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D E C I S I O N
of 27 March 2006

Case Number: T 0334/04 - 3.4.02

Application Number: 01310121.7

Publication Number: 1260841

IPC: G02B 6/26

Language of the proceedings: EN

Title of invention:
GRIN fiber lenses

Applicant:
LUCENT TECHNOLOGIES INC.

Opponent:

-

Headword:

-

Relevant legal provisions:
EPC Art. 52(1), 54, 56

Keyword:
"Novelty (yes)"
"Inventive step (yes)"

Decisions cited:

-

Catchword:

-



Case Number: T 0334/04 - 3.4.02

D E C I S I O N
of the Technical Board of Appeal 3.4.02
of 27 March 2006

Appellant: LUCENT TECHNOLOGIES INC.
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Representative: Sarup, David Alexander
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Decision under appeal: Decision of the Examining Division of the
European Patent Office posted 7 November 2003
refusing European application No. 01310121.7
pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: A. G. Klein
Members: F. J. Narganes-Quijano
M. J. Vogel

Summary of Facts and Submissions

I. The appellant (applicant) has lodged an appeal against the decision of the examining division to refuse European patent application No. 01 310 121.7 (publication No. 1 260 841). The application pertains to the optical coupling between optical fibres having a graded refractive index (GRIN) fibre lens attached thereto, and to the manufacture of the GRIN fibre lens.

During the examination procedure the examining division referred to the following documents:

D1: WO-A-0111409,
D2: US-B1-6172817,
D3: SE-C2-512393,
D4: US-A-6131413,
D5: EP-A-1035083,
D6: EP-A-0972752, and
D7: JP-A-60166244 and English abstract.

In the decision under appeal the examining division held that claim 1 then on file directed to an apparatus comprising a GRIN fibre lens having a predetermined radial refractive index profile was anticipated by each of documents D1 and D2 (Articles 52(1) and 54 EPC), and in any case rendered obvious by the disclosure of document D1 (Articles 52(1) and 56 EPC). In its decision the examining division also noted that, in view of the disclosure of documents D1 to D7 and of the objections already advanced during the examination procedure, no inventive step (Articles 52(1) and 56 EPC) could be seen in the subject-matter of additional independent claims then on file directed to an

apparatus comprising first and second optical fibres optically coupled to each other and each having a GRIN fibre lens attached thereto, and to a method of fabricating the GRIN fibre lens, the GRIN fibre lens having a predetermined radial refractive index profile.

- II. With the grounds of appeal the appellant submitted a set of amended claims, and requested setting aside of the decision under appeal and the grant of a patent.

In response to a telephone consultation with the rapporteur, the appellant filed with its letter dated 6 February 2006 a new set of amended claims 1 to 6 and amended pages 1 to 7, 9 to 12, 14 and 15 of the description replacing the corresponding application documents, it being apparent that the expression "-17- REPLACEMENT PAGE" at line 6 of the text of the amended claim 4 results from an obvious page layout error and is not intended to constitute an integral part of the text of the claim.

- III. Independent claims 1 and 4 according to the appellant's request are worded as follows (omitting in claim 4 the expression "-17- REPLACEMENT PAGE" referred to in point II above):

" 1. An apparatus (46, 46', 46'', 70, 80, 90) comprising:

a first optical fiber (48, 72, 82₁, 92);

a first GRIN fiber lens (49, 77₀, 85₁, 96) attached to the first optical fiber;

a second optical fiber (52, 74₁, 84₁, 94)

a second GRIN fiber lens (49'', 77₁, 86₁, 98)

attached to the second optical fiber; and

an optical device (54, 54', 76, 88) capable of directing a portion of a light beam emitted from a free end (58) of the first GRIN fiber lens to the second GRIN fiber lens, characterized in that;

the GRIN fiber lenses have silica-glass cores and refractive indexes with radial profiles, the profiles having negative radial second derivatives with average magnitudes in the cores of less than about 1.7×10^{-6} microns⁻² times the refractive index on the axes of the respective GRIN fiber lens."

