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OPTICAL IMAGE INFORMATIVITY IN OPTIC AND ELECTRONIC DEVICES LIMITED BY ABERRATIONS

Petar Getsov, Zhivko Zhekov, Garo Mardirossian

SPACE RESEARCH AND TECNNOLOGY INSTITUTE, BULGARIAN ACADEMY OF SCIENCES, SOFIA 1113, ACAD. GEORGI BONCHEV ST., BL.1 e-mail:
director@space.bas.bg, zhekov_z@abv.bg; garo@space.bas.bg

Abstract. Some interrelations of two dimensional image entropy of optic and electronic devices are developed in this paper. The informativity of the object image is investigated through the use of multi spectral optic system, limited by aberations.

Key words: aberrations, optical system

The transmitting function of the optic system and the structure of optic analyzer of the object image define the optic tract characteristics of optic and electronic device, as a channel for transmitting of information over dimensional and power producing attributes [1…9]. The non-ideality of the optical system, revealed in residual aberrations leads to image curve in comparison with the object. In this the non-correlated microstructure of object and background brightness, becomes correlated when being transmitted through the optic system. When confining the investigated wave lengths, the diffraction of the dispersion circle - S, depending on the diameter of the object - glass D and the working length of the wave λ, is defined by the interrelation:

(1) $$\delta = \frac{2.44\lambda}{D}.$$

The strip of omission in the optic system, when the focal distance f' is equal to:

(2) $$\omega(\rho) = \frac{1}{f'\sin\delta}.$$

When reporting the lower value of the angular quantity of the dispersion circle $\sin\delta \approx \delta$, and the equality of the relative aperture $\frac{D}{f'} = 2tg\alpha'$ we have:

(3) $$\omega(\rho) = \frac{0,82tg\alpha'}{\lambda},$$

where: α' - the half of the aperture angle of the object – glass.

According to Kotelnikov's theorem [10] for discretization of a certain number of points in a function, limited by the strip of omission $\omega(\rho)$ and the criterion for discernibility of adjacent elements over the diameter of the circle of Eri - over the diffraction image of light distribution, the amount of points, basing the light distribution on a single surface unit of two-dimensional image will be:

(4) $$n = \left[\omega(\rho)\right]^2.$$

Considering the value of (3) we have:

(5) $$n = 0,67\left[\frac{tg\alpha'}{\lambda}\right]^2.$$

Considering the range of the entire visual field of optical system 2β:

(6) $$N = 0,67\pi\left[\frac{f'}{\lambda}tg\alpha'\sin\beta\right]^2.$$

If there are other criteria for discernability, the digit coefficient in formulae (5) and (6) could be different.

For narrow - angular optic system $\sin\beta = \beta$ and then we have:

(7) $$N = 0,67\pi\left[\frac{f'}{\lambda}tg\alpha'\beta\right]^2.$$

Formula (6) shows that the informativity of the optic image, created by a system, limited by diffraction, depends on the working length of the wave, the aperture and the visual field. The informativity increases with the decrease of length of wave λ, increase of the focal distance f', visual field β and the aperture α'.

In fact, for a single-channeled and single-spectral system, the image information is defined by the amount of light in a line of points, which could be defined with the condition of a matrix, describing a vector, non - correlated with the amount of light between points $a_1, a_2, a_3, ...n_1, n_2, n_3...$,in the field of the image [3].

(8) $$\overline{E_N} = \left\| \frac{b_{a_1}, b_{a_2}, b_{a_k} ... b_{a_k}}{b_{n_1}, b_{n_2}, b_{n_3} ... b_{n_k}} \right\|$$

The number of the elements in the matrix is equal to N.

For a system with top amount of light, $b_{a_1}...b_{a_k}$,equal to 0 or 1, the value of the elements in matrix (8) are:

$b_j = 0$ when $b_j < b'$

$b_j = 0$ when $b_j \geq b'$

where: b_j - the amount of light of an unspecified jth element of the matrix; b' - light amount threshold level.

The average informativity (entropy) of the image $H_N(E)$described in matrix (8), will be [1]:

(9) $$H_N(E) = -\sum_{j=1}^{N} P(b_j) \log_2 P(b_j).$$

If we assume equally possible $b_j = 0$ and $b_j = 1$, i.e. the probability $P(b_j) = 0{,}5$, then $\log_2 P(b_j) = -1$Then the average informativity of the image is directly connected with the number of the points N.

