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DEVICE FOR CONVERTING ELECTROMAGNETIC RADIATION TO A COHERENT FORM

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(54) DEVICE FOR CONVERTING ELECTROMAGNETIC FIELD TO A COHERENT FORM

(57) Patent claims

1. A device for converting electromagnetic radiation to a coherent form, containing a substrate bearing self-affine topologies that have common fractalization axes and center. Each topology's modules are similar to the corresponding modules in the first self-affine topology. Each topology is produced by successive fractalization of the first-level and then second-level modules following the design rule of the first-level module of the first self-affine topology. That first-level module consists of 1+N circumferences where $N=2^n$, and $n \geq 2$, radius R1, in which the first, basic, circumference is the geometric locus containing the centers of N circumferences with equal distances between the centers of neighboring circumferences. The center of the first circumference is the center of the circumference with radius $2R_1$ closing the first-level module and starting the second-level module that is limited by a circumference with radius $4R_1$.The third-level module is limited by a circumference of radius $8R_1$. The centers of the first-level modules are located on circumference $2R_1$ in the points of its intersection with the axes going through the center of the first circumference and the centers of N circumferences, which also are fractalization axes. Radius R_2 of the basic circumference of the second self-affine topology is equal to $R_1\sqrt{2}$, characterized in that the substrate contains a third self-affine topology with radius R_3 of the basic circumference thereof equal to $R_1\sqrt{3}$.

2. A device for converting electromagnetic radiation to a coherent form as per cl. 1, characterized in that the topologies made up by slits.

3. A device for converting electromagnetic radiation to a coherent form as per cl. 1, characterized in that the topologies embossed on the substrate.

4. A device for converting electromagnetic radiation to a coherent form as per cl. 1, characterized in that the topologies made as a hidden relief within the surface layer of the substrate.

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(54) DEVICE FOR CONVERTING ELECTROMAGNETIC FIELD TO A COHERENT FORM

(57) Summary:

The proposed invention relates to the area of Technical Physics and can be used as a two-dimensional converter of electromagnetic radiation to a coherent form. The device has a substrate containing two self-affine topologies that have common fractalization axes and center. Each topology's modules are similar to the corresponding modules in the first self-affine topology. In the device, the substrate additionally contains a third self-affine topology, with radius R_3 of the basic circumference equal to $R_1\sqrt{3}$.
The technical result consists in broader bandwidth of the generated coherent radiation and a greater degree of coherence of the radiation. 3 claims, 8 figs.

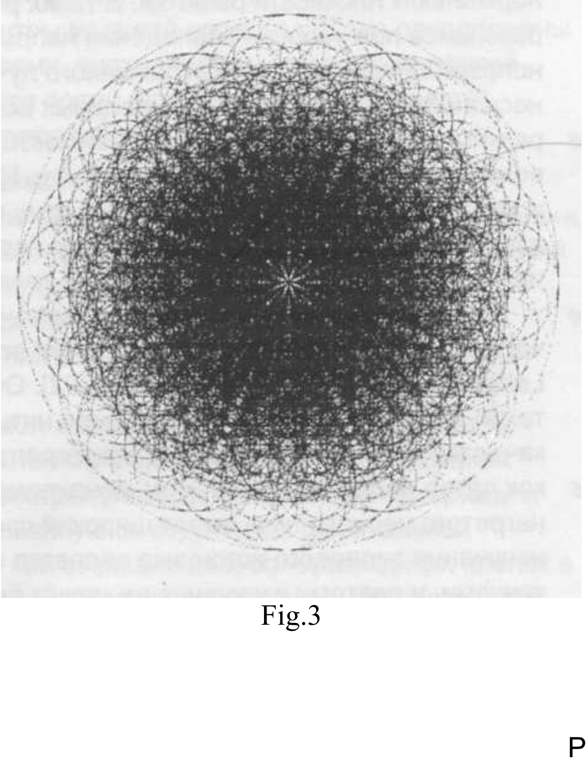

Fig.3

The proposed invention relates to the area of Technical Physics and can be used as a two-dimensional converter of electromagnetic radiation to a coherent form.

The term "coherence" means coordination, connection. In reference to electromagnetic radiation it means coordination, connection between electromagnetic oscillations and waves. Because radiation spreads in time and space, one can evaluate coordination of oscillations emitted by a source at different moments in time in the same point in space, as well as coordination of oscillations emitted at the same moment in time in different points in space [A. S. Mitrofanov. Principles of Amplification of Optical Emission. Training aid. Saint Petersburg, SPNITMO, 2005]. The Electronics Encyclopedia [V. G. Kolesnikov, ed. Electronics: Encyclopedia. Moscow, Sovetskaya Entsiklopedia. 1991. 688 p.], page 205, defines coherence as a property of two oscillatory wave or other processes that determines their ability to amplify or weaken each other when combined. Oscillations are called fully-coherent if the difference of their phases in the observation point remains constant in time, and if that difference determines the amplitude and intensity of the total (resulting) oscillation when the oscillations are combined. Oscillations (waves) are called partially-coherent if the difference of their phases changes rather slowly (as compared to the time of observation), and non-coherent if the difference of their phases changes sporadically.

Known is structuring of an electromagnetic field by means of different diffraction gratings. From the physical point of view, a diffraction grating converts a plane wave falling on it to an aggregate of plane waves propagating from the grating at certain angles and an infinite superposition of surface waves playing an important part only near the grating.