" 4. A method of fabricating a GRIN fiber lens (18), comprising:

forming a tube of silica-glass having a tubular core and a concentric tubular cladding located adjacent and external to the tubular core, the core having a dopant density with a radially graded profile;

partially collapsing the tube by applying heat thereto, the partially collapsed tube having a central channel;

passing a glass etchant through the central channel to remove an internal layer of silica glass,

then, collapsing the etched tube to a rod-like preform; and

drawing a GRIN fiber from the preform, whereby the core of the GRIN fiber has a refractive index with a profile having a negative radial second derivative whose average magnitude is less than about 1.7×10^{-6} microns⁻² times the value of the refractive index on the axis of the GRIN fiber lens."

Claims 2 and 3, and claims 5 and 6 all refer back to claims 1 and 4, respectively.

IV. The arguments of the appellant in support of its requests are essentially the following:

Document D1 describes an optical imaging probe made up of an optical fibre having a GRIN lens attached to the end of the probe. The document also discusses GRIN lens types that are commercially available and the advantage of using a custom made lens, and describes the ideal gradient profile for a customized GRIN lens. The document sets forth design parameters and mathematical formulations for the ideal GRIN lens but, contrary to the present invention, does not describe how such a lens could be made. Thus, the document sets forth a problem without providing a solution. The document at most provides mathematical support for the present invention, but does not enable to obtain the GRIN lens. The present invention provides the sole motivation to look at document D1.

Document D2 does not disclose an apparatus made up of optical fibres with attached GRIN fibre lenses and an optical device arranged to direct light from one to another one of the GRIN fibre lenses. The document does not even disclose GRIN fibre lenses having the features of the invention. The document discloses the manufacture of GRIN lenses, but not the manufacturing steps of a GRIN fibre lens according to the invention.

Reasons for the Decision

1. The appeal complies with all the requirements mentioned in Rule 65(1) EPC and is therefore admissible.

2. *Amendments*

After due consideration of the amendments made to the claims and to the description of the application according to the present request of the appellant, the Board is satisfied that the amended application documents comply with the formal requirements of the EPC, and in particular with those set forth in Article 123(2) EPC. In particular, claim 1 is based on claim 4 as originally filed together with Figure 3B and the corresponding description, independent claim 4 is based on claims 7 and 8 as originally filed, and dependent claims 2, 3, 5 and 6 are based on original claims 5, 6, 9 and 10, respectively. Furthermore, the description has been adapted to the invention as defined in the amended claims (Article 84 EPC, second sentence and Rule 27(1) EPC).

3. *The prior art*

3.1 Document D1 discloses ultra-small optical imaging probes for use in insertional diagnostic medical devices, the probes comprising an optical fibre optically coupled to a lens having a large working distance and a large depth of field (abstract, and page 1, line 1 to page 3, line 4). In one of the embodiments, the lens is a GRIN fibre lens having a quadratic or nearly quadratic refractive index radial profile given by

$$n(r) = n_c (1 - (A/2)(r/a)^\alpha),$$

where n_c is the refractive index on the axis of the fibre core, a is the radius of the core, and the index power α is between 1.8 and 1.9, ideally close to 2 (Figure 2E together with page 12, line 12 to page 13, line 24). The document describes GRIN fibre lenses obtained from standard, commercially available GRIN multimode optical fibres having a value of α of 1.8 and a value of A of 0.038 (page 13, line 25 to page 14, line 12), and proposes GRIN fibre lenses having a customized gradient profile with a value $(\sqrt{A})/a$ of 1.2074 mm^{-1} determined following a theoretical approach (page 14, line 13 to page 15, line 14).