(10) $$H_N(E) = \frac{1}{2} N.$$

When we use a multi spectral optic system, the informativity of the object image increases with the increase of the quality of the investigated wavelengths λ. The dependence of the image informativity of the wavelengths leads to transformation of the matrix condition of the light amount $\overline{E_N}$, which stays dimensional, i.e. it consists of a several independent matrixes dependent on the amount I of the spectral scope.

$$\overline{E_N}(\lambda_1); \overline{E_N}(\lambda_2); ...\overline{E_N}(\lambda_i)$$

For evaluation the informativity of multi spectral image in correspondence to the methods for discretization and formula (6) we could find:

$$(11)\qquad \left| \begin{array}{l} N(\lambda_2) = \left(\dfrac{\lambda_1}{\lambda_2}\right)^2 N(\lambda_1) \\ N(\lambda_3) = \left(\dfrac{\lambda_1}{\lambda_3}\right)^2 N(\lambda_1). \\ N(\lambda_i) = \left(\dfrac{\lambda_1}{\lambda_i}\right)^2 N(\lambda_i) \end{array} \right.$$

Formulae (7) and (10) define the informativity in the first spectral range:

$$(12)\qquad H\left[E(\lambda_1)\right] = \frac{0,67\pi}{2}\left[\frac{f'\beta}{\lambda_1} tg\alpha'\right]^2$$

The total number of elements for three-spectral matrix is:

$$(13)\qquad N_{\sum}(\lambda_1, \lambda_2, \lambda_3) = N\lambda_1 + N\lambda_2 + N\lambda_3.$$

Considering formula (11), we have:

$$(14)\qquad N_{\sum}(\lambda_1, \lambda_2, \lambda_3) = \left[1 + \left(\frac{\lambda_1}{\lambda_2}\right)^2 + \left(\frac{\lambda_1}{\lambda_3}\right)^2\right] N(\lambda_1).$$

The informativity of the image, considering the three united independent systems, is defined by the sum of their entropy.

$$(15)\qquad H_N\left[E(\lambda_1, \lambda_2, \lambda_3)\right] = \frac{1}{2}\left[1 + \left(\frac{\lambda_1}{\lambda_2}\right)^2 + \left(\frac{\lambda_1}{\lambda_3}\right)^2 N(\lambda_1)\right]$$

or

$$(16)\qquad H_N\left[E(\lambda_1, \lambda_2, \lambda_3)\right] = \frac{0,67\pi}{2}\left[\frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2} + \frac{1}{\lambda_3^2}\right](f'\beta.tg\alpha')^2$$

For multi-spectral systems:

$$(17)\qquad H_N\left[E(\lambda_i)\right] = \frac{0,67\pi}{2}\sum_1^i (f'\beta tg\alpha')^2.$$

In a particular case, when the spectral ranges are closer and in formula (16) if we assume that $\lambda_1 \approx \lambda_2 \approx \lambda_3$, then we have $N\lambda_1 = N\lambda_2 = N\lambda_3$

(18) $$\left| \begin{array}{l} N_{\sum}\left(\lambda_1 = \lambda_2 = \lambda_3\right) = 3N \\ H_N\left[E\left(\lambda_1 = \lambda_2 = \lambda_3\right)\right] = 3H_N \end{array} \right. .$$

The image informativity, defined from real optic systems, limited by aberrations, is always lower. For single-spectral system, limited by aberrational circle δ_a using the interrelation:

(19) $$\left| \begin{array}{l} \omega_a = \dfrac{1}{f'\delta_a} \\ n_a = \omega_a^2 = \dfrac{1}{\left(f'\right)^2 \delta_a^2} \\ N_a = \pi\left(f'\beta\omega_a\right)^2 \end{array} \right.$$

We can find the number of elements in matrix (8)

(20) $$N_a = \frac{\pi\beta^2}{2\delta_a^2}$$

And the informativity of the image:

(21) $$H_N\left[E\left(\delta_a\right)\right]\frac{\pi\beta^2}{2\delta_a^2}$$

For a three-spectral system, limited by aberrations $\delta_{\lambda_1}, \delta_{\lambda_2}, \delta_{\lambda_3}$:

(22) $$N_a\left(\lambda_1, \lambda_2, \lambda_3\right) = \frac{\pi\beta^2}{2}\left[\frac{1}{\delta_{\lambda_1}{}^2} + \frac{1}{\delta_{\lambda_2}{}^2} + \frac{1}{\delta_{\lambda_3}{}^2}\right],$$

(23) $$H_{N_a}\left[E\left(\lambda_1, \lambda_2, \lambda_3\right)\right] = \frac{\pi\beta^2}{2}\left[\frac{1}{\delta_{\lambda_1}{}^2} + \frac{1}{\delta_{\lambda_2}{}^2} + \frac{1}{\delta_{\lambda_3}{}^2}\right].$$

In general, for multi-spectral optic systems we have:

(24) $$N_a\left(\lambda_i\right)=\pi\beta^2\sum_1^i\left[\frac{1}{\delta\lambda_i^2}\right],$$

(25) $$N_{N_a}\left[E\left(\lambda_i\right)\right]=\pi\beta^2\sum_1^i\left[\frac{1}{\delta\lambda_i^2}\right].$$

In conclusion we could state that:

1. The image informativity, created by a real optic system, limited by aberrations, depends mainly on the power producing parameters of the signals in each channel.

2. For the investigated type of optic and electronic devices, the information limit is defined by the strip of the investigated optic signal from the object, by the dimensional - frequency characteristic of optic system, by its geometric characteristics (visual field, aperture, focal distance of the object - glass), the power producing characteristics of the signal (fluctuation of the image light amount, caused by photon noises).

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