PATENT

FOR INVENTION

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DEVICE FOR CONVERTING ELECTROMAGNETIC FIELD TO A COHERENT FORM

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Head of the Federal Service of Intellectual Property, Patents and Trademarks

/signature/ ***B. P. Simonov***

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

(57) Patent claims

A device for converting electromagnetic field to a coherent form, containing a semiconductor substrate, on which slits form a self-affine topological layout based on a fractalizing module that consists of an aggregate of circumferences of radius R, wherein the first circumference is the geometric locus containing the centers of the other circumferences of the aggregate with equal distances between the neighboring circumferences, the center of the first circumference coincides with that of the circumference of radius 2R and is the center of the whole self-affine topological layout, and fractalization of the module occurs on the axes going through the center of the first circumference and the centers of the other circumferences of the aggregate characterized in that the self-affine structure is earthed.

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(12) PATENT DISCLOSURE

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

(57) Summary:

The invention relates to Technical Physics. The task was set to expand the range of devices for converting electromagnetic field to a coherent form. The device has a semiconductor substrate, on which slits form a self-affine topological layout based on a fractalizing module that consists of an aggregate of circumferences of radius R, wherein the first circumference is the geometric locus containing the centers of the other circumferences of the aggregate with equal distances between neighboring circumferences, the center of the first circumference coincides with that of the circumference of radius 2R and is the center of the whole self-affine topological layout, and fractalization of the module occurs on the axes going through the center of the first circumference and the centers of the other circumferences of the aggregate. The self-affine structure is earthed here. The technical result consists in creating a planar source for converting electromagnetic radiation to a coherent form. 6 ill.

