysulphide

λ, Å	Phot. en., keV	Thick. of lumin., µm	Trans-mit. of lumin., %
0.632	19.605	109	71
0.709	17.476	109	73
1.392	8.904	123	61
1.500	8.263	112	46
1.541	8.046	123	54
1.621	7.648	104	45
1.658	7.477	112	38
1.757	7.057	102	60
1.789	6.929	104	43
1.936	6.403	102	50
2.086	5.945	121	14
2.290	5.414	121	11

Supervidicon, КЛ3-3

λ, Å	Phot. en., keV	Thick. of lumin., µm	Trans-mit. of lumin., %
0.632	19.605	110	57
0.709	17.476	110	48
1.392	8.904	110	2
1.500	8.263	74	22
1.541	8.046	110	1
1.621	7.648	74	16
1.658	7.477	74	16
1.757	7.057	118	4
1.789	6.929	74	12
1.936	6.403	118	2
2.086	5.945	118	4
2.290	5.414	118	14

Fig. 9.

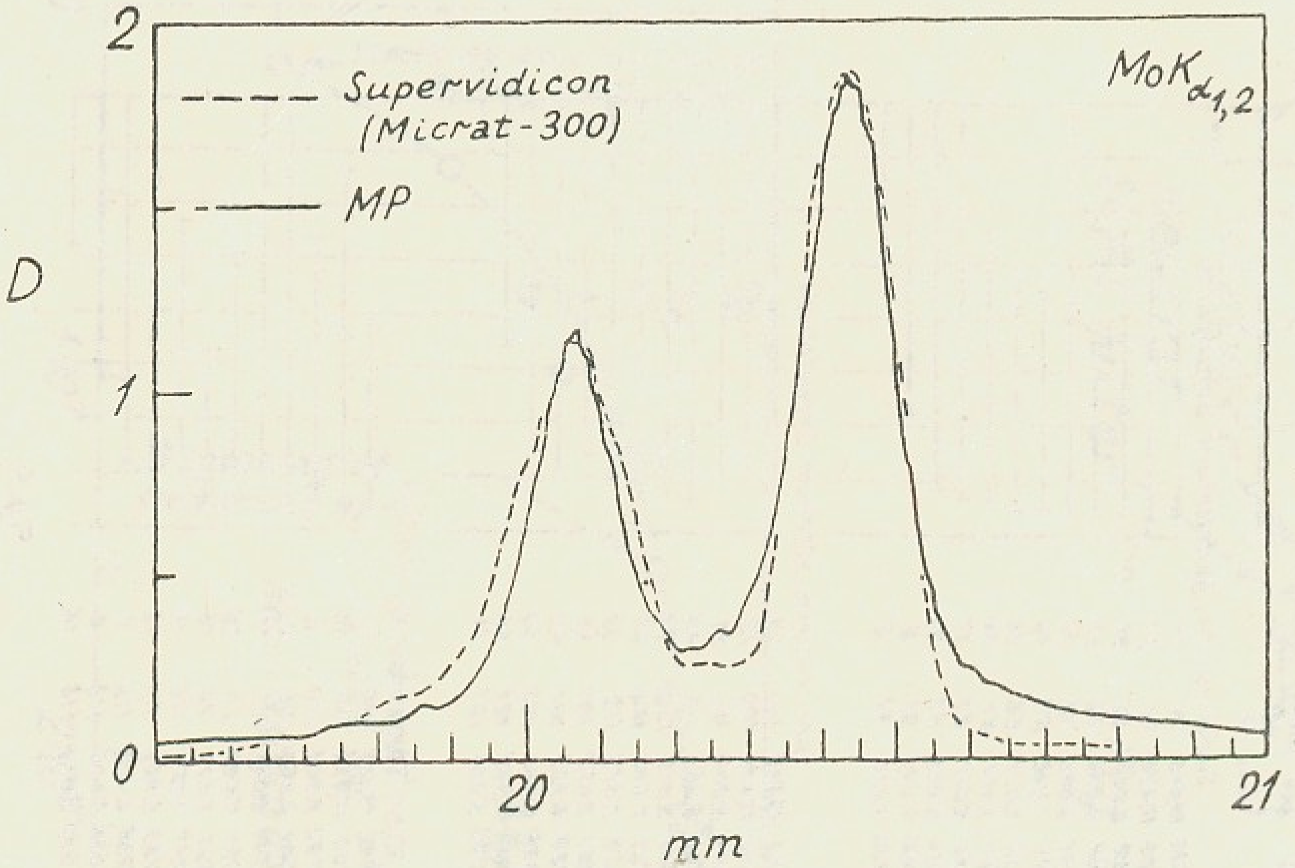
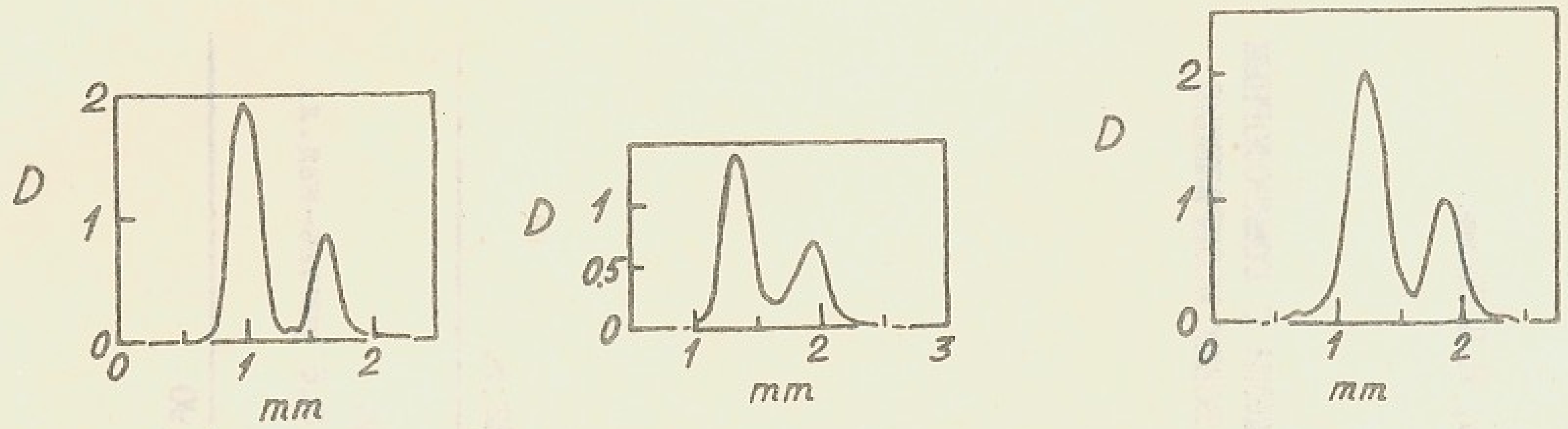


