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Improvement of optical systems for detection of smokes

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Abstract. The theory of electromagnetic radiation dispersion by polydisperse particles is analyzed. Methods of reliable optical indication of smokes to identify Fire Danger are considered. The conventional method of optical smoke detection implies measuring optical characteristics of the environment under control. After that the results obtained are converted into microphysical parameters which can be compared to the known microphysical properties of smokes.The calculated optical portrait of smokes is offered. The portrait of smokes is the field of representation points in coordinates of the degree of diffusion radiation polarization for two diffusion angles. Each of the spots indicates one of the numerous realizations of smokes. The direct match of the representation spots in the optical increases the probability of smoke A different way to protect optical system is to use the device with mutually orthogonal polarizers of the light source and detector. If hindrance is nonspherical aerosol, the signal from the device is used to correct the signals from smoke detectors.

1.Introduction

Smoke detection to identify fire condition in many cases is based on the registration of intensity of electromagnetic radiation (EMR), scattered the smoke particles at an angle Θ to the probing beam. It contributed to the smoke particles and particles such as dust, noise. To enhance the reliability of the identification of the fire needs to minimize the contribution of scattering dust particles in the total signal.

We shall consider the elements of the theory of dispersion of electromagnetic radiation by aerosol particles. Let flat linearly-polarized wave of electromagnetic radiation $\varepsilon_0 = \mathrm{Im}\,\{\mathrm{E}_0\, \mathrm{e}^{\mathrm{iwt-\,ikz}}\}$ extend along the axis Z. At its interaction with a particle in a point of M the spherical scattered wave is formed:

$$\mathcal{E}(t,r,\Theta,\varphi) \;=\; \mathrm{Im}\Big\{\dot{\mathrm{S}}(\Theta,\varphi)\,\frac{\mathrm{e}^{\mathrm{iwt-\,ikz}}}{\mathrm{ikr}}\Big\}$$

here, $\dot{S}(\Theta,\varphi)$=$S\mathrm{e}^{\mathrm{i}\sigma}$ – the complex amplitude function defining the module and a phase of a wave, disseminated in the direction characterized by Θ, φ; r – distance; $k=\frac{2\pi}{\lambda}$ wave number.

Having chosen the plane of dispersion and having spread out the electric vector E_0 on mutually orthogonal components $\dot{\mathrm{E}}_{0l}$ and $\dot{\mathrm{E}}_{0r}$, it is possible to express $\dot{E}_l$ and $\dot{E}_r$ of a scattered wave through Maxwell-Jones's matrix:

$$\begin{bmatrix}\dot{\mathrm{E}}_{\,l}\,(\Theta,\varphi)\\ \dot{\mathrm{E}}_{\,r}\,(\Theta,\varphi)\end{bmatrix} = \begin{bmatrix}\dot{\mathrm{S}}_2(\Theta,\varphi) & \dot{\mathrm{S}}_3(\Theta,\varphi)\\ \dot{\mathrm{S}}_4(\Theta,\varphi) & \dot{\mathrm{S}}_1(\Theta,\varphi)\end{bmatrix} \mathrm{x} \begin{bmatrix}\dot{\mathrm{E}}_0\cos\varphi\\ \dot{\mathrm{E}}_0\sin\varphi\end{bmatrix} \frac{e^{-iwt+\,ikz}}{\mathrm{ikr}} \qquad (1)$$

Here, $\dot{\mathrm{S}}_1 \div \dot{\mathrm{S}}_4$ – components $\dot{S}$ (Θ,φ). For smoke particles – spheres: $\dot{S}_1(\Theta,\varphi)=\dot{S}_1(\Theta)$, $\dot{S}_2(\Theta,\varphi)=\dot{S}_2(\Theta)$, $\dot{S}_3=\ \dot{S}_4=0$, according to [1], thus:

$$\dot{E}_l = \dot{S}_2(\Theta)\dot{E}_{ol}\,\frac{e^{-ikr+ikz}}{ikr},\quad \dot{E}r = \dot{S}_1(\Theta)\dot{E}_{or}\,\frac{e^{-ikr+ikz}}{ikr}$$

