PATENT

FOR INVENTION

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DEVICE FOR STRUCTURING OF ELECTROMAGNETIC RADIATION

Patentee(s): ***Igor Nikolayevich Serov (RU)***
Inventor(s): ***Igor Nikolayevich Serov (RU)***

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/signature/ B. P. Simonov

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Correspondence address:
5 ul. Prof. Popova, Saint Petersburg, 197376
K. I. Berkovsky, Patent Department, Saint Petersburg State Electrotechnical University (SPSEU)

(72) Inventor(s):
Igor Nikolayevich Serov (RU)

(73) Patentee(s):
Igor Nikolayevich Serov (RU)

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(54) DEVICE FOR STRUCTURING OF ELECTROMAGNETIC RADIATION

(57) Patent claims

1. A device for structuring of electromagnetic radiation in the wavebands between submicron and millimeter, containing a substrate bearing a topological layout, including an aggregate of concentric circumferences with each radius equal to $R \cdot \sqrt{2^{n-1}}$, where n is the ordinal number of the circumference from the center, characterized in that the topology is made in the form of an aggregate of circumferences with radius R, each of the circumferences is the geometric locus containing the same number of the centers of the neighboring circumferences; each of the centers located on the same circumference is at equal distances from the two neighboring ones, and each center of a circumference with radius R is the center of the same number of concentric circumferences, with each of their radius equal to $R \cdot \sqrt{2^{n-1}}$, where $n_{max}=7$.

2. A device for structuring of electromagnetic radiation as per cl. 1 where the substrate is made of silicon, and the topology is made of metal.

3. A device for structuring of electromagnetic radiation as per cl. 1 characterized in that the substrate is made of aluminum, and the topology is graphite.

4. A device for structuring of electromagnetic radiation as per cl. 1 characterized in that the substrate is made up by slits with a width and depth of at least 1 mcm.

5. A device for structuring of electromagnetic radiation as per cl. 4 characterized in that the substrate is made of polyvinyl.

6. A device for structuring of electromagnetic radiation as per cl. 4 characterized in that the substrate is a layered structure with the upper layer in the form of a semi-transparent reflective coating that ensures reflection from the lower layer.

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(12) PATENT DESCRIPTION

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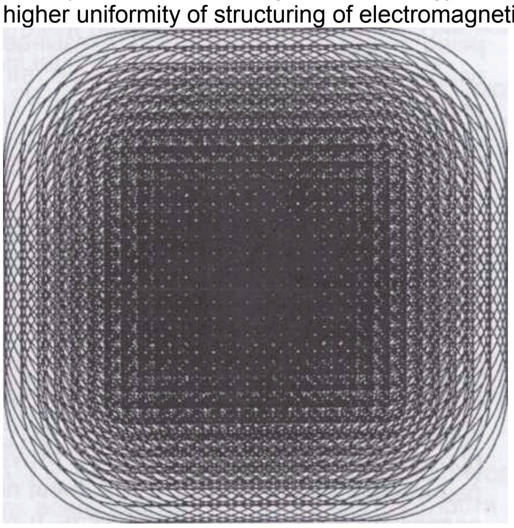
(54) DEVICE FOR STRUCTURING OF ELECTROMAGNETIC RADIATION

(57) Summary:
The invention relates to Technical Physics and can be used to secure influence of structured electromagnetic radiation on various physical, chemical and biological processes. The device has a substrate bearing a topological layout containing an aggregate of concentric circumferences with each radius equal to $R \cdot \sqrt{2^{n-1}}$, where n is the ordinal number of the circumference. The topology is made in the form of an aggregate of circumferences with radius R, each of the circumferences is the geometric locus containing the same number of the centers of the neighboring circumferences; each of the centers located on the same circumference is at equal distances from the two neighboring ones, and each center of a circumference with radius R is the center of the same number of concentric circumferences, with each of their radius equal to $R \cdot \sqrt{2^{n-1}}$. Because the dimensions of the sector where the density of the lines making up the topology are equal and can be arbitrarily large, the technical result shall consist in higher uniformity of structuring of electromagnetic radiation along the surface of the device. 5 claims, 5 figs.



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The proposed invention relates to the area of Technical Physics and can be used mainly in areas where one has to secure influence of structured electromagnetic field on various physical, chemical and biological processes, for example, in manufacture of thin nano-scale films with fractal structure, protection of biological objects from harmful effect of anthropogenic electromagnetic field etc.

