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Method of Elimination of the Residual Lumination of the Luminescent Covering of Screen

Marina B*, Narkiza B, Borodina K and Sorokina S

Department of Physics and General Technical Disciplines, Institute of Technical Systems and Information Technologies of Yugra State University, Russian Federation

Abstract

In the laboratory of physics and general technical disciplines of the Ugra State University, an optoelectronic measuring system based on a high-speed Video Sprint video camera is used for research. The calibration of ECO has revealed a number of nonlinear effects. In the paper, a method is described that allows eliminating the afterglow of the screen of the image converter. The method is based on revealing the law of attenuation of the afterglow of a phosphor. As a result of the application, data loss is reduced, the signal-to-noise ratio is increased.

Introduction

The main indicator of the quality of the measuring device is the amount of information obtained from it about the value of the measured quantity. The general equation of any measuring device (Novitsky's theory):

$$\gamma^2 \cdot t \cdot P = const.$$

Concerning other measuring means, the optoelectronic system (ECO) appreciably wins the information capacity. Information capacity Ie of one element of the photosensor:

$$I_э = \log_2 m,$$

Where m quantization levels, then the information capacity of the system

$$I = N \times n \times \log_2(m+1),$$

Where N is the number of elements in the frame, n is the number of transmitted images per second, m is the number of brightness gradations. Therefore, for studies of fast processes, ECO is often chosen [1-5]. At the same time, video shooting takes place in conditions of low irradiation of the photosensitive sensor. To compensate for the lack of illumination, an electron-optical converter (EOP) is used on microchannel plates (MCPs). In such conditions, the shortcomings of the optoelectronic tract have a significant effect on the results of the experiment. In the laboratory of physics and general technical disciplines of the Ugra State University, high-speed processes of self-propagating high-temperature synthesis, high-speed micropyrometry, etc. are engaged in research. An optoelectronic measuring system based on a high-speed Video Sprint video camera is used for research. The calibration of ECO has revealed a number of nonlinear effects. In the general case, the brightness of the screen of the image intensifier has a nonlinear dependence of the luminescence intensity of the phosphor. In addition, a long afterglow leads to the appearance of false images in the frame. This paper describes a method for eliminating the afterglow of a phosphor screen.

Experimental Setup

The functional scheme of the work of ECO can be presented as follows (Figure 1) [6-9].

Photocathode current [7]

$$i_{fk} = \eta \Phi(t),$$

Where η is the sensitivity of the photocathode, $\Phi(t)$ is the luminous flux, which can be considered constant during small accumulation times. The gain of the MCP is 10^5-10^6, the amplified current is described by the formula [6-14].

$$I_{fk} = \mu \eta \Phi.$$

In the correcting-accelerating field of the MCP-screen interval, the electron beam is focused. For gating, the photocathode gap is used-the input of the MCP. Under the influence of the electron flux incident on the screen, the phosphor begins to glow if the electron energy exceeds the threshold value. Which depends on the nature of the phosphor, the method of its production? Due to the luminescence of the screen, the electronic image is converted into visible. For each phosphor, from some moment, the proportionality between brightness and current density becomes nonlinear. The effect of saturation with respect to the current depends on a large number of factors, but other things being equal, it is specific for each phosphor. For the current density does not exceed 100 μA/cm², the dependence of the intensity (brightness) L of the phosphor emission on the current density of the exciting electron beam I_{fk} and the applied voltage U. When a finite area dS of the phosphor screen of an EOS having an energy brightness L_e and source dimensions dS << l to him:

$$L = kf(j_{fk})(U - U_0)^q,$$

$$\Delta^{\phi} = L.\frac{dS.S_D}{l^2},$$

$$I_{PH} \sim n_e.\frac{k.f(j_{fk}).(U - U_0)^q}{hv}.dS.S_D$$

Where q-for different phosphors takes the value from 1 to 3; k is a constant that depends on the nature of the phosphor; $f(j_{fk})$ is a function expressing the dependence of the luminescence intensity on the electron beam current density; U_0 is the minimum voltage required

***Corresponding author:** Marina B, Department of Physics and General Technical Disciplines, Institute of Technical Systems and Information Technologies of Yugra State University, Khanty-Mansiysk, Chekhov Street, 16, 628012 Russian Federation, Tel: 08- (3467) -357-797; E-mail: m_boronenko@ugrasu.ru