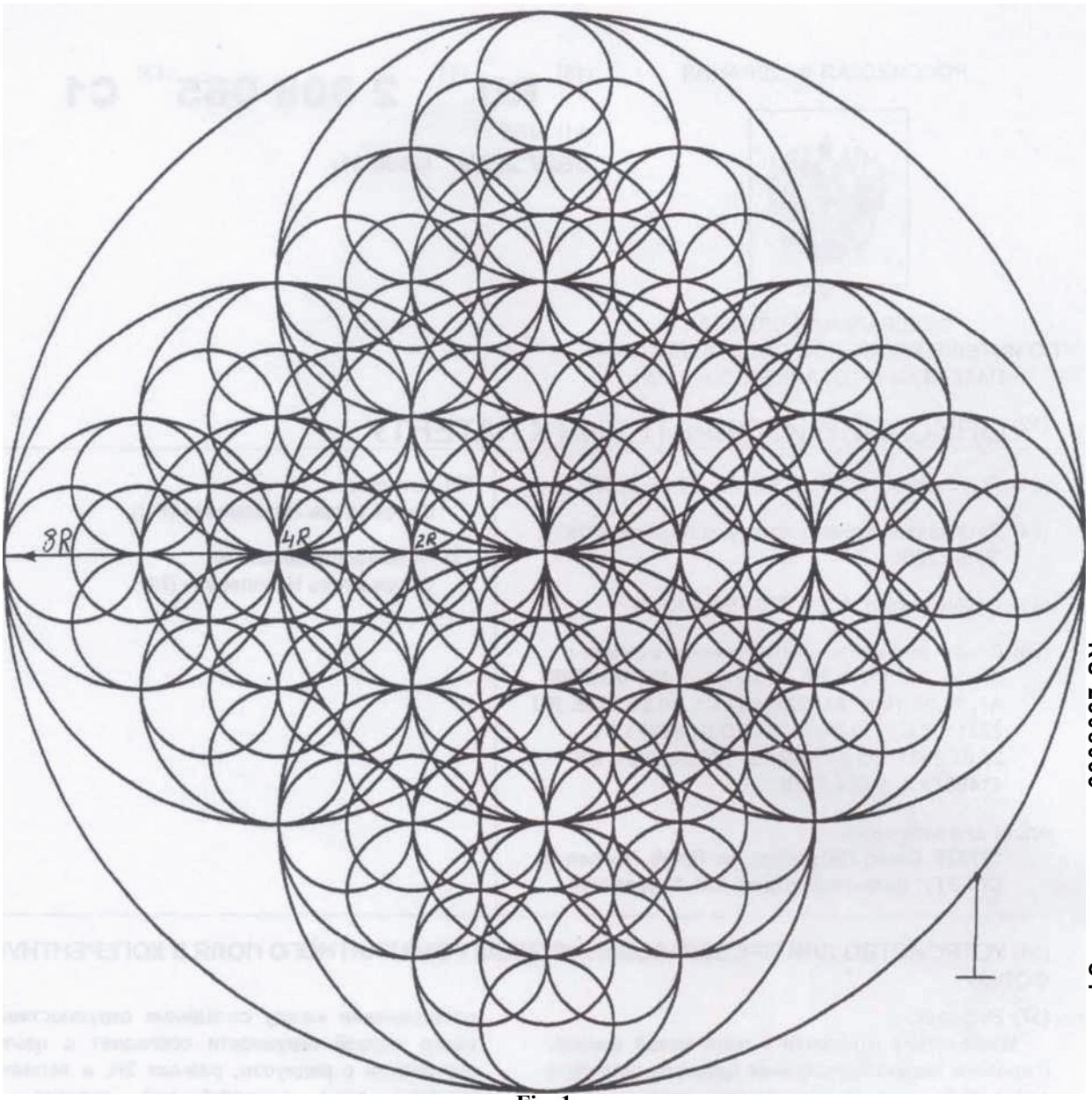

Fig. 1

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The proposed invention relates to Technical Physics and can be used mainly in areas where one has to secure influence of a coherent electromagnetic field on various physical, chemical and biological processes.

The word "coherence" means coordination, connection. In reference to electromagnetic radiation it means coordination, connection between electromagnetic oscillations, waves. Because radiation spreads in time and space, one can evaluate coordination of oscillations emitted by the source at different moments in time, at the same point in space (temporal coherence), as well as coherence of oscillations emitted at the same moment in time at different points in space (spatial coherence)
(A. S. Mitrofanov. Principles of Amplification of Optical Emission. Training aid. Saint Petersburg, SPNITMO, 2005).

There already exists 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, p.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. Whereas laser is a source of monochromatic and narrowed radiation, radiation of a heated black body has a broad spectrum and is normally quasi-isotropic.

Self-evidently, light spontaneously emitted by different points of a thermal source cannot interfere. And vice versa, radiation from different points of an antenna interferes in certain directions creating lobes. Intensity of radiation of a thermal source equals the sum of intensities emitted by different points, and thus radiation can not be narrowed one. Still, the work at hand proves 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 possibility to create a wave of λ=11.36 mcm. To meet that condition, the heated plate has to be 5 mm long, a depth of the slits is $\lambda/40$, slit period d is 0.55λ. This produced quasi-monochromatic radiation in the zone removed from the substrate surface for 10–100 nm. This 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.

The set of essential parameters closest to the proposed ones is demonstrated by the device for structuring of electromagnetic field (Patent RU №2249862). A known device has a semiconductor substrate, on which slits form a self-affine (self-similar) topological layout based on a fractalizing module that consists of an aggregate of circumferences of radius R, wherein the first circumference is the geometric locus containing the centers of the other circumferences of the aggregate with equal distances between neighboring circumferences, the center of the first circumference coincides with that of the circumference of radius 2R and is the center of the whole self-affine topological layout, and fractalization of the module occurs on the axes going through the center of the first circumference and the centers of the other circumferences of the aggregate.

In the known device, the self-affine structure formed by the slits was used as a diffraction grating with complex ordered structure comprised of curved closed elements made up by the closed slits. Along those slits, electromagnetic waves spread like in the system of waveguides. In the slits, there appears interference of several constant electromagnetic waves causing full resonance reflection of energy, which affects the interference pattern in the near and remote zones.

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

The task at hand is accomplished owing to the semiconductor substrate in the proposed, as well as the known device, on which slits form a self-affine (self-similar) topological layout based on a fractalizing module that consists of an aggregate of circumferences of radius R, wherein the first circumference is the geometric locus containing the centers of the other circumferences of the aggregate with equal distances between neighboring circumferences, the center of the first circumference coincides with that of the circumference of radius 2R and is the center of the whole self-affine topological layout, and fractalization of the module occurs on the axes going through the center of the first circumference and the centers of the other circumferences of the aggregate. However, unlike the known device, the self-affine structure is earthed here.