Electromagnetic field can be structured 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 infinitesmally 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 up an angle. In such gratings there appears a 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 amplitude ratios of divergent waves on the frequency and parameters of the grating. Interference of a TEM wave and the first waveguide wave in slits causes full resonance reflection of energy.

In terms of its application, a drawback of the existing device is the narrow frequency range of electromagnetic field conversion.

The set of critical attributes closest to the proposed ones is demonstrated by the device (patent RU No. 2231137) for structuring of electromagnetic field that has a substrate bearing a topological layout containing an aggregate of concentric circumferences with each radius equal to $R \ \sqrt{2}^{n-1}$, where n is the ordinal number of the circumference from the center. Such devices are called fractal-matrix structurizers (FMS).

A peculiarity of manufacturing this device is the fact that the center of the topology is a fractal structure of the first fractalization level, around which a structure of a higher fractalization level is built. As a rule, the highest level does not exceed three. The lines of the circumferences make up a multicomponent diffraction grating.

One of the crucial properties of multicomponent gratings is expansion of the polarization susceptibility area. As frequency rises, the wavelength becomes commensurable with finer details in the lattice spacing; therefore the resonance region in multicomponent gratings is wider than in single-component ones. The effect of the existing device is based on its ability to convert electromagnetic field to a three-dimensional spatial system of diffraction maximums and interference minimums that are localized in the space above the FMS 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, structures grow that tend to replicate the topology of the existing device.

A drawback of the existing device is lack of uniformity in structuring of the electromagnetic field along the entire surface of the device. This is because the packing density of the lines that make up the topology generated on the substrate decreases from the center to the periphery. This phenomenon is predetermined by the regularity of the fractal-matrix structure. To produce a topology with a more uniform packing density of lines, a square is cut out of every matrix that contains its central part; and those squares are "stitched" together to form the topology. However, it should be remarked that even in a small square packing density of the lines decreases from the center to the periphery; but the greatest flaw is that the lines in the square junctions show uncontrolled irregularity, which breaks regularity of the field under structurization.

The purpose of the proposed invention is to design a device for structuring of the electromagnetic field that contains a sector with uniform packing density of the lines comprising the topology.

The achieved technical result is a more uniform structuring of the electromagnetic field along the surface of the device.

The task at hand is accomplished owing to the fact that the proposed device, as well as the earlier one, has a substrate bearing a topological layout containing an aggregate of concentric circumferences with each radius equal to $R \ \sqrt{2}^{n-1}$, where n is the ordinal number of the circumference. However, unlike the earlier device, the middle part of the topology is made as an aggregate of circumferences with radius R; each of the circumferences is the geometric locus containing the same number of the centers of the neighboring circumferences; each of the centers located on the same circumference is at equal distances from the two neighboring ones, and each center of a circumference with radius R is the center of the same number of concentric circumferences, with each of their radius equal to $R \cdot \sqrt{2}^{n-1}$.

The structure under consideration has a sector on the substrate where the density of the lines that make up the topology will be uniform (the sector filled with the circumferences with radius R). Its dimensions can be arbitrarily large and are determined based on the urgency of the specific task. Preferably, the size of the substrate should suffice for circumferences with the greatest diameter that are concentric in relation to the outermost circumferences with radius R. Failure to meet that condition will result in distorting phenomena caused by the breaks in the circumference lines affecting the electromagnetic field.

The substrate and the above-described topology generated on it are a diffraction grating with a complex design comprised of curved closed elements. The minimum size of the diffracting element and, consequently, the wavelength of the diffracting radiation will depend on the minimal size of peak of the angle formed by intersection of the radial arcs. Considering that mutual interfacing occurs at different angles in the broadest range of angles whose sizes are determined by the geometric parameters of the lines, their mutual configuration and layout, there will be continuous accumulation of diffracting elements characterized by different geometric features beginning from submicron (minimum possible wavelengths of diffraction spectrum lie within optical spectrum and UV). Considering that the topology in question can be treated as a continuous accumulation of diffracting elements of various sizes up to the largest one, limited by the borders of the topology and lying as far as the millimeter bandwidth area, the proposed device is a broadband converter and structurizer of electromagnetic field in that bandwidth. It should be taken into account that even a topology with moderately dense graphics, with a line size of several microns will contain approximately 400,000 orderly arranged diffracting elements that will produce a diverse, ordered diffraction pattern. Orderliness will depend on whether all circumferences are built in compliance with the same law. The part of the substrate with uniform line density, i. e. filled with the circumferences of radius R, will evenly structure the field along the whole sector with uniform line density. Thus, the part of the substrate is evenly filled with lines of different radii without the "seams" that were used to generate quasi-uniform line density in the existing device and made the structuring of the electromagnetic field non-uniform.