Known is a device (V. P. Shestopalov e.a. Diffraction of Waves on Gratings. Kharkov, Kharkov University Publishing House, 1993, p. 287) made in the form of a periodic structure that consists of infinitesimally thin and infinitely long perfectly conductive stripes of a certain width and a certain period; the plane of the stripes and the normal line of the grating's plane make an angle. In such gratings there appears mirror resonance if the direction of wave propagations above the grating coincides with the direction of the specularly reflected ray. Also, in the slits between the stripes there are several constant waveguide waves, interference between which causes spikes on the curves of dependencies of divergent wave amplitude ratios on the frequency and parameters of the grating. Interference between a TEM wave and the first waveguide wave in the slits causes resonance total reflection of energy. In terms of its application, a drawback of the existing device is an extremely narrow frequency range of electromagnetic field conversion.

Known is a source of quasi-coherent radiation that is made on the basis of a heated black body [Greffet J-J et an, Coherent Emission of Light by Thermal Sources.
Letters to nature. Vol.416, h.61-64, 2002]. Usually thermal light-emitting sources like an absolute black body or incandescent filament are treated as the examples of sources of non-coherent radiation, as opposed to laser, which is a source of monochromatic and parallel radiation. Radiation of a heated black body has a broad range and is normally quasi-isotropic. Intensity of radiation of a thermal source equals the sum of intensities emitted by different points; therefore radiation cannot be parallel. The work at hand asserts the possibility of making a planar source of coherent radiation. To use a black body as a source of coherent radiation, a plate was cut out of polarizing material, whereon a periodic structure of parallel slits was made. The parameters were calculated based on the ability to create radiation with a wavelength of λ=11.36 mcm. To meet that condition, a heated plate had to be 5 mm long, a slit depth was $\lambda/40$, a slit period d was 0.55 λ. This produced quasi-monochromatic radiation in the zone removed from the substrate surface for 10–100 nm. Radiation is narrow-beam and shaped like the directional diagram of an antenna. Obviously, presence of a narrow sector of coherent radiation in the infrared spectrum is ensured by the regular structure of the slits made in a material exhibiting the property of polarization. However, the size of the sector where monochromatic radiation exists is so small that all observable physical effects can be only seen in a microscope.

However, it should be noted that in this case the black body remains a source of non-coherent scattered radiation. There was no change in the characteristics of the source itself. The plate of self-polarizing material containing the system of parallel slits remains a passive element in the structure, it is not an active emitting source as opposed to a black body. This case is about conversion of scattered non-coherent radiation from a source (black body) to coherent radiation by means of a passive structure, i. e. the system of parallel slits made in the surface layer of the substrate of polarizing material.

The set of critical attributes closest to the proposed ones is demonstrated by the device for structuring of electromagnetic field (Patent RU №2249862), which has a substrate bearing self-affine topologies that have common fractalization axes and center. Each topology's modules are similar to the corresponding modules in the first self-affine topology. Each topology is produced by successive fractalization of the first-level and then second-level modules following the design rule of the first-level module of the first self-affine topology, consisting of 1+N circumferences with radius R_1. The first (basic) circumference in the module is the geometric locus containing the centers of N circumferences with equal distances between the centers of neighboring circumferences. The center of the first circumference is the center of the circumference with radius $2R_1$ closing the first-level module and starting the second-level module that is limited by a circumference with radius $4R_1$. The third-level module is limited by a circumference of radius 8R. The centers of the first-level modules are located on circumference $2R_1$ in the points of its intersection with the axes going through the centers of the first circumference and the centers of N circumferences, which also are fractalization axes. Radius R_2 of the basic circumference of the second self-affine topology is equal to $R_1\sqrt{2}$.

A peculiarity of manufacturing this device is the fact that the center of the self-affine topology is a fractal structure of the first fractalization level, around which a structure of a higher fractalization level is built. The highest level does not exceed three. The lines of the circumferences make up a multicomponent fractal-type diffraction grating. Application of the principle of fractality ensures self-coordination of the interference fringe pattern.

The effect of the existing device is based on its ability to convert electromagnetic field to a three-dimensional spatial system of interference maximums and minimums that are localized in the space above the fractal graphics and have an ordered structure correlating with the structure of the fractal graphics. It is clear, for example, where nanoscale films are grown in the presence of one or more existing devices (Patent RU No. 2212375) within the deposition volume, but outside the transport area of the deposited material. On the substrate, fractal self-affine structures grow that tend to replicate the topology of the existing device.

A drawback of the existing device is the insufficiently broad frequency range of electromagnetic field conversion. Also, such a structure does not guarantee that the radiation generated in space will be coherent.

The purpose of the proposed invention is to design a broadband device for converting electromagnetic radiation to coherent radiation.

The technical result consists in a broader bandwidth of the generated coherent radiation and a greater degree of coherence of the radiation.

The task at hand is accomplished owing to the fact that the proposed device for converting electromagnetic field to a coherent form, like the existing one, contains a substrate bearing self-affine topologies that have common fractalization axes and center. Each topology's modules are similar to the corresponding modules in the first self-affine topology. Each topology is produced by successive fractalization of the first-level and then second-level modules following the design rule of the first-level module of the first self-affine topology. That first-level module consists of 1+N circumferences where $N=2^n$, and $n \geq 2$, radius R1, where the first (basic) circumference is the geometric locus containing the centers of N circumferences with equal distances between the centers of neighboring circumferences. The center of the first circumference is the center of the circumference with radius $2R_1$ closing the first-level module and starting the second-level module that is limited by a circumference with radius $4R_1$. The third-level module is limited by a circumference of radius 8R. The centers of the first-level modules are located on circumference $2R_1$ in the points of its intersection with the right lines going through the centers of the first circumference and the centers of N circumferences, which also are fractalization axes. Radius R_2 of the basic circumference of the second self-affine topology is equal to $R_1\sqrt{2}$. The difference form the existing device is that, in the proposed device, the substrate contains a third self-affine topology, with radius R_3 of the basic circumference equal to $R_1\sqrt{3}$.

