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Information capability of the thermal radiation noise (Analytical overview)

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Abstract. The main purpose of this overview is to make an effort at joining the widely spread practical tendency of "damping the noise" with the non-apparent but presumably perspective thesis "using the noise" through the realization of "information properties of noise". The paper deals with physical peculiarities of the equilibrium thermal radiation, which have been considered within the black body model for the case of ultimate restrained photon flows inside an ideal ("lossless") optical communication channel. Restrictions connected with the uncertainty relations have been used to determine critical interrelations between the thermal radiation parameters and the sizes of the thermal radiator and the ideal photodetector. The conception of the "intrinsic micro-amounts of chaos" has been proposed, and its usefulness was discussed. Principle feasibility has been considered for a distant identification of a small-sized thermal radiator by means of detecting its thermal radiation. A single small-size radiator has been phenomenologically treated within the black body model. It has been shown that it is possible to obtain a quantitative evaluation of the temperature and the size of a small-size radiator through measurement of the thermal radiation fluctuations in case when the optical image of the radiator is unavailable.

Keywords: blackbody thermal radiation, uncertainty relations, size-restrictions, quantum limitations.

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1. Introduction

Nowadays, the fluctuation diagnostics can be considered as one of the most promising methods to reveal hidden defects in functional systems (starting from the mechanical up to biological ones, including highly organized systems). The early diagnostics of undesirable changes in operation of functional systems can be reached using the spectrum of fluctuations (noise) in their working parameters. The major advantage of these fluctuation methods lies in the fact that defects in functional blocks can be revealed not by finding the defect itself but using the permanent registration of changes in fluctuation spectra of respective parameters inherent to these weak functional blocks. In this way, the virtual defect can be marked much earlier than it begins to act as a direct "danger in a real time-scale".

Well known are critical situations arising in operation of modern electronic structures, which take place as a result of aging and fatigue in crystalline materials, crystallization of amorphous materials and structural changes in compounds, adhesives and many other constructive materials.

Modern electronic equipment based on VLSIC is also dependent on "tyranny of quantities", and, naturally, every electronic microelement cannot be controlled directly.

From the viewpoint of these considerations, a specific interest is related with distant "noise" identification of small objects, sizes of which can be changed with time (objects wear or degrade). So, for example, information capability of thermal radiation (TR) noise related to the size of the cavity for the absolutely black body (ABB) can be confirmed by TR energy distributions $E(\lambda)$ as well as its fluctuations within the ABB cavity $\langle \Delta E^2 \rangle^{1/2}$ for various sizes of the cavity.

The dependences are drawn in accordance with the Einstein formula [1] for $\langle E(\lambda) \rangle$ and its dispersion $\langle \Delta E^2 \rangle$ with dimension correction [2i)]. It can be seen that in the cavities with the linear dimension $R_{cav} > 70$ µm the intrinsic fluctuations of TR ($\langle \Delta E^2 \rangle^{1/2}$ within the definite wavelength range around the peak of the TR spectrum do not exceed the mean value $\langle E(\lambda) \rangle$. However, there are crosspoints $\langle E(\lambda) \rangle$ and $\langle \Delta E(\lambda)^2 \rangle^{1/2}$ both in the range of short (λ_{sw}) and long (λ_{lw}) waves. So, for $R_{cav} = 200$ µm $\lambda_{sw} = 4.95$ µm, $\lambda_{lw} = 105.8$ µm; for $R_{cav} = 100$ µm (not shown in Fig. 1) $\lambda_{sw} = 7.56$ µm, $\lambda_{lw} = 42.58$ µm. For $R_{cav} = 70$ µm, there is one tangent point $\lambda_{tg} = 16$ µm.

In cavities with linear dimensions < 70 µm, TR fluctuations $\langle \Delta E(\lambda)^2 \rangle^{1/2}$ can exceed $\langle E(\lambda) \rangle$ quite considerably (see, for instance $I(\lambda)$ and $i(\lambda)$ for $R_{cav} =$ 20 µm). These facts can be used to verify specific calculations of TR for small objects. To measure adequate statistical data (mean values and dispersions) for multi-element objects or stochastic systems (e.g., VLSIC or stochastic ensemble of small objects), one should, first of all, estimate the principle optical-and-physical limitations for obtained optical information.

Optimistic conclusions [3] (see Chapter 3) as to the application of remote diagnostic methods are not absolutely obtainable in practice; they require further investigation based on fundamental positions. The general aspects of ABB TR physics solved long ago do not comprise, however, the set of problems arising as a consequence of growing interest in TR. We mean the above mentioned remote "noise" identification of radiators with small sizes (RSS) [3] that, in definite conditions, can be used to control the correspondence of RSS to the factors of their reliability [4]. The main physical differences between TR of RSS and TR of ABB are determined by the size limitations in the number of TR modes within the RSS cavity [2ii]. Peculiarities of RSS TR behavior in various physical conditions providing transfer of optical information are determined not only by the size of the RSS cavity but also by the respective fundamental limitations [1, 6-10] related to the smallness of RSS and/or photodetector (PD) operating as an element of an ideal ("without losses") optical information channel (OIC).

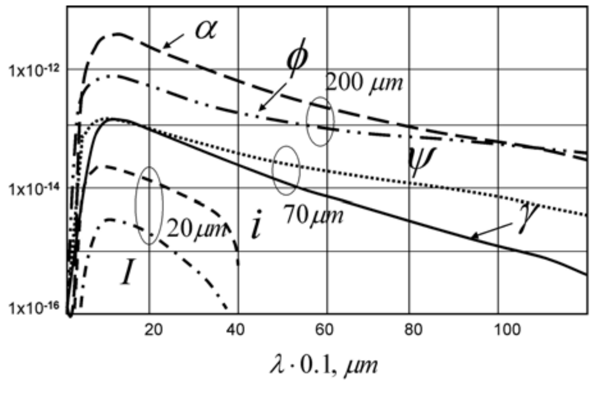

Fig. 1. Spectral distributions $\langle E(\lambda) \rangle$ and $\langle \Delta E(\lambda)^2 \rangle^{1/2}$ within the ABB cavity of finite sizes ($\alpha(\lambda)$, $\varphi(\lambda)$ $R_{cav} = 200$; $\gamma(\lambda)$, $\psi(\lambda)$ $R_{cav} = 70$; $I(\lambda)$, $i(\lambda)$ $R_{cav} = 20$ µm).

