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Model of Combined Solid Plasma Material for the Protection of Radio-Electronic Means of Optical and Radio Radiation

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ABSTRACT

The results of the development of a model of combined solid plasma material for the protection of radio-electronic means of optical and radio-frequency radiation intended to protect radioelectronic means (REM). The basic structure of the physical model of solid-state plasma material is presented. It has been found out that the generation of the Langmuir noise in the protective layer of solid-state plasma of the screen of radio-electronic means provides shielding from laser radiation at a sufficiently small value of the field strength of the Langmuir wave. In this case, there is a re-emission of optical energy in the opposite direction. The effect of pulsed ultrashort duration (USD) electromagnetic radiation (EMR) on a nonequilibrium solid-state plasma arising in a semiconductor matrix depending on the activity of the ionization source and the concentration of hexaferrite inclusions in reflecting and absorbing properties of the material is taken into account.

Key words: radio electronic means, electromagnetic radiation, ultrashort pulse duration, plasma protection technologies, gaseous plasma media.

1. INTRODUCTION

Nowadays, powerful optical and radio radiation generators are rapidly developing, which can lead to unintentional destructive effects and the destruction of the radio-electronic means.

The most well-known and effective methods of laser radiation protection are ablative protection and structural insulation.

Yet, the use of known methods for protecting radio-electronic means from destructive effects of laser radiation is not always appropriate due to the impossibility of reusable user, weight-dimensional characteristics (the inadmissibility of its usage on light aircraft objects), the lack of the ability to protect the mounting holes, cable entries of the body of the electronic means.

It is possible to make a qualitative leap in improving the effectiveness of remedies on the basis of the usage of environmentally-friendly technologies, the use of physical mechanisms of which will ensure effective absorption, reflection and removal of laser radiation.

Such technologies can be used by environmentally-friendly plasma technologies, which satisfy a complex of requirements for the means of protection to the greatest extent [1, 2, 5, 16 17].

1.1 Problem analysis

Analysis of the available literature indicates the great interest of scientists to study the processes of generating powerful EMR [1 - 5], the use of generators of powerful EMR including for influencing the element base of a radio electronic system. The results characterizing the state of the latest achievements in the field of protection of REM from EMR are presented in

[1, 3, 5, 13 - 16]. There are also many works devoted to traditional methods and means of protecting radio electronic devices against the effects of microwave radiation (MVR) [1, 2, 7]. Recently, there have been publications devoted to the use of radioisotope technologies for the protection of radio-electronic devices from exposure to electromagnetic radiation, which are nature-like [5, 10].

The nature of these technologies is associated with the use of reflecting and absorbing properties of plasma, which is the most common state of matter. Also associated with the use of properties of lightning, as a discharge in air, which in the first approximation can be used to create a highly conductive state of air in the holes in the slots of the housing-screens to protect against powerful electromagnetic radiation by breakdown and further energy removal of electromagnetic radiation.

At the same time, there are no mathematical models for describing the modified electrophysical properties of a solid-state plasma medium with hexaferrite elements.

The aim of research is development of a model of combined solid plasma material for the protection of radio-electronic means of optical and radio radiation

2. MAIN MATERIAL

The impact of high-power optical radiation on materials leads to the appearance of a plasma layer, the parameters of which are determined by laser radiation and the characteristics of the material itself. The flux of the electromagnetic energy falling on the surface of the REM screen is partially reflected, while the remaining part of the flux, penetrating deep into the substance, is absorbed.

Under the influence of the laser energy, there is an increase in the temperature of the protective material made on the magnitude [1, 4, 12, 13]:

$$\Delta T(r,z,t) = f\left(W(r,z,t), t_i\right),$$

where $W(r,z,t) = \bar{W}_z W_0 \left(\sigma(r) - \sigma(r-\alpha)\right) e^{-\alpha z} \times f_0(t)$ – is the vector of energy of optical radiation.

In order to protect from optical radiation, the plasma layer can be supplemented with an artificially created solid-state plasma by introducing, for example, the radioisotope elements into a semiconductor layer of the protective screen [1, 4, 8]. Determining the possibility of using solid-state plasma to protect REM from high-power laser radiation calls for an analysis of the interaction of this radiation with the plasma of the shielding material.

