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D E C I S I O N
of 12 January 2000

Case Number: T 0215/98 - 3.4.2

Application Number: 91200156.7

Publication Number: 0442553

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Language of the proceedings: EN

Title of invention:
Optical amplifier having a single-mode curved active fibre

Patentee:
PIRELLI CAVI S.p.A.

Opponent:
Corning Incorporated

Headword:
-

Relevant legal provisions:
EPC Art. 54, 56

Keyword:
"Novelty and inventive step (confirmed)"

Decisions cited:
G 0009/91, G 0010/91, T 1002/92

Catchword:
-

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Case Number: T 0215/98 - 3.4.2

D E C I S I O N
of the Technical Board of Appeal 3.4.2
of 12 January 2000

Appellant: (Opponent)
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Decision under appeal: **Decision of the Opposition Division of the European Patent Office posted 9 January 1998 rejecting the opposition filed against European patent No. 0 442 553 pursuant to Article 102(2) EPC.**

Composition of the Board:

Chairman: E. Turrini
Members: A. G. Klein

V. Di Cerbo

Summary of Facts and Submissions

I. European patent No. 0 442 553 was granted on the basis of European patent application No. 91 200 156.7.

Claim 1, the only independent claim as granted reads as follows:

"1. An optical amplifier insertable in series in an optical fiber telecommunication line for amplifying optical signals propagating in this fiber line, comprising
at least a luminous pumping source (6) for generating optical radiation having a wavelength shorter than that of said optical signal,
an active optical fiber (7) containing a fluorescent dopant in its optical core, being capable to emit light in the wavelength range of the optical signal when pumped at the wavelength of the pumping source, and a dichroic coupler (4) having two inputs connected to the optical fiber line and to the luminous pumping source respectively, and an output (5) connected to one end of said active fiber,
wherein
the active optical fiber (7) is a fiber that when arranged in a substantially rectilinear configuration permits single-mode propagation at the wavelength of the optical signal and multi-mode propagation at the pumping radiation wavelength and in that the active fiber is disposed in a curved configuration at least over 70% of its overall length, with a bending radius such that said fiber provides only single mode

propagation of the fundamental mode at the pumping radiation wavelength."

II. The opposition filed against the patent was rejected by the opposition division. The opposition was founded on the grounds that the claimed subject-matter lacked novelty and inventive step in view in particular of the contents of the following documents:

D6: M. J. F. DIGONNET, SPIE Vol. 1171, Fiber Laser Sources and Amplifiers, 6-8 Sept. 1989, pages 8 to 26;

D9: L. B. JEUNHOMME, Single-Mode Fiber Optics, Marcel Dekker Inc., 1983, pages 8 to 26 and 87 to 94;

D13: S. SHIMIDA, Optics & Photonics News, Jan. 1990, pages 6 to 12; and

D14: WO-A-87/01246.

III. The appellant (opponent) filed an appeal against the decision. In support of his arguments he filed a series of further citations, quoted D16 to D19 and Annex 2 to Annex 5, amongst which

Annex 2: M. YAMADA et al., Er^{3+}-Doped Fiber Amplifier Pumped by 0.98 µm Laser Diodes, IEEE Photonics Technology Letters, Vol. 1, No. 12, December 1989.

IV. Oral proceedings were held on 12 January 2000, at which the appellant requested that the appealed decision be set aside and that the patent be revoked.

The respondent (proprietor of the patent) for his part requested that the appeal be dismissed.

V. The appellant's arguments in support of his request can be summarised as follows.

The further citations filed only at the appeal stage, in particular document D19 and Annex 2, provided evidence that optical fiber amplifiers with a fiber permitting single-mode propagation at the wavelength of the optical signal and multi-mode propagation at the pumping radiation wavelength had actually been realised in practice at the priority date of the patent, and that they had not been contemplated only as a theoretical possibility, as had been alleged by the respondent in view of the rather abstract content of the document D6 used so far in the procedure. The newly filed Annexes 4 and 5 similarly showed that the general effect of bends in an optical fiber, consisting in attenuating propagation of higher order radiation modes, as was known per se from document D9, had also already been applied in practical constructions, to shift the effective cut-off wavelength of a fiber system down to a value below the system's operating wavelength. These documents therefore were highly relevant to the question of inventive step, and they should be admitted into the procedure, accordingly.