2. Fundamental limitations of TR

It is suggested that ABB keeps its physical model for RSS and allows to determine the differences between TR from RSS and ABB. In what follows, we shall use the conventional characteristics of photons [6-10]:

photon energy –

$$h\nu = hc / \lambda \tag{1.1}$$

(c – light velocity; $h = 6.62 \cdot 10^{-27}$ erg·s; $\hbar = h / 2\pi$),

photon momentum –

$$\vec{M} = \hbar \vec{k} \; ; \left| \vec{M} \right| = h / \lambda \,, \tag{1.2}$$

as well as uncertainty relations between the energy E and time t:

$$\Delta E \cdot \Delta t \geq h / 2 \; ; \tag{1.3}$$

the momentum M and coordinate x:

$$\left| \Delta \vec{M} \right| \cdot \Delta x \geq h / 2 \; ; \tag{1.4}$$

the number of photons N and photon phase φ:

$$\Delta N \cdot \Delta \varphi \geq 1/2 \,. \tag{1.5}$$

The equilibrium ABB TR is determined by the Bose-Einstein statistics; the mean number of photons in the mode with the frequency ν at the temperature T(K) is calculated using the Planck formula

$$\langle n \rangle = \left[\exp(h\nu / kT) - 1 \right]^{-1} . \tag{1.6}$$

The TR energy density in the ABB cavity with the dimension correction [2i)] in the square brackets of the formula (1.7)

$$\varepsilon(\lambda) = \frac{hc}{\lambda} \cdot \frac{8\pi}{\lambda^3} \cdot \left[1 - \frac{\lambda^2}{4 \langle R \rangle^2} \right] \cdot \left(\frac{\Delta\lambda}{\lambda} \right) \cdot \langle n \rangle \,, \tag{1.7}$$

where $\langle R \rangle$ is the linear dimension of the ABB cavity that, for simplicity, is suggested to be of a cubic form.

2.1 Radiator and PD in the scheme OIC "without losses"

To find the conditions for the realization of an ideal ("without losses") OIC that contains RSS and an ideal PD, we use the expressions (1.1) to (1.5).

It seems obvious that in the case of an open OIC the greater the distance between the radiator and the PD, the more profitable to form of the most narrow beam. It provides a minimum in power losses of TR transferring information. Taking into account that photons do not interact between each other in a free space [7], the minimal angular dimension of the light beam θ_{min}, when the mode population $\langle n \rangle$ of TR is low, can be determined through the uncertainty of the photon momentum ΔM_1 as $\theta_{min} = \Delta M_1 / M_1$. It follows from the inequality (1.4) that using a definite TR wavelength λ and the radiator dimension $R \cong \Delta x$ we cannot obtain the beam angular dimension less than

$$\theta_{min} \geq \lambda / 2R . \quad (1.1.1)$$

Also, it seems obvious that the linear dimension of PD – D and the maximal trace length – L_{max} for the ideal OIC are related geometrically; within the range of small angles it is

$$\theta_{min} \cong D / 2L_{max} \quad (1.1.2)$$

(the case is schematically shown in Fig. 2: the dimension D exactly covers the open side of the angle θ_{min}).

When setting the values, for example, $\lambda = 10$ μm, $R = 1$ cm and $D = 10$ cm, the maximal trace length for OIC "without losses" will only be $L_{max} = R \cdot D / \lambda =$ 100 m. This trivial estimate shows that these principal limitations for optical information transfer in the visible (0.4 to 0.7 μm) and near infrared (1 to 10 μm) ranges of the spectrum are valid in real space scales, and they should be taken into account.

Starting from the principle of reversibility for optical rays [8], when detecting TR, and taking into account the relation (1.4), it is easy to obtain the conditions that limit PD dimensions in dependence of essential λ and $\Delta\lambda$:

$$D_{min} \cdot (\Delta\lambda/\lambda) \geq \lambda / 2 . \quad (1.1.3)$$

D_{min} corresponds to the minimal PD dimension that is capable of keeping the condition of OIC ideality. The inequalities (1.1.1)-(1.1.3) are the analogs of diffraction limitations [9i)]. A departure from (1.1.3) lowers the probability for a photon hitting the PD area ($S_{PD} = \pi \cdot D^2$), which results in losses of received TR. Thus, accounting for the expressions (1.1.1)-(1.1.3) the PD dimension should be defined by the following inequality

$$D_{min} \geq \lambda L_{max} / R . \quad (1.1.4)$$

Inverting the inequality sign in (1.1.4), we obtain the condition which allows us to observe interferential fringes in the classical Young experiment [8-10]. As a result, one can draw the conclusion that the minimal linear dimension of PD D_{min} in an ideal OIC should exceed some "interferential length" L_{int}. The latter corresponds to the distance between the slits in the first screen within the framework of the Young experiment. It means that the minimal PD dimension should be larger than the length of coherency for detected radiation L_{coh}.

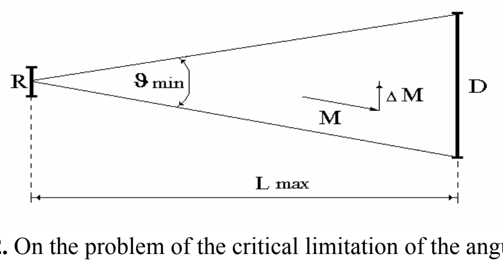

Fig. 2. On the problem of the critical limitation of the angular parameters of the light beam.

Using the second power of (1.1.4), one can obtain the inequality

$$D^2 \cdot \Omega \geq \lambda^2 \quad (1.1.5)$$

that is equivalent to the Sigman antenna theorem [11] regarding light detection by using the method of optical heterodyne.

Thus, as it follows from (1.1.1), (1.1.4), (1.1.5) these two criteria of maximal efficiency both for direct detecting in OIC "without losses" and for limiting efficient optical heterodyning are reduced to the problem of "parallelizing" the radiation beams.

A simple combination of the expressions (1.1.1) and (1.1.2) with (1.1.3) gives a "total" inequality that defines possible relations both between sizes R, D and parameters of TR – λ, $\Delta\lambda$, and geometry of OIC – θ_{min} (or L_{max}):

$$2\theta_{min} R \cdot D \cdot \Delta\lambda = \frac{R \cdot D^2 \cdot \Delta\lambda}{L_{max}} \geq \lambda^3 . \quad (1.1.6)$$

Thus, the set of parameters that defines the "extremely efficient" properties of optical information systems is limited by the photon volume λ^3. Note that the widely used inequalities (1.1.1)-(1.1.5) were obtained in [5] using the shortest of the known ways based on only two theses:

i) applicability of the uncertainty relations and

ii) conception of the ideal optical channel "without losses", physical definition of which is reduced to two inequalities following from (1.1.1), (1.1.2) and (1.1.3):

$$\theta_{min} \geq \frac{\lambda}{2R} \cong \frac{D}{2L} .$$

The process of measuring the physical efficiency of the ideal optical channel "without losses" assumes that the condition of constancy, for example in the case of the ratio λ / D, is valid.

2.2. Information content of TR

The statistical analysis [12] shows that the maximum efficiency of optical transfer of information can be obtained providing the way of light modulation which endue it with statistical properties of TR. It is this circumstance that forces us to consider here these aspects of principle for the limitation of the amount of information transferred by the ideal OIC, the information carrier in which being only the TR photon flows from the radiator to the PD input. Below, we shall consider the cases when information is coded only by the amplitude of the TR pulse $\langle N_{imp} \rangle = \langle F_D \rangle \cdot \Delta t$ (Δt is pulse duration). The average information amount within the single light pulse (designated as $\langle T_{imp} \rangle$) may be approximately expressed by the Shennon formula [13, 14]

$$\langle T_{\rm imp}\rangle \cong \log_2\left(1+\frac{\langle F_D\rangle\cdot\Delta t}{\Delta N_{\rm thr}}\right). \qquad (1.2.1)$$

Here, $\Delta N_{\rm thr}$ is the differential threshold for single pulse amplitudes as to the number of photons in the pulse.