Modeling and experiments revealed that immediately after interaction with the above mentioned self-affine structure, electromagnetic field acquires a stable form that remains virtually unchanged as frequency of incident radiation changes. The structure is long enough to be seen by naked eye.

The invention is illustrated by means of drawings:

Fig. 1 shows a model execution of the proposed device;

Figs. 2a and 3a show amplitude distribution of radiation at different frequencies after interacting with the self-affine structure; Figs. 2b and 3b — phase distribution of radiation at different frequencies;

Fig. 4 demonstrates a section of radiation above the substrate with the earthed structure on a plane perpendicular to the substrate;

Fig. 5 shows spatial amplitude distribution of radiation on the structure's surface (different projections);

Fig. 6 is a photo of the resulting radiation.

Fig. 1 shows a version of the proposed device. There are nine circumferences with radius R, so there are eight fractalization axes, and the maximum circumference radius equals 8R. The structure is made on a 1 mm thick silicon substrate with a diameter of 6 mm. The structure is made on its surface by 1 mcm wide and 1.2 mcm deep slits. The structure is earthed.

Modern technology produces far more complex structures but even with a simple increase in the number of circumferences of the basic module, the lines in the drawing merge and become indiscernible.

The process was simulated using Schrodinger's formula that describes interaction of an electromagnetic wave with the surface of a plate.

$$\frac{\partial^2 E}{\partial \varphi^2} + \frac{\partial^2 E}{\partial r^2} = -a^2 E - b,$$

where E is the function proportionate to intensity of radiation, r is the length of the radius-vector, φ is the polar angle, and a and b are constants.

Frequency of radiation was changed during simulation.

Figs. 2a and 2b show, accordingly, amplitude and phase distribution of the field over the area of the device with a wavelength of incident radiation equal to 0.5 lengths of the largest circumference of the self-affine structure. Figs. 3a and 3b show amplitude and phase distribution of the field with a wavelength of 1/64 of the length of the largest circumference.

Analysis of the Figures shows that equal amplitudes gather in the same areas with alternating peaks and troughs. The same applies to phase distribution with alternating peaks and troughs.

Comparison of those images proves that there is virtually no change in the structured field when frequency (wavelength) changes.

Simulation was performed taking into account that the surface reflects most of radiation, and the slits absorb most of radiation. The surface reflectance was taken as a value varying within the limits of $1 \geq \rho \geq 0.6$, and the slit absorption factor — within the limits of $1 \geq a > 0.6$. The deeper the slit, the greater the absorption factor. Different values of those factors yielded similar results of distribution of intensity E in space.

Fig. 4 demonstrates a section of radiation above the substrate with the earthed center on a plane perpendicular to the substrate. In this chart, the substrate lies on the Y-axis and takes up the space from coordinate 30 to coordinate 90. A diameter of the self-affine structure is 6 mm, a slit depth is 1.6 mcm. Intensity E was in the form of pulses. The X-axis is the level above the surface of the structure. Zone 1 corresponds to the intensity trough, and zone 2 — to the intensity peak. The stretch of the coherent sector of the field reaches 20 mm.

A condition of existence of the coherent form of electromagnetic radiation is a substrate made of a semiconductor material. It is known that semiconductors are characterized by polarization, i. e. spatial separation of charges under the influence of an electric field. When radiation hits the surface of a semiconductor substrate, the phenomenon of shifting takes place; and because the substrate is thinner in the area of slits, the concentration of charge carriers in the grooves will be significantly higher than in the neighboring areas. For simplicity, one can maintain that all charge carriers are concentrated in slits. When the potential difference in the neighboring slits reaches a certain critical value, a spark over the shortest distance between slits occurs, i. e. current of a certain wavelength appears and, accordingly, the electric component of intensity, which will be constant for each sector. Modeling (Fig. 6) shows that regardless of a situation on the surface border, stable and soliton-like distribution of amplitude establishes after a while on the surface of the plate.

Main conclusions that can be drawn from the simulation: a self-affine structure made on a semiconductor substrate and earthed will convert electromagnetic radiation to a coherent form. The outcome of the breakdown of radiation does not depend on the parameters of incident radiation.