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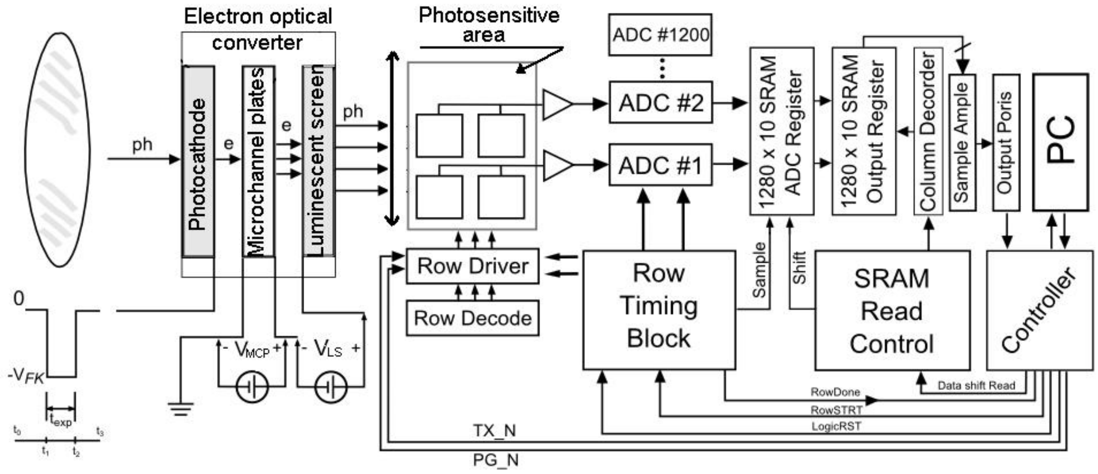

Figure 1: Functional operation circuit ECO [7-10].

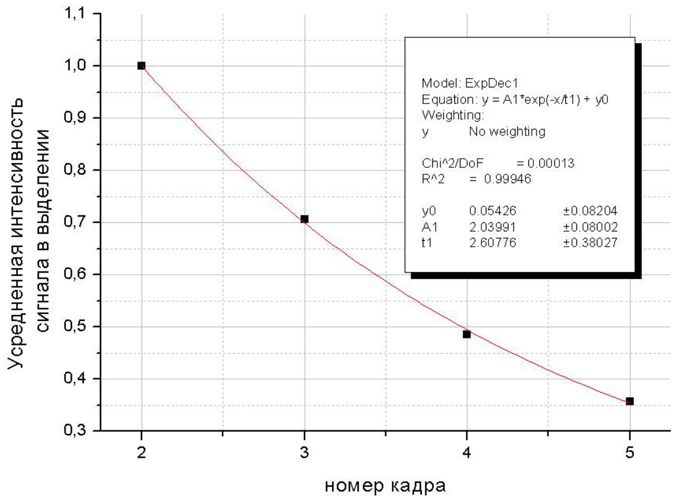

Figure 2: The regularity of the decay of the afterglow.

for the electron to pass through the surface layer; Flux Φ_e; S_D-area of the diode; n_e is the efficiency of conversion of photons into electrons. Thus, in the general case, the brightness of the screen of an image tube has a nonlinear dependence of the luminescence intensity of the phosphor.

Readout of the signal from the screen of the image intensifier occurs in the photosensitive region of the CMOS matrix. The electronic shutter of the global type is implemented in the ECO. To receive and process information, ImageJ was chosen as a freely distributed program written in the Java programming language. Programs written in Java are very fast, capable of processing data in real time. ImageJ provides all the necessary tools for image analysis. To automatically start the video shooting, we used hardware synchronization with the TTL level signal from "Arduino", connected to the camera via the external synchronization connector. To synchronize the start of video shooting on an event, a sketch was written in the Arduino language.

Method for Eliminating Phosphor Afterglow

The experimental data of the ECO represent the object under study in the form of an image-the spatial distribution of the energy illumination in the plane (a two-dimensional array of points). The pixel represents the energy illuminance at the appropriate grid location. When using ECO as a high-speed micro-pyrometer, the brightness of pixels in the gray scale is measured. The brightness micropyrometry depends strongly on the accuracy of measuring the brightness of micro-objects in the image. The residual glow of the phosphor is observed in several consecutive frames. Therefore, afterglow very much interferes with measurements. It is necessary to get rid of the afterglow. The idea of the method is as follows. If you know how much "passes" the additional brightness from frame to frame, you can enter a correction factor. In the process of calibration we obtain video frames of one short flash. The signal is observed on several frames. We reveal the regularity of the damping of the phosphor. Calculate the correction factor. For each phosphor there will be a coefficient.

