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Datasheet for the decision of 5 June 2008

Case Number: T 1381/04 - 3.4.02

Application Number: 97306745.7

Publication Number: 0828143

IPC: G02B 13/14

Language of the proceedings: EN

Title of invention:
Optical system employing terahertz radiation

Applicant:
Lucent Technologies Inc.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 84, 56

Relevant legal provisions (EPC 1973):
-

Keyword:
"Clarity - main, first auxiliary request (no)"
"Clarity, inventive step - second auxiliary request (yes)"

Decisions cited:
-

Catchword:
-

Case Number: T 1381/04 - 3.4.02

D E C I S I O N
of the Technical Board of Appeal 3.4.02
of 5 June 2008

Appellant: Lucent Technologies Inc.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 27 September 2004 refusing European application No. 97306745.7 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: A. Klein
Members: M. Rayner
M. Vogel

Summary of Facts and Submissions

I. The applicant has appealed against the decision of the examining division refusing European patent application number 97 306 745.7 relating to optical systems employing terahertz radiation. The following documents have been referred to in the examination and appeal proceedings:

D1 Nuss, C: "Chemistry is Right for T-ray Imaging", IEEE Circuits and Devices magazine, vol. 12, no. 2, 01.03.96, p. 25-30,

D2 Van Exter et al: "Characterization of an Optoelectronic Terahertz Beam System", IEEE Transactions on Microwave Theory and Techniques, vol. 38, no. 11,01.11.90, p. 1684-1691,

D3 Rebeiz, G.: "Millimeter-Wave and Terahertz Integrated Circuit Antennas", Proceedings of the IEEE, vol. 80, no. 11/1992, p. 1748-1770.

II. According to the decision under appeal, the reason for refusal of the application was that the claims sets presented to the examining division, namely sets A (main request) and B (first auxiliary request), contained claims directed to subject matter amounting to a result to be achieved, i.e. not meeting the requirements of Article 84 EPC in that the matter for which protection is sought is not defined. The subject matter concerned can be defined in more concrete terms and it is clear from the description that the desired result can only be achieved by an aplanatic hemispherical or hyperhemispherical substrate lens as set out in connection with Figures 3B and 3C. There are no other examples given in the description. The division remarked further that the subject matter of the claims was not new or did not involve an inventive step having regard to the disclosures of documents D1, D2 and D3 for reasons already set out in preceding official communications.

The division also observed, according to the penultimate section of its communication dated 21.05.2004, that it could not be seen what difference might exist between the subject matter even of clarified claims and the disclosure of document D1. The division moreover raised an objection against the number of independent claims, which it considered had been drafted in a manner not complying with Rule 29(2) EPC 1973 (Rule 43(2) EPC 2000).

The applicant responded that subject matter of the independent claims involves alternative solutions to a particular problem - a case falling within Rule 29(2) EPC 1973 (Rule 43(2)(b) EPC 2000). In particular, the applicant proposed at least two systems, two lens arrangements and two methods for generating a parallel diffraction limited beam that can be propagated over large distances. One of the solutions involves focusing broadband THz radiation to a diffraction limited spot. Another involves collimating received radiation into a beam having substantially frequency independent diameter and substantially no wavefront curvature. The objection was not subsequently pursued by the examining division.

III. The appellant requests that the decision under appeal be set aside and that a patent be granted, implicitly on the basis of claims according to a Main Request (Set A), filed with the letter of 09.07.2003 or in the alternative, according to a First Auxiliary Request (Set B) or a Second Auxiliary Request (Set C), both filed with the letter of 22.04.2008. The appellant requested that in line 12 on page 9 of the description, "frequency dependent" be "changed to frequency independent".

The appellant argues that it is not possible to define the invention in more concrete terms because the invention is in no way limited to an aplanatic hemispherical or hyperhemispherical lens. If the applicant is force to amend claim 1 to include a limitation to an aplanatic hemispherical or a hyperhemispherical lens, the invention will be unreasonably narrowed. The invention is directed, at least in part, to a coupling system with a coupling lens structure enabling achievement of a parallel, diffraction limited beam with frequency-dependent beam diameter and without wavefront curvature, which can also be focused to a diffraction limited spot size. The invention is defined in terms of lenses or combinations of which the physical properties satisfy the equations recited in the specification. Only examples thereof are contained in the description.