To protect REM from optical radiation, the best screen is a mirror, which, regardless of the magnitude of the energy in the EMR, is able to reflect it. Therefore, we will estimate the reflective capabilities of the plasma material. To screen the optical radiation when creating a plasma “mirror”, a plasma of sufficiently high density n_p is needed. Electromagnetic waves penetrate into the plasma only to the depths of the skin layer on the condition that $\omega_p > \omega$, where $\omega_P = \sqrt{\dfrac{4\pi e^2 n_p}{m_e}}$ is the plasma frequency; ω is the optical radiation frequency; m_e, e – the electron mass and charge, respectively. The creation of the plasma mirror is possible on the condition that:

$$n_p > n_{cr} = \frac{\omega_p{}^2 m_e}{4\pi e^2}, \qquad (1)$$

where n_{cr} is the critical electron density in plasma.

For radiation frequencies corresponding to the optical ones, $n_{cr} \approx 10^{18}\text{sm}^{-3}$. The plasma of such density occurs when optical radiation reacts on metal. Therefore, of particular interest is the problem of determining of point of reflection of laser radiation of energy from the surface of a plasma protective REM screen, that is, the determination of the screening conditions of the optical radiation with plasma of lower density than n_{Cr}. It is possible for optical radiation of sufficiently high power due to a number of nonlinear processes.

A significant decrease in the density of the plasma screen reflecting the laser radiation can be achieved by stimulating the parametric decay instabilities that look like this:

$$t' \to t'' + l\,,$$

where t' is the incident electromagnetic wave; l – is the Langmuir wave; s' – the ion-acoustic wave; t'' – the reflected electromagnetic wave; v_{Te} – the electron thermal velocity; $\omega_{t'}, \omega_l, \omega_{t''}$ – the frequency of the incident, Langmuir and reflected waves, respectively; $\omega_{s'}$ – the ion-acoustic wave; k_0 – the wave vector; E_0 – the electric field strength.

In terms of our studies, of particular interest are the parametric instabilities with the re-emission of electromagnetic waves, i.e. the decay of a transverse electromagnetic wave t' into a Langmuir l or ion-acoustic s' and another electromagnetic wave t'', spreading in the reflected direction $\left(t' \to l + t'', \quad t' \to t'' + s'\right)$.

The conditions of this type of decay have the following form [3]:

$$\omega_p \geq \omega\left(\frac{v_{Te}}{c}\right) \text{ or } n_p \geq n_{cr}\left(\frac{v_{Te}}{c}\right)^2.$$

It means that the plasma density, which reflects the optical radiation due to decay processed, can be lowered, as compared with n_{cr}, by the value of $\left(\frac{v_{Te}}{c}\right)^2$, which under normal plasma parameters is about 10^{-4}.

Let us consider the example of decay $t' \to t'' + l$, that if the plasma density is $n_p \approx n_{cr} \cdot 10^{-4}$, it is possible to achieve the complete reflection of laser radiation. To do this, we assume that the Langmuir noises (waves) with the wave vector k_l, directed to the plasma boundary are created in the plasma layer. The resonance conditions of the merging of the incident electromagnetic wave with the wave vector $k_{t'}$ and frequency $\omega_{t'}$ and Langmuir waves (k_l, ω) look like:

$$k_{t'} + k_l = k_{t''};\ \omega_l + \omega_{t'} = \omega_{t''}.$$

Since $|k_l| >> |k_{t'}|$, the electromagnetic wave spreads in the reflected direction, i.e. in the reverse one compared to the incident electromagnetic wave. Let us present the estimations for the amplitude of the provoked Langmuir noises, which is necessary for the reflection of optical radiation. The equation describing the scattering of a electromagnetic wave by a Langmuir wave looks like:

$$\frac{d^2 H^{(t'')}}{dz^2} + \frac{\omega^2}{c^2} H_x^{t''} = F(z), \qquad (2)$$

where $F(z) \cong \frac{e}{2m_e c\omega} \frac{d}{dz}\left(E_y^{t'} \frac{d}{dz} E_z'\right)$;

$H^{(t'')}$ – is the magnetic field of the reflected electromagnetic wave;

$E_y^{(t')}, E_z^{(1)}$ – the electric fields of the incident and Langmuir waves, respectively.

The flux of energy into the re-emitted electromagnetic wave can be found from (2) and looks like:

$$S_{t''} \approx \frac{cH_x^{(t'')}}{8\pi} \approx \frac{e^2}{(2m_e\omega)^2 c}\left(\frac{k_l}{k_{t''}}\right)^2 A_L^2 A_ш^2, \qquad (3)$$

where A_L– is the optical field amplitude; $A_ш$ – the Langmuir waves amplitude.

