CHARACTERISTICS OF AN LI-702-3 SUPERVIDICON AS AN ELEMENT OF A MULTICHANNEL PHOTON COUNTER

A.A. Makarov and V.A. Chikurov

Institute of Atmospheric Optics,
Siberian Branch of the USSR Academy of Sciences, Tomsk
Received June 5, 1989

The sensitivity, the "memory" characteristic, and the light characteristic obtained in recording signal-pulse images ~ 0.15 mm in diameter and λ = 569 mm with a supervidicon were determined experimentally. It is concluded that there exists an optimal intensity of the recorded image.

Multichannel photon counters (MPCs), used for detecting extremely weak images (for example, fluorescence spectra, Raman scattering spectra, etc.), are often constructed based on microchannel brightness amplifiers and picture tubes. In these devices the picture tubes are employed to count photoelectronic scintillations on the screen of the brightness amplifier. The scintillations counted are usually characterized as follows.

1. By the energy distribution of the photoelectronic scintillations (EDPES), which, for a highly efficient MPC, has a single-hump form.[1] For example, for a brightness amplifier containing two microchannel wafers laid in a chevron pattern, a large fraction of the scintillation energy (in photons) lies in the range $(2.5–300) \cdot 10^5$ photons/scintillation, and the most probable value is $\simeq 5 \cdot 10^6$ photons/scintillation.[2]

2. The duration of the scintillations, which does not exceed hundreds of microseconds.[3]

3. The average diameter, which does not exceed 0.1 mm.[4] Obviously, in this case the supervidicon, which records only the existence of scintillations, operates under different conditions that is usually the case in television, and for this reason there is virtually no published information on the basic characteristics of this regime — the light and "memory" sensitivity.

We assembled an experimental apparatus for determining these characteristics (Fig. 1). A pulsed voltage from a G5-56 oscillator or a constant voltage from the source E_2 was applied to an AL-307B LED with the help of the switch S_2. As a result the LED illuminated the diaphragm through a neutral light filter NLF with a pulsed or continuous flux of light. The image formed by the objective lens 0 of the diaphragm was constructed on the photocathode of an LI-702-3 supervidicon, installed in the PTU-50 applied television apparatus. The voltages on the electrodes of the supervidicon were set in accordance with the rated values. The image was displayed on the screen of the video control unit VC. The G5-56 oscillator, actuated by the first frame synchronous pulse (FSP) after the button S_1 of the former unit is pressed, also generated a delayed signal pulse, which actuates scanning of the S8-2 storage oscillograph. The video signal from the output of the PTU-50 unit was fed into the signal input of this oscillograph. Thus this apparatus made it possible to form on the photocathode of the supervidicon a small constant image or to simulate photoelectronic scintillations, and to record with the help of the oscillograph the video signal generated in these cases.

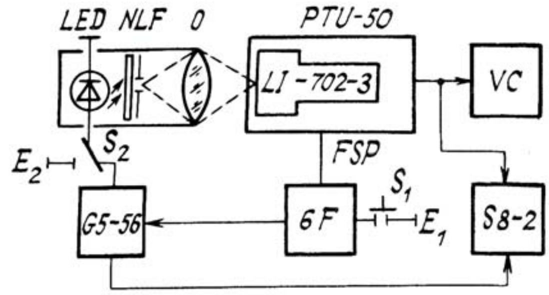

FIG. 1. Structural layout of the experimental apparatus.

The intensity of the image on the photocathode was evaluated (in lumens) based on the laws of geometric optics using the following relation:

$$E \simeq \Phi(I_{\text{LED}}) \left[\frac{R_{\text{d}}}{R_{\text{LED}}} \right]^2 \left[\frac{R_{\text{ob}}}{F} \right]^2 4\pi K_{\text{ob}} \; K_{\text{NLF}}$$

where $\Phi(I_{\text{LED}})$ intensity of the light from the LED as a function of the current I_{LED} flowing through it (handbook data); R_{d} is the radius of the diaphragm d; R_{LED} is the radius of the emitting part of the LED; R_{ob}, F, and K_{ob} are the radius, focal length, and transmission coefficient of the objective 0; and, K_{HLF} is the transmission coefficient of the neutral light filter NLF.

The experiment showed that the maximum sensitivity for a constant point image on a photocathode ≃ 0.15 mm in diameter is equal to $8 \cdot 10^{-12}$ lm. This corresponds to illumination of this point of $3.0 \cdot 10^{-3}$ lx or a flux of $3.0 \cdot 10^{4}$ photons/sec (1200 photons per frame). The signal/noise ratio at the output, determined visually with the help of the video control unit VC, was equal to unity. All further measurements were performed with the supervidicon illuminated with single pulses of light, which generate on the photocathode an analogous small image. In this case twice the flux ($2.4 \cdot 10^{3}$ photons per light pulse) was required to obtain the same signal/noise ratio at the output. The drop in sensitivity can be explained (partially) by the incomplete reading of the charge of the target of the, picture tube per frame. Since the potential relief on the target caused by the small image is read in several lines of a half-frame, a packet of pulses is formed in the video signal. In the course of the experiment it was observed that as the intensity of illumination by the light pulse is increased the width of this packet (the number of pulses) increases the most while the average amplitude of the pulses increases the least. Within the variable intensity of pulsed illumination an increase of the "diameter read" D (width of the packet) by more than a factor of three was recorded (Fig. 2). The diameter was determined from the number of lines in a half-frame, which refer to the image being read. The observed effect can be explained by the spreading of the charge formed by the image on the target of the picture tube. Here and subsequently the intensity of the light pulses was changed by varying both the duration and the power of the illumination, making the assumption that the law of the interchangeability holds for the picture tube,[5]

$$i_s = \text{const at } P_i/\tau_p = \text{const},$$

where i_s is the current of the picture-tube signal; τ_p is the duration of the light pulse; and P_i is the power of the pulse.