The topology of the proposed device contains information on the structure of the generated coherent radiation, encoded as a relevant geometry, and an algorithm of its construction. As the founder of synergetics H. Haken remarked [H. Haken. Information and Self-Organization: A Macroscopic Approach to Complex Systems. Translation from English. Moscow, KomKniga, 2005. 248 p.], "information can also assume the role of a kind of environment supported by individual parts of the system; and from that environment those parts receive specific information regarding how they should function coherently and cooperatively." In the same work, Haken considers the example of a solid laser. Individual atoms in its working body thereof can emit light waves independently of each other, thus there appears a superposition of non-correlated, albeit amplified wave trains, and a completely irregular pattern is generated. "However, when the signal amplitude becomes sufficient, a completely different process is triggered. Atoms begin to oscillate coherently, and the field itself becomes coherent, i. e. it no longer consists of non-correlated wave trains, but turns into a single virtually endless sinewave. Here is a typical example of self-organization: the temporal structure of the coherent wave originates without any interference from the outside. Chaos is replaced by order. This mathematical theory shows that the originating coherent light wave acts as a kind of order parameter that makes atoms oscillate coherently, or, in other words, subjugates atoms [...]. We deal here with cyclic causality: the order parameter subjugates atoms on the one hand, and is engendered by the joint action of the atoms on the other hand." Thus, the laser is a device for converting structured, but non-coherent radiation to virtually unidimensional system of coherent wave trains.

The prototype device has self-affine topologies where one topology's elements are divisible by R_1, and the other one's elements by $R_1\sqrt{2}$; it converts electromagnetic field in a rather narrow band; whereas the proposed device, when an additional self-affine structure is generated with the elements divisible by $R_1\sqrt{3}$, ensures that the remaining part of electromagnetic spectrum, which falls on the substrate surface but did not earlier correlate with the topology's structure, is brought to a coherent form, and that a system of coherent radiation in space is built.

The achieved technical result consists in a broader bandwidth of the generated coherent radiation, and a greater degree of coherence of the radiation.

Similarly to Haken's theory, it can be maintained that, when generating only one topology with the elements divisible by R_1, we have two unidimensional systems generating coherent radiation on orthogonal axes (like in the laser, which is essentially a unidimensional system generating coherent radiation). To implement a two-dimensional version of coherent radiation (in the substrate plane or the near zone above it), two self-affine structures together have to influence on electromagnetic field; the elements of the second structure should be divisible by $R_1\sqrt{2}$. To implement a coherent pattern in three-dimensional space above the surface of the topology, all three self-affine topologies should act together, with the elements of the third one divisible by $R_1\sqrt{3}$.

The more possibilities microelectronic technology has in terms of creating topologies with small-sized lines and the more fractalization axes can be used, the smoother the frequency spectrum of converted coherent radiation will be. If the spectrum of coherent radiation using only two self-affine topologies can be compared to a coarse tooth comb, then introduction of the third topology with each step of fractalization will increase the number of "teeth", and do so not additively (the combined effect is larger than the sum due to intercoupling interaction), but it also increases their density.

The minimal wavelength is determined by the minimal possible line width in the topology and, consequently, capabilities of modern technology. Taking into account that on the territory of Russia and the former USSR today the limit of technological capabilities of resolution is a value of about 0.5 mcm (Scientific Development and Production Center "Integral", Republic of Belarus), for us a ceiling value is 0.5 mcm. For Intel, which uses 0.12 mcm resolution in mass production and planning to use lines of approximately 70 nm, ceiling values will be 0.12 and 0.07, respectively. Waves of a smaller wavelength can also be generated; however, they will not take part in creating the coherent cooperative structure, but simply be structured electromagnetic radiation.

At the same time, the size of the substrate should preferably suffice for circumferences with the greatest diameter, i. e. of R_3. Failure to meet that condition will result in distorting phenomena caused by the breaks in the circumference lines affecting the electromagnetic field.

The choice of materials for the substrate and fractal topology is of great importance. Upon general consideration, efficiency of conversion will clearly be the longer, the greater the difference in the characteristic parameters of the substrate and topology materials is, for example, their densities. Significant difference in refraction ratio in the two materials ensures the distinctly pronounced coherent form of the field.

The topology itself can be generated by different methods.

The set of attributes stated in cl. 2 of the Claims characterizes a device for converting electromagnetic field to a coherent form, where the topology is made of slits within the surface layer of the substrate.

The slits in the diffraction grating act as waveguides on which electromagnetic waves propagate. In the slits, there appears interference of several constant electromagnetic waves. The originating resonance phenomena lead to full refection of energy. The resonance phenomena influence the interference fringe pattern in the remote and near zones. This phenomenon can be interpreted as expansion of the near zone into the remote one.

The minimum slit width is 0.1 mcm. Its size is related to the covered spectral band of electromagnetic radiation (0.1 mcm is the UV wavelength). However, experiments show that even 7-mcm slits are sufficient to structure the whole optical spectrum. The minimum slit depth is 0.1 mcm. It is chosen empirically, by general physical consideration: the height of a step as of a diffracting element cannot be less than the wavelength of electromagnetic radiation. Creating a topology by means of slits is most efficient for producing a distinctly pronounced coherent diffraction pattern.

The set of attributes stated in cl. 3 of the Claims characterizes a device for converting electromagnetic field to a coherent form, where the topology is embossed.

The substrate and embossed lines can be a combination of any materials as long as their densities are different.

The relief can be a topology produced by depositing a thin-film coating followed by fine-line lithography to make a pattern. Similarly to the slit structures, the deposited film cannot be thinner than 0.1 mcm because the height of a step as of a diffracting element cannot be less than the wavelength of electromagnetic radiation. Besides, it should be taken into account that with a film thinner than 0.1 mcm most materials become semi-transparent for electromagnetic radiation, which will cause losses as well as distortions. Essentially, any combination of materials used for the substrate and the thin-film relief is possible since the point is to ensure a difference of potentials between the materials of the substrate and the film.