- 3.2 Document D2 discloses GRIN lenses attached to optical fibres (column 1, line 9 *ff.*, and Figure 2 together with column 5, lines 38 to 67) and the manufacture of the GRIN lenses (abstract). The GRIN lenses have a refractive index profile that is approximately parabolic (Figure 5 together with column 1, lines 19 to 28).
- 3.3 Document D3 pertains to opto-mechanical light switching devices for selectively optically coupling different pairs of optical fibres (Figures 1 to 3). Each of the optical fibres has a GRIN lens attached thereto (abstract and figures).
- 3.4 Each of documents D4 to D7 discloses the manufacture of optical fibres having a refractive index profile. The fibres are drawn from a fibre preform that has been obtained by thermally collapsing a tube of doped silica

glass, and the disclosed methods also involve etching the central channel of the collapsing tube (D4, column 2, lines 4 to 20 and 52 to 55, and column 3, lines 19 to 30; D5, column 3, line 20 to column 5, line 39; D6, abstract, column 6, line 56 to column 7, line 4, and column 8, lines 23 to 45; and D7, abstract).

4. *Claim 1*

4.1 *Novelty*

The imaging probes disclosed in document D1 and comprising a GRIN lens attached to an optical fibre are arranged to directly image a sample (point 3.1 above), and there is no disclosure in document D1 of an additional optical fibre optically coupled to the probe optical fibre by means of an optical device as required in claim 1.

Each of documents D2 and D3 discloses optical fibres optically coupled to each other by means of respective GRIN lenses attached thereto (points 3.2 and 3.3 above), the refractive index profile of the GRIN lenses of document D2 having, according to the estimation made by the examining division on the basis of the approximately parabolic profile represented in Figure 5, a negative radial second derivative with an average magnitude within the claimed value range. However, the disclosure of both documents is confined to so-called GRIN rod lenses, i.e. to GRIN lenses having a diameter much greater than that of the optical fibres to which they are attached (document D2, Figures 2a and 2b, and all the figures of document D3). In particular, the GRIN lenses of document D2 are manufactured from glass

rods having a radius of the order of the millimetre (Figure 5 and column 6, lines 27 to 31) and, contrary to the examining division's contention, they cannot be considered to constitute GRIN fibre lenses within the proper technical meaning of the expression. Thus, documents D2 and D3 fail to disclose GRIN fibre lenses as claimed. In addition, there is no disclosure in document D2 of optical means for directing light between the optical fibres, and document D3 fails to disclose refractive index profiles satisfying the claimed condition.

Documents D4 to D7 disclose the manufacture of GRIN optical fibres (point 3.4 above), but none of them disclose GRIN fibre lenses, let alone devices involving the use of GRIN fibre lenses.

It follows that none of the documents considered by the examining division during the examination procedure anticipates the subject-matter of present claim 1 (Articles 52(1) and 54 EPC).

4.2 *Inventive step*

- 4.2.1 The invention defined in claim 1 is primarily directed to improving the optical coupling between two optical fibres (paragraph bridging pages 1 and 2, and lines 9 to 28 of page 3 of the description as filed). Among the documents considered during the examination procedure, only documents D2 and D3 pertain to the coupling of light between optical fibres and, among these two documents, only document D3 discloses the use of means for directing light from a first to a second one of the optical fibres. Thus, among the documents considered by

the examining division, document D3 constitutes the closest state of the art in the assessment of inventive step of the claimed subject-matter.

- 4.2.2 The apparatus defined in claim 1 differs from the apparatus of document D3 in that the lenses attached to the optical fibres are not GRIN rod lenses, but GRIN fibre lenses having silica-glass cores and refractive index radial profiles as defined in the claim, i.e. having negative radial second derivatives with average magnitudes in the cores of less than about $1.7 \times 10^{-6} \mu\text{m}^{-2}$ times the refractive index on the axes of the fibre lens.

According to the disclosure of the invention, the use of fibre-type instead of rod-type GRIN lenses results in a more compact arrangement, and the refractive index profile of the GRIN fibre lenses specified in the claim achieves better beam collimation and therefore improved transverse alignment and coupling efficiency of light over large distances (page 2, lines 3 to 5, page 3, lines 13 to 28, and page 6, lines 6 to 21). Accordingly, the problem solved by the claimed subject-matter over the disclosure of document D3 can be seen in achieving a more compact arrangement while facilitating transverse alignment of, and improving optical coupling efficiency between the optical fibres.