The teaching of document D1 admits to the shortcomings solved by the present invention, specifically reciting that with its transmitter structure, a significant portion of the electric power can be radiated out from the photoconductive switch, collimated with lenses and mirrors into a parallel terahertz beam and focused back to a small spot with a diameter only limited by Fresnel diffraction. It is also evident that the teaching of document D2 is not the same as the application because the diameter of the resultant beam there is dependent on wavelength. Document D3 is also different because it teaches using a hyperhemispherical lens with an objective lens, such that if the optical system is designed such that all the rays are being focused to a point, this remains the case when the hyperhemispherical lens is added to the system.

Therefore, the subject matter of the independent claims presented is both novel and involves an inventive step over documents D1 to D3.

IV. In a communication during the appeal proceedings, the board advanced the following opinion.

According to the application, what has been realised is that the THz beam produced according to Figure 3A cannot be collimated into a diffraction limited beam as assumed in the prior art (see lines 52-53 in column 7 of the "A"-publication). Therefore, modifications according to Figures 3B or 3C are necessary, where in both cases, the lens is cut to accommodate the substrate, according to the formula either in lines 36-39 or 52-58 of column 8. The problem with the independent claims presented by the appellant is that rather than the invention being defined in terms of lenses of which the physical properties satisfy the equations recited in the specification, the functional language used amounts largely to desiderata, i.e. to results to be achieved. It therefore seems that the examining division is essentially correct in its position in relation to Article 84.

The appellant has referred to being "forced" to limit the claim to an aplanatic hemispherical or hyperhemispherical lens. While the board understands that the appellant would like to claim any possible lens configuration, it is not clear just what other configurations the appellant has in mind. If the contribution of the application is, as seems to be the case, starting from Figure 3A and cutting the hemispherical or hyperhemispherical lens to accommodate the substrate and meet the equations in the specification, then this subject matter should be in the claim. It is not a question of "forcing" the appellant to limit the claims, but of not recommending claims for grant if they do not satisfy the requirements of the Convention.

V. The reply of the appellant to the communication of the board did not persuade the board that a patent should be granted on the basis of the requests made. In its reply the appellant offered an amendment to the claims of the first auxiliary request.

VI. Oral proceedings were appointed by the board. In a communication attached to the summons, the board observed that in its reply to the board's communication, the appellant had offered rather minor amendments to one set of claims. The board further observed that exchanges between the board and appellant could go on for a whole sequence of communications and replies. Thus, in order to reach a conclusion to the case in an efficient way, while dealing with the amendments made, oral proceedings had become necessary.

In response to the summons, the appellant amended claims of the first auxiliary request, involving a reference to the distance between lens tip and substrate surface, and amended claims of the second auxiliary request along the lines indicated by the board in its first communication. The appellant underlined that there are no details in document D1, D2 or D3 regarding lens shape and lens tip distance to substrate.

VII. Nine days before the oral proceedings, the appellant informed the board that it would not be attending, requested cancellation of the oral proceedings and continuation of the procedure in writing. The board maintained the oral proceedings as scheduled, these being held in the absence of the appellant. The board gave its decision at the end of the oral proceedings.

VIII. The independent claims of the current main and auxiliary requests are worded as follows:

Main Request-Set A

"1. An optical system, comprising:

a source for emitting radiation in a range of frequencies within from 100 GHz to 20 THz,

a coupling lens structure for coupling radiation emitted by said source into free space, the wavelength of the coupled radiation being greater than 1/100th of the beam diameter at an exit pupil of said coupling lens structure, wherein said coupling lens structure is adapted to generate a diffraction limited beam such that at least one collimating optical element of said optical system collimates received coupled radiation

into a beam having a substantially frequency independent diameter and substantially no wavefront curvature; and
a detector for detecting the beam collimated by said at least one collimating optical element.