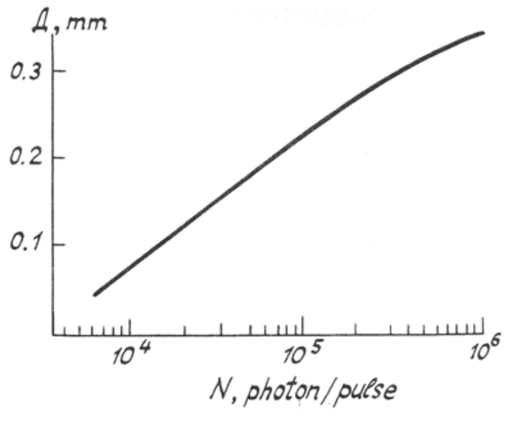

FIG. 2. The diameter read" versus the intensity of pulsed illumination.

Figure 3 shows experimentally obtained "light" characteristics. Curve 1 characterizes the dependence of the average energy of the packet of pulses while curve 2 characterizes the dependence of the average amplitude of the packet of pulses in the first half-frame after the light pulse on the intensity of this pulse. The results obtained confirm that the intensity of illumination depends directly on the magnitude of the spreading of charge on the target. The "memory" characteristic of the supervidicon was also evaluated in the experiment. To this end, the supervidicon was illuminated with a single light pulse and the average energy of the packet of pulses in several half-frames following one another after the light pulse was measured. Experiments showed that within the previously received intensities of the illumination pulses (10^3–10^6 photons/pulse) the residual signal in the second frame did not exceed 10% (rated value). The results of the measurements are summarized in Table I.

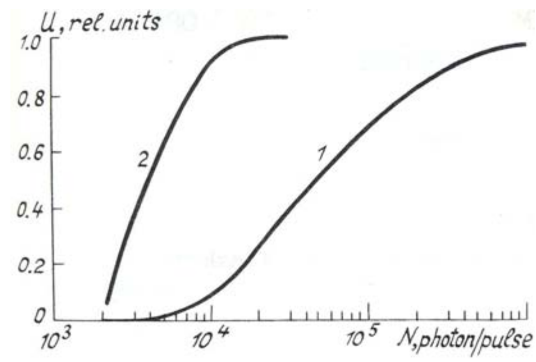

FIG. 3. The average energy of a packet of pulses (1) and the average amplitude of a packet of pulses (2) versus the intensity of pulsed illumination.

TABLE I

Number of half-frame	1	2	3	4
Residual signal	100%	22%	7%	1.5%

The experimental measurements showed the following.

1. The LI–702–3 supervidicon can read single-electron scintillations from the screen of the microchannel brightness amplifier.

2. There exists an optimal intensity of the scintillation read E^0_{sc}, because when $E_{sc} < E^0_{sc}$ the uncertainty in the determination of the coordinates of scintillation increases owing to the noise of the TV apparatus, while for $E_{sc} > E^0_{sc}$ it increases owing to an increase in the spreading of the charge on the target (E_{sc} is the intensity of scintillation). Since there is a spread, which is at least 10^2, in the intensities of the scintillations read it can be

conjectured that to improve the accuracy of measurements performed with MPCs the intensity of the low-energy "signal" scintillations should fall within the limit of sensitivity of the picture tube. Obviously, this can be easily realized by, for example, varying the efficiency of the optics employed to "transfer" the image from the screen of the microchannel amplifier to the photocathode of the supervidicon.

3. As we have already mentioned, the dynamic range of the intensities of the counted scintillations may not be less than 10^2, so that to prevent the same scintillations from being counted more than once not less than four half-frames must be reserved in order to erase the target of the picture tube or a target erasure mode must be employed.

REFERENCES

1. A. Wick Robert, Appl. Opt., **26**, No. 16, 3210 (1987).
2. N.V. Zamyatin, V.M. Klimkin, G.V. Fedotova, and S.D. Chikurov, Opt. Atmos., **2**, No. 6, 665 (1988).
3. N.V. Zamyatin, V.M. Klimkin, and S.D. Chikurov, Opt. Atmos., **1**, No. 3, 104 (1988).
4. M.M. Butslov, B.M.Stepanov, and S.D.Fanchenko, *Image-Converter Tubes and their Applications in Scientific Research* (Nauka, Moscow 1978).
5. A.V.Petrakov and B.M.Kharitonov, *High-Precision Television Complexes for Measuring Fast Processes* (Atomizdat, Moscow. 1979).