The solutions for $\dot{S}_1$ and $\dot{S}_2$ according to [2] in [1] are presented in the form of:

$$\dot{S}_1(\Theta) = \sum_{n=1}^{\infty}\frac{2n+1}{n(n+1)}\left[\dot{a}_n\pi_n(\cos\Theta) + \dot{b}_n\tau_n(\cos\Theta)\right],$$

$$\dot{S}_2(\Theta) = \sum_{n=1}^{\infty}\frac{2n+1}{n(n+1)}\left[\dot{b}_n\pi_n(\cos\Theta) + \dot{a}_n\,\tau_n(\cos\Theta)\right].$$

$$\dot{a}_n = \frac{A_n(y)\psi_n(\rho) - m\psi_n'(\rho)}{A_n(y)\xi_n(\rho) - m\zeta(\rho)},\quad \dot{b}_n = \frac{mA_n(y)\psi_n(\rho) - \psi_n'(\rho)}{mA_n(y)\zeta(\rho) - \zeta_n'(\rho)}, \tag{2}$$

– $\pi_n(\cos\Theta), \tau_n(\cos\Theta)$ – angular functions, $= x = m_a\frac{2\pi a}{\lambda}$, $y = \frac{m_i}{m_a}\frac{2\pi a}{\lambda} = m\rho$, diffraction parameters, m_a, m_i – indices of refraction of environment and substances of a particle, $\psi_n(\rho), \zeta(\rho)$ – Bessel and Hankel's functions, $\psi_n(\rho), \zeta(\rho)$. Deyrmendzhan presented (2) in the form of [3]

$$\alpha_0 = \pi a^2 K(\rho,\dot{m}) = \pi a^2\frac{2}{\rho^2}\sum_{n=1}^{\infty}(2n+1)Re\left(\dot{a}_n + \dot{b}_n\right)$$

$$\sigma_0 = \pi a^2 \mathrm{K}_p(\rho,\dot{m}) = \pi a^2\frac{2}{\rho^2}\sum_{n=1}^{\infty}(2n+1)\left[|\dot{a}_n|^2 + |\dot{b}_n|^2\right]$$

where K and K_p –are factors of the efficiency of weakening and diffusion.

The real stream of dispersed electromagnetic radiation is the mixture of simple waves, and the definition of the total result of their transformation is a statistical task. For this reason, the probing bunches of electromagnetic radiation (of optical range) are described with the help of statistical parameters that consider the characteristics of simple waves and additivity of incoherent components of intermixture: four square and bilinear forms regarding to $\dot{E}_l$ and $\dot{E}$. They determine completely the condition of polarization of electromagnetic radiation (Stokes parameters) and are registered by square devices:

$$\left.\begin{aligned} I = \dot{E}_l\widehat{E_l} + \dot{E}_r\widehat{E_r} \qquad Q = \dot{E}_l\widehat{E_l} - \dot{E}_r\widehat{E_r} \\ U = \dot{E}_l\widehat{E_r} + \dot{E}_r\widehat{E_l}\; V = -i\left(\dot{E}_l\widehat{E_r} - \dot{E}_r\widehat{E_l}\right)\end{aligned}\right\}, \tag{3}$$

where I - intensity, интенсивность, energy stream through unit of area in unit of time, dimension is the same of Q, U, V. From (1) and (3) it is possible to formulate the equation of transformation of probing electromagnetic radiation.

$$\begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} = \frac{1}{k^2r^2}\begin{bmatrix} 0{,}5(M_2+M_3+M_4+M_1) & 0{,}5(M_2+M_3-M_4-M_1) & (A_{23}+A_{41}) & -(D_{23}+D_{41}) \\ 0{,}5(M_2+M_3-M_4-M_1) & 0{,}5(M_2-M_3-M_4+M_1) & (A_{23}-A_{41}) & -(D_{23}-D_{41}) \\ (A_{24}+A_{31}) & (A_{24}+A_{31}) & (A_{21}+A_{34}) & -(D_{21}+D_{34}) \\ (D_{24}+D_{31}) & (D_{24}-D_{31}) & (A_{21}+A_{34}) & (A_{21}-A_{34}) \end{bmatrix}\begin{bmatrix} I_0 \\ Q_0 \\ U_0 \\ V_0 \end{bmatrix},$$

$$or\ [S_i] = [F_{ik}][S_{0k}],$$

where $[S_i]$, $[S_{0k}]$ – Stokes column vector, dispersed and probing bunches, $[F_{ik}]$ – matrix of light dispersion (MLD) or Muller matrix [5],