Fig. 10.



63 μm

127 μm

190 μm

Fig.11.

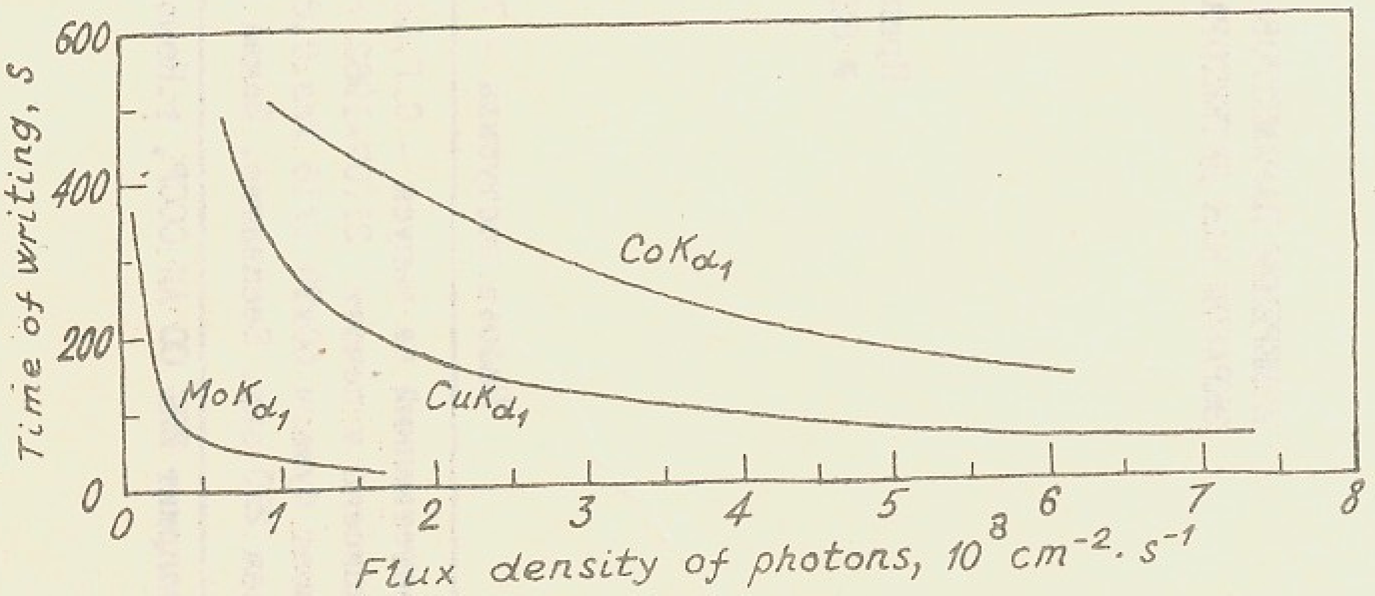


Fig.12.

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ИЗМЕРЕНИЕ ПАРАМЕТРОВ СУПЕРВИДИКОНА С ЛЮМИНОФОРНЫМ ЭКРАНОМ КАК ДЕТЕКТОРА РЕНТГЕНОВСКИХ ИЗОБРАЖЕНИЙ

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