2.3. Information efficiency of OIC without losses

Below, we consider the cases relating to the so-called regime of detection limited by noises of the signal itself (SNL [15]). It is this situation that allows us to estimate extreme limitations of the efficiency of TR in OIC. So, the uncertainty relation (2.4) results in limitations in the space angle Ω_D (1.1.1), which "provides" the condition of absent losses in OIC

$$D^2_{\min}/L^2_{\max} = \lambda^2/R^2. \qquad (1.3.1)$$

Thus, fixing both physical (λ/D) and aperture (Ω_D) parameters of OIC without losses and measuring the resultant TR spectrum, one can obtain information about the physical properties of TR in OIC. Let us illustrate two cases.

1. Signal is not limited in principle; $\Delta N_{\rm thr}$ is set by the uncertainty "number of photons – phase" (1.5)

The distinction for this extreme limitation is the fact that $\Delta N_{\rm thr}$ is formed by fluctuations of photon phases $\Delta\varphi$ during the time equal to the duration of the TR pulse carrying information. Using the quadratic form of the relation (1.3) [16], one can deduce the condition adequate to the relation (1.5)

$$\langle \Delta F_D^2\rangle^{1/2}\cdot(\nu\cdot\Delta t) \ge \frac{1}{2}. \qquad (1.3.2)$$

In this case, the extremely low differential threshold for TR pulses can be defined through the pulse duration Δt as $\Delta N_{\rm thr} = \langle \Delta F_D{}^2\rangle^{1/2} = (2\nu\cdot\Delta t)^{-1}$, which allows us to change the value $\Delta N_{\rm thr}$ in (1.3.1) with the inverse phase uncertainty $(2\nu\cdot\Delta t)^{-1}$. With these assumptions, one can obtain

$$\langle T\rangle_1 = \log_2\left[1+\left(8\pi c/\lambda^4\right)\cdot\left(1-\frac{\lambda^2}{4R^2}\right)\times \right.$$
$$\left.\times\left(\frac{\Delta\lambda}{\lambda}\right)\cdot\langle n\rangle\cdot\left(\frac{c}{2}\right)\cdot A\cdot\frac{D^2}{4L^2}\cdot(\Delta t)^2\right]. \qquad (1.3.3)$$

2. The photon flux is limited by inequalities (1.4), (1.1.1); $\Delta N_{\rm thr}$ is set by the uncertainty "number of photons – phase" (1.5)

For this doubly limited signal (i.e., both (1.1.1) and (1.3.2) are valid), it follows that

$$\langle T\rangle_2 = \log_2\left[1+2\pi\cdot\left(\frac{c}{\lambda}\right)^2\cdot\left(1-\frac{\lambda^2}{4R^2}\right)\cdot\left(\frac{\Delta\lambda}{\lambda}\right)\cdot\langle n\rangle\cdot(\Delta t)^2\right]. \qquad (1.3.4)$$

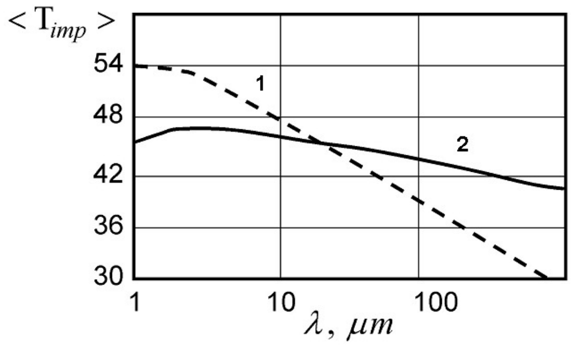

Fig. 3. Spectral distributions for the information amount within the TR pulse for single (*1*) and doubly (*2*) limited photon fluxes.

Fig. 3 demonstrates both spectra, namely: $\langle T_{\rm imp}\rangle_1$ and $\langle T_{\rm imp}\rangle_2$.

The regime of double limitation (formula (1.3.4)) at the long-wave range ($\lambda > 20$ μm) appears to be more informative than the single-limited one (formula (1.3.3)). This result begets the hypothesis that the TR photon flux limited both spatially ($\theta \ge \lambda/2R$) and in time ($\Delta t \ge (2\,\Delta N\cdot\nu)^{-1}$) is, to some extent, "protected on noise".

The result concerning the spectra $\langle T_{\rm imp}\rangle_1$ and $\langle T_{\rm imp}\rangle_2$ (Fig. 3) can be obtained using the uncertainty relations, both (1.3) and (1.5), that is assuming the differential threshold for pulses $\Delta N_{\rm thr} = \langle \Delta N_D{}^2\rangle^{1/2}\Delta t = (2\nu\cdot\Delta t)^{-1}$. It is indicative of the principal possibility to realizing a "noise-proof" regime. But it practical realization is not yet obvious.

3. Information model for the reliability of an "organized structure"

Offered in [4] is the model for determining the *a priori*-probabilistic reliability of an "organized structure", for example semiconductor electronic device or its element (*p-n* junction, quantum well, etc.), which is based on the opportunity to determine the initial value of the information entropy (negentropy [13, 14]). It can serve as an initial condition when solving the equation for negentropy production, which is analogous to the equation for the thermodynamical entropy production.

The initial conceptions of the work are as follows. Every unit can be presented in a single way by a definite sequence of Numbers set by technical requirements, drawings and technological charts. The given number can be realized only with a definite probability, therefore, in the initial technical documents the number is set with an acceptable departure from the mean value, i.e., with the allowance = ±ΔNumber. The main assumption is as follows: the allowance is given in the form ±ΔN and, consequently it (at least, in a formal way) can be approximately expressed through the dispersion of N as

$$\langle[\Delta(\text{Number})]^2\rangle^{1/2} \cong \pm\Delta\text{N}. \qquad (2.1)$$

When operating or storing, such processes as wearing or aging destroy the unit and distort the allowances of the given Number sequence, which is accompanied by an inevitable growth of entropy. Consequently, every unit has its negentropy that gives way to the calculations.

The major definitions of the subject under discussion in terms of calculus of probability do not rearrange the currently developed methods of a priori (APR) or a posteriori (APO) estimation of the reliability [17, 18]. Here, we offer only a possible information model of the problem.

The idea for the offered model is based on the following probabilistic hypotheses:

A – Rigorously determined sequence of Numbers, which is set by technical requirements, drawings and technological charts, is an information model of the organized structure (OS) that has respective negentropy as mentioned above.

B – Every Number from this sequence is given with an accessible departure from its mean value ⟨Number⟩, i.e., its allowance = ± ΔN. In the course of manufacturing OS, the Number and its allowance are realized with a definite probability $P(J)$.

C – Dispersion for each Number is equal to $\langle[\Delta(\text{Number})]^2\rangle$ and can be expressed via its allowance defined by a designer as well as realized by a technologist.

D – Technological operation (TO) is set by a complex of conditions $\Re$ [19], with realization of which the event A takes place, i.e., realization of ⟨Number⟩ within the allowance ±ΔN. There exists some distribution of the probability for realization of each acceptable departure set for the given technological operation.