Document D1 teaches reducing the size of - and therefore rendering more compact - optical imaging probes having a bulky GRIN lens attached to an optical fibre (page 1, lines 12 to 16, and page 5, lines 8 to 27) by replacing the GRIN lens by a GRIN fibre lens having the same diameter as the optical fibre (page 2,

lines 7 to 11 together with page 2, line 30 to page 3, line 4, page 6, line 3 *ff.*, and page 12, line 21 *ff.*). According to the examining division, this teaching would suggest rendering more compact the arrangement of document D3 by replacing the GRIN rod lenses by GRIN fibre lenses.

However, document D1 focuses on the light collimating characteristics of the lenses and on the alignment tolerances between the mechanical and the optical elements of the optical imaging probe (page 5, lines 2 to 7, and page 19, line 27 to page 20, line 6), but fails to address these aspects in the more critical context of the optical coupling between two optical fibres. For this reason, the skilled person would not have seen in the disclosure of document D1 relating to the optical characteristics of the GRIN fibre lenses a clear teaching that would have suggested a solution to the further problem of facilitating transverse alignment of, and improving optical coupling efficiency between two optical fibres.

In addition, even assuming that the skilled person would have recognised in the measures taught by document D1 and in the effects achieved therewith a solution to the aspect of the problem formulated above relating to the transverse alignment of, and the optical coupling efficiency between optical fibres, in the Board's view he would not have reached the claimed subject-matter in an obvious way. The examining division's finding that document D1 teaches the use of GRIN fibre lenses having a refractive index profile anticipating the claimed value range was based on the proposal of document D1 relating to GRIN fibre lenses

having a customized gradient profile with a theoretical value $(\sqrt{A})/a$ of 1.2074 mm^{-1} (page 14, line 13 to page 15, line 14). Assuming values of α between 1.8 and 2 (page 13, lines 14 to 16), the proposed refractive index profiles would have indeed an average magnitude of the negative radial second derivative of the index profile

$$- \langle d^2n/dr^2 \rangle = - (1/a) \int_0^a d^2n/dr^2 dr = A\alpha n_c/2a^2$$

within the claimed range. However, as submitted by the appellant, the customized refractive index profiles proposed in the document are only based on a mathematical approach (page 14, line 16 to page 15, line 14) and the document itself acknowledges that the proposed refractive index profiles are not found in commercially available GRIN fibres (page 13, lines 14 to 16). In addition, the document addresses the manufacture of the optical probe and gives several indications as to how lenses according to the different embodiments disclosed in the document can be manufactured (page 6, line 23 *ff.*, page 10, line 8 *ff.*, page 11, line 18 *ff.*, page 12, line 15 *ff.*, and page 13, line 13 *ff.*), but fails to address specifically the manufacture of GRIN fibres having the customized refractive index profile calculated following the theoretical approach. In view of these considerations, and in the absence of evidence to the contrary, the disclosure of document D1 relating to the GRIN fibre lenses having the customized refractive index profile was not enabling at the publication date of the document. In addition, there is no evidence that during the relatively short period of time between the publication of document D1 (15.02.2001) and the

priority dates of the present invention (19.05.2001 and 29.06.2001) the aforementioned disclosure would have become enabling.

In these circumstances, assuming that the skilled person would have seen in the disclosure of document D1 a promising teaching towards a solution to the aforementioned problem, in the Board's view he would then have followed the alternative approach disclosed in the document (page 12, line 21 to page 14, line 12) based on commercially available GRIN fibres of the multimode type (page 12, lines 26 and 27, page 13, lines 16 and 17, and page 14, lines 6 to 12), and not that based on a purely theoretical approach for which no fibres were commercially available at that time and for which no manufacturing method was disclosed or suggested in the document. The commercially available GRIN fibres considered in the document, however, have a value of α between 1.8 and 2 (page 13, lines 13 to 17) and a value of A of the order of 0.038 (page 13, line 25 to page 14, line 12), and consequently the average magnitude of the negative radial second derivative of the index profile is - for the values of the core radius of the fibres considered in the document, see page 6, lines 28 and 29 - greater than the upper value $1.7 \cdot 10^{-6} \mu\text{m}^{-2}$ of the value range defined in claim 1. Thus, this approach would not have resulted in GRIN fibre lenses having the claimed refractive index profile characteristics.