$S_{t'} = \frac{cH_0{}^2}{8\pi} \approx cA_L^2$ – the incident energy flux;

$S_l = V_g \frac{E^2}{8\pi} \approx v_{Te} A_ш^2$ – the flux density of the provoked Langmuir noises.

The conversion factor for the electromagnetic energy flow of the incident wave into the reflected one equals

$$T = \frac{S_{t''}}{S_{t'}} \cong \frac{e^2}{(2m_e c\omega)^2}\left(\frac{k_l}{k_{t''}}\right)^2 A_ш^2. \qquad (4)$$

Since $|k_l| >> |k_{\omega'}|$, $|k_l| \sim |k_{\omega''}|$, and $\omega \sim 10\omega_p$, then by substituting the known numerical values in (2), we will get the following:

$$T = \frac{e^2 A_ш^2}{4m_e^2 c^2 10^2 \omega_p^2} = \frac{(4.8)^2 10^{-20} 10^{-6} A_ш^2}{4(9.1)^2 10^{-56} 9\cdot 10^{20}\cdot 32\cdot 10^{20}} \approx 2.4\cdot 10^{-10} A_ш^2.$$

Thus, for the total reflection of the electromagnetic wave (T=1) we need $2.4\cdot 10^{-10} A_ш^2 = 1$, that is, if the decay instability is not taken into account, then it is necessary to create the Langmuir noises with a large amplitude equaling $\alpha_ш = 1/3 \cdot 10^5$ (sgs) in the plasma.

In accordance with the expression (2), the reflection coefficient does not depend on the power of the incident optical radiation, but is completely determined by the parameters of the plasma and provoked Langmuir noise. It means that the reflection coefficient has a certain universality with respect to the optical radiation power, that is, the parameters of the plasma and Langmuir noise are identical for different optical powers. Let us estimate the amplitude of the Langmuir noise with the total reflection of laser radiation (T=1) with increasing decay instability.

From the expression (2) with T=1 we will get:

$$a_ш^2 \approx \left(\frac{k_{t''}}{k_l}\right)^2 \frac{(2m_e c\omega)^2}{e^2}.$$

Hence, since $|k_{t''}| \approx |k_l|$, $A_ш^2 \geq 10^{-14}$, ω^2 (sgs). It should be mentioned that with the development of parametric (delay) instability, the Langmuir noise is amplified:

$$A_ш = a_0 e^{\gamma_н t}, \qquad (5)$$

where α_0 – is the amplitude of plasma noise provoked by an external source;

$\gamma_н = \frac{eA_L}{m_e c}\sqrt{\frac{\omega_p}{\omega_{t'}}}$ – the instability increment $t' \to t'' + l$.

Given that $t = L/c$, we will present the expression (2) in the following form:

$$a_0^2 e^{\frac{2\gamma_H L}{c}} \geq 10^{-14}\omega^2$$

$$\text{or} \quad a_0^2 > 10^{-14}\omega^2 e^{\frac{-2\gamma_H L}{c}}, \qquad (6)$$

where L is the thickness of the plasma layer.

If the optical energy flux equals

$$S_{t'} = \frac{cE_{t'}^2}{8\pi} \approx \frac{cA_L^2}{8\pi} \approx 10^{10} W/sm^2 \approx 10^{10} \cdot 10^7 sgs,$$

then $A_L \leq 10^4$.

If L = 30 sm, $\omega = 10^{14}$ we will get:

$$A^2_ш > 10^{14} \times 10^{-10}; \quad A_ш \geq 10^2.$$

If $\alpha_0 \approx 10 A_ш$; $A_ш = 10^3 V/sm$.

If $L = 20$ sm, $\omega = 10^{15}$, $E_1 \leq 10^3$ V/sm.

Thus, with the directed generation of the Langmuir noises in the protective layer of solid-state plasma of the REM screen, the possibility arises of shielding from optical radiation at a sufficiently small value of the field strength of the Langmuir wave. In this case, there is a re-emission of the optical energy in the opposite direction.

In order for the above described mechanism to work in the appearing plasma, it is necessary that during the development of nonlinear interaction $1/\gamma_н = \tau_н$, the density of the expanding plasma of a solid body is reduced to values not less than 10^{10} sm^{-3}, i.e.

$$1/\gamma_н = \tau_н < \tau_b,$$

where τ_b is the time scale of plasma density drop during the evaporation into vacuum:

$$\tau \approx L_f / C_s,$$

where L_f is the characteristic torch size of the scattering plasma;

C_s – the velocity of the solid-state plasma dispersion in vacuum.

