MATHEMATICAL MODELLING OF INTERACTION OF ELECTROMAGNETIC RADIATION WITH THE SURFACE HAVING THE SELF-AFFINE BAS-RELIEF

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Abstract
Regular self-affine bas-reliefs on a surface of semi-conductor materials generate thermal and electromagnetic coherent radiation. The structure of coherent radiation is defined by a bas-relief on a semiconductor surface. Research of structure of such radiation is developed.

Key words:
surface electromagnetic wave, semiconductor, fractal, self-affine surface

1. Introduction

Interaction of various spatial forms with electromagnetic radiation is a basis of functioning of a great number of technical devices, such as aerials, diffraction lattices, diffraction optical elements, etc. The dominant roles in such interaction are played by a superficial relief or the product form. Numerous studies, including computer simulation, are the base of contemporary radar, computer optics and holography.
Particular interests represent fractals and self-affine objects which possess resonant properties in a wide range of lengths of waves. Comparison of behaviour of similar devices with various superficial structures allocates self-affine objects which possess the best resonant properties. The made natural and computer experiments have allocated advantage of self-affine structures. It is necessary to stop especially on computer modelling provided that the argument represents a complex variable. Such modelling has been spent by authors earlier. The received results have shown that the most interesting behavior is shown that the decision, unlike a material case, asymmetrically. Therefore profound studying of those cases when asymmetry becomes especially obvious has been spent.
Development nano-technologies and research of new principles of construction of electronic and optical devices, does actual a problem of development of physical models which accordingly describe their work [1, 2]. Interaction of structure of a surface with electromagnetic radiation which was generated on a surface of a material of the semiconductor, considered earlier:
1.A surface with a self-affine bas-relief formed circles (Fig. 1) [Kopyltsov, Lukyanov, 2003, Kopyltsov, Lukyanov, Serov, 2007].

2. A surface with relief in the form of carpet Sierpinski [Kopyltsov, Lukyanov, 2003].
3. A casual surface [Kopyltsov, Lukyanov, 2003].

It is earlier shown that the self-affine surface at interaction with radiation generates coherent structure of electromagnetic radiation [Kopyltsov, Lukyanov, 2003, Kopyltsov, Lukyanov, Serov, 2007]. Interaction of radiation with above mentioned surfaces is considered earlier. Calculations have been spent in complex area.

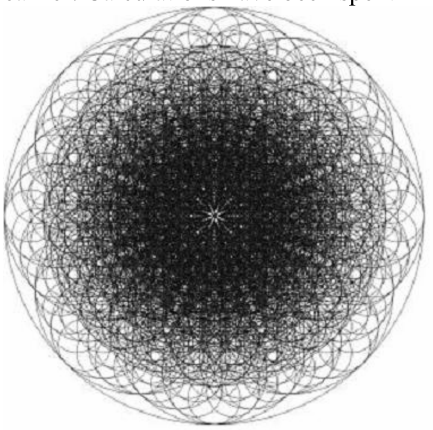

Fig.1. Self-affine bas-relief.

2. Description of models and results of calculations

The real case (τ=0) considered earlier is particular case of a general case, for which the equation is [Kopyltsov, Lukyanov, 2003, Kopyltsov, Lukyanov, Serov, 2007]:

$$\frac{\partial^2 E}{\partial T^2} = D\left(\frac{\partial^2 E}{\partial x^2} + \frac{\partial^2 E}{\partial y^2} + \frac{\partial^2 E}{\partial z^2}\right) + aE,$$

where $E = E_1 + iE_2$ is electrical tension (E_1 is real and E_2 is imagine), $T = t + i\tau$ is time (t is real и τ is imagine) (Fig. 2), D and a are constants.

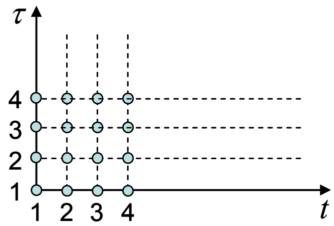

Fig.2. Points on a plane of complex time (t, τ) to which calculations were spent.

The calculations were considered in a limited area of the circular cylinder of Cartesian coordinates (x,y,z) (Fig. 3). It is assumed that at the border of the cylinder there is not flow.

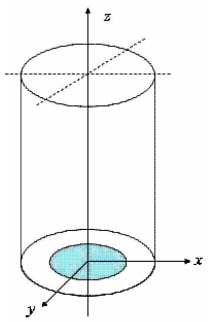

Fig.3. Circular cylinder of Cartesian coordinates.