Document D2 addresses the problem formulated above (Figure 2 together with column 1, lines 9 to 11, column 2, lines 61 to 65, and column 5, lines 38 to 67) and proposes the use of GRIN lenses having a refractive

index radial profile having the claimed characteristics (point 4.1 above). Nonetheless, document D2 only considers GRIN lenses in the form of GRIN rod lenses and, consequently, the application of the teaching of the document to the disclosure of document D3 would not have resulted in the claimed subject-matter which requires fibre-type GRIN lenses. It cannot be denied that the skilled person could have considered the possibility of replacing the GRIN rod lenses by the corresponding GRIN fibre lenses having the same optical characteristics and that the resulting arrangement would have reproduced the claimed arrangement. However, there is no evidence on the file that such fibre lenses were available at the priority date of the application in suit, and document D1 appears at least to confirm that they were not commercially available at the filing date of the document (08.08.2000). There is no evidence on file either indicating the manufacture of such fibre lenses. In particular, the manufacture of GRIN lenses disclosed in document D2 involves steps like extrusion and grinding of melted preforms (abstract); such manufacturing steps are adapted to the manufacture of rod lenses, i.e. lenses having a relatively large diameter of the order of the millimetre, but, by its very nature, cannot be applied to the manufacture of fibre-type lenses. In these circumstances, any consideration by the skilled person of the possibility of replacing the GRIN rod lenses by GRIN fibre lenses having the same refractive index profile would have resulted in the skilled person being confronted in practice with the problem of obtaining or manufacturing such fibre lenses and therefore (contrary to the present invention which also provides a method of manufacturing the fibre lenses) such considerations

would have stayed at a theoretical level without a clear prospect of immediate technical implementation.

Documents D4 to D7 are silent as to the problem mentioned above and also fail to disclose GRIN fibre lenses, let alone GRIN fibre lenses with refractive index profiles as claimed.

Thus, starting with document D3 as the closest prior art, the prior art considered by the examining division does not render obvious the apparatus of claim 1.

- 4.2.3 For the sake of completeness it is added that no other conclusion could be drawn if document D2 were to be considered as an alternative closest prior art. The subject-matter of claim 1 differs from the disclosure of document D2 in the provision of a coupling device for directing light from one to another one of the optical fibres and by the replacement of the GRIN rod lenses by GRIN fibre lenses having the same refractive index profile as the GRIN rod lenses. However, for reasons analogous to those set forth in point 4.2.2 above with regard to the application of the teaching of document D2 to the disclosure of document D3, in the absence of evidence relating to the availability, or to the enabling manufacture of GRIN fibre lenses having the refractive index profile of the GRIN rod lenses disclosed in document D2, it was not obvious at the priority date of the application in suit to replace the GRIN rod lenses of document D2 by GRIN fibre lenses having the same functional characteristics, and in particular the same optical properties.

4.2.4 In view of the above, the Board concludes that the prior art considered by the examining division does not render obvious the subject-matter of claim 1 within the meaning of Article 56 EPC.

5. *Independent claim 4*

Claim 4 is directed to the manufacture of a GRIN fibre lens having a refractive index profile satisfying the condition also specified in claim 1 and considered in point 4 above. As acknowledged by the examining division, the claimed method is not anticipated by the available prior art.

As regards inventive step, documents D4 to D7 are silent as to the specific optical characteristics of the refractive index profile of the GRIN fibres obtained by the corresponding manufacturing methods, they even fail to address the production of GRIN fibre lenses from the resulting GRIN fibres. In addition, the sole incentive that can be found in the prior art for considering the manufacture of a GRIN fibre lens having a refractive index profile as claimed is the GRIN lens fibre proposed in document D1 (see point 4.2.2 above). Accordingly, irrespectively of the number of manufacturing steps that the methods of documents D4 to D7 may have in common with the claimed method, in the Board's view a realistic and objective assessment of inventive step of the claimed method should start from the closest state of the art represented by the disclosure of document D1 relating to the proposed GRIN fibre lens.