3. An optical system, comprising:

a source for emitting radiation iii a range of frequencies within from 100 0Hz to 20 THz,

a coupling lens structure for coupling radiation emitted by said source into free space, wherein said coupling lens structure is adapted to generate a diffraction limited beam such that at least one optical element of said optical system focuses received coupled radiation onto a diffraction limited focal spot; and

a detector for detecting the radiation focused by said at least one optical focusing element.

5. A lens arrangement for use in an optical system, comprising:

a coupling lens structure for coupling radiation emitted, in a range of frequencies from 100 0Hz to 20 THz, by a source into free space, wherein said coupling lens structure is adapted to generate a diffraction limited beam such that at least one collimating optical element of said lens arrangement collimates received coupled radiation into a beam having a substantially frequency independent diameter and substantially no wavefront curvature, the wavelength of the emitted radiation being 10 greater than 1/100th of the beam diameter at an exit pupil of said coupling lens structure.

8. A lens arrangement for use in an optical system, comprising:

a coupling lens structure for coupling radiation emitted, in a range of frequencies from 100 0Hz to 20 THz, by a source into free space, wherein said coupling lens structure is adapted to generate a diffraction limited beam such that at least one optical element of said lens arrangement focuses received coupled radiation onto a diffraction limited focal spot.

10. A method of investigating an object with radiation emitted by source over a range of frequencies within from 1000Hz to 20 THz, comprising the steps of:

coupling, with a coupling lens structure, the radiation emitted by the emission
source such that the wavelength of the coupled radiation is greater than 1/100th of the
beam diameter at an exit pupil of the coupling lens structure and such that a generated beam is diffraction limited, thus enabling the collimation of received coupled radiation into a beam having a substantially frequency independent diameter and substantially no wavefront curvature;

directing the collimated radiation at a medium under investigation; and

detecting one of radiation reflected by and transmitted through the medium during the directing step.

11. A method of investigating an object with radiation emitted by source over a range of frequencies within from 100 G1-Iz to 20 THz, comprising the steps

of:

coupling, with a coupling lens structure, the radiation emitted by the emission source into free space such that a generated beam is diffraction limited thus enabling the

focusing of received coupled radiation into a diffraction limited focal spot
associated with a medium under investigation; and

detecting one of radiation reflected by and transmitted through the medium
during the focusing step."

First Auxiliary Request - Set B

"1. An optical system, comprising:
a source for emitting radiation in a range of frequencies within from 100 GHz to 20 THz,
a coupling lens structure for coupling radiation emitted by said source into free space, the wavelength of the coupled radiation being greater than 1/100th of the beam diameter at an exit pupil of said coupling lens structure, wherein said coupling lens
structure comprises a lens formed on a substrate, the lens having a shape and a distance between a tip of the lens to the substrate surface that provide one of: no refraction of rays from said source at the substrate lens to free space interface, or substantially all rays from the source having an angle of incidence at the lens to free space interface below a critical angle for total internal reflection, such that substantially no diffraction effects occur at the exit pupil of said coupling lens structure and such that at least one collimating optical element of said optical system collimates received coupled radiation into a beam

having a substantially frequency independent diameter and substantially no wavefront curvature; and
a detector for detecting the beam collimated by said at least one collimating optical element.

3. An optical system, comprising:
a source for emitting radiation in a range of frequencies within from 100 GHz to 20 THz,
a coupling lens structure for coupling radiation emitted by said source into free space, wherein said coupling lens structure comprises a lens formed on a substrate, the lens having a shape and a distance between a tip of the lens to the substrate surface that provide one of: no refraction of rays from said source at the substrate lens to free space interface, or substantially all rays from the source having an angle of incidence at the lens to free space interface below a critical angle for total internal reflection, such that substantially no diffraction effects occur at the exit pupil of said coupling lens structure;
at least one optical element for focusing received coupled radiation onto a diffraction limited focal spot; and
a detector for detecting the radiation focused by said at least one optical focusing element.