We are working on experimental proof of the results obtained by simulation. Namely, a plate with a self-affine structure was radiated by a halogen lamp. The 6 mm substrate was made of silicon, a depth of slits was 1.2 mm, the basic module contained nine circumferences with radius R and nine circumferences with radius $R\sqrt{2}$, i. e. there were eight fractalization axes, and the greatest circumference had a radius of $8R\sqrt{2}$. A scaly semi-sphere was visible beneath a slightly visible cylinder, inside which there was a slightly visible cone. Quality photographs could not be taken due to brightness of radiation. The photo in Fig. 6 was treated in order to make something discernible apart from the bright spot; therefore this photo is not informative.

Patent Claims

A device for converting electromagnetic field to a coherent form containing a semiconductor substrate, on which slits form a self-affine topological layout based on a fractalizing module that consists of an aggregate of circumferences of radius R, wherein the first circumference is the geometric locus containing the centers of the other circumferences of the aggregate with equal distances between neighboring circumferences, the center of the first circumference coincides with that of the circumference of radius 2R and is the center of the whole self-affine topological layout, and fractalization of the module occurs on the axes going through the center of the first circumference and the centers of the other circumferences in the aggregate characterized in that the self-affine structure in the device is earthed.

a b

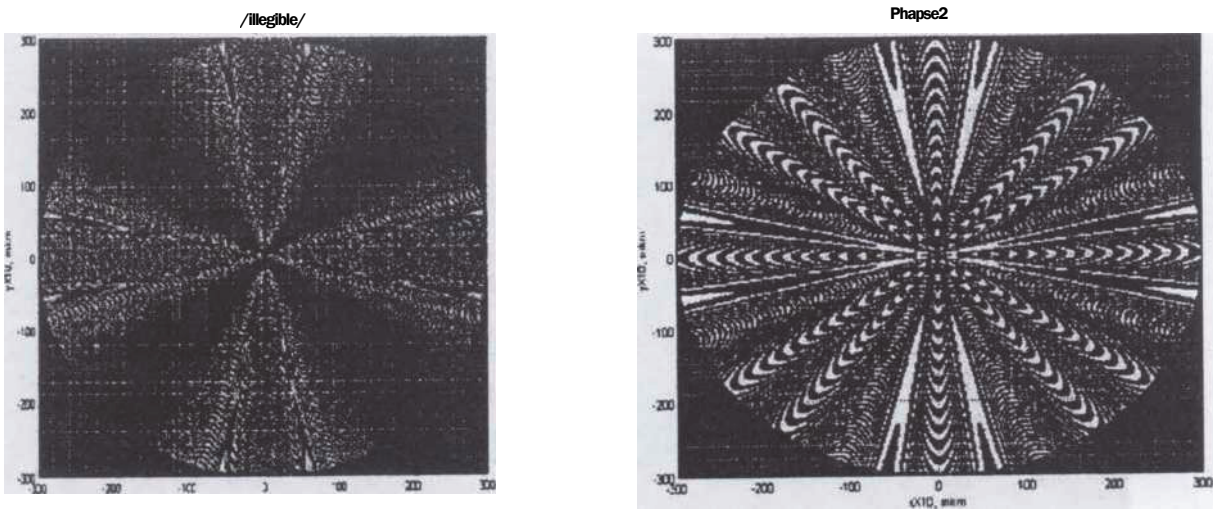

Fig. 2

a

b

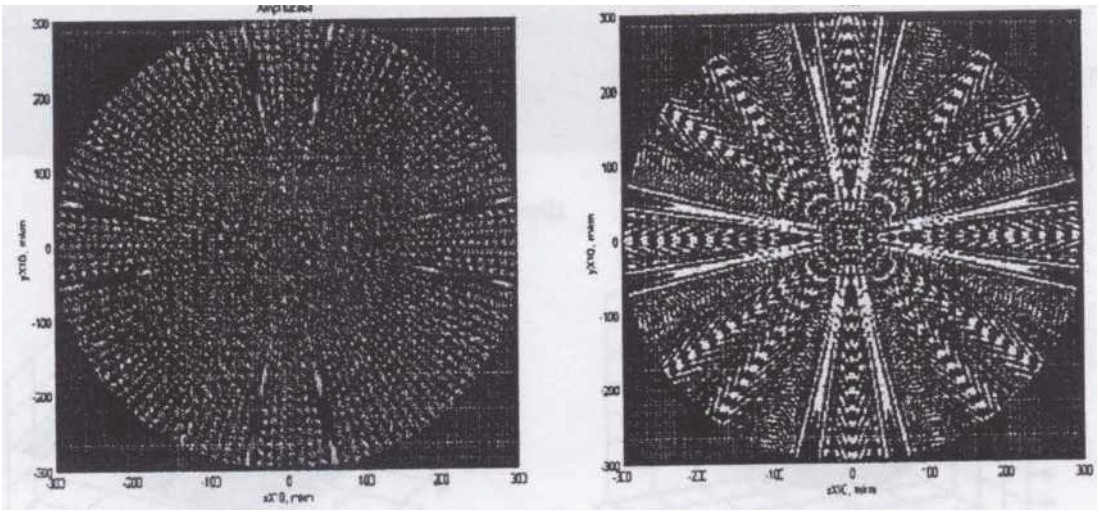

Fig. 3

Fig. 4

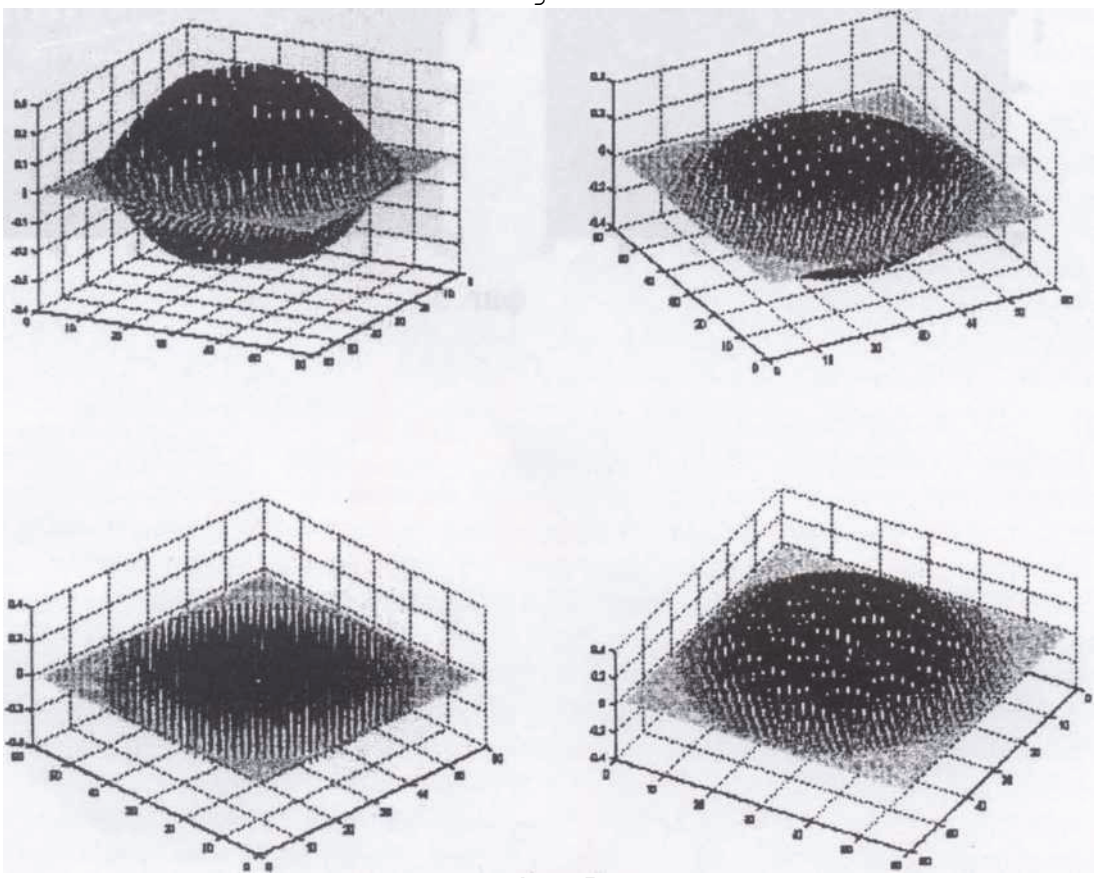

Fig. 5