To completely shield the optical radiation, it is necessary to conduct the closure process with the help of the appearing plasma, i.e. $L_f = L$ – it is the size of the evaporation depth of a semiconductor at the same time. That is, during the time $\tau_н$ the laser must melt a depth of L. Hence,

$$L = \tau_н v_{pl},$$

where v_{pl} – is the melting point of the protective material.

The melting point of the protective material can be found from the following ratio:

$$V_{пл} = \frac{S_{t'}}{\lambda_1 (1 + 2.2/y_0)\rho_0}, \qquad (7)$$

where ρ_0 is the electron density in the semiconductor in the solid phase; λ_1 – the connection energy of the crystal lattice; $y_0 = \frac{\lambda_1}{kT_0}$, T_0 – the temperature of the surface of the protective screen; k – the Boltzmann constant.

For $n_0 = 10^{23} sm^{-3}$, $S_{t'} = 10^{10} W/sm^2$, $l_1 \sim 5eV$ и $T_0 \sim 0{,}1\ eV$ we will get $L \sim 0{,}1sm$.

Thus, the aforementioned estimations show that the reflection of the optical radiation can be carried out with the usage of materials having a small thickness and weight.

The structure of the model of combined solid plasma material for the protection of radio-electronic means of optical and radio radiation is shown in Figure 1.

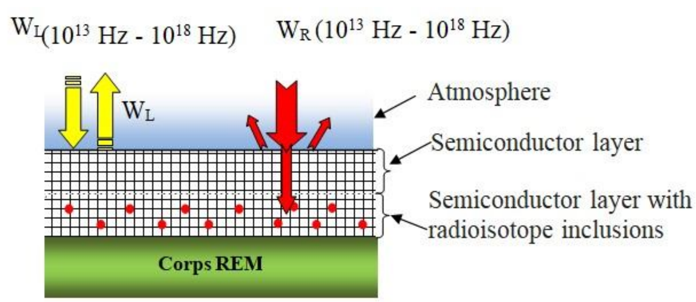

Figure 1: The structure of the model of combined solid plasma material for the protection of radio-electronic means of optical and radio radiation

The temperature distribution satisfied the inhomogeneous heat conduction equation with the corresponding initial and boundary conditions

$$div(k_T + gradT) - cr\frac{d}{dt}T = y(r,z,t) = -div\overline{W}(r,z,t) \qquad (8)$$

The solution of the equation in question (8) will determine the growth of the temperature of the protective material over time along the axis of the optical beam. The ratio (1) - (4), (8) is a formalized mathematical model for describing the interaction of the optical radiation with a plasma material designed to protect REM by reflecting this radiation.

3.THE PROTECTION OF RADIO-ELECTRONIC MEANS OF RADIO RADIATION

It is known that the synthesis of effective shielding materials necessitates the selection of appropriate types of matter and the determination of the electrophysical characteristics of the synthesized material, first of all, the dielectric and magnetic permeability. To create a solid-state plasma medium, according to the results of the well-known works [1, 5, 7, 9], let's use a semiconductor matrix in which elements of a radioactive substance will be placed to create a complex dielectric constant. The use of a radioactive substance is necessary for ionization and the occurrence of a nonequilibrium state of the electronic subsystem. The radioactive substance in the form of a film can be placed between the metal case and the semiconductor matrix. In addition, a radioactive substance can be randomly placed in a semiconductor matrix in the form of elements of the corresponding form (round, horseshoe). Taking into account the above, the dielectric constant of plasma material with hexaferrite inclusions is included in the representation by the following expression:

$$\varepsilon_{\Pi}\left(\omega,\vec{k}\right)=\varepsilon_{M}+\sum_{i=1}^{N}\delta\varepsilon_{in_g}\left(\omega_{\rho},\vec{k}\right)+\sum_{\xi=1}^{M}\delta\varepsilon_{noneq_{\xi}}\left(\omega,\vec{k},Q\right)+ +\sum_{\psi=1}^{U}\delta\varepsilon_{in_i}\left(\omega,\vec{k}\right)+\sum_{\nu=1}^{J}\delta\varepsilon_{noneq_{\nu}}\left(T(\vec{E},\vec{H})\right)+ +i\left\{\frac{4\pi}{\omega}\left[\sigma_{eff}\left(\omega,\vec{k}\right)+\sigma_{eff}\left(T(\vec{E},\vec{H})\right)+\alpha_e E^2\right]\right\}, \quad (9)$$

where ε_M – dielectric constant of the semiconductor material;

