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D E C I S I O N
of 30 August 1994

Case Number: T 0943/93 - 3.4.1

Application Number: 85305572.1

Publication Number: 0174729

IPC: H01S 3/23

Language of the proceedings: EN

Title of invention:
Optical amplification

Patentee:
BRITISH TELECOMMUNICATIONS public limited company

Opponent:
Siemens AG

Headword:
-

Relevant legal norms:
EPC Art. 54(2), 56

Keyword:
"Novelty (yes): no inevitable working of the nearest prior art within the wavelengths region claimed"
"Inventive step (yes): non-obvious application of unforeseeable interdependence of parameters"

Decisions cited:
-

Catchword:
A hypothetical possibility of operating within the claimed region per se is legally not sufficient to destroy the novelty of this region, in particular not if the skilled person has no technical motive and thus no practical necessity to work within this region (see paragraph 2.5, page 14).

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Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 0943/93 - 3.4.1

D E C I S I O N
of the Technical Board of Appeal 3.4.1
of 30 August 1994

Appellant: (Opponent)
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Representative: -

Respondent: (Proprietor of the patent)
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Decision under appeal: **Interlocutory decision of the Opposition Division of the European Patent Office dated 25 August 1993 concerning maintenance of European patent No. 0 174 729 in amended form.**

Composition of the Board:

Chairman: G. D. Paterson
Members: H. J. Reich
U. G. O. Himmler

Summary of Facts and Submissions

I. The Respondent is owner of European patent No. 0 174 729.

II. This patent was opposed by the Appellant on the grounds mentioned in Article 100(a) EPC, citing the following documents:

D1: "Electronics Letters", volume 18, 1982, pages 438 to 439;

D2: "IEEE Journal of Quantum Electronics", volume QE-4, 1968, pages 125 to 131;

D3: "Electronic Letters", volume 19, 1983, pages 295 to 297; and

D4: "IEEE Journal of Quantum Electronics", volume QE-18, 1982, pages 575 to 581

and filing after the expiry of the opposition period additionally documents:

D5: H. C. Casey et. al.: "Hetero-structure Lasers", part A, Academic Press, New York, 1978, pages 167 to 165, and

D6: "IEEE Journal of Quantum Electronics", volume QE-11, 1975, pages 65 to 69.

III. The Opposition Division in accordance with Article 114(2) EPC did not take into consideration document D6 and under Article 114(1) EPC introduced into the proceedings document D5 and document:

D7: "Japanese Journal of Applied Physics", volume 21, No. 11, November 1982, pages L680 to L682.

By an interlocutory decision within the meaning of Article 106(3) EPC the Opposition Division decided on the amended form in which the European patent could be maintained.

The six independent Claims 1, 6, 8, 11, 16 and 18 on which the decision was based, read as follows:

"1. A **method** of amplifying an optical signal which comprises coupling the optical signal to be amplified into the active layer of a semiconductor laser hetero-structure through which a driving current is passed, the amplified signal being emitted from the active layer, in which method the wavelength of the gain maximum at that driving current for the low power limit of optical power input λ_{max}, the longer of the two wavelengths of zero gain at the driving current for the low power limit of optical power input λ_{upper}, and the wavelength of the optical signal to be amplified λ are related by the relations chips

$$\lambda_{upper} > \lambda > \lambda_{max},$$

and

$$(\lambda - \lambda_{max})/(\lambda_{upper} - \lambda_{max}) \geq 0.1.$$

6. A **method** of amplifying an optical signal which comprises coupling the signal to be amplified into the active layer of a semiconductor laser structure and applying a driving current to the laser structure such that lasing occurs, the wavelength of the signal to be amplified being such that injection locking is avoided and the amplified signal is emitted from the active layer.

8. A **method** of amplifying an optical signal which comprises coupling the signal to be amplified into the active layer of a semiconductor laser structure through which a driving current is passed, which layer emits the amplified signal, and monitoring the light emission from the active layer at a wavelength or over a wavelength range distinct from that of the amplified signal, and controlling the driving current to the laser structure so as at least partly to compensate for the decrease in the monitored output with increasing optical input.

11. An amplification **assembly** for amplifying an optical signal which comprises an optical signal source, a semiconductor laser hetero-structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser hetero-structure, and means for passing a driving current through the semiconductor laser hetero-structure, the amplified signal being emitted from the active layer in use, wherein the wavelength of the gain maximum of the semiconductor laser hetero-structure at that driving current for the low power limit of optical power input λ_{max}, the longer of the two wavelengths of zero gain at the driving current for the low power limit of optical power input λ_{upper}, and the wavelength of the optical signal to be amplified λ are related by the relations chips

$$\lambda_{upper} > \lambda > \lambda_{max},$$

and

$$(\lambda - \lambda_{max})/(\lambda_{upper} - \lambda_{max}) \geq 0.1.$$

16. An amplification **assembly** for amplifying an optical signal which comprises an optical signal source, a semiconductor laser structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser structure, and means for passing a driving current through the semiconductor laser

structure such that lasing occurs, the wavelength of the signal to be amplified being such that injection locking is avoided and the amplified signal being emitted from the active layer.

