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Power installations geometrical parameters optical control method steady against thermal indignations

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Abstract. The analysis of optical signals distortions statistical properties of contactless control of heat power installations is carried out. It is established that image distortions have normal distribution and stochastic characteristics in conditions existence of phase refraction distortions. It is shown that to ensure dynamic objects control in conditions of refraction distortions, it is possible to apply optical radiation spatial modulation based methods.

Heat power installations geometrical parameters complex control allows to significantly increase working resource of a difficult power system and practically exclude emergence probability [1]. Optical control methods are most perspective as they are contactless and provide rather high metrological characteristics [2]. Nevertheless, application of heat power installations parameters of optical control methods is strongly limited. It is connected with existence of refraction distortions of the optical signals in close proximity to the working unit caused by high temperatures, vibrations, existence of water and buttered aerosols in the measurement field.

The purpose of this work consists in statistical property research of optical signals distortions and optical control method development steady against refraction distortions of optical signals.

Let refraction heterogeneity, caused by the drifting temperature gradients of the air, are available in the optical environment located between radiation source and object and between object and the optical signal receiving system. As a result refraction light index in the optical environment that leads to distortions of an optical signal will change. The deviations created by phase n_0 uniformity will have stochastic characteristics. We will consider the monochromatic wave extending in the set volume. Air refraction index can be presented in the form

$$n(r,t) = n_0 + n_1(r,t). \tag{1}$$

We assume that refraction index has constant value n_0 and the amendment n_1 which depends on time t, temperature gradient of air, situation in the disseminating volume r. From Maxwell's equations we will receive:

$$\nabla^2 U + \frac{w^2 n^2}{c^2} U = 0. \tag{2}$$

As $|n_1| \ll n_0$, it is possible to present a field U in the form of the sum of the member U_0 which would be received in the case that optical volume air has uniform refraction index n_0, and the small correction member of U_1 which considers indignations influence of refraction index n_1. In such approach the wave

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equation is:

$$\nabla^2(U_0+U_1)+\frac{w^2(n_0+n_1)^2}{c^2}(U_0+U_1)=0. \tag{3}$$

Considering that U_0 – not indignant decision, it has to satisfy to the Eq. (2) for $\mathrm{n}=\mathrm{n}_0$ and $U=U_0$. Then

$$\nabla^2 U_1+\frac{w^2n_0^2}{c^2}U_1=-\frac{2w^2n_0n_1}{c^2}U_0. \tag{4}$$

The solution of expression (4) can be found as a convolution of Green function for free space of $\exp\left(j\frac{wn_z}{c}|r|\right)/|r^{f()}$. As a result we have

$$U_1(r)=\frac{1}{4\pi}\iiint\frac{\exp\{\frac{jwn_0}{c}|r-r'|\}}{|r-r'|}\left[2\frac{w^2n_0^2}{c^2}n_1(r)U_0(r)\right]d^3r, \tag{5}$$

where integration is carried out on all disseminating volume.

This expression means that field indignation of U_1 can be found by summation of the spherical waves set generated in various points of r' in the disseminating volume of V. Amplitude of the spherical wave generated in r' point is proportional to multiplication of the falling not indignant radiation amplitude and indignation refraction index in this point. Considering that the maximum cross shift within which light from the lens hits the set nail, is much less than axial distance from the lens to a photo detector, the Fresnel's approach can be used in expression (5) that leads to expression:

$$U_1(r)=\frac{w^2n_0^2}{2\pi c^2}\iiint\frac{\exp\left\{\frac{jwn_0}{c}\left[(z-z')+\frac{|\rho-\rho'|^2}{2(z-z')}\right]\right\}}{|z-z'|}n_1(r)U_0(r)d^3r, \tag{6}$$

where ρ and ρ' – cross shifts of vectors r and r' relative to an axis z.

The received expression gives field indignation of U_1, as superposition of huge number of independent deposits of the non-uniform environment various parts. According to the central limit theorem the valid and imaginary part of the size U_1 submit to normal distribution. it is possible to present distribution of intensity of a full wave in the form of the sum of constant complex values and casual complex value, which have normal distribution.

It is known that the marginal density of amplitude distribution of the complex random variable presented in the form of the sum of a constant U_0 and the random complex variable U_1 have normal distribution, it is possible to present in the form of Raise density of distribution [3]:

$$p_A(a)=\frac{a}{\sigma^2}\exp\left(-\frac{a^2+s^2}{2\sigma^2}\right)I_0\left(\frac{as}{\sigma^2}\right), \tag{7}$$

where σ – dispersion of the random complex variable U_1 with normal distribution, s – amplitude of a constant U_0, I_0 – modified Bessel's function with first sort and zero order.

As the deviation caused by heterogeneity of refraction index is significantly less than wave amplitude, in most cases it is possible to consider that approach $\mathrm{s}\gg\sigma$ is true. In this case, the random variable will aspire to a Gaussian random variable.

$$p_A(a)\approx\frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{(a-s)^2}{2\sigma^2}\right). \tag{8}$$

Therefore, casual thermal lenses existence gives the casual image distortions having stochastic character and normal distribution at big accumulation of time.

In dynamic object measurements, as a rule, there is no opportunity to carry out long data accumulation. In this case we can suggest to use methods based on optical source spatial modulation which have high measurement precision provided not temporary, but spatial accumulation of data. As a result there is an opportunity to take high-precision optical measurements of dynamic objects even in the refraction vortex optical distortions conditions.

In this work the analysis of optical signals distortions statistical properties of contactless control of heat power installations is carried out. It is established that image distortions have normal distribution and stochastic characteristics in conditions existence of phase refraction distortions. It is shown that to ensure dynamic objects control in conditions of refraction distortions, it is possible to apply optical radiation spatial modulation based methods.

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References

[1] Dvoynishnikov S. Development methods of steam turbines 3D geometry optical control for effective heat power equipment quality improvement / Thermophysical Basis of Energy Technologies, EPJ Web of Conferences, **76**, 2014. 1003-4

[2] Anufriev I.S., Kuznetsov G.V., Shadrin E.Yu., Sharypov O.V., Anikin Yu.A., Dvoynishnikov S.V., Kulikov D.V., Rakhmanov V.V. The study of flow structure in a new construction of vortex furnace by the particle image velocimetry / Bulletin of the Tomsk Polytechnic University, **322**, No 4. P. 31–35

[3] Goodmen J.W. Statistical Optic/Wiley Classics Library Edition published 2000. - 572 p.