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Effect of pro-proximity pulse voltage on the noise characteristics of generation III low-light-level image intensifiers

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ABSTRACT

To improve the noise performance of low-ligh-level (LLL) image intensifiers, the evaluation of the noise characteristics of a typical generation III image intensifier has been made through the measurement of signal to noise ratio at the output end (SNR_{out}) of this image intensifier in different work conditions. One of the most meaningful work is to discuss the effect of the pro-proximity pulse voltage applied between photocathode and microchannel plate (MCP) on the SNR_{out} of a sample of LLL image intensifier (2008III138). The experimental result shows that the optimal values of voltage across GaAs photocathode and that across MCP are −300 V and 800 V, respectively. More importantly, the optimal values of high level, low level, and duty circle of the pro-proximity pulse voltage are −300 V, 0.2 V, and 60%, respectively. This research will provide a theoretical guide and experimental support for developing low noise LLL image intensifiers.

1. Introduction

Many characteristics must be considered in the evaluation of any imaging system [1–4]. The apparently dominant characteristic for a Low-light-level (LLL) image intensifier is the noisy appearance of the intensified image [5,6]. This image is made up of numerous scintillations which are each the result of one photon being detected at the primary photocathode. Particularly, for an actual LLL image intensifier, the noise characteristics varies when it is in different work conditions such as the applied voltage. To obtain an optimal value of the applied voltage, the evaluation of this noise characteristics is needed.

Theoretically, the noise characteristics of a LLL image intensifier should be described by its noise factor [7]. However, in fact, since the signal-to-noise ratio at the input end (SNR_{in}) of the image intensifier is closely related to the illuminance of incident light, the signal-to-noise ratio at the output end (SNR_{out}) of the image intensifier is naturally introduced to denote the noise characteristics of a LLL image intensifier [8]. More importantly, the measurement of SNR_{out} has been an effective tool to evaluate the noise characteristics of LLL image intensifiers, and then the SNR_{out} has also been an important parameter to describe the imaging performance of a LLL image intensifier. With the advent of image intensifiers emloyed autogated

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power supply [9], the effect of pulse voltage on SNR_{out} does merit concern. Unfortunately, at present, most research into the SNR_{out} has focused on the effect of direct current (DC) voltage on SNR_{out} [5–7,10,11], and relatively little attention has been paid into the effect of pulse voltage on SNR_{out}. Therefore, in this paper, by adjusting the duty circle of pulse voltage applied between the potocathode and microchannel plate (MCP), i.e., the duty circle of pro-proximity pulse voltage, we have measured the SNR_{out} of a generation III LLL image intensifier, and thus its noise characrteristics have been effectively evaluated.

2. Measurement principle

The value of SNR_{out} of a generation III LLL image intensifier is affected by the measurement conditions, and these conditions mainly include the illuminance of incident light, the diameter of light spot, and a bandwidth of the system [6]. Thus, it is necessary to specify the conditions for the measurement. Those most commonly used conditions are an incident illumination of 1.08×10^{-4} lx from a tungsten filament at a color temperature of 2856 ± 50 K, a light spot of 0.2 mm diameter, and a bandwidth of the system of 10 Hz [12]. The measurement principle is as follows:

First, for a LLL image intensifier in normal operation, when a beam of light with an illumination of 1.08×10^{-4} lx is irradiated to the circular area of 0.2 mm diameter at the center of photocathode, a circular spot is formed on the phosphor screen. The diameter of this circular spot is defined as a multiplication of the diameter of incident light spot and the magnification of this image intensifier. Second, the output light is detected by a low-dark-current photomultiplier. After suitable amplification and filtering, the alternating current (AC) component (root mean square) and DC component (averages) of the signal with the input light are determined, respectively. Similarly, the AC component and DC component of the background brightness signal without the input light are also measured, respectively. Finally, the SNR_{out} can then be obtained from the following equation [12]:

$$SNR_{out} = K \cdot \frac{S_{dl} - S_d}{\sqrt{{N_{al}}^2 - {N_a}^2}} \cdot \sqrt{\frac{1.08 \times 10^{-4}}{E}} \cdot \sqrt{\frac{3.14 \times 10^{-8}}{A}}, \tag{1}$$

where S_{dl}, N_{al} represent the DC component and AC component of the output signal with the input light, respectively, S_d, N_a denote the DC component and AC component of the output signal without the input light, respectively, E is the actual incident illumination, A is the circular spot area at the photocathode, and K is correction factor. Additionally, K is governed by the properties of phosphor screen and the cut-off frequency of measurement system. In this paper, K is normally taken as 1.06.

3. Measurement system

Fig. 1 shows that the schematic diagram of SNR_{out} measurement system for LLL image intensifiers, it consists mainly of light source, filter, integrating sphere, optical system, power supply module, signal acquisition and processing module, industrial computer, and corresponding testing software. The workflow of this measurement system is as follows:

(1) The light from the light source module which is made up of halogen lamp, filter, and aperture enters into the integrating sphere, and then after multiple diffuse reflections, the uniform light is generated. Subsequently, this uniform light enters into the test box and irradiate the input surface of the photocathode through an aperture of 0.2 mm diameter and conjugate lens. Consequently, the required incident illumination of 1.08×10^{-4} lx can be achieved.
(2) The image on the input surface of the photocathode is intensified by a LLL image intensifier, and its diameter is dominated by the multiplication of this image intensifier.
(3) By using a low-dark-current photomultiplier and the signal acquisition and processing units, the output signal is detected and then processed. Furthermore, according to Eq. (1) and with the aid of the test software, the SNR_{out} of a LLL image intensifier can be obtained.

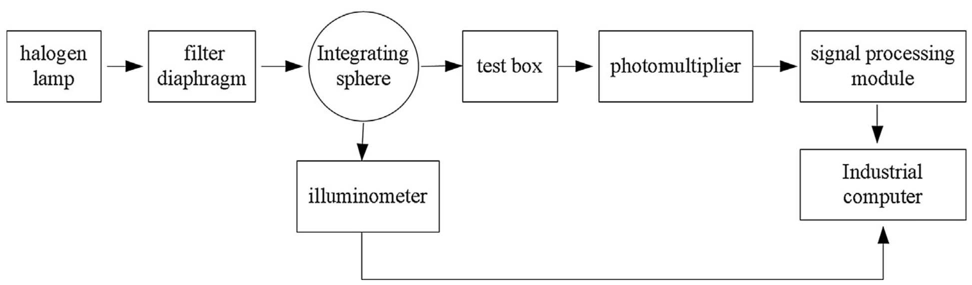

Fig. 1. Schematic diagram of SNR_{out} measurement system for LLL image intensifiers.