The claimed subject-matter lacked novelty in view of the construction disclosed in document D14 with reference to Figure 10. Figure 10 and the corresponding passage of the description did not explicitly describe the coiled arrangement of the amplifying fiber nor the

claimed features directed to its transmission modes at both the pumping and signal wavelengths. These elements could however be easily derived from the other embodiments disclosed in the same document, relating to the use of the same amplifying fiber in laser arrangements.

The claimed subject-matter also lacked an inventive step in view of the closest prior art constituted by the device disclosed in Annex 2, from which it was distinguished only by its disposition into a curved configuration in such a way as to achieve single-mode propagation also at the pumping radiation wavelength.

This distinction could not however be considered inventive, since in particular it did not solve any technical problem other than achieving the obvious benefit of making the amplifier more compact. As was evidenced by the declarations by Dr Nolan and Dr Hempstead filed with the appellant's grounds of appeal, pump light that was solely in the fundamental mode when launched into a multi-fiber waveguide would not transfer any power to a higher mode, so that reducing the cut-off wavelength below the pumping wavelength would not provide any benefit to the efficiency of the amplifier. If multi-mode pumping light was introduced into the fiber, illuminating all but the fundamental mode would only result in a lower pumping efficiency. The higher efficiency shown by the examples of the opposed patent did not result from the claimed invention, but only from the use of a fiber of higher numerical aperture.

Document D6 which provided a review of theoretical

models of fiber amplifiers, was the only document on the file to provide any support for the respondent's allegation of the occurrence, in prior art fiber amplifiers, of gain fluctuations induced by power exchange between the pump modes resulting from environmental changes, as was referred to in paragraph 3.4 of the document. From the declaration by Mr Digonnet, the author of document D6, joined to the statement of the grounds of appeal it was however clear that the above passage would not have been interpreted by the skilled person as meaning that such fluctuations normally occurred under real life conditions. Neither did the experimental conditions of the tests described in the declaration by Mr Vavassori and relied upon by the respondent, which tests involved repetitive deformation of a fiber coil, in any way replicate such real life conditions. Anyway, there was no mention in the patent in suit of an effect of the claimed arrangement on power stability. Such effect could not therefore be invoked in order to re-define the technical problem addressed by the invention.

Thus, the alleged invention only comprised the unrelated feature of the amplifier fiber being coiled up. This was a common means of achieving a compact arrangement of such optical fibre amplifiers, which used to comprise tens or hundreds of metres of fiber. Such coiling up would necessarily result in the claimed reduction of the cut-off wavelength, for the reasons explained for instance in document D9, and therefore also necessarily provide the technical effect relied upon by the respondent, if any.

VI. The respondent for his part submitted that the newly filed documents relied upon by the appellant did not in effect shed any new light on the prior art as already identified in the opposition procedure. Annex 2, in particular, was an article of which the manuscript was received by the editor on 11 August 1989, which was earlier than the effective date of document D6, in September 1989. Document D6, which so far had been considered to disclose the closest prior art, thus better reflected the latest developments in the field and the actual starting point of the invention at the priority date of the patent in suit than Annex 2.

Document D14 did not disclose any arrangement comprising all the features of present claim 1. Since it was not permissible for the proper interpretation of a document to arbitrarily combine selected features disclosed independently of each other in connection with the description of different devices, the document could not jeopardise novelty of the claimed subject-matter.

Concerning inventive step, the invention was distinguished from the arrangement recommended in document D6 in that it comprised a fiber having a nominal cut-off wavelength comprised between the pump wavelength and the signal wavelength, instead of the known amplifier fiber which was single-mode for both the pump radiation and the signal radiation. In addition, the fiber was bent in the specific manner set out also in the claim, so as to reduce the incidence of signal power fluctuations, the occurrence of which had been foreseen in document D6 and confirmed by the experimental set-up described in the declaration by

Mr Vavassori as filed on 13 December 1999.

The prior art did not in anyway hint at bending optical fibers designed for multi-mode radiation propagation so as to achieve single mode propagation.