$M_k = S_k^2,\ A_{kj} = A_{jk} = \frac{1}{2}\left(\dot{S}_J\widehat{S_k} + \dot{S}_k\widehat{S_J}\right),\ D_{jk} =-D_{kj} = \frac{1}{2}\left(\dot{S}_J\widehat{S_k} - \dot{S}_k\widehat{S_J}\right)$ so i-th Stokes parameter of dispersed electromagnetic radiation:

$$S_i = \sum_{k=1}^{4} F_{ik}\,S_{0k}$$

For a smoke particle (sphere):

$$\mathrm{F_{ik}} = \frac{1}{\mathrm{k^2r^2}}\begin{bmatrix} 1/2(\mathrm{M_2+M_1}) & 1/2(\mathrm{M_2\text{-}M_1}) & 0 & 0 \\ 1/2(\mathrm{M_2\text{-}M_1}) & 1/2(\mathrm{M_2+M_1}) & 0 & 0 \\ 0 & 0 & (\mathrm{A_{21}}) & \text{-}(\mathrm{D_{21}}) \\ 0 & 0 & (\mathrm{D_{21}}) & (\mathrm{A_{21}}) \end{bmatrix}$$

$$M_1 + M_2 = i_1 + i_2 = \alpha_1;\ \ M_1 - M_2 = i_1 - i_2 = \alpha_2;$$
$$2A_{12} = 2Re\{\dot{S}_1\widehat{S_2}\} = 2i_3 = \alpha_3;\ \ 2D_{21} = -2Im\{\dot{S}_1\widehat{S_2}\} = 2i_4 = \alpha_4.$$

During the transition from the matrix of light dispersion of a smoke particle to the matrix of light dispersion of particles in unit of volume, N, the function of their distribution by the sizes is considered

$$F(\rho) = Nf(\rho)$$

where (ρ)– spectral density, meeting the condition:

$$\int_{\rho_{min}}^{\rho_{max}} f(\rho)d\rho = 1$$

ρ_{min}, ρ_{max} – limits of the interval ρ. Therefore, the matrix of light dispersion of *N* particles system is:

$$[D_{ik}] = \begin{bmatrix} (D_{11}) & (D_{12}) & 0 & 0 \\ (D_{21}) & (D_{22}) & 0 & 0 \\ 0 & 0 & (D_{33}) & (D_{34}) \\ 0 & 0 & (D_{43}) & (D_{44}) \end{bmatrix} \tag{4}$$

$$D_{ik} = k^{-3}\int_{\rho_{min}}^{\rho_{max}} F(\rho)\frac{ai}{2}d\rho$$

For optically active [6] smoke particles:

$$F(a) = NAa^{-\nu}$$

$$F(\rho) = k^{\nu}NA\rho^{\nu}$$

$$D_{ik} = \pi NAk^{\nu-3}\int_{\rho_{min}}^{\rho_{max}} \rho^{-\nu}\frac{ai}{2}d\rho$$

$$\alpha = \pi N A k^{\nu-3} \int_{\rho_{min}}^{\rho_{max}} \rho^{-(\nu-2)} K(\rho, \dot{m}) d\rho$$

$$\sigma = \pi N A k^{\nu-3} \int_{\rho_{min}}^{\rho_{max}} \rho^{-(\nu-2)} K(\rho, \dot{m}) d\rho$$

Using the matrices $[f_{ik}]$, $[f'_{ik}]$, $[\widetilde{f_{ik}}]$, received by rationing (4) on $\frac{\sigma}{4\pi}$, σ, D_{11}, as well as angle structure of dispersed electromagnetic radiation:

$$f'_{11}(\Theta) = \frac{D_{11}}{\sigma} = \varkappa$$

For calculation of $D_{ik}$the form of the light dispersion matrix from [3] is used:

$$[D'] = \begin{bmatrix} (D'_{11}) & 0 & 0 & 0 \\ 0 & (D'_{22}) & 0 & 0 \\ 0 & 0 & (D'_{33}) & (D'_{34}) \\ 0 & 0 & (D'_{43}) & (D'_{44}) \end{bmatrix}$$

$$D'_{11} = D_{11} + D_{21};\ D'_{22} = D_{11} - D_{21};\ D'_{33} = D_{33};\ D'_{44} = D_{44}; D'_{34} = D_{34};\ D'_{43} = D_{43}$$