Technologically, such structures can be manufactured by methods of modern microelectronic processing as described below.

1. On a substrate where a topology has to be made, a film is deposited by magnetron sputtering, the film is made of the material that will be used to form the topology, for example, chrome or titanium as the most widely-spread microelectron-processable materials that adhere well to the substrate. It is very important because the generated topology should hold up well on the substrate without flaking.

2. The substrate with the film is coated with a layer of photoresist, preferably positive-working because it has the best resolving power, for example, the FPRN-7 resist (ФПРН-7, positive-working resolving naphthoquinone-diazide photoresist, grade 7) The resist is best deposited by method of centrifugal separation at 3,000–3,500 rpm, although atomizing can also be employed.

3. After the standard procedure of double drying and heat treatment, the resist is exposed by method of fine-line photolithography using UV radiation, preferably within the 400–450 nm wavelength range providing maximum absorption of resist. Exposure can be done directly by contact method via a photomask or by multiplication on an image repeater.

4. After exposure, the substrate with the resist is developed in a corresponding developer (the right aqueous alkaline composition for FPRN-7) and baked.

5. The next step is etching the metal-film windows open in the resist by methods of plasma-chemical etching or reactive plasma-chemical etching that remove the metal film from the open windows and create the necessary topology.

6. The final step is removal of the no longer necessary resist film by burning it in oxygen plasma.

Thus, a topological raised pattern is produced on the substrate surface.

The set of attributes stated in cl. 4 of the Claims characterizes a device for converting electromagnetic field to a coherent form, where the topology is made as a hidden relief within the sub-surface layer of the substrate.

Because it is necessary to ensure a difference in densities of the materials of the substrate and the generated topology, or a difference in the structural characteristics (amorphous and crystalline), the most suitable method is ion-implant doping. In this method a flow of accelerated high-energy ions (energy from 30–50 keV to hunreds keV and MeV) focused to a narrow needle-point bunch (diameter up to mcm units) irradiates the substrate surface according to a certain program. Latest research in nanotechnology revealed that processing methods can be adopted where impurity or defective layers can form even on the opposite side of the 500–600 mcm-thick substrate [I. N. Serov, V. I. Margolin, V. A. Zhabrev et al. "Effects of Remote Action in Mirco- and Nano-Scale Structures." Engineering Physics. 2005. No. 1: pp. 51-67], so there is a viable technological possibility of generating a hidden layer at any depth; however, taking into account the penetration depth of electromagnetic radiation into different solid structures, it is advisable to make the hidden relief directly in the sub-surface layer. The topology structure made of a material whose properties have been altered by ion-implant doping will egress directly to the substrate surface, and the substrate surface itself will remain as even and smooth as before the ion-implant doping procedure. The advantage of ion-implant doping is that it allows virtually all elements of the periodic table to be introduced in the form of ions. Building the structure in the upper layer permits the use of ion energy of about 30–80 keV. Ion-implant doping can be performed using plants similar to ILU-4 (Pulsed Linear Accelerator ИЛУ-4), IOLLA-2 (ИОЛЛА-2, e-beam alloying machine), and the Vezuvy -type series of industrial plants. The average-doze plant Vezuvy 7M generates an ion beam with a diameter of approximately 1 mcm, the doze range is 10^{10}–10^{15} cm^{-2}, energy of implantation is 20–100 keV, maximum current of the beam is 300 μA for boron, 500 μA for phosphor, and 300 μA for arsenic. The high-current implanter Vezuvy 8 operates ions with a mass of up to 200 amu, current of 2–5 μA, ion energy of 100 keV.

The ion path, for example, in silicon will be 0.06 mcm for aluminum ions, 0.05 mcm for phosphor, 0.03 mcm for stibium with ion energy of 40 keV; or it will be 0.15 mcm for aluminum ions, 0.13 mcm for phosphor, 0.05 mcm for stibium with ion energy of 100 keV. Thus, hidden structures will be generated virtually on the surface of the substrate, but in the form of a hidden relief.

Technologically, such structures can be manufactured by methods of modern microelectronic processing as described below.

1. On a substrate where a topology has to be made, a film is deposited by magnetron sputtering, the film is made of material that arrests ions well, for example, chrome or titanium — the most widely-spread microelectron-processable materials that adhere well to the substrate.

2. The substrate with the film is coated with a layer of photoresist, preferably positive-working because it has the best resolving power, for example, the FPRN-7 resist (ФПРН-7, positive-working resolving naphthoquinone-diazide photoresist, grade 7). The resist is best deposited by method of centrifugal separation at 3,000–3,500 rpm, although atomizing can also be employed.

3. After the standard procedure of double drying and heat treatment, the resist is exposed by method of fine-line photolithography using UV radiation, preferably within the 400–450 nm wavelength range providing maximum absorption of the resist. Exposure can be done directly by contact method via a photomask or by multiplication on an image repeater.

4. After exposure, the substrate with the resist is developed in a suitable developer (a suitable aqueous alkaline composition for FPRN-7) and baked.

5. The next step is etching of the metal-film windows open in the resist by methods of plasma-chemical etching or reactive plasma-chemical etching that remove the metal film from the open windows, create the necessary surface topology, and allow ions to penetrate the substrate.

6. Ions with required energy and radiation dose are implanted in the open windows.

7. The final step is removal of the no longer necessary resist film by burning it in oxygen plasma and removal of the buffer metal film by precision etching.

Thus, a topological pattern in the form of a hidden relief is generated on the substrate surface. Essentially, this pattern can be formed in a simpler way by scanning the substrate surface with an ion beam, without any buffer or protective layers of resist or metal. The advantage of such a method is high precision, its drawback is extremely low performance.