Reasons for the Decision

1. The appeal meets the requirements of Articles 106 to 108 and of Rule 64 EPC. It is admissible, accordingly.

2. *Admissibility of late-filed documents into the procedure*

Documents D16 to D19 and Annexes 2 to 5 as cited by the appellant in support of his argumentation against the patentability of the claimed subject-matter were filed in the appeal procedure only. They thus constitute evidence which goes beyond the "indication of facts, evidence and arguments" presented in the notice of opposition pursuant to Rule 55(c) EPC in support of the grounds of opposition. According to the case law of the Board's of appeal, based on the judicial character of the appeal procedure, which is "less investigative" that the administrative procedure in the first instance, as was emphasised in particular in the decision G 9/91 and the opinion G 10/91 of the Enlarged Board of Appeal (OJ EPO 1993, 408 and 420), such late-filed evidence should only very exceptionally be admitted into the appeal procedure in the appropriate exercise of the Board's discretion, if such new material is *prima facie* highly relevant in the sense

that it can reasonably be expected to change the eventual result and is thus highly likely to prejudice maintenance of the European patent (see in particular T 1002/92 (OJ EPO 1995, 605).

In the present case, the Board having scrutinised all the late-filed documents reached the conclusion that Annex 2 discloses an arrangement which comes substantially closer to the claimed subject-matter than the prior art disclosed in document D6, which during the opposition procedure and in the decision under appeal had been considered to represent the closest prior art. As a matter of fact, for the reasons which will be indicated more in detail below, Annex 2 discloses a concrete embodiment of an optical fiber amplifier of a type permitting single mode propagation at the wavelength of the optical signal and multi-mode propagation at the pumping radiation wavelength, in accordance with one essential feature of claim 1. In contrast, document D6 only refers to such a possibility as a less favourable comparative example in a theoretical model calculation. For that reason, Annex 2 *prima facie* constitutes a highly relevant citation, which might seriously question the correctness of the reasoning in the appealed decision.

The other late-filed citations do not in the Board's opinion shed any substantially different light on the prior art as illustrated by the evidence already presented in the notice of opposition. In particular, the respondent did not deny that the general effect of bends on the propagation of radiation in an optical fiber, as referred to in Annexes 4 and 5, was known in the art, and illustrated also in document D9. These

annexes are dedicated to the different technical problem of avoiding modal noise generated for instance at imperfect connections in single mode fiber systems, which is solved by providing an additional length of fiber bends in the radiation path. These annexes however do not relate to the operation of an optical fiber amplifier. They neither suggest to dispose an active fiber in a curved configuration over at least 70% of its overall length, nor to render mono-mode a fiber device actually designed for being multi-mode as set out further in present claim 1.

For the above reasons, the Board decided to admit Annex 2 in the appeal procedure, and to disregard the other citations not submitted in due time by the appellant, by virtue of Article 114(2) EPC.

3. *Novelty*

3.1 Document D14, which is the sole citation relied upon by the appellant in support of his attack against the novelty of the claimed subject-matter, discloses both optical fiber lasers and optical amplifiers. The only embodiment of an amplifier is described with reference to Figure 10 (see page 15, line 9 to page 16, line 7). This passage neither states the pump and signal radiation wavelengths, nor the cut-off wavelength of the fiber, above which only mono-mode propagation is permitted. The appellant in this respect referred to indications given in the same document in conjunction with other arrangements, using an active fiber as a laser rather than as an amplifier. The document in the Board's view however lacks any explicit or implicit teaching that specific features disclosed in relation

with optical fiber lasers also applied to the optical fiber amplifier of Figure 10. Quite on the contrary it is noticed that the passage directed to the amplifier of Figure 10 refers to an erbium-doped fiber (see the sentence bridging pages 15 and 16), whilst the laser fiber said to exhibit a cut-off wavelength of 1 µm is specified to be of the neodymium-doped typed (see page 8, lines 3 to 11) which shows that different fibers are used for the respective embodiments. Document D14 also fails to disclose that coiling up of the amplifier fiber, if any, should be performed in such a way as to meet the conditions set out at the end of present claim 1 in respect of the pump mode propagation, and at least over 70% of the overall length of the fiber.

3.2 Annex 2 discloses an optical amplifier insertable in series in an optical fiber telecommunication line for amplifying optical signals propagating in this fiber line, comprising at least a luminous pumping source for generating optical radiation having a wavelength shorter than that of said optical signal (0.98 µm as compared to between 1.49 and 1.58 µm), an active optical fiber containing a fluorescent dopant (erbium) in its optical core being capable to emit light in the wavelength range of the optical signal when pumped at the wavelength of the pumping source, and a dichroic coupler having two inputs connected to the optical fiber line and to the luminous pumping source respectively, and an output connected to one end of said active fiber, wherein (since the cut-off wavelength is of 1.1 µm) the active optical fiber is a fiber that when arranged in a substantially rectilinear

configuration permits single-mode propagation at the wavelength of the optical signal and multi-mode propagation at the pumping radiation wavelength (see page 422, "Experimental Procedures").