Elements f'_{11}, $\widetilde{f_{11}}$, are received through D'_{ik}, by rationing on $\frac{\sigma}{4\pi}$, D_{11} [3]:

$$P_i(\Theta) = \frac{4\pi D'_{ik}}{\sigma} = \frac{4\pi}{\sigma} k^{-3} \int_{\rho_{min}}^{\rho_{max}} F(\rho) i_k d\rho$$

$$f'_{11} = \varkappa = \frac{D_{11}}{\sigma} = \frac{(D'_{11} + D'_{22})}{2\sigma} = \frac{(P_1 + P_2)}{8\pi}$$

$$\widetilde{f_{21}} = \frac{D_{21}}{D_{11}} = \frac{(P_1 - P_2)}{(P_1 + P_2)}$$

$$\widetilde{f_{33}} = \frac{D_{33}}{D_{11}} = \frac{2P_3}{(P_1 + P_2)}$$

$$\widetilde{f_{43}} = \frac{D_{43}}{D_{11}} = \frac{2P_4}{(P_1 + P_2)}$$

2. About smokes identification

Authors with employees are engaged in researches in the field of optical and micro structural characteristics of the smoke aerosols received at low-temperature pyrolysis (decay) of wooden, electro – heat-insulating, decorative, constructional and other materials and surfaces [7–9] since the beginning of the 1970th.

These researches were conducted with the Tomsk Scientific Center of Siberian Branch of the Russian Academy of Science, in particular, with the Doctors of Physico-mathematical Sciences: B.V. Kaul, I.V. Samokhvalov, V. F. Belov, O. A. Krasnov, V. S. Kozlov, to whom authors express their deep gratitude.

At the same time the authors of the research develop, test and implement highly sensitive to smoke, few dimensional sensors of smoke concentration and systems of fire detection [10–14] in cooperation with NPO Meridian, NPO Energiya, Institute of medicobiological problems of the Russian Academy of Sciences, nowadays the All-Russian Scientific Research Institute of Fire-prevention Defence, and with many other organizations.

Some results of the researches in the field of optical-polarizing protection of optical systems of early detection of the fire-dangerous state that, nowadays, are based, mainly, on registration of the radiation, dispersed by smoke particles, are given below. That means it is based on the registration of the first parameter of a Stokes column vector I – intensity (brightness). Therefore, the basis of optical-polarizing protection concept is the idea of using the Muller matrix and Stokes column vector or derivatives of them in order to identify the smokes of other parameters, for example, the degree of polarization of the radiation dispersed by the environment.

Two approaches to identification of smokes are formulated. According to the first one, the classical approach, optical characteristics of the environment are measured and transferred into microphysical parameters which are compared to known microphysics of smokes. Its basis is in the solution of the integrated equation:

$$\int_a^b K(x,y) f(x)\,dx = \varphi(y),\ a \le x \le b;\ \ c \le y \le d$$

or in the operator form:

$$Kf = \varphi \tag{5}$$

where, K – equation kernel, f – function of dispersion of particles according to the sizes, φ – result of optical experiment. So, the solution (5) is the solution of the system:

$$\sum_{i=1}^{n} K_{ij} f_i = \varphi_i,\ j = 1,2,\ \ldots .n \tag{6}$$

The problem of the solution (6) – is to find out the closest to true solution from a set of *F* solutions. Trial and error method [15] is used under a known subclass of solutions *M* for correct tasks according to Tikhonov: the function f_δ, meeting the following requirement is selected:

$$\| K f_\delta - \varphi_\delta \| \le \delta \tag{7}$$

where, $\delta = \Delta^2,\ \Delta -$ measurement error φ. If φ_δ does not belong to the set KM, the reverse operator $K^{-1}\varphi_\delta$ cannot make any sense.

In the method of regularization [15] there is a solution f_δ^α, minimizing the functional with the discrepancy (7) and with the functional of smoothness of solution with a regulating multiplier α. In [16] for definition of $f(x)$ and n multifrequency measurements $D_{11}(\pi)$ and α, are used. According to zero approach n^0 the method of regularization is used to find out f^1, that is further used by the following iteration to specify n with the discrepancy $\|D_{11}(\pi) - K_\pi(n) f^1\|$ etc.