The invention is illustrated by means of designs:

Fig. 1 shows an example of building a first-level module of the first self-affine topology;

Fig. 2 shows an example of building first-level modules of three self-affine topologies;

Fig. 3 shows a model execution of the proposed device;

Fig. 4 is a photograph of electromagnetic field converted by the proposed device;

Fig. 5 shows distribution of intensity of a coherent electromagnetic field on the substrate surface with a topology made up by slits;

Fig. 6 shows distribution of intensity of a coherent electromagnetic field on the substrate surface with an embossed topology;

Fig. 7 shows distribution of intensity of a coherent electromagnetic field on the substrate surface with a topology in the form of a hidden relief;

Fig. 8 shows distribution of intensity of a coherent electromagnetic field depending on the distance form the substrate, with a topology made up by slits;

Fig. 3 shows a model execution of the proposed device. It involved eight fractalization axes. For that purpose, the centers of N (N=8) circumferences with radius R1 were placed on the circumference with radius R_1 in the first-level module of the self-affine topology. The axes going through the center of the first circumference and the centers of N circumferences are the fractalization axes of the whole topology. Fig. 2 shows an example of building the first-level modules of three self-affine structures. The first-level module with the basic circumference with radius R_1 is limited by a circumference with radius $2R_2$ for the first self-affine topology, with radius $2R_3$ equal to $2R_1\sqrt{2}$ for the second one, and with radius $2R_3$ equal $2R_1\sqrt{3}$ for the third one. Here, the radius of the basic circumference of the first-level module of the second self-affine topology is equal to $R_1\sqrt{2}$, and of the third one — to $2R_1\sqrt{3}$. Each of the circumferences limiting the modules contains the centers of the first-level modules of the corresponding self-affine topologies thus making up the second-level modules limited by circumferences with radii $4R_1$, $4R_1\sqrt{2}$, and $4R_1\sqrt{3}$ respectively, which contain the centers of the second-level modules limited by circumferences with radii $8R_1$, $8R_1\sqrt{2}$, and $8R_1\sqrt{3}$.

Fig. 4 shows a photograph of a dome-shaped field converted to a coherent form. The substrate material was silicon, in which 0.6-mcm-deep and 0.6-mcm-wide slits were made.

Fig. 5 shows the results of a computer experiment in calculating the distribution of an electromagnetic field converted to a coherent form due to interaction of incident scattered electromagnetic radiation with a topology made up by slits in a semiconductor silicon substrate. The slit dimensions: depth 1.5 mcm, width 1 mcm. In the computer experiment, the process of interaction occurred as absorption and reflection. The following approximation was used: electric field on the topology surface is a superposition of harmonic oscillations random in time and space. In Fig. 5, spatial coordinates are marked on the x-axis and y-axis, and electric field intensity on z-axis, with all values obtained from simulation. The resulting three-dimensional image represents two-dimensional distribution of intensity of the electrical component of the coherent electromagnetic field engendered by interaction of incident radiation with the fractal slit topology (Fig. 3). A proof of the coherent nature of the electromagnetic field converted by the interaction is that there occurs redistribution of intensity of incident radiation on the topology surface in compliance with its geometrical characteristics. In the center of Fig. 5, a minimum is clearly visible, then there is an increase along the radius that forms the circular structure. Also, one can see shorter waves distributed over the surface. Thus, the surface has converted incident radiation of sporadic nature to regular radiation with clear distribution by wavelength by spatial coordinates. Color-coding in the presented image is conventional and denotes relative electric field intensity, where red is the maximum value, and violet is the minimum. Intermediate values are in orange, yellow, green, turquoise, and blue.

Fig. 6 shows the results of a computer experiment in calculating the distribution of an electromagnetic field converted to a coherent form due to interaction of incident scattered electromagnetic radiation with a topology (Fig. 3) embossed in the form of a thin-film titanium structure on a semiconductor silicon substrate. The dimensions of the topological line: thickness 1 mcm, width 0.5 mcm. In the computer experiment, the process of interaction occurred as reflection and absorption. The following approximation was used: electric field on the topology surface is a superposition of harmonic oscillations random in time and space. Spatial coordinates are marked on the x-axis and y-axis, and electric field intensity on the z-axis, with all values obtained from simulation. The resulting three-dimensional image represents two-dimensional distribution of intensity of the electrical component of the coherent electromagnetic field engendered by interaction of incident radiation with the embossed fractal topology. Like in the previous case, a proof of the coherent nature of the electromagnetic field converted by the interaction is that there occurs redistribution of intensity of incident radiation on the topology surface in compliance with its geometrical characteristics. In the center of Fig. 6, an undular dome is clearly visible, it flattens out towards the periphery. Also, one can see shorter waves distributed over the surface. Thus, the surface has converted incident radiation of sporadic nature to regular radiation with clear distribution by wavelength by spatial coordinates.

Fig. 7 shows the results of a computer experiment in calculating the distribution of an electromagnetic field converted to a coherent form due to interaction of incident scattered electromagnetic radiation with the topology (Fig. 3) executed as a hidden relief generated by implantation of stibium ions with an energy of 180 keV (a depth of occurrence of the hidden layer is 0.08 mcm) and a radiation dose of 10^{13} cm^{-2} in a semiconductor silicon substrate. The dimensions of the hidden relief lines: depth up to 0.1 mcm from the surface, width 1 mcm. The resulting two-dimensional image represents distribution of intensity of the electrical component of the coherent electromagnetic field engendered by interaction of incident radiation with the latent self-affine topology. A proof of the coherent nature of the electromagnetic field converted by the interaction are the clear undular structures diverging from the center.