The document does not refer to any bending of the fiber. Accordingly, the subject-matter of claim 1 of the patent in suit is distinguished from the optical amplifier disclosed in Annex 2 in that the active fiber is disposed in a curved configuration at least over 70% of its overall length, with a bending radius such that said fiber provides only single mode propagation of the fundamental mode at the pumping radiation wavelength.

3.3 The remaining documents on the file do not come closer to the claimed subject-matter.

In particular the set of parameters given in the third paragraph of page 15 of document D6 for use in the mathematical models presented there actually anticipates the same features of claim 1 as the fiber of Annex 2, and the document does not refer to any bending of the fiber either.

3.4 For these reasons, the subject-matter of claim 1 of the patent in suit is novel within the meaning of Article 54 EPC.

4. *Inventive step*

4.1 The closest prior art in the Board's opinion is constituted by the optical fiber amplifier disclosed in Annex 2. This document was published in December 1989 shortly before the priority date of the patent in suit,

which is 12 February 1990. It discloses a concrete example of a fiber amplifier with a fiber designed for multi-mode propagation at the wavelength of the pumping radiation, and it does not hint at any particular difficulty which would deter the skilled person from contemplating further development of the described device.

On the contrary, document D6 reviews **theoretical** models of fiber amplifiers. Although it uses as an example a set of parameters corresponding to a fiber which is for multi-mode propagation at the pumping radiation (see page 15, third paragraph), it also states that:

"If the fiber is multimoded at the pump wavelength, power exchange between the pump modes resulting from environmental changes will induce sizeable gain fluctuations. Inasmuch as possible, it is therefore preferable, as in four-level material fiber devices, to design the fiber such that it carries a single pump mode" (see page 16, point 3.4, second paragraph).

For these reasons, document D6 in the Board's opinion constitutes a less appropriate starting point for getting to the claimed amplifier, which - against the explicit warning in D6 - actually comprises an active fiber which is multi-moded at the pumping wavelength.

The Board cannot endorse the respondent's line argument to the effect that document D6, published in September 1989, illustrates a later stage of development of the art than Annex 2, the manuscript of which was received by the editor on 11 August 1989, as indicated at the bottom of the left-hand column on page 422 of the

annex. In addition to the fact that there is no evidence that the manuscript of Annex 2 was not substantially amended before its actual publication, the contents of document D6, published from 6 to 8 September 1989 also had to be conceived by its author some time before this date. In any case, both documents are timely so close to each other that they must be considered as illustrating technical and theoretical developments which resulted from substantially parallel research efforts.

4.2 The optical amplifier set out in claim 1 of the patent in suit is distinguished from the closest prior art amplifier as disclosed in Annex 2 in that the active fiber is disposed in a curved configuration at least over 70% of its overall length, with a bending radius such that said fiber provides only single mode propagation of the fundamental mode at the pumping radiation wavelength.

The respondent in this respect submitted that the claimed fiber configuration allowed to reduce output signal power fluctuations in practical use of the optical amplifier, which was denied by the appellant.

The Board agrees that the description of the patent does not refer to any reduction of the output signal power fluctuations as a result of the claimed arrangement, but that it stresses instead the achieving of a greater efficiency (see the results of the comparative example from page 6, line 21 to page 7, line 35). The whole description however starts from a prior art constituted by an optical fiber amplifier in which the active fiber is of the single-mode type both

at the signal wavelength and at the pumping wavelength (see page 2, lines 17 to 32 and the comparative example at the top of page 7). Since substantially closer prior art as disclosed in Annex 2 was brought to light by the appellant, the Board sees no objection to the respondent now founding its argumentation in favour of inventive step on a technical effect objectively derived from a direct comparison with this closest prior art, and also related to the general issue of the quality of signal amplification, namely the improving of output signal stability.

The Board is also satisfied that the claimed features actually achieve an improvement of the output signal stability, despite the appellant's denying that any noticeable gain variation would occur during normal use of the closest prior art arrangement.