Measuring the frequency ranges $D_{11}(\pi)$, α , $D_{11}(\Theta)$ it is possible to calculate $f(x),\ n,\ \chi$.

The complexity of multifrequency or multiangular [16] measurements of the elements of the light dispersion matrix, the necessity to use the computer programmes in order to convert the results of optical measurements and implementation of the criterion of "recognition" of a smoke etc. make the application of the "microphysical" approach of smokes identification very problematic.

Within the second approach the identification is organized by measuring of known parameters of light dispersion matrix of the environment and of their comparison with an optical portrait of smokes, to similar types of optical weather [17].

According to the theory of recognition of images an optical portrait the can be defined by a field of representation spots in n – measured space of the characteristic parameters of the light dispersion matrix, where each spot represents a certain degree of smoke (or hindrances). Characteristic parameters have to provide simplicity of measurements, compactness and discrepancy of fields of smokes and hindrances, diminutiveness of fire situation system. The simplest case of a field – in coordinates of two parameters, for example, the degree of polarization at two angles of dispersion, P_1 and P_2. At radiation of smoke particles by the monochromatic non- polarized radiation, the Stokes's vector parameter of dispersed electromagnetic radiation is:

$$[S_i] = [D_{ik}][S_{0K}] = \begin{bmatrix} (D_{11}) & (D_{12}) & 0 & 0 \\ (D_{21}) & (D_{22}) & 0 & 0 \\ 0 & 0 & (D_{33}) & (D_{34}) \\ 0 & 0 & (D_{43}) & (D_{44}) \end{bmatrix} \begin{bmatrix} I_0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = I_0 \begin{bmatrix} (D_{11}) \\ (D_{21}) \\ 0 \\ 0 \end{bmatrix}$$

$$\mathrm{P} = -\frac{\mathrm{Q}}{\mathrm{I}} = -\frac{\mathrm{D}_{21}}{\mathrm{D}_{11}} = \widetilde{\mathrm{f}_{21}}$$

When installing a polarizar Π with an azimuth ψ = 0 at a receiver with the angle Θ

$$[S_1(\Theta_1)] = [M_k][S_K(\Theta_1)] = K \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} I_0 \begin{bmatrix} D_{11}(\Theta_1) \\ D_{21}(\Theta_1) \\ 0 \\ 0 \end{bmatrix} = KI_0 \begin{bmatrix} D_{11}(\Theta_1) + D_{21}(\Theta_1) \\ D_{11}(\Theta_1) + D_{21}(\Theta_1) \\ 0 \\ 0 \end{bmatrix}$$

Here $[M_k]$ and K – matrices of conversion and transmission coefficient Π that are registered by the brightness receiver ψ = 0 и π/2 , $S_{1\parallel}$ и $S_{1\perp}$, $S_{1\parallel} = KI_0\left(D_{11}(\Theta_1) + D_{21}(\Theta_1)\right)$;

$S_{1\perp} = KI_0\left(D_{11}(\Theta_1) - D_{21}(\Theta_1)\right)$, therefore $\frac{(S_{1\parallel} - S_{1\perp})}{(S_{1\parallel} + S_{1\perp})} = \frac{D_{21}(\Theta_1)}{D_{11}(\Theta_1)} = -P_1 = \widetilde{f_{21}}(\Theta_1)$

Measurements of $S_{1\parallel}$ end $S_{1\perp}$ are possible by cyclic turning of Π on the angle π/2 and vice versa or by locating another identical receiver with Π on the other side from the axis of the lighter at the angle Θ_1. The same process is used to calculate P_2. A number of researches [13], of optical schemes for measuring of other elements of light dispersion matrix confirm the measurement scheme $P(\Theta_1)$ end $P(\Theta_2)$.

Realization of smokes identifier on the basis of control of environment-representing spot in coordinates P_1 end P_2.represents rather complex challenge. Therefore, the other principle of optical system protection from aerosol hindrances is investigated. It is based on the device with mutually orthogonal surfaces of polarization of light source and detector polarizers, for example, light source: ψ = 0, and detector: ψ = π/2. Such device is a cross-polarizing indicator of aerosol hindrances (dust) – CIH.