5. A lens arrangement for use in an optical system, comprising:
a coupling lens structure for coupling radiation emitted, in a range of frequencies from 100 GHz to 20 THz, by a source into free space, wherein said coupling lens structure comprises a lens formed on a substrate, the lens having a shape and a distance between a tip of

the lens to the substrate surface that provide one of: no refraction of rays from said source at the substrate lens to free space interface, or substantially all rays from the source having an angle of incidence at the lens to free space interface below a critical angle for total internal reflection, such that substantially no diffraction effects occur at the exit pupil of said coupling lens structure; and

at least one collimating optical element for collimating received coupled radiation into a beam having a substantially frequency independent diameter and substantially no wavefront curvature, the wavelength of the emitted radiation being greater than 1/100th of the beam diameter at an exit pupil of said coupling lens structure.

8. A lens arrangement for use in an optical system, comprising:

a coupling lens structure for coupling radiation emitted, in a range of frequencies from 100 GHz to 20 THz, by a source into free space, wherein said coupling lens structure comprises a lens formed on a substrate, the lens having a shape and a distance between a tip of the lens to the substrate surface that provide one of: no refraction of rays from said source at the substrate lens to free space interface, or substantially all rays from the source having an angle of incidence at the lens to free space interface below a critical angle for total internal reflection, such that substantially no diffraction effects occur at the exit pupil of said coupling lens structure; and

at least one optical element for focusing received coupled radiation onto a diffraction limited focal spot.

10. A method of investigating an object with radiation emitted by source over a range of frequencies within from 100GHz to 20 THz, comprising the steps of:

coupling, with a coupling lens structure, the radiation emitted by the emission source, wherein said coupling lens structure comprises a lens formed on a substrate, the lens having a shape and a distance between a tip of the lens to the substrate surface that provide one of: no refraction of rays from said source at the substrate lens to free space interface, or substantially all rays from the source having an angle of incidence at the lens to free space interface below a critical angle for total internal reflection, such that substantially no diffraction effects occur at the exit pupil of said coupling lens structure and such that the wavelength of the coupled radiation is greater than 1/100th of the beam diameter at an exit pupil of the coupling lens structure and received coupled radiation is collimated into a beam having a substantially frequency independent diameter and substantially no wavefront curvature;

directing the collimated radiation at a medium under investigation; and

detecting one of radiation reflected by and transmitted through the medium during the directing step.

11. A method of investigating an object with radiation emitted by source over a range of frequencies within from 100 GHz to 20 THz, comprising the steps of:

coupling, with a coupling lens structure, the radiation emitted by the emission source into free space, wherein said coupling lens structure comprises a lens formed on a substrate, the lens having a shape and a distance between a tip of the lens to the substrate surface that provide one of: no refraction of rays from said source at the substrate lens to free space interface, or substantially all rays from the source having an angle of incidence at the lens to free space interface below a critical angle for total internal reflection, such that substantially no diffraction effects occur at the exit pupil of said coupling lens structure and received coupled radiation is focused into a diffraction limited focal spot associated with a medium under investigation; and

detecting one of radiation reflected by and transmitted through the medium during the focusing step."

Second Auxiliary Request - Set C

"1. An optical system, comprising:
a source for emitting radiation in a range of frequencies within from 100 GHz to 20 THz,

an aplanatic hemispherical or hyperhemispherical lens for coupling radiation emitted by said source into free space, the wavelength of the coupled radiation being greater than 1/100th of the beam diameter at an exit pupil of said aplanatic hemispherical or hyperhemispherical lens, wherein said aplanatic hemispherical or hyperhemispherical lens is formed on a substrate surface and configured to have a distance between a tip of the lens and the substrate surface given by h;

wherein $h=r-(n_1/n_2)\ d$ for said hemispherical lens;

$h=r(1+1/n_1)-d[(n_1-n_2)/n_2 - 1]$ for said hyperhemispherical lens;

r is radius of the lens, n_1 is refractive index of the lens, n_2 is refractive index of the substrate, and d is thickness of the substrate;

at least one collimating optical element of said optical system collimates received coupled radiation into a beam having a substantially frequency independent diameter and substantially no wavefront curvature; and

a detector for detecting the beam collimated by said at least one collimating optical element.