Document D6 indeed explicitly refers to power exchange between the fundamental and higher pump modes inducing sizeable gain fluctuations as a result of environmental changes. The Board in this respect agrees to the statement made by Mr Digonnet, the author of document D6 in the declaration filed with the appellant's statement of the grounds of appeal, to the effect that the passage on page 16 of the document did not suggest that **all** and environmental effects would cause such a power coupling, nor that gain fluctuations would **necessarily** take place. The passage nevertheless clearly indicates that gain fluctuations can actually result from sufficiently large environmental changes, e.g. large variations in temperature or applied mechanical stress. This is confirmed by the experiment described in the declaration by Mr Varassori as filed

by the respondent. The Board agrees to the appellant's contention that the magnitude of the perturbation brought to the experimental arrangement, consisting in continuously varying the diameter of a turn of the active fiber, does not correctly reflect the much lower mechanical stresses imposed on an optical amplifier in normal use. Smaller perturbations can however reasonably be expected to still produce some gain fluctuation, even at a much lesser degree. In addition, optical amplifiers can certainly be used also under substantially higher-than-normal temperature or stress conditions.

The declarations by Dr Nolan and Dr Hempstead as filed with the appellant's grounds of appeal do not address the question of the stability of the output signal power.

Thus, the technical problem underlying the claimed arrangement as objectively determined from a comparison with the closest prior art is to improve the optical fiber amplifier of Annex 2 in such a way as to reduce the incidence of environmental changes on its gain stability.

4.3 The sensitivity to environmental perturbations of optical fiber amplifiers of the type disclosed in Annex 2 was known already from document D6 (see page 16, the second paragraph of point 3.4). The recognition of the technical problem does not per se contribute to inventive step, accordingly.

Thus it remains to be considered whether the claimed solution consisting in disposing the active fiber in a

curved configuration at least over 70% of its overall length with a bending radius such that said fiber provides only single mode propagation of the fundamental mode at the pumping wavelength was obvious to the skilled person at the priority date of the patent.

Document D6 is the sole prior art citation on the file to address the same technical problem as the patent in suit. It explicitly recommends "to design the fiber such that it carries a single pump mode" (see page 16, the second paragraph of point 3.4). When applied to the erbium-doped fiber amplifier pumped by 0.98 µm laser diodes of Annex 2, this teaching would either call for re-designing the fiber so that it exhibits a cut-off wavelength of 0.98 µm or less instead of its effective cut-off wavelength of 1.1 µm, or for selecting a different pumping means operating at a higher wavelength. The latter option is mentioned explicitly in the same passage of document D6, according to which, for erbium-doped silica fibers the result of the analysis provides an incentive for a pump near 1.49 µm. Document D6 therefore in effect teaches away from the claimed arrangement, which in contrast achieves a reduction of the effective cut-off wavelength by the effect of bending the fiber.

Document D9 is an excerpt from a book on the principles and applications of single mode fiber optics (see the Title), which in Chapter 3.3 reviews the various waveguide attenuation mechanisms, in particular the bending losses affecting the only, fundamental mode as it propagates in a bent single-mode fiber. This document does not therefore actually relate to the

situation prevailing in the closest prior art arrangement of Annex 2, in which it is the higher order modes which shall be removed from a fiber actually designed for multi-mode propagation, whilst the fundamental mode pumping and signal radiations should clearly not be affected by the bending losses referred to in document D9.

The other documents on the file, except for Annexes 4 and 5 which have not been considered more relevant than document D9 for the reasons set out in point 2 supra, and have not been admitted into the procedure, accordingly, do not establish any relationship between the bending of optical fibers and the propagation therein of higher radiation modes.

The appellant expressed his concern that the present patent could unduly cover optical fiber amplifiers comprising an active fiber coiled merely for the totally unrelated and common purpose of reducing the overall size requirement of the amplifier. He however failed to produce any evidence that the degree of coiling which the skilled person would normally impose on an available active fiber of the type permitting single mode propagation at the wavelength of the optical signal and multi-mode propagation at the pumping radiation wavelength, like the one disclosed in Annex 2, in order to fit it into a compact housing of the type shown for instance in Figure 6 of document D13 (size: 50 x 130 x 110 mm) would automatically result in the claimed reduction of the fiber's cut-off wavelength to a value equal to or less than the wavelength of the pumping radiation.

For these reasons, the optical fiber amplifier defined in claim 1 of the patent in suit cannot on the face of the elements on the file be considered to result in an obvious manner from the state of the art. It involves an inventive step within the meaning of Article 56, accordingly.

4.4 The same conclusion applies to the subject-matter of dependent claims 2 to 8, by virtue of their appendance to claim 1.

5. Thus, the grounds for opposition raised by the appellant do not prejudice the maintenance of the patent unamended, and the decision to reject the opposition as taken by the opposition division under Article 102(2) EPC can be upheld.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

P. Martorana E. Turrini