E – The total probability for OS to be performed in accord with the departures ±ΔN set in drawings for their mean value can be calculated using the a priori estimate of the Bayes method [17]. The total conditional probability by Bayes defines the probabilistic space for existing OS parameters set by the given construction (device) in the adopted technology (i.e., the sequence of technological operations) of OS production.

The negentropy value corresponding to the total conditional probability indicating that OS is performed in accord with the set departures $(\pm\Delta\text{N}) = \langle[\Delta(\text{Number})]^2\rangle$ can be used as an initial condition for a numeric solution of the entropy production equation [20] that expresses evolution of separate OS parameters caused by exploitation of OS or its storage (aging).

In the case of semiconductor technologies (growing, doping, preparation of *p-n* junctions, structures, etc.), the thermodynamic approach should be used when considering the process of entropy production (for example, diffusion and so on). Entropy production in thermodynamics [20-22] is related to the presence of spatial non-homogeneity in the distribution of temperature, partial chemical potentials μ_i and velocity of convective transfer U_0. For instance, non-homogeneity in μ_i is caused by non-homogeneous distributions of component concentrations C_i and/or temperature.

When solving a specific task, it is necessary to develop a mathematical (probabilistic) model for the process of OS defect generation as a result of testing (or exploitation), i.e., a specific mechanism for thermodynamic entropy production. This specific mechanism can be modeled using the same Baye methods for statistical estimation.

It follows from the posed above:

1. If in the process of storage or exploitation the real allowances lose their relation with the allowances set in the technical documentation, then OS cannot correspond to the requirements of reliability.

2. It seems indisputable that OS (semiconductor device) can be represented in a unique way by a definite sequence of Numbers that contain specific parameters of this OS in themselves. Any produced OS is allotted with the respective informational (negative) entropy.

3. The initial value of this informational entropy can be calculated to solve the negentropy production equation by using physical-and-chemical and other numerical data of properties inherent to various elements (structures) of the OS.

4. Considering critical values of the negentropy changing in time, it is natural to include them into the list of technical requirements as parameters allowing to calculate a priori quantitative characteristics of the device reliability.

It is known from practice that whatever complex the device would be its regular (standard) breakdown is caused by failure of the so-called "weak elements", but not of all the elements of the device in the whole. In relation to this, the method offered here can be applied only to weak elements, which essentially constricts the area for researching the specific mechanisms of thermodynamic entropy production and, using the respective computer software, will aid processing of the data of negentropy production.

Note in summary that if the Number allowances setting the design and technological content of OS to relate in a definite approximation with dispersions in respective probabilistic distributions

$$(\text{Dispersion})^{1/2} \cong \pm(\text{Allowance}),$$

then one can obtain access to APR estimation of the OS reliability, and then compare it with the initial technical documentation.

It seems natural to perform the "inverse operation", i.e., to estimate the opportunity to determine stability of ±(Allowance) through remote measuring of the statistic characteristics (Dispersion) of system parameters.

Especially attractive is the possibility to remotely control the physical state of multi-element both organized and stochastic structures via their thermal or scattered radiation.

With the aim to ascertain the possibility of the "inverse operation", it is expedient to estimate the opportunity for remote metric analysis of TR emitted by a stochastic ensemble of radiators with small sizes.

4. Remote identification of a stochastic ensemble of RSS

If the remote measurements of physical parameters inherent to the RSS system are performed using the detection of TR, then attention should be focused at providing the ideal conditions (without reactive losses within the trace) and at the possibility of measuring respective photocurrents at the PD output. The principal opportunity to identify a single RSS through its TR has been considered in [23] using the relations between the dispersion $\langle \Delta F^2 \rangle$ of a random value F and its mean value $\langle F \rangle$

$$q_F = \frac{\langle \Delta F^2 \rangle}{\langle F \rangle} . \qquad (3.1)$$

Thermodynamic adequacy of the value (3.1) was grounded in [24, 25] being based on established literature data [1, 6, 15, 26, 29-32] and others. The value q_F is clearly defined from the physical viewpoint. When the thermodynamic conditions (P, V, T) are set, q_F behaves in chaos like to some "non-changible" basic parameter (by another words, as an "eigen-parameter"). Below, we have given several expressions for $q(F)$ [3, 23-25] that can be applied to TR within the cavity of ABB:

intrinsic energy of TR in one mode

$$q(m) = \langle E(\nu) \rangle / Z(\nu) \cdot \Delta\nu = \langle n \rangle \cdot h\nu, \qquad (3.2)$$

intrinsic number of photons in the field of TR

$$q(n) = (1 + \langle n \rangle), \qquad (3.3)$$

intrinsic photon flux within the frequency band $\Delta\nu_q$

$$q(f) = (1 + \langle n \rangle) \cdot \Delta\nu_q, \qquad (3.4)$$

intrinsic energy in the field of TR

$$q(E) = (1 + \langle n \rangle) \cdot h\nu, \qquad (3.5)$$

intrinsic density of energy in the field of TR

$$q(\varepsilon) = (1 + \langle n \rangle) \cdot h\nu / V, \qquad (3.6)$$

intrinsic TR power within the frequency band $\Delta\nu_q$

$$q(P) = (1 + \langle n \rangle) \cdot h\nu \cdot \Delta\nu_q. \qquad (3.7)$$

Here, $\langle n \rangle = \left[\left(\exp \frac{hc}{\lambda \cdot kT} \right) - 1 \right]^{-1}$ is the Planck function; other notations are common. $Z(\nu) \cdot \Delta\nu = V \cdot \frac{8\pi \cdot \nu^2 \Delta\nu}{c^3}$ is the number of spatial TR modes inside the ABB cavity of $V = R^3$ volume; density of TR energy inside the ABB cavity

$$\varepsilon(\lambda) = \frac{hc}{\lambda} \cdot \frac{8\pi}{\lambda^3} \cdot \left(\frac{\Delta\lambda}{\lambda} \right) \cdot \langle n \rangle ; \qquad (3.8)$$

ν is the frequency of observed TR, which corresponds to the center of the observation band $\Delta\nu$; $\Delta\nu_q$ is the "intrinsic band" of frequencies, one of the variants of which can be defined via identical rewriting the ordinary formula for TR power [6, 15] $P_{A\Omega} = \varepsilon(\lambda) \cdot \left(\frac{c}{2} \right) \cdot A \cdot \Omega$. It allows to separate the band $\Delta\nu_q = c / 2R$ with a phenomenologicaly clear role of the temporal factor that determines the TR power in one mode:

$$P_{A\Omega} = \frac{R^3}{R^3} \cdot \varepsilon(\lambda) \cdot \frac{c}{2} \cdot A \cdot \Omega = \left[\frac{hc}{\lambda} \cdot \langle n \rangle \cdot \frac{c}{2R} \right] \times$$
$$\times \left[R^3 \cdot \frac{8\pi}{\lambda^3} \cdot \frac{\Delta\lambda}{\lambda} \right] \cdot \left[\frac{A}{R^2} \cdot \Omega \right] \equiv$$
$$\equiv [\text{power in one mode}] \times$$
$$\times [\text{number of modes inside the cavity}] \cdot [\text{aperture factor}].$$

Applicability of $q_\varepsilon = \frac{h\nu}{\langle V \rangle} \cdot (1 + \langle n \rangle)$ (3.6) to determine the fluctuations of TR energy $E(\nu) = \langle V \rangle \cdot \varepsilon(\nu)$ inside the ABB cavity with the volume $\langle V \rangle$ can be confirmed in the following manner: when the size of the cavity is constant, in accord with statistical rules [19], the TR energy dispersion $\langle [\Delta E(\nu)]^2 \rangle$ can be written through the dispersion of the TR energy density as follows: $\langle [\Delta E(\nu)]^2 \rangle = \langle V \rangle^2 \cdot \langle [\Delta\varepsilon(\nu)]^2 \rangle$. In terms of (3.1) and (3.6) this expression becomes

$$\langle [\Delta E(\nu)]^2 \rangle = \langle V \rangle^2 \cdot \langle \Delta\varepsilon(\nu) \rangle \cdot \frac{h\nu}{\langle V \rangle} \times$$
$$\times (1 + \langle n \rangle) = \langle E(\nu) \rangle \cdot h\nu \cdot (1 + \langle n \rangle),$$

which is in full accordance with the conventional formulae [1, 26-32].