Stokes column vector of polarizing radiation of a light source:

$$[S_i] = K \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = K \begin{bmatrix} I_0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Stokes column vector of radiation by dispersed smokes:

$$[S_i] = \begin{bmatrix} D_{11} & D_{12} & 0 & 0 \\ D_{21} & D_{22} & 0 & 0 \\ 0 & 0 & D_{33} & D_{34} \\ 0 & 0 & D_{43} & D_{44} \end{bmatrix} K \begin{bmatrix} I_0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = KI_0 \begin{bmatrix} D_{11} + D_{12} \\ D_{21} + D_{22} \\ 0 \\ 0 \end{bmatrix}$$

At the polarizer output in front of the receiver:

$$[S_i]_\Phi = K \begin{bmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} KI_0 \begin{bmatrix} D_{11} + D_{12} \\ D_{21} + D_{22} \\ 0 \\ 0 \end{bmatrix} = K^2 I_0 \begin{bmatrix} (D_{11} + D_{12}) - (D_{11} + D_{22}) \\ -(D_{11} + D_{12}) + (D_{21} + D_{22}) \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

If for sphere particles $D_{11} = D_{12}$, $D_{21} = D_{12}$, so in a smoked environment an output optical signal of cross-polarizing indicator of aerosol hindrances is equal to zero, and in sensors it is formed "purely smoke" signals proportional to the size $I_0 D_{11}$.

In case of an aerosol hindrance with light dispersion matrix $[D_{ik}^n]$ sensors produce additional signals $I_0 D_{11}^n$, and CIH form dispersed radiation with Stokes column vector:

$$[S_i^n] = \begin{bmatrix} D_{11}^n & D_{12}^n D_{13}^n\, D_{14}^n \\ D_{21}^n & D_{22}^n D_{23}^n\, D_{24}^n \\ D_{31}^n & D_{32}^n D_{33}^n\, D_{34}^n \\ D_{41}^n & D_{42}^n D_{43}^n\, D_{44}^n \end{bmatrix} K \begin{bmatrix} I_0 \\ I_0 \\ 0 \\ 0 \end{bmatrix} = K I_0 \begin{bmatrix} D_{11}^n + D_{12}^n \\ D_{21}^n + D_{22}^n \\ D_{31}^n + D_{32}^n \\ D_{41}^n + D_{42}^n \end{bmatrix}$$

The sensor receives the radiation with parameters:

$$[S_i^n] = K \begin{bmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} K I_0 \begin{bmatrix} D_{11}^n + D_{12}^n \\ D_{21}^n + D_{22}^n \\ D_{31}^n + D_{32}^n \\ D_{41}^n + D_{42}^n \end{bmatrix} = K^2 I_0 \begin{bmatrix} D_{11}^n + D_{12}^n - D_{21}^n - D_{22}^n \\ -D_{11}^n - D_{12}^n + D_{21}^n + D_{22}^n \\ 0 \\ 0 \end{bmatrix}$$

with intensity $K^2 I_0 (D_{11}^n + D_{12}^n - D_{21}^n - D_{22}^n)$. The idea of system protection from aerosol hindrances is based on the selection of transformation coefficient $K_{К-П}$ of CIH signal, providing

$$K_Д I_0 D^{\,n}_{11} = K_{K-П}\, K^2 I_0 (D_{11}^n + D_{12}^n - D_{21}^n - D_{22}^n)\,,$$

where, $K_Д$– transformation coefficient of optical signal of smoke detector and a component $K_Д I_0 D^{\,n}_{11}$–smoke detector signals before their processing in the main system unit.