Beginning condition:

1) $E_1(x, y, z, t, \tau = 0)$ was determined by solving of the real equation

$$\frac{\partial^2 E_1}{\partial t^2} = D\left(\frac{\partial^2 E_1}{\partial x^2} + \frac{\partial^2 E_1}{\partial y^2} + \frac{\partial^2 E_1}{\partial z^2}\right) + aE_1$$

with the help of numerical methods,

2) $E_1(x, y, z, t = 0, \tau) = 0$,

3) $E_2(x, y, z, t, \tau = 0) = 0$,

4) $E_2(x, y, z, t = 0, \tau) = 0$.

It has been shown, that for a self-affine surface nonlinear transition of electric charges leads to formation of the steady coherent response to external radiation [Kopyltsov, Lukyanov, 2003, Kopyltsov, Lukyanov, Serov, 2007].

1. As on a surface of a considered plate there is a relief in the form of ring grooves at a premise of a plate in an electric field, owing to the phenomenon of polarization, in it there is a spatial division of charges.
2. Because of presence of flutes concentration of charges on a surface non-uniform. In grooves it essentially above, than on a surface.
3. The charges concentrated in the next grooves cannot have identical density; therefore occur jump carriers of a charge from a groove.
4. As a surface is self-affine, waves represent densely grouped, coherent clot phased waves of different length.

Conditions of the non-linearity can be described as follows. If some time $T^* = t^* + i\tau^*$ a certain point in (x^*, y^*, z^*) running condition

$$E_1^2(x^*, y^*, z^*, t^*, \tau^*) + E_2^2(x^*, y^*, z^*, t^*, \tau^*) > s^2$$

(where s is threshold value of a potential difference at which occurs jump a charge between grooves [Kopyltsov, Lukyanov, 2003, Kopyltsov, Lukyanov, Serov, 2007]), then

$E_1(x^*, y^*, z^*, t^*, \tau^*) = 0$,

$E_2(x^*, y^*, z^*, t^*, \tau^*) = 0$.

The calculations for self-affine surface were conducted for a interval [10^{-5}, 10^{-3}] of electrical tension *E*. Calculations have shown that: near real-time components (about X axis, $(t, \tau) = (2,3)$, $(t, \tau) = (2,4), \ldots$) (Fig. 4 -11) is coherent as in case of real time [Kopyltsov, Lukyanov, 2003, Kopyltsov, Lukyanov, Serov, 2007] examined earlier. Furthermore, the solution for the present instance is asymmetrical in the space: at components E1 the positive half wave prevails at E2 prevails negative.

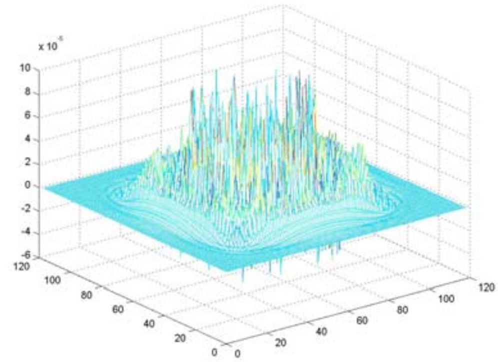

Fig.4a. Component E1 of the session 5. $(t, \tau) = (2,2)$. Cross-section section XY (component E1) on distance of 4 units from a surface of a plate at the moment of time $(t, \tau) = (2,2)$.

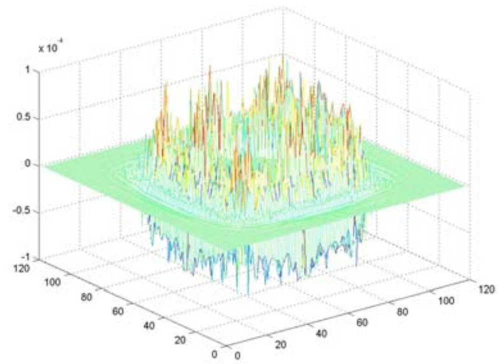

Fig.4b. Component E2 of the session 5. $(t, \tau) = (2,2)$. Cross-section section XY (component E2) on distance of 4 units from a surface of a plate at the moment of time $(t, \tau) = (2,2)$.