It is this aspect that provides formulation of the problem for the remote identification of a stochastic ensemble ("cloud") of radiators with small sizes [2i)], but the optical image of separate RSS is absent, which is a result of principal optical limitations. This aspect of TR photodetection is not yet reflected in the literature.

4.1. Model for possible identification of the RSS "cloud" [3]

Model (Fig. 4) can be represented as follows: the PD aperture allows to observe a part of the RSS "cloud" of the area S_{obs}, within the boundaries of which there is a

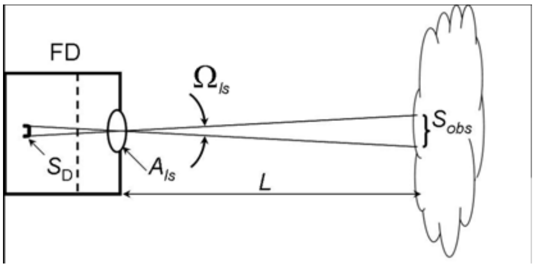

Fig. 4. Optical model to observe the RSS "cloud".

random number of RSS with the random size $S_i \approx R_i^2$ cm^2 distributed over the surface $S_{\rm obs}$ in a random manner with the density χ cm^{-2}, that is $\langle N\rangle = \langle\chi\rangle \cdot S_{\rm obs}$. The task is in measuring the current dispersion at the PD output. It is assumed that the dispersion $\langle \Delta P_{ND}^2 \rangle$ of the TR power at the input of PD (P_{ND}) is formed by TR energy density fluctuations $\varepsilon_i(\lambda)$ inside the RSS cavity, by fluctuations of the number $\langle \Delta N^2\rangle$ and sizes $\langle \Delta S_{ij}^2\rangle$ of RSS; it means that all three parameters determining the TR in the field of $S_{\rm obs}$ fluctuate. In this situation, it is convenient to represent the fluctuating (emitting this TR) part of $S_{\rm obs}$ as a random value $S_{\rm ran} = \sum_{j=1}^{N} S_{ij}$. The thermal background is created by the "cloud" itself; the external background is absent; the optical setup corresponding to this approach is illustrated by Fig. 4.

4.2. Fluctuations of TR and respective photocurrents at the PD output

Within the framework of the above model, the TR power flux orthogonal to the emitting surface $S_{\rm ran}$ takes the following form at the PD input

$$P_{N\rm ph} = \frac{hc}{\lambda}\cdot\frac{8\pi}{\lambda^3}\cdot\left[1-\left(\frac{\lambda}{2\langle R_i\rangle}\right)^2\right]\times$$
$$\times\left(\frac{\Delta\lambda}{\lambda}\right)\cdot\langle n_i\rangle\cdot\left(\frac{c}{2}\cdot\sum_{j=1}^{N} S_{ij}\cdot\frac{\Omega_{ls}}{2\pi}\right). \qquad (3.2.1)$$

The values $\varepsilon_i(\lambda)$, S_{ij}, and N (or χ), from the statistical viewpoint, are absolutely independent of each other. To define the respective dispersions, let us try to use the known statistical relations [19, 30, 31] as well as the dispersion theorem [28] for the case when $S_{\rm rad} = \sum_{j=1}^{N} S_{ij}$ and (in our case) both S_i and N fluctuate, and the following relations $\langle S_i^2\rangle = \langle S_i\rangle^2$, $\langle S_{\rm ran}\rangle = \langle N\rangle\cdot\langle S_i\rangle$ take place. Then, the dispersion of the "cloud" emitting area can be expressed as follows

$$Var\, S_{\rm ran} = \langle S_i\rangle^2\cdot\langle \Delta N^2\rangle + \langle N\rangle\cdot\langle \Delta S_i^2\rangle .$$

For the dispersion of the TR power, one can obtain

$$\langle \Delta P_{N\rm ph}^2\rangle = \left(\frac{c}{2}\cdot\frac{\Omega_{ls}}{2\pi}\right)^2\cdot Var\left\{\varepsilon_i(\lambda)\cdot\left[\sum_{j=1}^{N} S_{ij}\right]\right\} \cong$$
$$\cong\left\{\left(\frac{\langle\Delta\varepsilon_i^2\rangle}{\langle\varepsilon_i\rangle^2}+1\right)\cdot\left[\frac{\langle\Delta N^2\rangle}{\langle N\rangle}+\frac{\langle\Delta S_{ij}^2\rangle}{\langle S_{ij}\rangle^2}\right]+\langle N\rangle\cdot\frac{\langle\Delta\varepsilon_i^2\rangle}{\langle\varepsilon_i\rangle^2}\right\}\times$$
$$\times(P_{DN})\cdot(P_{Di}) \qquad (3.2.2)$$

The dispersion of the TR density inside the RSS cavity can be written

$$\langle\Delta\varepsilon_i^2\rangle = q_\varepsilon\langle\varepsilon_i\rangle, \qquad (3.2.3)$$

where the value q_ε, by its definition (3.6), is

$$q_\varepsilon = \frac{hc}{\lambda\langle V_i\rangle}\cdot\left(1+\langle n_i\rangle\right). \qquad (3.2.3^*)$$

Then, assuming that the number N within the limits of the observed part of the cloud surface obeys the Poisson distribution, i.e., $\langle \Delta N^2\rangle = 1\cdot\langle N\rangle$ [19], after some obvious algebraic transformations to deduce the mean value of TR power, one can find the general expression for the RSS TR power dispersion at the PD input:

$$\langle \Delta P_{N\rm ph}^2\rangle = \left(\frac{c}{2}\cdot\Omega_D\right)\times$$
$$\times\left\{\left(q_\varepsilon+\langle\varepsilon\rangle\right)\cdot\left[1+\frac{\langle\Delta S_i^2\rangle}{\langle S_i\rangle^2}\right]\cdot\langle S_i\rangle+\langle N\rangle\cdot\langle S_i\rangle\cdot q_\varepsilon\right\}\times \qquad (3.2.4)$$
$$\times\langle\varepsilon\rangle\cdot\left(\frac{c}{2}\cdot\Omega_D\right)\cdot\langle S_i\rangle\cdot\langle N\rangle .$$