$\sum_{i=1}^{N}\delta\varepsilon_{in_g}\left(\omega_{\rho},\vec{k}\right)$ – contribution of hexaferrite inclusions to dielectric constant;

$\sum_{\psi=1}^{U}\delta\varepsilon_{in_i}\left(\omega,\vec{k}\right)$ – contribution of radioisotope inclusions to dielectric constant;

$\sum_{\xi=1}^{M}\delta\varepsilon_{noneq_{\xi}}\left(\omega,\vec{k},Q\right)$ – contribution of the nonequilibrium state of the electron subsystem arises due to radioisotope inclusions Q to the dielectric constant;

$\sum_{\nu=1}^{J}\delta\varepsilon_{noneq_{\nu}}\left(T(\vec{E},\vec{H})\right)$ – contribution of the nonequilibrium state of the electronic subsystem arises due to heating under the influence of a pulsed high-power USD EMR to the dielectric constant;

$4\pi\omega^{-1}\left(\sigma_{eff}\left(\omega,\vec{k}\right)+\sigma_{eff}\left(T(\vec{E},\vec{H})\right)+\alpha_e E^2\right)$ – linear and nonlinear components of the imaginary part of the dielectric constant of the semiconductor layer;

α_e, E –effective nonlinear conductivity and average electric field, respectively;

$\omega, \vec{k}$ – frequency and wave vector, respectively.

Contribution of hexaferrite and radioisotope inclusions is determined by their electrophysical properties, and the contribution to the dielectric constant of the nonequilibrium state of the electronic subsystem arises due to radioisotope inclusions Q and is influenced by the powerful USD EMR expressions and is determined according to the 10 and 11:

$$\varepsilon^{\ell}\left(\omega,\vec{k}\right)=1+\delta\varepsilon^{\ell}, \; \delta\varepsilon^{\ell}=\frac{4\pi e^2}{k^2}\int d\vec{v}\frac{1}{\omega-\vec{k}\vec{v}}\vec{k}\frac{\partial f}{\partial\vec{v}}; \quad (10)$$

$$\varepsilon^{t}\left(\omega,\vec{k}\right)=1+\delta\varepsilon^{t}, \; \delta\varepsilon^{t}=\frac{4\pi e^2}{k^2\omega}\int d\vec{v}\frac{\left[\vec{k}\left[\vec{v}\vec{k}\right]\right]}{\omega-\vec{k}\vec{v}}\frac{\partial f}{\partial\vec{v}}. \quad (11)$$

where $\vec{v}$ - electron velocity;

f - velocity distribution function of particles.

By integrating in (10) the angles and, using the fact that $\lim_{\nu\to 0}\frac{1}{x+i\nu}=P\frac{1}{x}-i\pi\delta(x)$ (the symbol means that when integrating, the singularity at x = 0 should be understood in the sense of the main value), let's obtain:

$$\mathrm{Re}\,\delta\varepsilon=-\frac{16\pi^2e^2}{k^2}\int dv\frac{v^2f(v)}{\frac{\omega^2}{k^2}-v^2},$$

$$\mathrm{Im}\,\delta\varepsilon=-\frac{8\pi^3m^2e^2}{\omega^2}\left(\frac{\omega}{k}\right)^3 f\left(\frac{\omega}{k}\right). \quad (12)$$

It is possible to see (12) that the non-equilibrium states of a weakly ionized air medium are characterized when the phase velocity of the wave falls into the inertial range (v_-, v_+) by a high level of EMR absorption. In this case, the real and imaginary parts of the dielectric constant of a weakly ionized air medium are of the same order, which leads to the complete attenuation of electromagnetic waves. The distribution function of particles is determined by the basic physical processes occurring in the air environment of the orifice, which include collisions of fast ions resulting from the decay of a radioactive substance with electrons, neutral molecules and ions of weakly ionized air. On this basis, the determination of the corresponding macroscopic parameters through the distribution function of charged particles in the hole requires an analysis of the kinetic processes occurring in the medium of the hole. The results of this analysis will ensure the correct choice of a kinetic equation model. It is known that the electron distribution function $g = |\mathbf{v} - \mathbf{v}_1| f(\mathbf{r}, \mathbf{v}, t)$ determines the average number of electrons $dn_e(\mathbf{r}, t) = f(\mathbf{r}, \mathbf{v}, t)\, d\mathbf{r} d\mathbf{v}$ in an element of the phase space ($\mathbf{r}, \mathbf{v}$) and without taking into account the force term can be found from the Boltzmann kinetic equation:

$$\frac{df}{dt} + \nabla_r \cdot (Vf) = I_3(\mathbf{r}, \mathbf{v}, t), \qquad (13)$$

where ∇_r –gradient operator in the coordinate space r; $I_3(\mathbf{r}, \mathbf{v}, t) = \left(\frac{df}{dt}\right)_3$ – collision integral.

With additional ionization of α-air particles, stationary nonequilibrium states of electronic subsystems appear in the hole, which turns out to be close to power ones:

$$f(E) = A E^S, \qquad (14)$$

In power solutions to the Boltzmann kinetic equation, the exponent depends on the interaction potential of the particles on the mutual distance. To create a complex magnetic permeability of the protective material, let's use hexaferrite inclusions that are randomly arranged. The effect of the dielectric constant of hexaferrite inclusions $\varepsilon_{in_i}(\omega)$ in the dielectric constant of the material will be taken into account in accordance with the Maxwell-Garnet approximation. Then, taking into account (9), the dielectric constant of the protective material will be determined in accordance with the relation:

$$\varepsilon_{eff}(\omega, \vec{k}) = \varepsilon_\Pi(\omega, \vec{k}) \frac{1 + 2p \dfrac{(\varepsilon_{in_i}(\omega) - \varepsilon_\Pi(\omega, \vec{k}))}{(2\varepsilon_{in_i}(\omega) + \varepsilon_\Pi(\omega, \vec{k}))}}{1 - p \dfrac{(\varepsilon_{in_i}(\omega) - \varepsilon_\Pi(\omega, \vec{k}))}{(2\varepsilon_{in_i}(\omega) + \varepsilon_\Pi(\omega, \vec{k}))}}, \qquad (15)$$

where p – concentration of hexaferrite inclusions.

To ensure the effective shielding of the pulsed USD EMR of hexaferrite inclusions, it is necessary to choose taking into account the dependence of their absorbing properties in the frequency range. In this case, the material can be considered as multi-layered. The magnetic permeability of the solid-state plasma medium with regard to hexaferrite inclusions will be determined according to the expression:

$$\mu(\omega_\rho) = 1 + \sum_{i=1}^{N} \mu_{in_g}(\omega_\rho),$$

where $\sum_{i=1}^{N} \mu_{in_g}(\omega_\rho)$ – contribution of hexaferrite inclusions to the magnetic permeability, depending on the frequency range.

The components of the dielectric and magnetic permeability are frequency-dependent, which can provide, under certain conditions, the necessary absorbing and scattering properties of the shielding material to protect against the USD EMR effects.

4.CONCLUSION

1. The generation of the Langmuir noise in the protective layer of the solid-state plasma of the REM screen provides the possibility of shielding from the laser radiation at a sufficiently small magnitude of the field strength of the Langmuir wave. In this case, there is a re-emission of the laser energy in the opposite direction.

2. The reflection coefficient of the incident laser radiation on a solid-state plasma REM screen does not depend on the power, but is completely determined by the parameters of the plasma and the provoked Langmuir noise.

3. The peculiarity of the model that determines its novelty lies in the use of the mechanism of the delay parametric instability in order to provide the necessary magnitude of the concentration of electrons of a non-equilibrium plasma, in which the reflection of impulse laser radiation and its spatial and temporal evolution are carried out, as well as taking into account the dynamics of heating the plasma material depending on the magnitude of the energy of optical radiation and the width of the impulse; account the effect of a pulsed USD EMR on a nonequilibrium solid-state plasma arising in a semiconductor matrix depending on the activity of the ionization source and the concentration of hexaferrite inclusions in reflective and absorbing properties of the material.

REFERENCES

1 M. Iasechko. **Plasma technologies for the protection of radio electronic means from exposure to high-power electromagnetic radiations with ultrashort pulse duration**, *Proceedings of the 1-st Annual Conference*, Tallinn, Estonia, 2017, pp. 18–21. doi: /10.21303/2585-6847.2017.00480.