3. An optical system, comprising:

a source for emitting radiation in a range of frequencies within from 100 GHz to 20 THz,

an aplanatic hemispherical or hyperhemispherical lens for coupling radiation emitted by said source into free space, wherein said aplanatic hemispherical or hyperhemispherical lens is formed on a substrate surface and configured to have a distance between a tip of the lens and the substrate surface given by h; wherein $h=r-(n_1/n_2)\ d$ for said hemispherical lens;

$h =r(1+1/n_1)-d[(n_1-n_2)/n_2 - 1]$ for said hyperhemispherical lens;

r is radius of the lens, n_1 is refractive index of the lens, n_2 is refractive index of the substrate, and d is thickness of the substrate;

adapted to generate a diffraction limited beam such that at least one optical element of said optical system focuses received coupled radiation onto a diffraction limited focal spot; and

a detector for detecting the radiation focused by said at least one optical focusing element.

5. A lens arrangement for use in an optical system, comprising:

an aplanatic hemispherical or hyperhemispherical lens for coupling radiation

emitted, in a range of frequencies from 100 GHz to 20 THz, by a source into free space, wherein said aplanatic hemispherical or hyperhemispherical lens is formed on a substrate surface and configured to have a distance between a tip of the lens and the substrate surface given by h;

wherein $h=r-(n_1/n_2)$ d for said hemispherical lens;

$h =r(1+1/n_1)-d[(n_1-n_2)/n_2 - 1]$ for said hyperhemispherical lens;

r is radius of the lens, n_1 is refractive index of the lens, n_2 is refractive index of the substrate, and d is thickness of the substrate; and

at least one collimating optical element of said lens arrangement collimates received coupled radiation into a beam having a substantially frequency independent diameter and substantially no wavefront curvature, the wavelength of the emitted radiation being greater than 1/100th of the beam diameter at an exit pupil of said aplanatic hemispherical or hyperhemispherical lens.

7. A lens arrangement for use in an optical system, comprising:

an aplanatic hemispherical or hyperhemispherical lens for coupling radiation emitted, in a range of frequencies from 100 GHz to 20 THz, by a source into free space, wherein said aplanatic hemispherical or hyperhemispherical lens is formed on a substrate surface and configured to have a distance between a tip of the lens and the substrate surface given by h;

wherein $h=r-(n_1/n_2)\ d$ for said hemispherical lens;

$h = r(1+1/n_1)-d[(n_1-n_2)/n_2 - 1]$ for said hyperhemispherical lens;

r is radius of the lens, n_1 is refractive index of the lens, n_2 is refractive index of the substrate, and d is thickness of the substrate;

at least one optical element of said lens arrangement focuses received coupled radiation onto a diffraction limited focal spot.

9. A method of investigating an object with radiation emitted by source over a range of frequencies within from 100GHz to 20 THz, comprising the steps of:

coupling, with an aplanatic hemispherical or hyper hemispherical lens the radiation emitted by the emission source such that the wavelength of the coupled radiation is greater than 1/100th of the beam diameter at an exit pupil of the coupling lens structure and such that a generated beam is diffraction limited, thus enabling the collimation of received
coupled radiation into a beam having a substantially frequency independent diameter and substantially no wavefront curvature;

wherein the aplanatic hemispherical or hyperhemispherical lens is formed on a substrate surface and configured to have a distance between a tip of the lens and the substrate surface given by h;
wherein $h=r-(n_1/n_2)\ d$ for said hemispherical lens;

$h = r(1+1/n_1)-d[(n_1-n_2)/n_2 - 1]$ for said hyperhemispherical lens;

r is radius of the lens, n_1 is refractive index of the lens, n_2 is refractive index of the substrate, and d is thickness of the substrate;

directing the collimated radiation at a medium under investigation; and detecting one of radiation reflected by and transmitted through the medium during the directing step.