Assuming that the ratio $\langle\Delta S_i^2\rangle / \langle\Delta S_i\rangle^2 << 1$, i.e., the RSS sizes are characterized with moderate random scattering, and $\langle N\rangle >> 1$, and noting that the product of parameters outside the brackets in the formula (3.2.4), i.e., $\langle\varepsilon\rangle\cdot\left(\frac{c}{2}\cdot\Omega_D\right)\cdot\langle S_i\rangle\cdot\langle N\rangle$ is nothing but the mean value of TR power $\langle P_{N\rm ph}\rangle$ (3.2.1), we obtain a possible working version for the expression of TR power dispersion at the PD input:

$$\langle \Delta P_{N\rm ph}^2\rangle \cong \left(\frac{c}{2}\cdot\langle S_i\rangle\cdot\Omega_D\right)\times$$
$$\times\left\{\left(q_\varepsilon+\langle\varepsilon\rangle\right)+\langle N\rangle\cdot q_\varepsilon\right\}\cdot\langle P_{N\rm ph}\rangle , \qquad (3.2.5)$$

that contains three unknowns (temperature T, number N, and size S_i of radiating particles), which should be determined from the measurements of the mean power value and TR dispersion inherent to the stochastic ensemble of RSS. It is also worth emphasizing that within the framework of weak approaches $\langle\Delta S_i^2\rangle / \langle S_i\rangle^2 << 1$

and $\langle \Delta N^2\rangle = \langle N\rangle$ accepted above the power dispersion (3.2.5) can be expressed via the mean values of fluctuating amounts ($\langle \varepsilon(\lambda)\rangle$, $\langle S_i\rangle$, $\langle N\rangle$) as well as through the intrinsic internal parameter of RSS q_ε (3.2.3*).

4.3. Photocurrents at the PD output

The aforementioned relates to thecharacteristic values of RSS TR at the PD input. To proceed to possible realized calculations of the "cloud" TR parameters, it seems reasonable first to estimate respective photocurrents at the output of an ideal PD. Here, we assume that the total photocurrent I_Σ consist of three components:

1) the mean stationary photocurrent $I_{N\text{ph}}$ that is in proportional to the total stationary mean TR power at the PD input (3.2.3):

$$\left\langle I_{N\text{ph}}\right\rangle = \frac{e\eta}{h\nu}\cdot\left\langle P_{N\text{ph}}\right\rangle = \frac{e\eta}{h\nu}\cdot\left\langle \varepsilon_i\right\rangle \times \times\left(\frac{c}{2}\cdot\left\langle R_i\right\rangle^2\cdot\left\langle \chi\right\rangle\cdot S_{\text{obs}}\frac{\Omega_{ls}}{2\pi}\right), \quad (3.3.1)$$

where the value η is the quantum efficiency of PD [15] that can be set as equal to unity; e – electron charge.

2) the shot noise $\left\langle I_{sn}^2\right\rangle$ at the PD output, which is proportional to the current $I_{N\text{ph}}$ [15, 28]:

$$\left\langle I_{sn}^2\right\rangle = 2e\cdot\Delta f\cdot\left\langle I_{N\text{ph}}\right\rangle \quad (3.3.2)$$

(here and below Δf is the frequency band of the PD electronic circuit).

3) the stochastic component of photocurrent, which is caused by the intrinsic TR power fluctuations at the PD input [15] and is in proportion to the dispersion $\left\langle \Delta P_{N\text{ph}}^2\right\rangle$ (3.2.5):

$$\left\langle \Delta I_{N\text{ph}}^2\right\rangle = \left(\frac{e}{h\nu}\right)^2\cdot\left\langle \Delta P_{N\text{ph}}^2\right\rangle\cdot\left(2\frac{\Delta f}{\Delta\nu}\right). \quad (3.3.3)$$

The factor $(2\Delta f/\Delta\nu)$ in the formula (3.3.3), from the phenomenological viewpoint, is that fraction of the input TR power fluctuations what is registered indeed as a power of chaotic in time current at the PD output within the band Δf (frequency band for the PD electronic circuit). Thus, along with $I_{N\text{ph}}$ at the PD output we can observe the sum of two noise powers

$$\left\langle I_\Sigma^2\right\rangle = 2e\cdot\Delta f\cdot\left\langle I_{N\text{ph}}\right\rangle + (e\eta)^2\cdot\frac{\left\langle \Delta P_{N\text{ph}}^2\right\rangle}{(hc/\lambda)^2}\cdot\left(2\frac{\Delta f}{\Delta\nu}\right). \quad (3.3.4)$$

Below, the PD quantum efficiency [15] will be assumed to be equal to unity. Then, using the formulae (3.3.1)-(3.3.4) for output noise currents measured at two wavelengths, λ_1 and λ_2, with account of (3.6) and (1.7), we obtain following two relations $q_{1,2}$ corresponding to the formula (3.1):

$$q_{1,2} = 2e\Delta f\cdot\left[1+\frac{\Omega_{ls}}{4\pi}\left\{\frac{8\pi}{\lambda_{1,2}^2}\cdot\langle n\rangle\cdot\left(\left\langle R_i\right\rangle^2 - \frac{\lambda_{1,2}^2}{4}\right) + \langle N\rangle\cdot\frac{\lambda_{1,2}^2\cdot\langle n\rangle\cdot\exp\left(hc/\lambda_{1,2}^2\cdot kT\right)}{\left\langle R_i\right\rangle\cdot(\Delta\lambda/\lambda)}\right\}\right]. \quad (3.3.5)$$

Present in the expression (3.3.5) are three unknowns that should be determined. These are the same values: RSS temperature – T, RSS size – R_i and the number of RSS inside the area S_{obs} – N.

$$\left\langle R_i\right\rangle^3 - \left[\left(\frac{q_{1,2}}{2e\cdot\Delta f}-1\right)\cdot\frac{1}{\Omega_{ls}}\cdot\frac{1}{\pi\left\langle n_{1,2}\right\rangle}+1\right]\times \times\frac{\lambda_{1,2}^2}{4}\cdot\left\langle R_i\right\rangle + \langle N\rangle\cdot\frac{\lambda_{1,2}^3\exp\left(\frac{hc}{\lambda_{1,2}kT}\right)}{8\pi\,(\Delta\lambda/\lambda)} = 0\,. \quad (3.3.6)$$