The GRIN fibre lenses under consideration are proposed in document D1 in the context of GRIN fibre lenses obtained from commercially available GRIN multimode fibres (page 13, line 13 to page 14, line 12), and the document proposes a specific refractive index profile obtained following a mathematical approach (page 14, line 16 to page 15, line 14) to compensate for the fact that "commercially available multimode fiber as well as GRIN lens known in the art have a gradient coefficient that is too strong" (page 14, line 14 *ff.*). Thus, in the specific context in which the proposal is made, the skilled person would be confronted with the problem of achieving a method of manufacturing GRIN multimode fibres having a gradient coefficient lower than that of commercially available GRIN multimode fibres and from which the proposed GRIN fibre lenses could then be obtained.

The claimed method includes a series of process steps which are known in the manufacture of GRIN optical fibres as exemplified by documents D4 to D7 (point 3.4 above). However, none of these documents addresses specifically the manufacture of GRIN fibre lenses.

In addition, the method of document D6 is expressly confined to the manufacture of GRIN singlemode fibres (column 2, line 45 *ff.*, in particular column 3, lines 10 to 13; see also first line of each of claims 1 and 10, and column 3, lines 27 to 32), and although the skilled person could have considered the application of the corresponding method to the manufacture of GRIN multimode fibres, he would not have followed such an approach in view of the drawbacks referred to in the document (column 2, line 45 to column 3, line 9). The

manufacturing methods of documents D4 and D5 appear to be applicable to the manufacture of both singlemode and multimode optical fibres (see in particular document D5, column 4, lines 12 to 15); however, both document D4 and D5 fail to specify how the different manufacturing parameters and steps are to be monitored or controlled to achieve a specific graded refractive index profile, and in particular they fail to unambiguously disclose whether the refractive index profile results from the diffusion of the dopant during the collapsing step of the tubular preform (D4: column 3, line 40 *ff.*; D5: column 1, lines 15 to 20, column 5, lines 5 to 8, and column 6, lines 1 to 4 and 56 to 58), or - as required by the claimed method - from initially endowing the doped tubular core used in the manufacture of the final preform with a radially graded dopant density (D4: column 3, line 7 *ff.*; D5: column 4, lines 48 to 50, column 5, lines 45 to 47, and column 6, lines 39 to 41). As regards document D7, the abstract specifies that the collapsing step of the tubular preform is carried out while etching the interior of the preform, and therefore the document does not suggest carrying out the etching step of the tubular preform as a distinct step intermediate a partial and a final collapsing step of the preform as required by the claimed method.

Accordingly, the Board is not in a position to follow the examining division's contention that the method defined in claim 4 is rendered obvious by the prior art considered during the examination procedure (Article 56 EPC).

6. Claims 2 and 3, and claims 5 and 6 concern particular embodiments of the subject-matter of claims 1 and 4, respectively. Accordingly, claims 2, 3, 5 and 6 also define patentable subject-matter under Articles 52(1), 54 and 56 EPC for reasons analogous to those put forward above with regard to claims 1 and 4.

7. In view of the above, the decision under appeal is to be set aside. In addition, being satisfied that the patent application as amended according to the present request of the appellant and the invention to which it relates meet the requirements of the EPC (Article 97(2) EPC), the Board, in accordance with Article 111(1) EPC, considers it appropriate to exercise favourably the power within the competence of the examining division to order grant of a patent.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.
2. The case is remitted to the department of first instance with the order to grant a patent on the basis of the following application documents:
 - claims 1 to 6 filed with the letter dated 6 February 2006, with the expression "-17-REPLACEMENT PAGE" at line 6 of the text of claim 4 being deleted,
 - description pages 1 to 7, 9 to 12, 14 and 15 as filed with the letter dated 6 February 2006, and pages 8 and 13 as originally filed, and
 - drawing sheets 1/8 to 8/8 as originally filed.

The Registrar:

The Chairman:

M. Kiehl

A. G. Klein