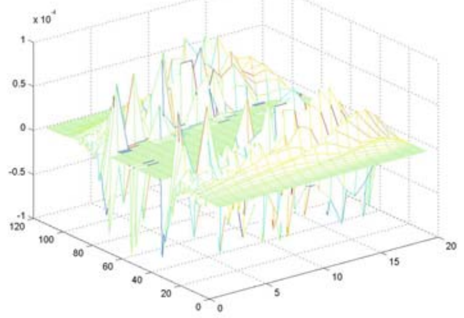

Fig.5a. Component E1, lateral view. $(t,\tau)=(2,2)$.
Longitudinal section XZ (component E1) at the moment of time $(t,\tau)=(2,2)$.

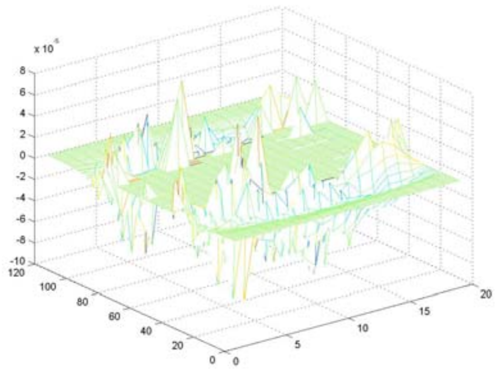

Fig.5b. Component E2, lateral view. $(t,\tau)=(2,2)$.
Longitudinal section XZ (component E2) at the moment of time $(t,\tau)=(2,2)$.

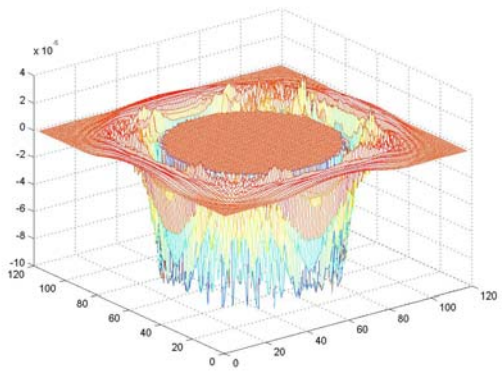

Fig.6a. Component E1 of the session 5. $(t,\tau)=(2,3)$.
Cross-section section XY (component E1) on distance of 4 units from a surface of a plate at the moment of time $(t,\tau)=(2,3)$.

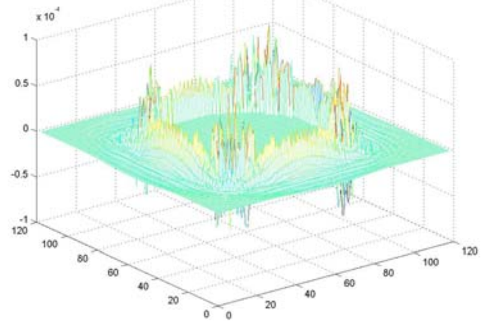

Fig. 6b. Component E2 of the session 5. $(t,\tau)=(2,3)$.
Cross-section section XY (component E2) on distance of 4 units from a surface of a plate at the moment of time $(t,\tau)=(2,3)$.

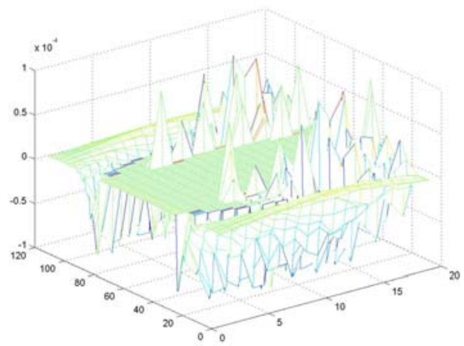

Fig.7a. Component E1, lateral view. $(t,\tau)=(2,3)$.
Longitudinal section XZ (component E1) at the moment of time $(t,\tau)=(2,3)$.

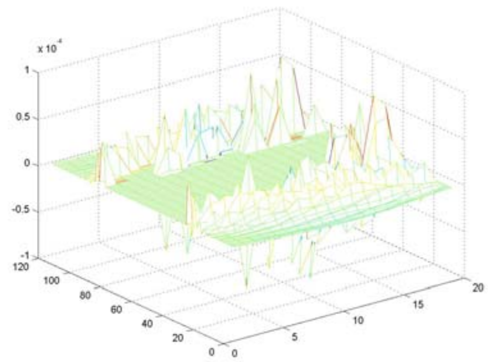

Fig.7b. Component E2, lateral view. $(t,\tau)=(2,3)$.
Longitudinal section XZ (component E2) at the moment of time $(t,\tau)=(2,3)$.