To solve the task, we used the following logic. As the "cloud" parameters, in particular $\langle R_i\rangle$, $\langle N\rangle$, and T values, remain unchanged at two different wavelengths, while the rest of the values ($\lambda_{1,2}$, $\Delta\lambda/\lambda$ and Ω_{ls}) are set by experiment conditions, each of the equations (3.3.6) being solved should result in the same value of R_i. It can be realized only on condition that the respective coefficients in both equations are equal, i.e., they can be equated correspondingly. Solving this new system of "coefficient" equations (but necessarily in combination!), we can find the temperature. For example, the equality of coefficients before R_i

$$\left(\pi\cdot\Omega_{ls} + \left(\frac{q_1}{2e\cdot\Delta f}-1\right)\cdot\left(\exp\left(\frac{hc}{\lambda_1 kT}\right)-1\right)\right)\cdot\frac{\lambda_1^2}{4\pi\cdot\Omega_{ls}} = = \left(\pi\cdot\Omega_{ls} + \left(\frac{q_2}{2e\cdot\Delta f}-1\right)\cdot\left(\exp\left(\frac{hc}{\lambda_2 kT}\right)-1\right)\right)\cdot\frac{\lambda_2^2}{4\pi\cdot\Omega_{ls}}. \quad (3.3.6^*)$$

contains the only unknown – temperature T, however, it should be solved only in combination with the equality for absolute terms in the equation (3.3.6), namely:

$$\lambda_1^3\cdot\exp\left(\frac{hc}{\lambda_1 kT}\right) = \lambda_2^3\cdot\exp\left(\frac{hc}{\lambda_2 kT}\right), \quad (3.3.6^{**})$$

i.e., by substitution of $\exp(hc/\lambda_1 kT)$, for instance from (3.3.6**) to (3.3.6*), which eventually gives

$$T = \frac{1.439}{\lambda_2\cdot\left\{\ln\left[\left(1-\frac{Q_2}{\pi}\right)-\left(1-\frac{Q_1}{\pi}\right)\cdot\frac{\lambda_1^2}{\lambda_2^2}\right] - \ln\left(\frac{Q_1}{\pi}\cdot\frac{\lambda_2}{\lambda_1}-\frac{Q_2}{\pi}\right)\right\}}, \quad (3.3.7)$$

where $Q_{1,2} = \left(\frac{q_{1,2}}{2e\cdot\Delta f}-1\right)\cdot\frac{2\pi}{\Omega_{ls}}$ are the values corresponding to $q_{1,2}$ measured in experiments at two wavelengths $\lambda_{1,2}$.

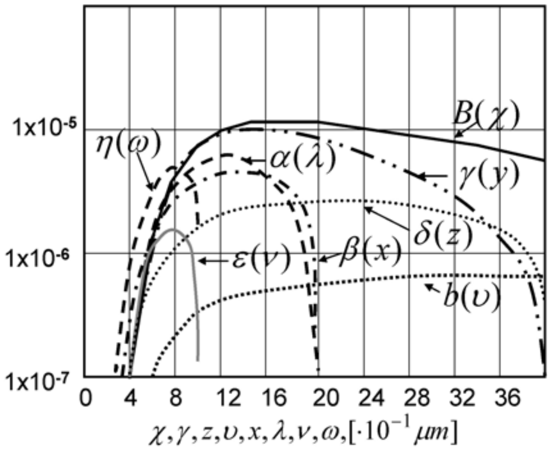

Fig. 5. Spectral distributions (T = 300 K; S_{obs} = 10^4 cm^2; for three RSS sizes: curves ε and η – R_i = 5 μm; α and β – R_i = 10 μm; γ and δ – R_i = 20 μm): photocurrents (solid lines): from ABB: $B(\lambda) = \langle I_{B\text{ph}} \rangle_{\text{ABB}}$; from RSS ε(λ), α(λ), $\gamma(\lambda) = \langle I_{N\text{ph}} \rangle_{\text{RSS}}$; photocurrent fluctuations (dashed curves): from ABB TR $b(\lambda) = \sqrt{\langle I^2_{B\text{ph}} \rangle_{\text{ABB}}}$; from RSS η(λ), β(λ), $b(\lambda) = \sqrt{\langle I^2_{N\text{ph}} \rangle_{\text{RSS}}}$. In doing so, to keep the possibility to juxtaposing the mean values with dispersions for various sizes $\langle R_i \rangle$, we kept the condition $\langle R_i \rangle \cdot \langle N \rangle = S_{obs} = 10^4$ cm^2.

The RSS temperature T = 300.17 K calculated using the formula (3.3.7) for Q_1 (λ_1 = 2 μm) = 5 and Q_2 (λ_2 = 12 μm) = 30.5 is very close to the temperature T = 300 K originally introduced into the calculation scheme. It allows to deem that the model and approaches used in the above calculation scheme do not contain, at least, any principal contradictions.

In the same manner, using the values of stationary photocurrents $\langle I_{N\text{ph}} \rangle_{1,2}$, (3.3.1), measured at two wavelengths $\lambda_{1,2}$, with the known temperature (3.3.7) one can obtain the equation easily solved relatively to $\langle R_i \rangle^2$:

$$\frac{\langle I_{N\text{ph}} \rangle_1}{\langle I_{N\text{ph}} \rangle_2} = \left\{ \frac{\lambda_2^3}{\lambda_1^3} \cdot \frac{\exp(hc/\lambda_2 kT) - 1}{\exp(hc/\lambda_1 kT) - 1} \right\} \times \frac{\left[4\langle R_i \rangle^2 - \lambda_1^2 \right]}{\left[4\langle R_i \rangle^2 - \lambda_2^2 \right]}, \quad (3.3.8)$$

which enables us to deduce the mean RSS size to the second power in the following form:

Substitution of $\langle R_i \rangle^2$ into either of the two (for λ_1 and λ_2) expressions (3.3.5) allows the calculation of the mean RSS number $\langle N \rangle$ within the limits of the observed "cloud" surface S_{obs}.

Along with the above illustrative calculation for the RSS "cloud" parameters, spectra $\langle I_{N\text{ph}} \rangle$ and $\sqrt{\langle \Delta I^2_{N\text{ph}} \rangle}$ (formulae (3.3.1) and (3.3.3)) can be used at the intersection points to make the same calculations.

Shown in Figs. 1 and 5 approximate calculations indicate that, from the numerical viewpoint, there are no principal problems with measuring the dispersion of the "cloud" TR power $\langle I^2_{N\text{ph}} \rangle_{\text{RSS}}$. In relation to this, one can use the TR information value at the intersection points for the spectra of the mean values of measured amounts with the spectra of their dispersions. As a result of the comparison between $\langle I_{N\text{ph}} \rangle$ and $\sqrt{\langle \Delta I^2_{N\text{ph}} \rangle}$ at the wavelengths of intersection points (shortwave – λ_{sw} and longwave – λ_{lw}) there also arise two (for λ_{sw} and λ_{lw}) cubic equations relative to the RSS size

$$R_i^3 - \frac{\lambda_{sw}^2}{4} \cdot R_i - \frac{\lambda_{sw}^4}{4\pi \cdot \frac{c}{\Delta f} \cdot \left(\frac{\Delta\lambda}{\lambda} \right)^2} \cdot \exp\left(\frac{1.439}{\lambda_{sw} \cdot T} \right) = 0 \text{ and}$$

$$R_i^3 - \frac{\lambda_{lw}^2}{4} \cdot R_i - \frac{\lambda_{lw}^4}{4\pi \cdot \frac{c}{\Delta f} \cdot \left(\frac{\Delta\lambda}{\lambda} \right)^2} \cdot \exp\left(\frac{1.439}{\lambda_{lw} \cdot T} \right) = 0. \quad (3.3.5)$$

Both equations give the same value of R_i despite the considerable difference between λ_{sw} and λ_{lw} values. For example, the shown in Fig. 6 graphic solution of the equations (3.3.5) for R_i = 20 μm (T = 300 K), where $\lambda_{sw} \cong 4$ μm and $\lambda_{lw} \cong 36$ μm, confirms the existence of clear relation between the values λ_{sw} and λ_{lw} (from Fig. 5) and the value R_i: the zeroth ordinate values are reached for the same $R_i(\lambda_{sw}) = R_i(\lambda_{sl})$ = 20 μm.

