Monochromatic light sources in testing image intensifier tubes

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Abstract— Military standards and literature sources recommend use of polychromatic light source of 2856K color temperature in testing image intensifier tubes. Tungsten halogen bulbs are standard sources of radiation used in commercially available test stations. However, there are two main disadvantages of tungsten bulbs: short life time and temporal changes of both light power and light spectrum. Application of monochromatic semiconductor sources in testing of image intensifiers as possible alternative of halogen bulbs is analyzed in this paper. It is shown that, if calibrated properly, monochromatic semiconductor sources can be used in stations for testing image intensifier tubes.

Military standards require use of polychromatic light sources of 2856K color temperature in testing image intensifier tubes[1.a.i.[1]-1.a.i.[6]]. Tungsten halogen bulbs have been standard sources of radiation used in commercially available test stations for last few decades in testing image intensifier tubes [1.a.i.[7],1.a.i.[8]]. However, tungsten halogen bulbs have several significant limitations. First, they are not stable and emitted flux varies significantly in time. Second, they are characterized by short life time. Third, due to significant temporal inertia it is necessary to use mechanical shutters to enable tests of temporal characteristics of image intensifier tubes (II tubes).

Sensitivity of image intensifier tubes depends significantly on wavelength. Therefore, illumination of the photocathode with 2856K color temperature light is not equivalent to illumination with monochromatic light of the same radiation power. However, let us analyze if properly calibrated monochromatic sources can replace 2856K color temperature halogen bulbs in test equipment to be used for testing image intensifier tubes and if accurate measurement of photometric parameters of II tubes is still possible.

Quantitative relationships between input illuminance and output luminance is measured during the photometric tests of II tubes. The MIL standards state very precisely the necessary illuminance levels of 2856K color radiation to be used during measurement of photometric parameters of II tubes. The conversion coefficient between the illuminance level of 2856K light and the equivalent illuminance level of monochromatic light depends on spectral sensitivity curve of the tested tube that can vary with different tubes. Therefore we should use different conversion coefficients in order to calibrate properly the monochromatic source used during tests of tubes of different spectral sensitivity.

This feature is a significant drawback of semiconductor light sources but still in case of testing large number of II tubes of the same spectral sensitivity such monochromatic sources should be an interesting alternative of typical halogen bulbs.

Here we will analyze possible application of monochromatic semiconductor sources (LED diodes) in testing of image intensifier tubes. These monochromatic sources are much more stable, are characterized by negligible temporal inertia and do not cause polychromatic aberration. Such sources are used sometimes in commercially available stations for testing II tubes [1.a.i.[7],1.a.i.[8]]. However, so far their applications have been limited to use in measurements of imaging parameters (resolution, MTF, image quality etc) of II tubes when, according to MIL standards, requirements on accuracy of illumination level are low. Here we are to investigate if it is possible to use semiconductor light sources in testing photometric parameters of II tubes (luminous sensitivity, luminance gain, etc) when requirements on accuracy of illumination level are high.

In order to calibrate properly monochromatic source to be used instead of standard polychromatic light sources we will need an instrument that is sensitive to both polychromatic and monochromatic light. Let us make an assumption that we will use typical illuminance meters of spectral characteristics identical as spectral characteristics of humans eye as the sensing instrument of both polychromatic and monochromatic illumination at tube photocathode plane. The illuminace meters of sensitivity over 1 mlx are relatively low cost meters available at photometric laboratories. Next, let as assume that we will use a monochromatic source emitting light in the spectral range where both the tested II tubes and the illuminance meters are sensitive: from about 0.5 μm to 0.65μm.

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Now, let us analyse a situation when the photocathode of the image intensifier tube was illuminated using polychromatic 2856 K light and the illuminance meter recorded illuminance level E_p, and when the photocathode of the image intensifier tube was illuminated using monochromatic light the illuminance meter recorded illuminance level E_m. Let us find what is the relationship between E_p and E_m necessary to achieve situation when both light sources generate the same luminance level at the screen of the illuminated II tube.

The light coming to the photocathode represent a certain stimulus that is measured by the illuminance meter in photometric units perfectly suitable for humans eye. Here however, let us analyse a case when the receptor of this stimulus is not human eye but image intensifier tube of significantly different spectral curve. If we use a light meter of spectral curve identical as tube curve then the corrected indication of the illuminace meter illuminated using polychromatic light $E_p(cor)$ would be

$$E_p(cor) = E_p \cdot \frac{\int ii(\lambda) \cdot M(\lambda, 2850) d\lambda}{\int vi(\lambda) \cdot M(\lambda, 2850) d\lambda} \qquad (1)$$

where

ii(λ) is the spectral curve of the tested image intensifier tube, vi(λ) is the spectral curve of human eye, *M*(λ, 2856K) is spectral exitance of polychromatic light source of 2856 K color temperature.