Fig. 8 shows the results of a computer experiment in calculating the distribution of intensity of an electromagnetic field converted to a coherent form due to interaction of incident scattered electromagnetic radiation with a slit topology formed in a semiconductor silicon substrate as a function of the distance from the substrate surface. The slit dimensions: depth 1.5 mcm, width 1 mcm.

In Fig. 8, the y-axis shows the spatial coordinate moving along the radius of the slit topology, and the x-axis shows the coordinate moving perpendicularly to the topology from its center, which is at coordinate 60 on the y-axis. The resulting image is a flat two-dimensional plane section of three-dimensional distribution of intensity of the electrical component of the coherent electromagnetic field engendered by interaction of incident radiation with the fractal slit topology; the plane of the section goes through the topology center along its diameter (the y-axis) and along the axis perpendicular to the topology center (the x-axis). A proof of the coherent nature of the electromagnetic field converted by the interaction is the clearly visible wave in Fig. 8. Its maximum is in coordinate x=10; and according to the conditions of the simulation, the surface is exposed to a wave that is a superposition of a great number of oscillations random in time and space.

Thus, natural and computer experiments prove that the proposed device converts electromagnetic radiation to a coherent form.

Patent Claims

1. A device for converting electromagnetic radiation to a coherent form, containing a semiconductor substrate bearing self-affine topologies that have common fractalization axes and center. Each topology's modules are similar to the corresponding modules in the first self-affine topology. Each topology is produced by successive fractalization of the first-level and then second-level modules following the design rule of the first-level module of the first self-affine topology. That first-level module consists of 1+N circumferences with radius R1, where $N=2^n$, and $n \geq 2$. The first (basic) circumference in the module is the geometric locus containing the centers of N circumferences with equal distances between the centers of neighboring circumferences. The center of the first circumference is the center of the circumference with radius $2R_1$ closing the first-level module and starting the second-level module that is limited by a circumference with radius $4R_1$. The third-level module is limited by a circumference of radius $8R_1$. The centers of the first-level modules are located on circumference $2R_1$ in the points of its intersection with the axes going through the centers of the first circumference and the centers of N circumferences, which also are fractalization axes. Radius R_2 of the basic circumference of the second self-affine topology is equal to $R_1\sqrt{2}$ The device is characterized in that the substrate contains a third self-affine topology, with radius R_3 of the basic circumference equal to $R_1\sqrt{3}$.

2. A device for converting electromagnetic radiation to a coherent form as per cl. 1, characterized in that the topologies made up by slits.

3. A device for converting electromagnetic radiation to a coherent form as per cl. 1, characterized in that the topologies embossed on the substrate.

4. A device for converting electromagnetic radiation to a coherent form as per cl. 1, characterized in that the topologies made as a hidden relief within the surface layer of the substrate.