2 E. M. Bazelyan and U. P. Raizer. **Lightning attraction mechanism and the problem of laser lightning control**, *Physics–Uspekhi*, *43:7*, Moscow, 2000, pp. 701–716.

3 V. L. Ginzburg and A. V. Gurevich. **Nonlinear phenomena in a plasma located in an alternating**

electromagnetic field, *SOV PHYS USPEKHI*, *3(1)*, Moscow, 1960, pp.115–146. doi:10.1070/PU1960v003n01ABEH003261.

4 O. G. Sytenko. **Electromagnetic plasma fluctuations**, KhGPU, Ukraine, Kharkiv, 1965, pp. 1-183.

5 S.A.Gutsev, A.A. Kudryavtsev, R.Yu. Zamchiy, V.I. Demidov, and V.I. Kolobov. **Diagnostics and modeling of ashort (without positive column) glow discharge in helium with nonlocal plasma**, *Proc. 40th European Physical Society Conference on Plasma Physics*, Finland, 2013, N 06.502.

6 M.M. Iasechko, and O.M. Sotnikov. **Advanced technologies of radio electronic equipment (means) protection from powerful electromagnetic radiations with ultra short duration of pulses exposure,** *Published by Izdevnieciba Baltija Publishing*, Collective monograph, Riga, 2018, pp.356-385.

7 I. Mac-Daniel. **Collision processes in ionized gases**, *World*, Moscow, 1967.

8 O.Skoblikov and V. Knyazyev. **Properties of Conductive Shells Exposed to Electromagnetic Impulse of Lightning**, *International Conference on Lightning Protection (ICLP'2012)*, Vienna, Austrian, 2012, pp. 1-8.

9 A.Tajirov, I.Cwhanovskaya, and Z. Barsova, N. Iluoykha. **Chemistry and technology of magnetite and barium-containing composite materials on its basis**, *European Science and Technology: materials of the II international research and practice conference*, Wiesbaden Germany, 2012, pp. 80-87.

10 V.A. Chernikov, S.A. Dvinin, A.P. Ershov, I.B.Timofeev, and V.M. Shibkov. **Experimental and Theoretical research of DC transversal gas discharge in a supersonic gas flow**, The 3rd workshop on Magneto-Plasma-*Aerodynamics in Aerospace Applications*, Moscow, 2001, pp. 129-134.

11 B.M..Smyrnov. **Low Ionized Gas Physics,** *The science*, Moscow, 1985.

12 S.A. Dvinin and A.A. Kuzovnikov. **Plane ionization waves caused by diffusion in high frequency fields**, *XVII International Conference on Phenomena in Ionized Gases*, Belgrade, 1989, pp. 818-819.

13 O. Sotnikov, M. Iasechko, V. Larin, O. Ochkurenko, and D.Maksiuta. **The model of a medium for creation of electric hermetic screens of the radio electronic means**, *IJATCSE. 8(2)*, 2019, pp. 300-304. doi:10.30534/IJATCSE/2019/32822019.

14 M. Iasechko, O. Tymochko, Y. Shapran, I. Trofymenko, D. Maksiuta, and Y. Sytnyk. **Loss definition of charged particles in the discharge gap of the opening of the box-screens during the formation of a highly conductive channel,** *IJATCSE. 8(1.3)*, 2019, pp. 1-9. doi: 10.30534/ijatcse/2019/0181.32019.

15 M. Iasechko, V. Larin, O. Ochkurenko, S. Salkutsan, L. Mikhailova, and O. Kozak. **Formalized Model Descriptions Of Modified Solid-State Plasma-Like Materials To Protect Radio-Electronic Means From The Effects Of Electromagnetic Radiation,** *IJATCSE. 8(3)*, 2019, pp. 393-398. doi: 10.30534/ijatcse/2019/09832019.

16 M. Iasechko, V. Larin, O. Ochkurenko, A. Trystan, T.Voichenko, A. Trofymenko, and O. Sharabaiko. **Determining the function of splitting the charged particles of the strongly ionized air environment in the openings of the case-screens of radioelectronic means,** *IJATCSE. 8(1.3)*, 2019, pp. 19-23. doi: 10.30534/ijatcse/2019/0481.32019.

17 M.M. Iasechko, and O.M. Sotnikov. **Protecting of radio electronic facilities is from influence of powerful electromagnetic radiation,** *Published by Izdevnieciba Baltija Publishing*, Collective monograph, Riga, 2019, pp.283-299.