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# RELATIONSHIP BETWEEN LIGHT DISPERSION AND BRIGHTNESS DURING TELESCOPIC DEVICE OBSERVATIONS

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***Abstract***

*Light diffraction is a very important telescope characteristic which affects the contrast of the image recorded by the observer's eye.*

*The purpose of the study is to determine to what extent the coefficient of light diffraction affects the brightness of the recorded image.*

*The subject of the theoretical research are the experimental results obtained during telescope system experiment in the process of observation of remote objects with different brightness of the background at fixed light diffraction coefficients and constant contrast of the object' background.*

*The received values and the subjection of the contrast of the image to light diffraction coefficient is shown in graphic form. It is found out that when increasing the value of background brightness in constant background contrast in respect to the object, the image contrast sharply decreases. The relation between increase of light diffraction coefficient and the decrease of image brightness can be observed by telescope apparatuses.*

Light dispersion is optical device characteristics which affects the contrast of the image recorded by the observer's eye.

Many objects disperse light falling onto them, so the brightness's values along the various directions appear to be close. According to Lambert's law [3,6], 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 (Fig. 1) equal in all directions.

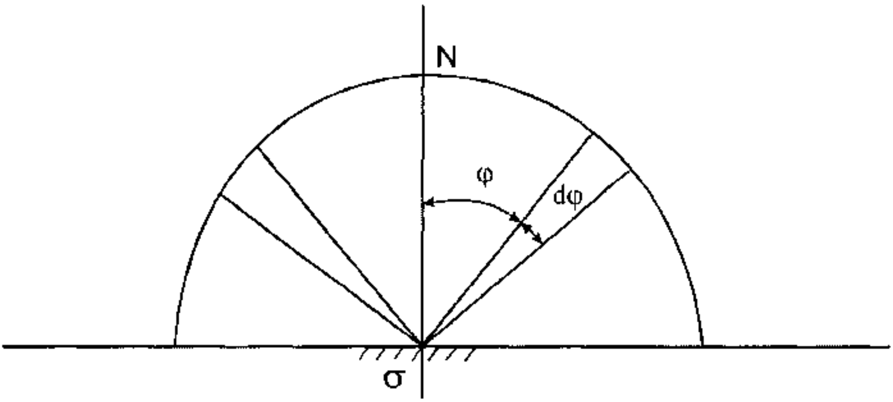


*Fig. 1. Definitions*

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

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

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 π/2. Then: $\psi = \pi B\sigma$.

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

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

The surface properties of each diffusely dissipating body differ greatly from those of the ideal light dissipater, i.e., the brightnesses in the various directions are 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 [1, 4].

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 [5] represented on Table 1 during the observation of remote objects with various background brightnesses ranging between $10^{-2}$ and $10^{-3}$ cd/m² 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 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\beta_\phi = 0{,}01$ | $\beta_\phi = 0{,}1$ | $\beta_\phi = 1$ | $\beta_\phi = 10$ | $\beta_\phi = 100$ | $\beta_\phi = 10^3$ | X |
| $\beta_1 = 0{,}1$ | 0,2999 | 0,2981 | 0,2431 | 0,0901 | 0,0125 | 0,0013 | $\overline{X_1} = 0{,}1566$ |
| $\beta_2 = 0{,}2$ | 0,2986 | 0,2868 | 0,2054 | 0,0517 | 0,0064 | 0,0006 | $\overline{X_2} = 0{,}1415$ |
| $\beta_3 = 0{,}3$ | 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 $\beta_1$, $\beta_2$, $\beta_3$, 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 [2]:

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

(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 $S^2$, $S_A^2$ è $S_R^2$ are evaluated using formulae [4]:

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

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

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

The obtained values are shown on Table 2.

*Table 2*

| Types of square sums | Square sum | Degree of freedom | Dispersion evaluation |
|---|---|---|---|
| Total | $\varsigma = 0{,}331486$ | $\nu 6 = 17$ | $S^2 = 0{,}019499$ |
| By factors | $\varsigma_A = 0{,}000537$ | $\nu_A = 2$ | $S_A^2 = 0{,}000268$ |
| Residual | $\varsigma_R = 0{,}022063$ | $\nu_R = 15$ | $S_R^2 = 0{,}022063$ |

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 for 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 for 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:

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

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. 2, 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.

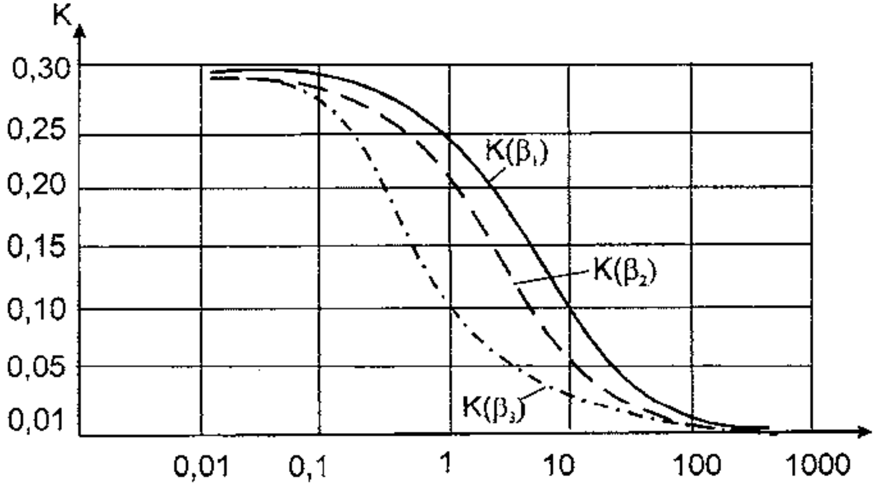


*Fig. 2. Dependence of the image contrast on the light dissipation factor*

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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# ЗАВИСИМОСТ МЕЖДУ СВЕТОРАЗСЕЙВАНЕТО И ЯРКОСТТА НА ОБЕКТА ПРИ НАБЛЮДЕНИЕ С ВИЗИРНИ ОПТИЧНИ УРЕДИ


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**Резюме**


Светоразсейването е характеристика на оптичните уреди, която влияе върху контраста на регистрираното изображение от окото на наблюдателя. Обект на теоретично изследване са резултати, получени от експеримент с визирна телескопична система при наблюдение на отдалечени обекти при различна яркост на фона при зададени три различни коефициенти на светоразсейване и постоянен контраст на фона на обекта. Направени са изводи за зависимостите между контраста на изображението, коефициента на светоразсейването, контраста на регистрираното изображение и яркостта.