In case of a monochromatic light source the corrected indication $E_m(cor)$ of the sensing instrument of spectral curve identical as spectral curve of the II tube is equal to

$$E_m(cor) = E_m \cdot \frac{ii(\lambda_m)}{vi(\lambda_m)}. \qquad (2)$$

The monochromatic light source is equivalent to polychromatic light source when

$$E_p(cor) = E_m(cor) \qquad (3)$$

This means that this equality is fulfilled when:

$$E_m \cdot \frac{ii(\lambda_m)}{vi(\lambda_m)} = E_p \cdot \frac{\int ii(\lambda) \cdot M(\lambda, 2850) d\lambda}{\int vi(\lambda) \cdot M(\lambda, 2850) d\lambda} \qquad (4)$$

Finally we get

$$E_m = E_p / \cdot CF \qquad (5)$$

where *CF* is the conversion factor that equals:

$$CF = \frac{\int vi(\lambda) \cdot M(\lambda, 2850) d\lambda}{\int ii(\lambda) \cdot M(\lambda, 2850) d\lambda} \cdot \frac{ii(\lambda_m)}{vi(\lambda_m)} \qquad (6)$$

The meaning of the formula (5) is that if the required by the MIL standards illuminance level of polychromatic light is E_p then we should use a monochromatic source that generate output signal at the illuminance meter equal to E_p/CF.

As we see in Eq.6 the conversion factor *CF* depends mostly on two parameters. First it depends on spectral curve of the tested tube *ii*(λ). This means that different conversion coefficients should be used when testing tubes of different spectral curves. Second, it depends on wavelength of the monochromatic source. As we see in (Fig.3) the value of conversion factor *CF* can vary rapidly over the wavelength 0.6 μm and therefore the wavelength of the light source should be determined accurately if we want to use the formula (6).

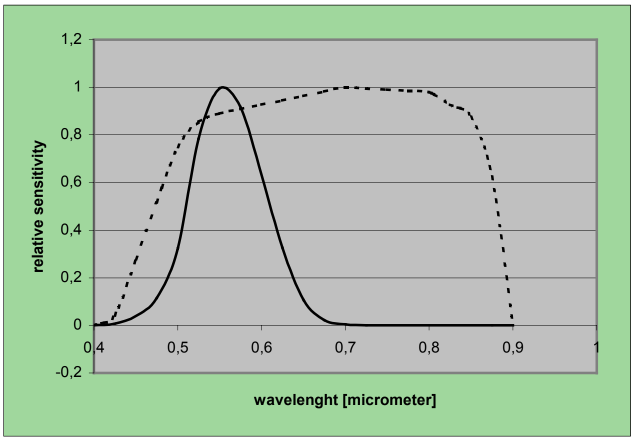

Fig.1. Relative sensitivity function a)continuous line: illuminance meter, b)dashed line: third generation image intensifier tube (III gen tube)

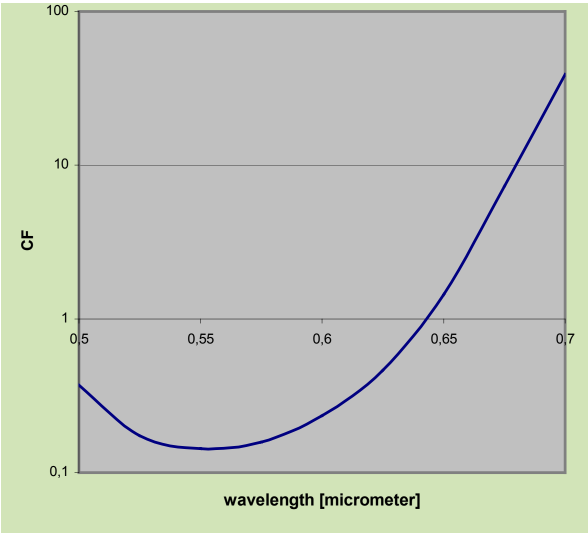

Fig.2. Dependence of CF conversion coefficient on wavelength of the semiconductor light source for a case of III gen tube

In order to verify the formula (6) there was carried our an experiment to measure luminance gain of three III generation II tubes using two versions of ITS-P stations from Inframet:

a)ITS-P/F test station equipped with typical halogen bulb as a light source

b) ITS-P/F2 test station equipped with 0.6 µm LED light source.

ITS-P/F2 station was recalibrated using the formula (6) using known spectral sensitivity curve of the tested II tubes and spectral sensitivity curve of the illuminance meter (both shown in Fig.2) and average wavelength of the monochromatic light source. The test results are shown in Tab.1.

Tab.1. Measurement results of luminance gain using two different stations

Tube number	Luminance gain [cd lx/m^2] (at 0.00002 lx)		Relative error [%]
	ITS-P/F	ITS-P/F2	
1	12400	12900	4.0
2	9800	10700	9.1
3	15200	14800	3.9

As we see in Tab. 1 two test stations that use different light sources generated different measurement results of luminance gain of tested II tubes. The differences are not negligible as they can be as high as almost 10%. However, if we consider that typical errors during measurement of photometric parameters of modern II tubes are often as high as 30% or more then we can consider the error level presented in Tab.1 as reasonably acceptable. We should also keep in mind that MIL standards accepts light sources of relative errors below the level 25% for most parameters.

To summerize presented above discussion we can say that it was shown in this paper that it is possible to replace short life time, bulky halogen bulbs by LED light sources and still keep the accuracy of a typical test station using calibrated halogen bulbs. In this way it was verified a possibility to design a new generation of test stations for testing image intensifier tubes equipped with semiconductor light sources of significantly extended reliability.

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