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RESEARCH OF THE RELATIONSHIPS BETWEEN LIGHT DISPERSION AND CONTRAST OF THE REGISTERED IMAGE AT DIFFERENT BACKGROUND BRIGHTNESS

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Abstract

The light diffraction is for telescope apparatuses an especially important characteristic which has an influence on the record image contrast from the eye observer.

The task of the investigation is to determine to what degree the coefficient of light diffraction influences the record image brightness.

The object of the theoretical research are experimental results provided from a telescope system experiment in the process of observation of remote objects with different brightness of the background in the fixed light diffraction coefficients and permanent contrast of the background in respect to the object.

The received values and the ratio of the image contrast to the light diffraction coefficient is shown in a graphic view. It's settled that with increasing of the value of background brightness in permanent background contrast in respect to the object, the image contrast sharply decrease. The relationship between the increase of the light diffraction coefficient and the decrease of the brightness of the project image from telescope apparatuses can be observed.

Light dispersion is optical device which characteristics affect the contrast of the image recorded by the observer’s eye [1, 5, 6, 8, 10, 11].

Many objects disperse light falling onto them, so the brightness’s values along the various directions appear to be strong. According to Lambert’s law [2], the brightness of a light-dispersing surface is equal in all directions. This assertion may be assumed only as an approximation.

Let σ be a small area with brightness β equal in all directions.

The light flow ψ emitted from area σ along the normal constituent of angle φ is calculated. Isolating the bodily angle $d\varphi$ located between two ring cones, generated by the rotation about normal N of two lines forming angles φ and $\varphi + d\varphi$, produces apparently:

(1) $$d_{\varphi} = 2\pi . \sin\varphi \, d\varphi \; .$$

The light intensity within this spatial angle is constant. Therefore, the light flow within the bodily angle $d\varphi$ will be:

(2) $$d\phi = I_{\varphi} d\varphi = 2\pi B \sigma \sin\varphi \cos\varphi \, d\varphi \; .$$

To determine the light flow ψ emitted by the area within the whole hemisphere, the above expression must be integrated within the limits from 0 to $\pi/2$. Then: $\psi = \pi B \sigma$.

(3) $$M = \frac{\phi}{\sigma} = \pi B \; .$$

The above shows that to brightness $B = 1\,\mathrm{cd/m^2}$ corresponds lightness: $M = 3{,}14\,\mathrm{lm/m^2}$.

The surface properties of each diffusely dissipating body differ greatly from those of the ideal light dissipater, i.e., the brightness in the various directions is different. To provide numerical characteristics of surface brightness change in various directions, the light dissipation factor for a given surface is used, i.e., the ratio of the brightness of the surface along an arbitrary direction and the brightness of an ideal dissipater, placed under the same illumination conditions. The light dissipation factor is usually denoted by β [9].

The task is to investigate whether the dissipation factor β affects the brightness of the recorded image.

The subject of theoretical research are the results obtained by an experiment with observation telescopic system [3] represented in Table 1 during the observation of remote objects with various background brightnesses ranging between 10^{-2} and 10^{-3} $\mathrm{cd/m^2}$ with given light dissipation factors: $\beta_1 = 0.1$; $\beta_2 = 0.2$; $\beta_3 = 0.3$ and constant contrast of the object's background $K = 0.3$.

Table 1

Light dissipation factor							X
	β_ϕ = 0,01	β_ϕ = 0,1	β_ϕ = 1	β_ϕ = 10	β_ϕ = 100	β_ϕ = 10^3	
β_1 = 0,1	0,2999	0,2981	0,2431	0,0901	0,0125	0,0013	$\overline{X_1}$ = 0,1566
β_2 = 0,2	0,2986	0,2868	0,2054	0,0517	0,0064	0,0006	$\overline{X_2}$ = 0,1415
β_3 = 0,3	0,2979	0,2806	0,1124	0,0379	0,0043	0,0004	$\overline{X_3}$ = 0,1239
							$\overline{X}$ = 0,1407

In the last column of Table 1, the obtained data is presented, considered as values of the brightness x for the group of factors β_1, β_2, β_3, i.e., z = 3, where the mean group values are denoted by $\overline{X_1}$, $\overline{X_2}$, $\overline{X_3}$ and the overall mean value $\overline{X}$ for the considered brightnesses n = 6 are calculated using formulae [7]:

(4) $$\overline{X} = \frac{1}{2}\sum_{i=1}^{z} xij \qquad i = 1,2 \ldots z$$

(5) $$\overline{X} = \frac{1}{zn}\sum_{i=1}^{z}\sum_{i=1}^{n} = \frac{1}{z}\sum_{i=1}^{z}\overline{xi} \; .$$

The hypothesis H which must be verified suggests that the light dissipation factor β does not affect brightness, while the alternative hypothesis suggests the opposite. To check up the zero hypotheses H, the averaged data from the 18 performed studies must be processed. The data processing includes calculation of the square sums $\varsigma, \varsigma_A, \varsigma_R$ using formulae:

(6) $$\varsigma = \sum_{i=1}^{Z}\sum_{i=1}^{n}\left[x_{ij} - \overline{x}\right]^2$$

(7) $$\varsigma_A = \sum_{i=1}^{z}\sum_{i=1}^{n}\left[\overline{x} - \overline{x}_i\right]^2 = n\sum_{i=1}^{z}(\overline{x} - \overline{x}_i)^2$$

(8) $$\varsigma_R = \sum_{i=1}^{z}\sum_{i=1}^{n}(x_{ij} - \overline{x}_i)^2$$

while the dispersions S^2, S_A^2 and S_R^2 are evaluated using formulae [4]:

(9) $$S^2 = \frac{2}{\nu} = \frac{2}{k\pi - 1}$$

(10) $$S_A^2 = \frac{\varsigma_A}{\nu_A} = \frac{\varsigma_A}{k-1}$$

(11) $$S_R^2 = \frac{\varsigma_R}{\nu_R} = \frac{\varsigma_R}{k(\pi - 1)} \; .$$

The obtained values are shown in Table 2.