Thus, it seems possible to maintain that when using the relationship (3.1), at least in the ideal case (it means: ABB model, ideal PD, absence of supplementary fluctuations in TR flow within the trace the RSS "cloud" – PD), the task of remote identification of the RSS "cloud" components can be solved. Especially, if one has the possibility to measure the mean TR power value and the

$$\langle R_i \rangle^2 = \frac{1}{4} \cdot \frac{\frac{\langle I_{N\text{ph}} \rangle_1}{\langle I_{N\text{ph}} \rangle_2} \cdot \left(\exp(hc/\lambda_1 kT) - 1 \right) \cdot \lambda_2^2 - \frac{\lambda_2^3}{\lambda_1} \cdot \left(\exp(hc/\lambda_2 kT) - 1 \right)}{\frac{\langle I_{N\text{ph}} \rangle_1}{\langle I_{N\text{ph}} \rangle_2} \cdot \left(\exp(hc/\lambda_1 kT) - 1 \right) - \frac{\lambda_2^3}{\lambda_1^3} \cdot \left(\exp(hc/\lambda_2 kT) - 1 \right)} \quad (3.3.8^*)$$

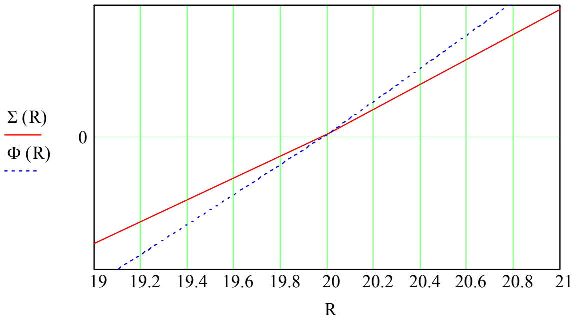

Fig. 6. Graphic solution of the equations (3.3.5) for $R_i = 20$ μm ($T = 300$ K).

dispersion of the intrinsic power fluctuations, when, in principle, the optical image of the separate small radiator is absent. It is obvious that this result can be reached only in those cases when the statistical character of chaos allows to allot the value q_F in the formulae (3.1) and (3.6) with the same statistical properties.

It is seen from the discussion above that the way (rather simplified) to solve this complex problem is surmountable due to information capability of the power dispersion inherent to RSS TR, which is realized via the relation (3.1), that is through the "eigen-parameter" q_ε (3.2.2*) that contains information about the RSS cavity size. The fundamental basis of this approach lies in the mutual statistical independency between the values $\varepsilon_i(\lambda)$, S_{ij}, and N.

An analogous problem, but more complex owing to the external thermal background, will be considered later.

4. Conclusions

1. In relation with the problem of registration of limited photon fluxes, it is important to emphasize the universal character of (λ / 2R) factor developing both in classical (limitation of the number of TR modes [2, 3] and in quantum (uncertainty relationships (1.3)-(1.5)) processes (1.2.1)-(1.2.4).

Limitation criteria can be connected both with sizes of RSS (R_i) and PD (D) and with physical parameters of TR flow. In the "total" composition of limitation parameters, the criterion is reduced to the "photon volume" = λ^3 (1.2.4).

2. It seems reasonable to make the spectral estimate of the information amount transferred by TR "without losses" in the regime of extreme limitation of beam angular sizes, in accord with (4.2.1). This way enables us to automatically realize the physical content of the information spectrum but not the "spectral losses" over the OIC trace.

3. The result relating to the spectra $\langle T_{\text{imp}} \rangle_1$ and $\langle T_{\text{imp}} \rangle_2$ (Fig. 3) can be obtained based on uncertainty relations (1.3)-(1.5) (i.e., assuming $\Delta N_{\text{thr}} = \langle \Delta N_D^2 \rangle^{1/2} \Delta t = (2\nu \cdot \Delta t)^{-1}$), which indicates the principal opportunity to realize the "noise-proof" regime. Consequently, it seems natural to use the hypothesis upon the possibility of remote controlling the correspondence of the acting organized system to the reliability parameters via its information model (i.e., growth of the negentropy).

4. Fundamental basics of the OS reliability are described by the equations for the production of thermodynamic entropy [23, 24]. However, to solve these equations it is necessary to determine its initial value, and in the case of OS it is only the zeroth value. The information model of the OS allows to calculate the probable initial value of the negentropy by determining the total conditional probability in accordance with the Bayes formula.

If in the course of storage or exploitation the real allowance loses the connection with allowances set by technical documentation, then this OS cannot correspond to requirements of reliability.

5. If one connects the allowances for the Numbers that define the design-and-technological content of OS with the dispersions of corresponding probabilistic distributions as the approximate equality (dispersion)$^{1/2} \cong$ ±(allowance), then Bayes formula gives a numeric characteristic of the fact that this OS is made in accordance with the requirements of its initial parameters. Consequently, it allows calculating the initial value of its information entropy to solve the equation of negentropy production being based on physical-and-chemical and other numerical data about the properties of various elements (structures) of OS.

6. It is known from practice that whatever complex is the device its regular (standard) breakdown is caused by failure of the so-called weak elements. Respectively, the offered method can be applied only to these weak elements, which can make it essentially easier to process data by using the corresponding software.

7. Thus, it seems possible to maintain that when using the relationship (3.1), at least in the ideal case (it means: ABB model, ideal PD, absence of supplementary fluctuations in TR flow within the trace of the RSS "cloud" – PD), the task of remote identification of the RSS "cloud" components can be solved. Especially, if one has the possibility to measure the mean TR power value and the dispersion of the intrinsic power fluctuations, when, in principle, the optical image of the separate small radiator is fully absent. It is obvious that this result can be reached only in those cases when the statistical character of chaos allows to allot the value q_F in the formulae (3.1) and (3.6) with the same statistical properties.

8. The conception "intrinsic micro-amounts of chaos" [24, 25] in the above example of small radiators is described as $q_\varepsilon = \dfrac{hC}{\lambda \cdot \langle R_i \rangle^3} (\langle n \rangle + 1)$, and its usefulness can be also seen in the following:

– comparison of the value $\langle \Delta F^2 \rangle_{\text{exp}}$ obtained by integration of the noise spectrum $S_F(\omega)$ or calculating the correlation function $K_F(0)$, with the value $\langle \Delta F^2 \rangle_q$ deduced in accord with the formula (1) for a given (assumed) q_F gives information on the adequacy of our conceptions of the fluctuation physical mechanism in the studied system;

– in the case when the stochastic phenomenon is not studied sufficiently, computation of the value q_F itself by using the formula (3.1) taking into account the dispersion $\langle \Delta F^2 \rangle_{\exp}$ obtained from experimentally measured $S_F(\omega)$ and $K_F(0)$ gives quantitative information on the main micro-parameter of the fluctuating system. This parameter with its numeric value close to known physical (may be fundamental) values can be an initial element to build the physical model of the phenomenon under consideration.

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