10. A method of investigating an object with radiation emitted by source over a range of frequencies within from 100 GHz to 20 THz, comprising the steps of:

coupling, with an aplanatic hemispherical or hyperhemispherical lens the radiation emitted by the emission source into free space such that a generated beam is diffraction limited thus enabling the focusing of received coupled radiation into a diffraction limited focal spot associated with a medium under investigation;

wherein the aplanatic hemispherical or hyperhemispherical lens is formed on a substrate surface and configured to have a distance between a tip of the lens and the substrate surface given by h;

wherein $h=r-(n_1/n_2)\ d$ for said hemispherical lens;

$h =r(1+1/n_1)-d[(n_1-n_2)/n_2 - 1]$ for said hyperhemispherical lens;

r is radius of the lens, n_1 is refractive index of the lens, n_2 is refractive index of the substrate, and d is thickness of the substrate, and

detecting one of radiation reflected by and transmitted through the medium during the focusing step."

Reasons for the Decision

1. The appeal is admissible

2. *Main Request - Clarity (Article 84)*

The board concurs with the view of the examining division that claim 1 defines its subject matter in terms of a result to be achieved, i.e. "a substantially frequency independent beam" and "substantially no wavefront curvature". The board also considers that the subject matter can be positively defined with reference to an aplanatic hemispherical or hyperhemispherical substrate lens as set out in connection with Figures 3B and 3C of the description. The appellant submits that other lenses or combinations of lenses achieve the result and that therefore such a limitation would be too restrictive. However, despite the board indicating in its communication that it is not clear what other lenses or combinations the appellant has in mind, no further indication of what might be meant has been provided. Accordingly, the appellant has provided no reason for the board to question its view. Accordingly, the request fails for lack of clarity.

3. *First auxiliary Request - Clarity (Article 84)*

Independent claim 1 of this request is subject to the same lack of clarity as those of the first auxiliary request because the lens structure is again not positively claimed in relation to the results to be achieved. While the reference to shape and distance between lens tip and substrate introduced into the claims is directed to a problem of internal reflection, it does not cure the lack of clarity in relation to definition of the lenses because it still does not make clear what the "other lenses or combinations of lenses" as referred to in the appellant's submissions might be.

As the board has not been given any information at all in this direction, it remains unconvinced that the structure required to achieve the results claimed is present in the claim. Accordingly, this request also fails for lack of clarity.

4. *Second Auxiliary Request*

This request involves claims directed to developments of aplanatic hemispherical or hyperhemispherical substrate lens, thus meeting the lack of clarity established by the examining division and confirmed by the board. In the prior art according to document D1, the dipole source is at the focus of the lens. The problem solved by the feature introduced in this request is that of improving radiation utilisation. The features of the independent claims pertaining to definition of distance between lens tip and substrate are those necessary to solve the problem. In particular, effects resulting from total internal reflection at the lens-air interface are mitigated.

The board accepts the appellant's view that these features are not suggested in the other prior art documents D2 and D3 and therefore sees no convincing objection to inventive step of the subject matter concerned.

5. *Number of claims*

While the number of independent claims may be striking, at first glance, the board sees no reason to reopen the issue following the procedural steps before the first instance as referred to in the last part of section II of the Facts and submissions above.

6. The board sees, furthermore, no other reason for objection under the EPC arising against the application papers according to the second auxiliary request (Set C).

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the first instance with the order to grant a patent based on the following documents:

   Description,
   pages 1-14 as filed, wherein, in line 12 on page 9, "frequency dependent" is changed to "frequency independent" according to the Appellant's request filed with the letter of 18 November 2004,

   Claims 1-10 filed as Second Auxiliary Request (Set C), with the letter dated 22.04.2008,

   Drawings Sheets 1/5 to 5/5 as originally filed.

The Registrar | The Chairman

M. Kiehl | A. G. Klein