3. **Conclusions**

1. Classical way of smoke detection in a controlled space is the measurements of optical characteristics of environment and their transfer into microphysical parameters with further comparison and known microphysics of smokes. The complexity of conversion procedures of optical characteristics into microphysical parameters makes the process of implementation of "microphysical" identification rather problematic.
2. More preferable way is the method of measuring of certain parameters of the light dispersion matrix of the controlled environment, for example, degree of radiation polarization by dispersed smokes at two diffusion angles, and their comparisons with an optical portrait of smokes. Optical smoke portrait is a set of diffusion spots for the maximum number of realization of smokes calculated using the known parameters of microphysics of real smokes: distribution of particles by the sizes, complex index of substance refraction of smoke particles. The fact of entrance of the current representing spot into the area of an optical portrait increases the probability of fire detection.
3. The other method is the use of cross-polarizing indicator of aerosol hindrances of CIH, when the polarization surfaces of light source and receiver polarizers are mutually orthogonic. Then, at output of the polarizer in front of the receiver all Stokes vector column components are equal to zero. It means that in a controlled space there are only smoke, i.e. spherical particles, and smoke sensors produce "purely smoke" signals, proportional to size $I_0 D_{11}$. In case of an aerosol hindrance (dust) with light dispersion matrix $[D_{ik}^n]$ smoke sensors produce additional signals $I_0 D^{\,n}_{11}$, and the CIH detector (receiver) produces a signal which is proportional to $K^2 I_0 (D_{11}^n + D_{12}^n - D_{21}^n - D_{22}^n)$. The idea of optical system protection from aerosol hindrances consists in selection of the transfer coefficient $K_{-П}$ of a CIH signal that provides the equality of $K_Д I_0 D^{\,n}_{11} = K_{K-П}\, K^2 I_0 (D_{11}^n + D_{12}^n - D_{21}^n - D_{22}^n)$ and the compensation of $K_Д I_0 D^{\,n}_{11}$component of CIH signals produced by smoke detectors before their processing in the main system unit.

References

[1] Van de Hulst 1981 *Light scattering by Small Particles (*New York: Dover Publications) 470 p
[2] Mie G 1908 *Annalen der Physik* 25 **3** pp 377 – 445
[3] Deirmendjian D 1969 *Electromagnetic radiation scattering by spherical polydisperse particles* (New York: Elsevier) 290 p

[4] Shifrin K S, Zelmanovich I L 1968 *Tablitsyi po svetorasseyaniyu v 2-h t. T.2. Tablitsyi matrits rasseyaniya i sostavlyayuschih rasseyannogo polya* (L.: Gidrometeoizd) 471 p.
[5] Gerrard A, Burch J M 1975 *Introduction to Matrix Methods in Optics* (London, New York: wiley) 355 p
[6] Zuev V E 1970 *Rasprostranenie vidimyih i infrakrasnyih voln v atmosphere* [in Russian] (M.: Sov. Radio) 496 p
[7] Kozlov V S, Panin V F, Rapoport G A 1976 Rasseyanie i refraktsiya optich. voln v atmosphere [in Russian] (Tomsk) p 78 – 95
[8] Grozdov G M, Kopyilov N P, Panin V F *Massovyie pozharyi* **5** pp 61 – 74
[9] Dashkovskiy A G, Kozlov V S, Panin V F 1986 *Materialyi VIII Vsesoyuzn. simpoz. po rasprost. lazern. izluch. v atmosfere* [in Russian] (Tomsk) pp 45 – 49
[10] Panin V F, Trampiltsev V N 1978 *Elektr. sistemyi i upr. imi.* [in Russian] **4** pp 52 – 55
[11] Panin V F, Trampiltsev V N 1980 *Vsesoyuzn. sovesch. po atmosfernoy optike. Tez. dokl.* ch. I. pp 26 – 29
[12] Shmoylov A V, Panin V F, Gusev A S 1984 A.S. 1065864 (SSSR) Ustroystvo dlya kontrolya avariynoy opasnosti *Opubl. v B. I.* **1**
[13] Dashkovskiy A G, Panin V F, Trampiltsev V N 1985 *Koord.-chuvstvit. fotoprYomn. i optiko-elektronnyie ustroystva na ih osnove* pp 131 – 132
[14] Balashov E V, Dashkovskiy A G, Panin V F A.S. 262081 (SSSR) Dyimovoy datchik Prioritet izobr. 28.04.86., zaregistr. v Gos. reestre izobr. SSSR 01.10.87.
[15] Tihonov A N, Arsenin V Ya 1986 *Metodyi resheniya nekorrektnyih zadach* [in Russian] (M: Nauka) 286 p.
[16] Naats I E 1980 Teoriya i metodyi lazernogo zondirovaniya aerozolnyih polidispersnyih sistem: Dis… dokt.f.–m. nauk Tomsk 437 p.
[17] Rozenberg G V 1981 *Nekotoryie probl. sovr. fiz. atmosferyi* [in Russian] (M.: Nauka) pp134 – 157