Increasing the noise immunity of optical-electronic systems based on video cameras with an optical converter

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Abstract. The luminophor coating of an electro-optical converter afterglow introduces an additional error to the measurement. The ratio that allows to calculate the intensity of spurious illumination at each subsequent frame have been determinate according to experimental data of luminescence kinetics. The proposed method increases the noise immunity of the electro-optical converter by eliminating luminophor afterglow.

1. Introduction
Application of optoelectronic systems based on video cameras with an electro-optical converters in scientific experiments [2], related to the problem of low sensitivity at high speed shooting and low exposures. The afterglow time of luminophor, covering the screen of OEC, presence is another problem. For some fields fast processes research the screen residual glow is the main limiting factor [1]. In different with low speed experiment where afterglow can be cleaned by several miniature lamp brief (5-10 seconds) screen backlight [4, 5] the proposals for solving this problem for high speed experiment without changing the hardware of the OEC were not found.

2. Experimental techniques
Experimental stand, which is composed of following equipment (fig. 1a): 1 - optical bench; 2 - sparkler; 3 - high speed camera VideoSprint based on 4 electron-optical converter (EOC); 5 – PC, was build for accomplish the task. Self-luminous sparkling fire was used as source of luminescence particles provoking glow luminophor. Flying glowing particles are shifted by a distance depending on their velocities during the accumulation of charge in the light-sensitive sensor area. Stroboscopic effect achieving by additional EOC shutter firing on the interval photocathode – micro channel substrate. At the same time on the EOC screen the number of images equal to the number of additional shutter releases N is forming. This track of moving particle is divided into N parts. The average brightness of each track part is forming with contribution of particles radiation which was absorbed by photosensitive element during the exposure time. It is obvious that in the filmed sequence of combustion particles frames, the brightness of the left track will fade gradually from frame to frame, if the time of luminophor afterglow is longer than frame interval. According to that it becomes possible to study the kinetics of luminophor afterglow.
3. Luminophor afterglow time measurement

To determine the decay time [3] the search for a sequence of frames, which was clearly evident gradual extinction of the moving object luminous trail registered in the image, was carried out. The study track must be chosen to avoid crossing with other particles tracks precipitating into the viewing area of camera. Afterglow luminophor observed in a frame sequence and the brightness profile line is shown in Figure 1. b). The luminescence intensity of the luminophor corresponds to the brightness of the pixels constituting the tracks. The measurements were carried out by the ImageJ program. The brightness measurement of photosensitive cells, which registering radiation one of the particle track part, is held in each frame where the track is still visible. The measured brightness was normalized by the maximum value. The measured data of time depended changing the track brightness shown in Figure 2. The coefficient, characterizing residual luminophor luminescence from frame to frame decreasing, is possible to determine by the plot.

![Figure 1. The experimental setup (a), observation of luminophor afterglow](image)

![Figure 2. The time dependence of the residual luminescence brightness (a), the experimental data approximation (b).](image)

4. Electro-optical converter noise immunity increasing method

In order to reduce the error introduced by the luminophor afterglow, it is necessary to subtract remaining afterflow background of previous frame from the study frame. Drawings explaining the process of removing the residual luminescence OEC screen shown in Figure 3.
Let registered by each detector brightness on the first frame $I_1$ has noise $I_{\text{noise}}$ components and useful signal $I_{01}$:

$$I_1 = I_{\text{noise}} + I_{01},$$

Then the next frame is due to $I_{\text{noise}}$, $I_{02}$ and afterglow of luminophor $I_{1\text{res}}$:

$$I_2 = I_{\text{noise}} + I_{02} + I_{1\text{res}},$$

And $I_{1\text{res}}$ may be calculated from the calculated law of luminophor luminescence decay. Using inter frame subtraction, the accuracy of the tracks brightness measuring on the 30% can be achievable:

$$I_{1\text{res}} = \mu I_1,$$

$$I_2 = I_{\text{noise}} + I_{02} + I_{1\text{res}} - \mu I_1$$

where $\mu$ is the determined from the graph and depending on the type of luminophor afterglow decay coefficient.

The brightness measurement accuracy increasing method performed in ImageJ program consists four items:

1. Creation a duplicate of processed frame. This step creates a new window containing a copy of the active frame or rectangular selection on it. For stack, specify a range of channels (c) fragments (z) and shots (t) is possible.

2. Deleting the last frame in original file and first frame of duplicate file.

3. In accordance with the luminescence decay graph the coefficient, which is necessary to multiply the brightness value of each pixel in subtracted file, is selected. Changing the brightness of each pixel is performed by using command "Macro". This command performs arithmetic operations on each pixel of the image, using the user specified equation. This tool can be used to create a completely new image, or perform precise pixel manipulation of existing images.

4. Inter frame subtraction (subtracting the original file from duplicate) is carried out in the image calculator.
5. Conclusion
The proposed method of increasing the noise immunity of the OEC allows to consider remaining afterglow in the study frame, subtract it, thereby increasing the accuracy of brightness temperature measurements up to 30% without changing the hardware. The method is limited to the specific type of the luminophor and the detected objects radiation intensity.

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