Table 2

Types of square sums	Square sum	Degree of freedom	Dispersion evaluation
Total	ς = 0,331486	ν 6 = 17	S^2 = 0,019499
By factors	ς_A = 0,000537	ν_A = 2	S_A^2 = 0,000268
Residual	ς_R = 0,022063	ν_R = 15	S_R^2 = 0,022063

The calculation of the disperse ratio F is performed using formula:

(12) $$F = \frac{S_A^2}{S_R^2} = 0,\,0121831.$$

The obtained disperse ratio (12) is compared with the table value F_T at significance level $\alpha = 0.05$ [2] and it is observed that $F > F_T$, which evidences that light dissipation affects image brightness.

Accounting to the fact that the contrast K depends on the object's brightness B_{ob} and the background B_b, K may be determined from:

(13) $$K = \frac{B_{об} - B_{ф}}{B_{ф}}$$

and, accounting to the additional brightness ΔB, due to light dissipation, which may be written as:

(14) $$\Delta B = (B_{об} + B_{ф})$$

the contrast of the image K′ recorded by a visual optic system during observation of a remote object will be equal to:

$$K^{`} = \frac{B_{об} - B_{ф}}{B_{ф} + \beta(B_{об} + B_{ф})} = \frac{K}{1 + \beta(B_{об} + B_{ф}} = \frac{K}{1 + \Delta B}. \tag{15}$$

From expression (15) it follows that, with definite object contrast with respect to the surrounding background, the image contrast K will be reduced, while the light dissipation factor increases.

In Fig. 1, the curves for the appropriate dissipation factors are shown. Apart from the image contrast’s reduction with the light dissipation factor β’s increase, the curves presented in Fig. 2 also reveal that the contrast K′ of the recorded image drops abruptly when the background’s brightness exceeds (24…30) cd/m^2, i.e., the specified background contrast with respect to the object, which is 0.3, does not provide proper image of the observed remote objects. Therefore, at some given contrast of the object with respect to the surrounding background, the contrast of the recorded image K′ is reduced while the light dissipation factor increases. At background brightness within the range from 10^{-2} to 10^{3} cd/m^2 it may be shown that, when the value of background brightness increases, while the background contrast with respect to the object K = 0.3, the image’s contrast drops abruptly.

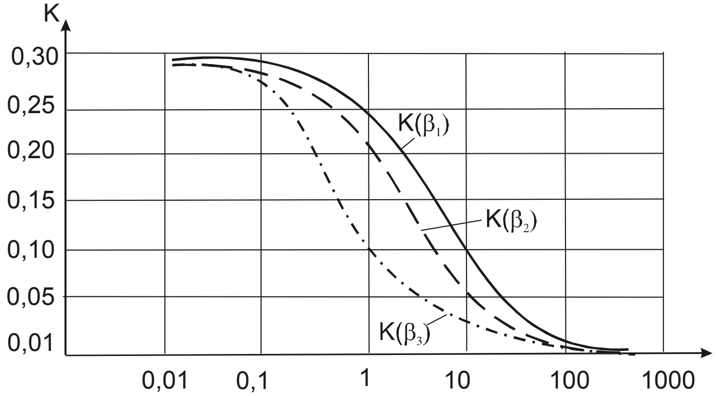

Fig. 1. Dependence of the image contrast on the light dissipation factor

The graphic relationship displays reduction of the image contrast with increase of the light dissipation factor β. Moreover, when the background’s brightness exceeds 24…30 cd/m^2, the contrast of the recorded image drops abruptly.

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ИЗСЛЕДВАНЕ НА ЗАВИСИМОСТИТЕ МЕЖДУ СВЕТОРАЗСЕЙВАНЕТО И КОНТРАСТА НА РЕГИСТРИРАНОТО ИЗОБРАЖЕНИЕ ПРИ РАЗЛИЧНА ЯРКОСТ НА ФОНА

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Резюме

Светоразсейването е важна харктеристика на оптичните уреди, която влияе върху контраста на регистрирания образ. Повърхността на всяко дифузно разсейващо тяло в значителна степен се различава по свойства от идеалния светоразсейвател, т. е. яркостите в различни посоки се оказват различни. За да се характеризира числено изменението на яркостта на повърхнина в различни направления, се използва коефициент на светоразсейване за дадена повърхност, като се разбира яркостта на тази повърхност, в произволна посока, към

яркостта на идеален разсейвател, намиращ се в същите условия на осветеност.

Обект на разработката са резултати от изследване на отдалечени обекти при различна яркост на фона с определени коефициенти на светоразсейване.

Получените стойности и отношението на контраста на образа към светоразсейването е представено в графичен вид. Наблюдава се връзка между нарастване на коефициента на светоразсейване и намаляване на яркостта на образа. От представената графика се вижда, че освен намаляване на контраста на образа с нарастване на коефициента на светоразсейване β, контрастът $K^{|}$ на регистрирания образ рязко спада над яркост на фона (24... 30) cd/m^2 т. е. зададеният контраст на фона спрямо обекта 0,3 не осигурява качествен образ на наблюдавания отдалечен обект. Следователно при определен контраст на обект спрямо заобикалящия го фон, контрастът на регистрирания образ $K^{|}$ се намалява с нарастване на коефициента на светоразсейване. При яркост на фона в диапазона от 10^{-2} до 10^{3} cd/m^2 се установява, че при нарастване на стойността на яркостта на фона, при постоянен контраст на фона и обекта К = 0,3, контрастът на образа стремително спада.