The set of attributes stated in cl. 2 of the Claims characterizes a device for structuring of electromagnetic field, where the substrate is made of silicon, and the topology is made of metal.

The set of attributes stated in cl. 3 of the Claims characterizes a device for structuring of electromagnetic field, where the substrate is made of aluminum, and the topology is graphite.

The choice of materials for the substrate and fractal topology is of great importance. Upon general consideration, efficiency of a diffraction structure will clearly be the longer, the greater the difference in their density is. Considerable difference in refraction ratio in every pair of the materials specified in cls. 2 and 3 of the Claims ensures distinctly pronounced diffraction pattern in both cases.

The set of attributes stated in cl. 4 of the Claims characterizes a device for structuring of electromagnetic field, where the fractal topology is made up by slits with a width and depth of at least 1 mcm.

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 minimal slit width, i. e. 0.1 mcm, 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. It can be explained by the fact that the minimal covered wavelength will depend not only on the slit parameters, but also on the dimensions of the most acute angle in the implemented fractal graphic.

The minimal slit depth of 0.1 mcm 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. With that depth, the structured area reaches several centimeters.

Creating a topology by means of slits is most efficient for producing a distinctly pronounced diffraction pattern.

The set of attributes stated in cl. 5 of the Claims characterizes a device for structuring of electromagnetic field, where the topology is made of slits, and the substrate is made of polyvinyl.

Such flexible structures can act as protective screens, for example, for cathode ray tube devices.

The set of attributes specified in cl. 6 of the Claims characterizes a device where the topology is made of slits, and the substrate is a layered structure with the upper layer in the form of a semi-transparent reflective coating that ensures reflection from the lower layer.

The semi-transparent reflection layer adds another structuring element. Each beam (Fig. 3) hitting the coating will be reflected twice: first time from the outer surface, and second time upon entering the coating with refraction, from the borderline between the coating and the next layer. Thus, different wavelength bands will be reflected from every element of the structure. The reflected packet waves of different length from a large number of elements will interfere.

The invention is illustrated by means of designs:

Fig. 1 shows a device for structuring of electromagnetic field;

Fig. 2 shows an example of origination of a topology.

Fig. 3 shows a diagram of progress of beams for a device in the form of a layered structure;

Figs. 4 and 5 are photographs of the structured electromagnetic field.

Fig. 1 shows the type of topology generated by concentric circumferences, with each radius determined as $R\sqrt{2^{n-1}}$, where n is the ordinal number of the circumference. In this case the last circumference is the seventh. The topology is made on a substrate. Fig. 2 shows the initial stage of building a topology. The middle part of the substrate is filled with nine circumferences with a minimum radius equal to R; the center of each circumference is located on the neighboring circumference. The center of each of them is the center of seven concentric circumferences. The materials of the substrate and lines should have different refraction ratios. The more they differ from each other, the greater the structuring effect of the electromagnetic field will be. Consider an example of making a device where the topology is made up by slits. The slits are formed as follows. The substrate is coated, for instance, with a positive resist. The required pattern of graphics is formed within the layer, for example, by means of contact printing. Then a metal film is deposited. It is thinner than the resist layer. Then the resist is subjected to explosive lithography, where the resist along with the metal film on its surface are removed, and the metal film with the generated fractal topology remains on the substrate, the open parts of the substrate to undergo etching. The next stage is dry etching. The ratio of the slit depth to the width can be up to 6–10. A device was manufactured where the substrate was made of glass, and the slits were 3 mcm wide and 2 mcm deep. Uniformly structured field extends for 3 cm from the substrate (Fig. 4). A device like the one above was also made, but the glass was additionally coated with a 0.1 mcm thick nickel film. The structured field extends for 4 cm from the substrate (Fig. 5). When the substrate was silicon, and the lines making up the matrix were made of aluminum, the structured electromagnetic field extends for 1 cm from the substrate. Experiments that confirm structuring of the electromagnetic field were conducted using a nonmonochromatic light source.

Experiments reveal that the proposed device ensured uniform distribution of the electromagnetic field along the surface of the substrate sector where the topology is formed with uniform line density, and that effect is ensured by the uniform structure of the matrix.