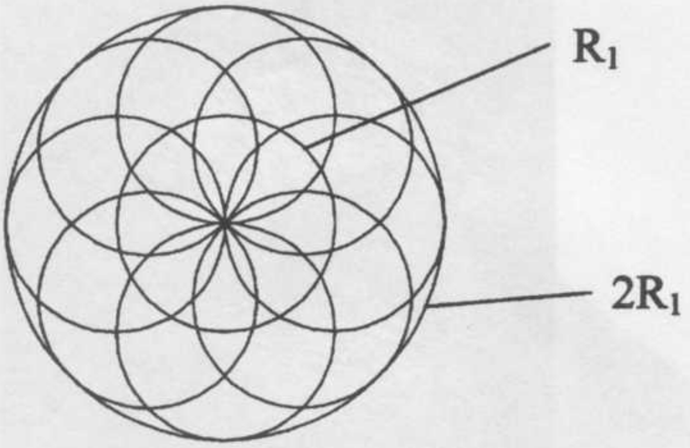

Fig. 1

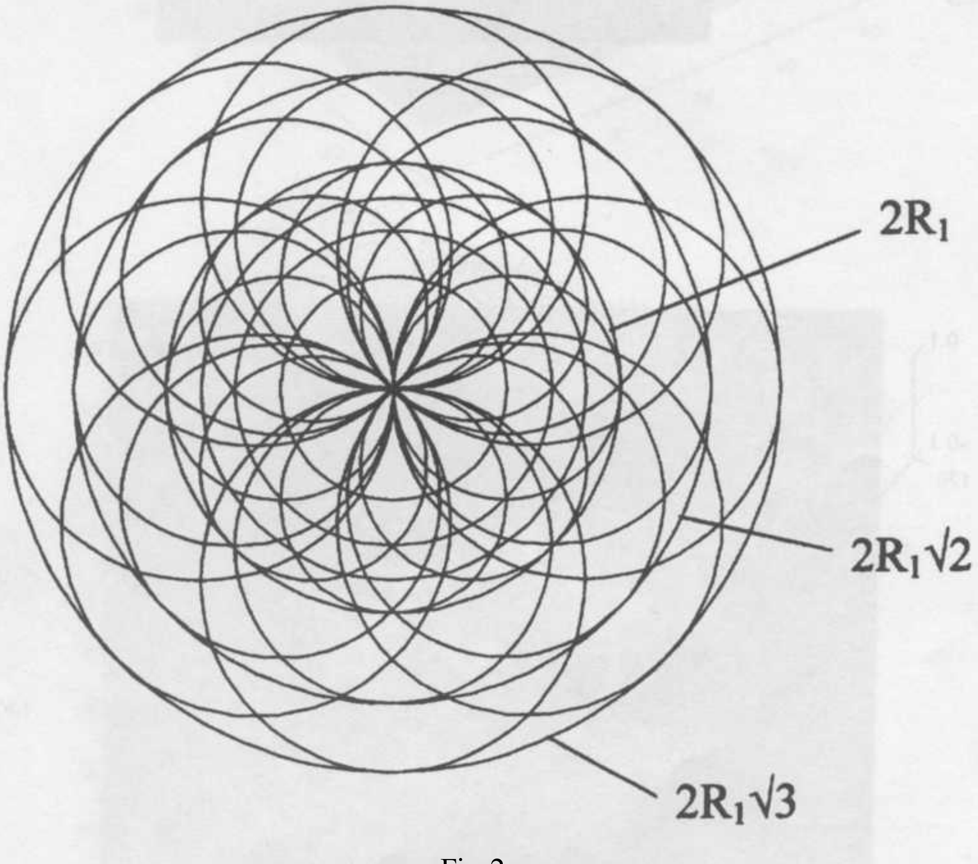

Fig. 2

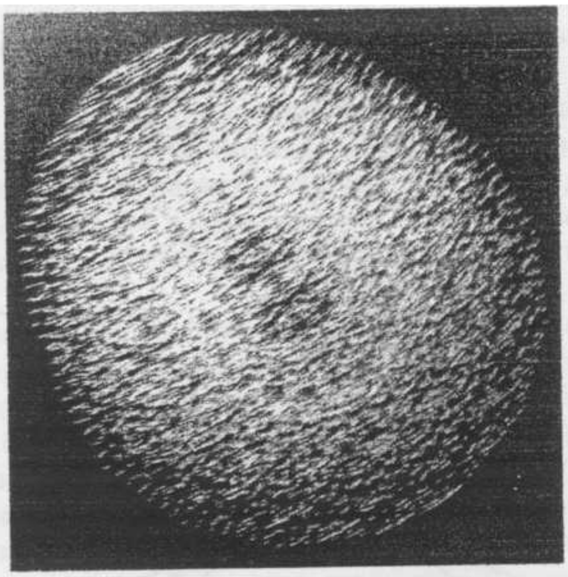

Fig. 4

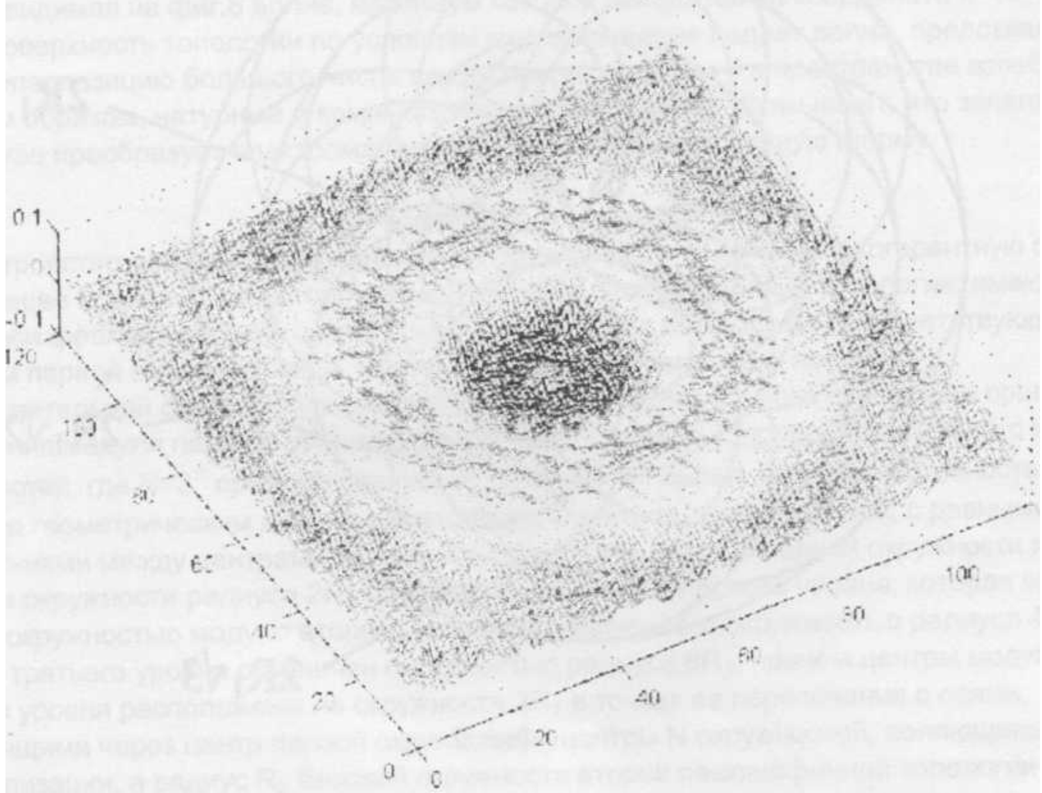

Fig. 5

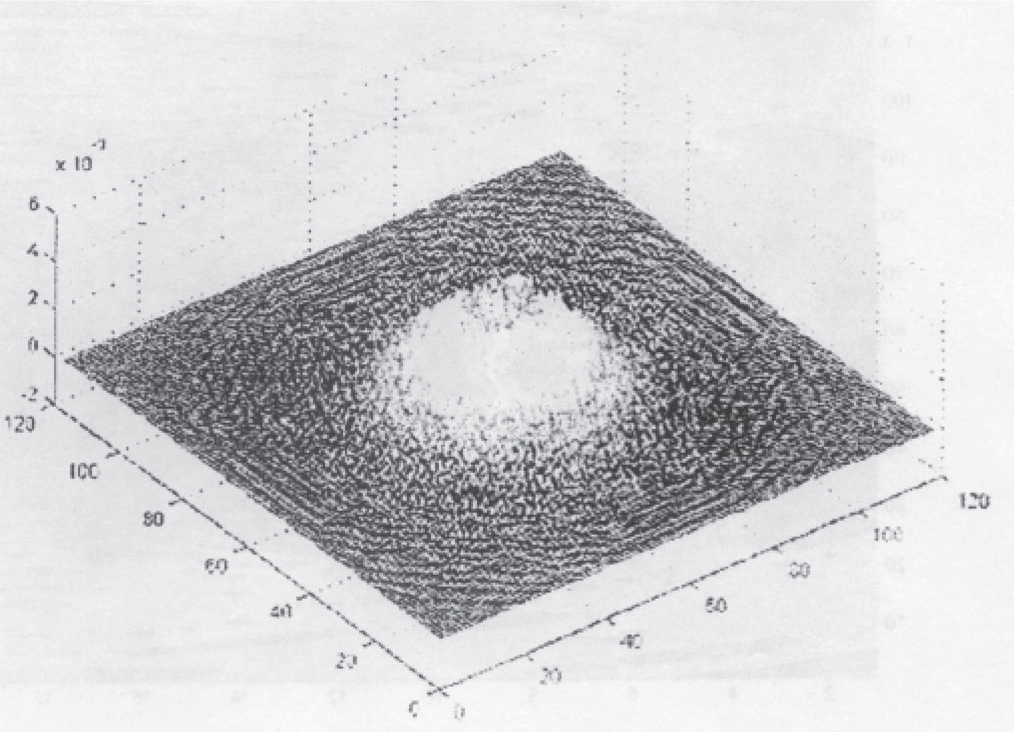
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Fig. 6