The regularity of the attenuation of the residual luminescence emission is determined as follows. Select an area (a group of pixels) in which a new signal is present. We measure the intensity of the signal (brightness) in this region at several (as long as there is afterglow) consecutive frames. The allocated area should not receive another signal. Based on the data obtained, we construct the dependence of the average brightness of the pixels of the selected region on time (Figure 2).

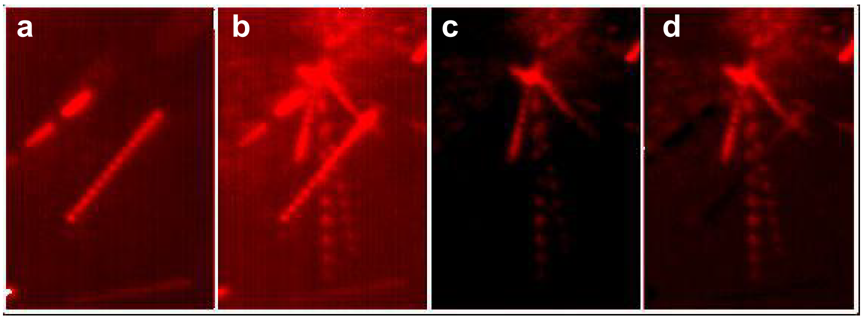

Figure 3: a) the first frame; b) the second frame; c) interframe difference; d) the interframe difference, taking into account the regularity of the afterglow of the phosphor.

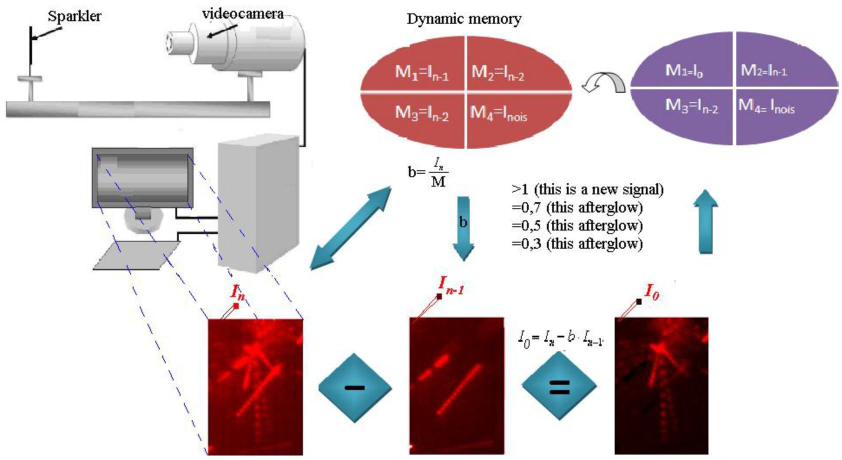

Figure 4: Part of the algorithm, pixel-by-pixel processing.

To reduce the error introduced by the afterglow of the phosphor, it is necessary to subtract it. Let the current frame (n) contain the new signal I_{02} and the afterglow of the previous frame I_{nois}. For manual analysis of one frame (area of interest), the afterglow of frames (n-4) ... (n-2) can be neglected. With the usual interframe difference, a uniform coefficient of 0.7 is introduced for all pixels of the subtracted frame. In Figure 3c, the result of the usual interframe differences. In Figure 3d, the interframe difference taking into account the afterglow. Obviously, in the first case there is data loss.

To get a more accurate picture and automate the process, you can use the algorithm (Figure 4).

Thus, the algorithm for accounting for the phosphor afterglow allows suppressing the non-linear afterglow effect, to avoid data loss and to increase the signal-to-noise ratio without changing its hardware part of the ECO.

Main Results and Conclusions

The average time of the residual luminescence of the phosphor covering the screen of the phosphor is established; due to the processes of the recharge in the channels of the photomultiplier is 0.4 ms. Up to now, the problem of residual phosphor luminescence has been solved by hardware methods. A method for eliminating afterglow is proposed, based on the discovery of the law of attenuation of the afterglow of a phosphor. The method allows you to increase the signal-to-noise ratio and avoid data loss.

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