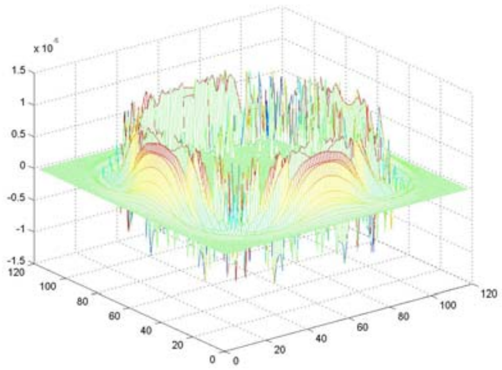

Fig.8a. Component E1 of the session 5. $(t,\tau)=(3,2)$.
Cross-section section XY (component E1) on distance of 4 units from a surface of a plate at the moment of time $(t,\tau)=(3,2)$.

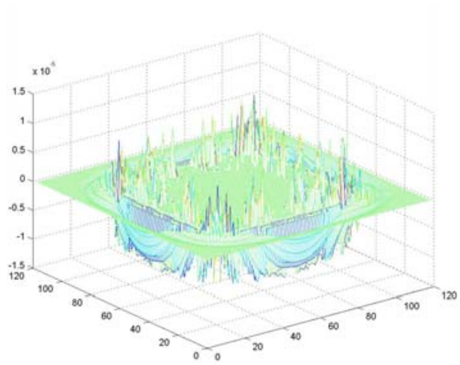

Fig.8b. Component E2 of the session 5. $(t,\tau)=(3,2)$.
Cross-section section XY (component E2) on distance of 4 units from a surface of a plate at the moment of time $(t,\tau)=(3,2)$.

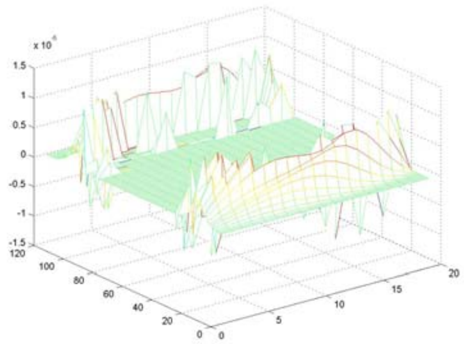

Fig.9a. Component E1, lateral view. $(t,\tau)=(3,2)$.
Longitudinal section XZ (component E1) at the moment of time $(t,\tau)=(3,2)$.

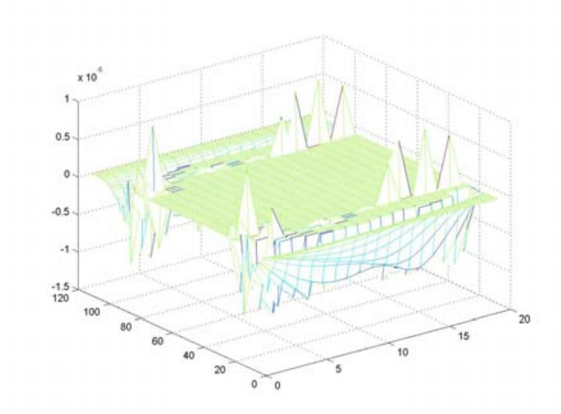

Fig.9b. Component E2, lateral view. $(t,\tau)=(3,2)$.
Longitudinal section XZ (component E2) at the moment of time $(t,\tau)=(3,2)$.

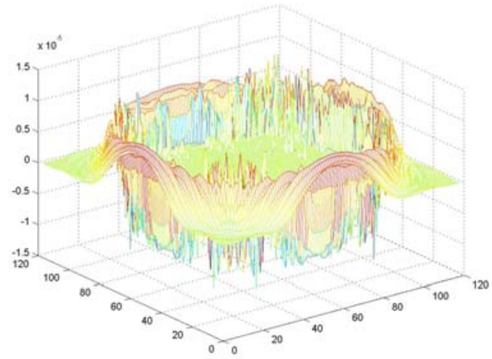

Fig.10a. Component E1 of the session 5. $(t,\tau)=(3,3)$.
Cross-section section XY (component E1) on distance of 4 units from a surface of a plate at the moment of time $(t,\tau)=(3,3)$.