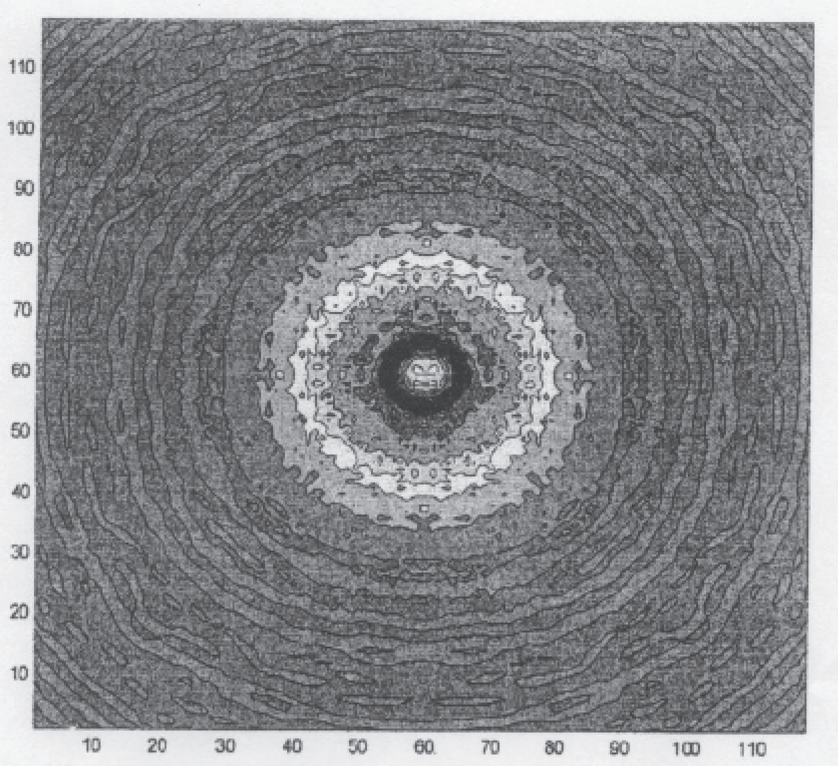
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Fig. 7

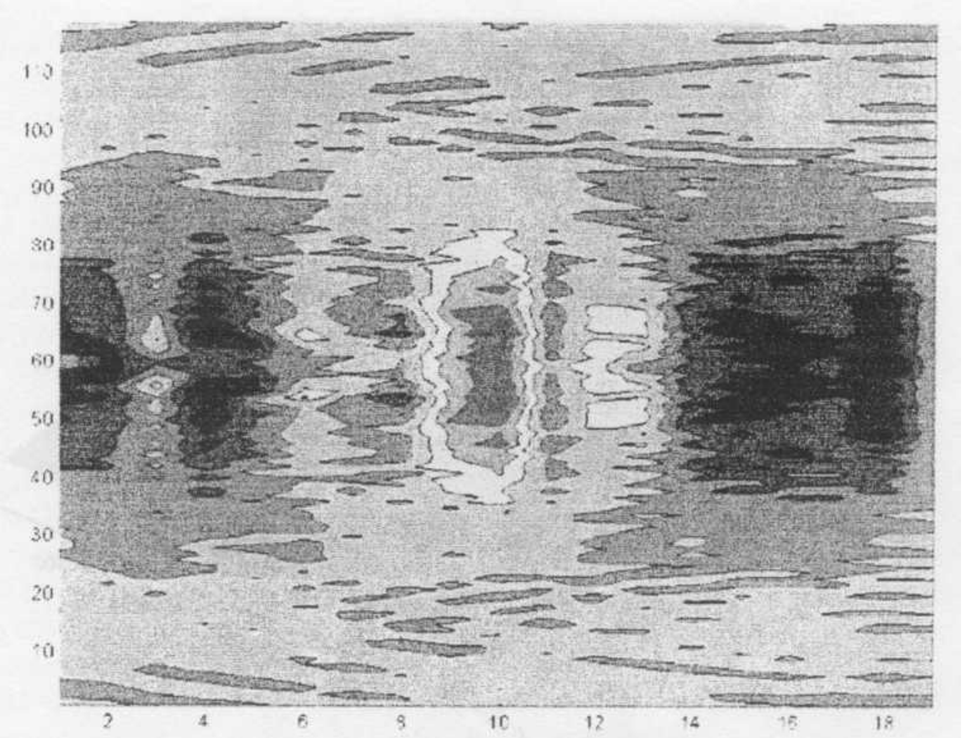

Fig. 8