Patent Claims

7. A device for structuring of electromagnetic radiation in the wavebands between submicron and millimiter; it has a substrate bearing a topological layout containing an aggregate of concentric circumferences with each radius equal to $R \cdot \sqrt{2}^{n-1}$, where n is the ordinal number of the circumference from the center, characterized in that the topology is made in the form of an aggregate of circumferences with radius R, each of the circumferences is the geometric locus containing the same number of the centers of the neighboring circumferences; each of the centers located on the same circumference is at equal distances from the two neighboring ones, and each center of a circumference with radius R is the center of the same number of concentric circumferences, with each of their radius equal to $R \cdot \sqrt{2}^{n-1}$, where $n_{max}=7$.

8. A device for structuring of electromagnetic radiation as per cl. 1 characterized in that the substrate is made of silicon, and the topology is made of metal.

9. A device for structuring of electromagnetic radiation as per cl. 1 characterized in that the substrate is made of aluminum, and the topology is graphite.

10. A device for structuring of electromagnetic radiation as per cl. 1 characterized in that the substrate is made up by slits with a width and depth of at least 1 mcm.

11. A device for structuring of electromagnetic radiation as per cl. 4 characterized in that the substrate is made of polyvinyl.

12. A device for structuring of electromagnetic radiation as per cl. 4 characterized in that the substrate is a layered structure with the upper layer in the form of a semi-transparent reflective coating that ensures reflection from the lower layer.

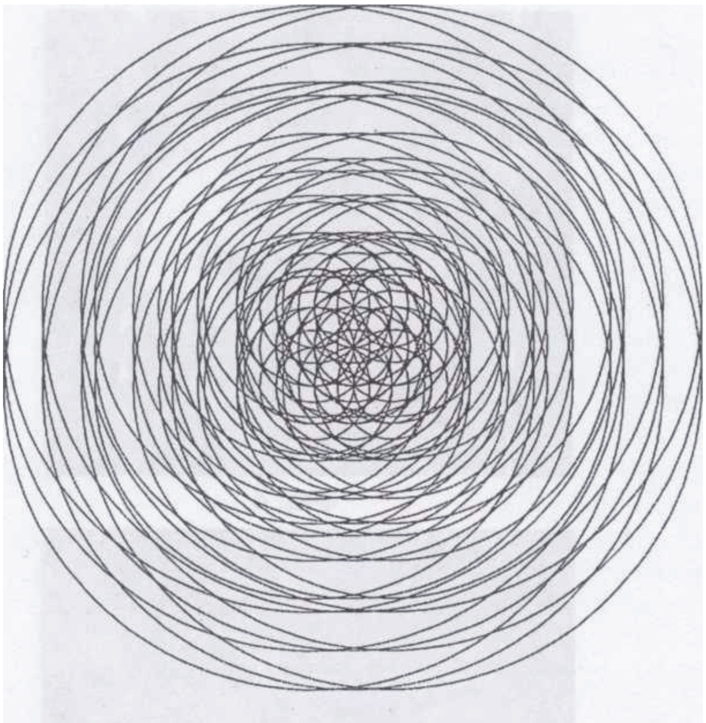

Fig. 2

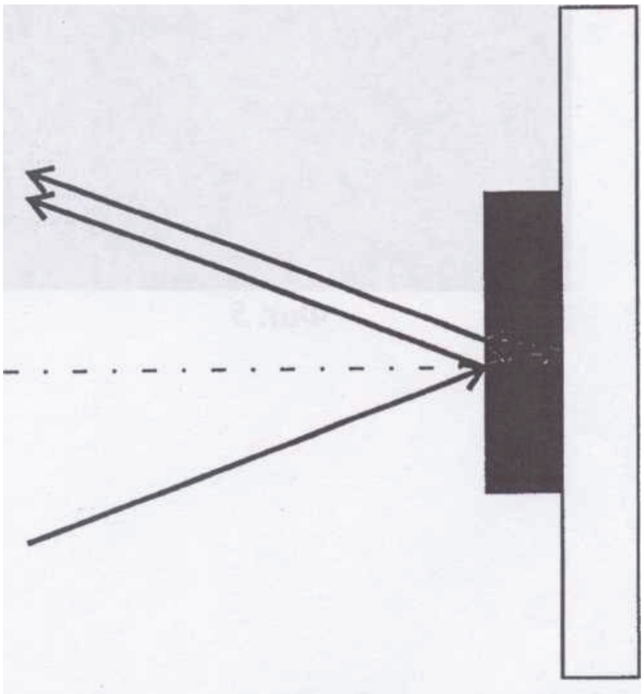

Fig. 3