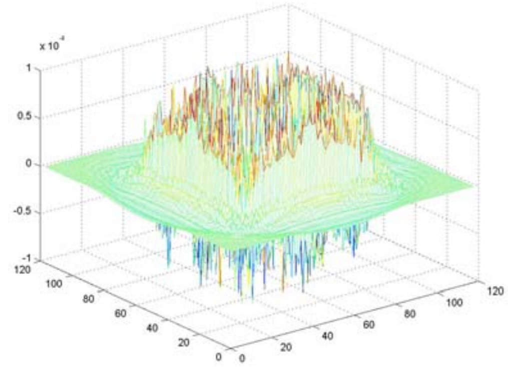

Fig.10b. Component E2 of the session 5. $(t,\tau)=(3,3)$.
Cross-section section XY (component E2) on distance of 4 units from a surface of a plate at the moment of time $(t,\tau)=(3,3)$.

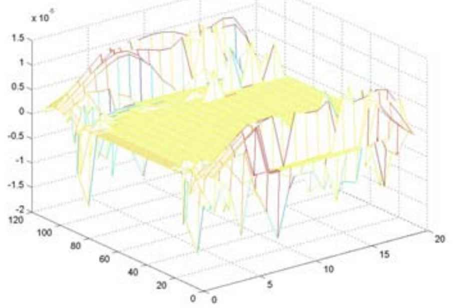

Fig.11a. Component E1, lateral view. $(t,\tau) = (3,3)$. Longitudinal section XZ (component E1) at the moment of time $(t,\tau) = (3,3)$.

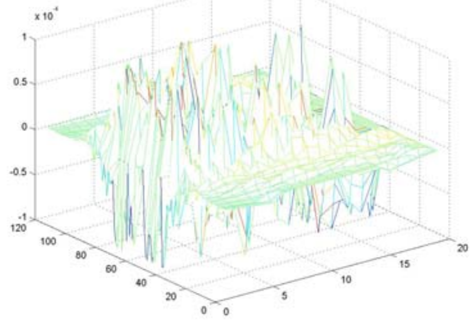

Fig.11b. Component E2, lateral view $(t,\tau) = (3,3)$. Longitudinal section XZ (component E2) at the moment of time $(t,\tau) = (3,3)$.

3. Conclusions

Comparison of components E1 and E2 at $t = \tau$ shows that values of E1 (content of -0,9$10^{-4}$ to 0,9$10^{-4}$ at $t = \tau = 2$ and of -0,16$10^{-4}$ to 0,12$10^{-4}$ at $t = \tau = 3$) and E2 (content of -0,8$10^{-4}$ to 0,9$10^{-4}$ at $t = \tau = 2$ and of -1,0$10^{-4}$ to 1,0$10^{-4}$ at $t = \tau = 3$) have an order 10^{-4} (Fig.4,5,10,11).
Comparison of components E1 and E2 at $t < \tau$ shows that values of E1 content of -1,0$10^{-4}$ to 1,0$10^{-4}$ and E2 of -1,0$10^{-4}$ to 0,9$10^{-4}$ (Fig.6,7).
Comparison of components E1 and E2 at $t > \tau$ shows that values of E1 content of -0,11$10^{-4}$ to 0,12$10^{-4}$ and E2 of -0,10$10^{-4}$ to 0,09$10^{-4}$ (Fig.8,9).
Comparison of settlement values of sizes E1 and E2 at various values of complex time (t,τ) shows that at approach to a real axis (for example at $(t,\tau) = (3,2)$) longitudinal values E1 and E2 have an order 10^{-5} , and at approach to an imaginary axis (for example at $(t,\tau) = (2,3)$) longitudinal values E1 and E2 have an order 10^{-4}. Thus

1. Coherence is observed in all area of space (in a wide range of lengths of a wave (Fig. 4-11). It is shown also earlier [Kopyltsov, Lukyanov, 2003, Kopyltsov, Lukyanov, Serov, 2007].
2. Strong infringement of symmetry occurs to electromagnetic area only in case of a self-affine surface (Fig. 1).
3. If to assume that distinction of conditions of interaction of radiation with a surface, leads to various fields, in particular electromagnetic and gravitational [Brillouin, L,1970], gravitational component sharply increases at approach to an imaginary axis. This asymmetry is shown only in case of a self-affine surface (Fig. 1).

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