18. An amplification **assembly** for amplifying an optical signal which comprises an optical signal source, a semiconductor laser structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser structure, and means for passing a driving current through the semiconductor laser structure, the amplified signal being emitted from the active layer in use, wherein means is provided to monitor the output of the semiconductor laser structure at a wavelength or over a wavelength range distinct from that of the amplified signal and a feedback control loop is provided which acts to control the driving current so as at least partly to compensate for the decrease in the monitored output with increased optical input power."

Claims 2 to 5, 7, 9 and 10 are inter alia dependent on Claim 1 and Claims 12 to 15, 17 and 19 to 22 are inter alia dependent on Claim 11.

IV. In the interlocutory decision the Opposition Division took essentially the following view:

(a) **Claims 1 and 11** (first aspect of the invention)

Claims 1 and 11 are novel with regard to the nearest prior art disclosed in document **D1**, since a clear relative position of the wavelengths of the gain maximum and the signal is not derivable from this document. It would not be obvious to solve the problem of amplifier saturation and linearity by making use of the effect that the maximum of the material gain in a semiconductor laser hetero-

structure amplifier shifts to longer wavelengths with increasing signal input power. This effect would not be known from any of the cited documents, in particular not from document **D5** which shows that the maximum of gain moves to higher energies as the minority carrier density is increased via the driving current, and not from document **D7** which discloses that the Fabry-Pérot resonances shift to longer wavelength when the refractive index increases by a reduction of the carrier density caused by increasing optical signal power. Document **D2** deals with a homo-structure amplifier and document **D3** does not indicate any shift between gain maximum and wavelength.

(b) **Claims 6 and 16** (second aspect of the invention)

The cited prior art would not suggest to a skilled person to increase the output power and simultaneously maintain a dependence of the output power on the input signal power by setting the signal wavelength remote enough from the driving current-determined lasing wavelength so that the amplifier will emit the lasing wavelength **and** the amplified signal wavelength and injection locking is avoided. The oscillator/amplifier pair disclosed in document **D2** suppresses injection locking by a perpendicular arrangement of the lasing output and the amplified signal output. The oscillator/amplifier arrangement of document **D4** operates at the same wavelength and, when the amplifier is driven in the explicitly recommended parameter range above the lasing threshold, in a mode wherein injection-locking occurs.

(c) **Claims 8 and 18** (third aspect of the invention)

It would be neither obvious nor trivial to make use of the recognition that saturation occurs over the entire emission range of the amplifier, in monitoring light emission which is distinct from the amplified signal wavelength, in a feedback loop for controlling the driving current of the amplifier in order to further improve its linearity.

V. The Appellant lodged an appeal against the interlocutory decision, in which the following new document was cited:

D8: DE-A-3 210 980.

VI. The Appellant requested the Board to set aside the decision under appeal and to revoke the opposed patent.

VII. In his Statement of Grounds the Appellant argued essentially as follows:

(a) The fact that documents occasionally recommend the wavelength at maximum gain as favourable for amplification, does not exclude that a skilled person as a rule will be dependent on using neighbouring wavelength regions for amplification. Hence, a skilled person will usually not exclude the claimed wavelength region in the use of a semiconductor laser for amplification. Thus, any disclosure of such a use before the priority date of the patent under appeal would destroy the novelty of Claim 1 independent from the question whether particular advantages have been recognised or not.

(b) The physical law evidenced by Figure 3.7-7 of document D5 according to which the wavelength of maximum gain is shifted to longer wavelength with increasing minority carrier density (i.e. with increasing driving current of the amplifier) would have as result that any expert who works above the "low power limit" where an amplified signal output starts to be detectable, and who follows the conventional rule to select the signal wavelength to be identical with the wave length of the gain maximum, would automatically work at a wavelength λ which is longer than "the wavelength of the gain maximum at that driving current for the low power limit of optical power input λ_{max}" as claimed in Claim 1.

(c) Moreover, a skilled person would as well inevitably work within the wavelength region as claimed, if he amplifies wavelengths at the gain maximum and works according to Claims 9, 10, 19, 20 and 21 at 5 mW input power, i.e. in an appropriate distance over the minimum input power of the signal which is in practice not usable. Figure 2 of the patent in suit demonstrates that the gain maximum already at 0.05 mW input power is shifted from the low-power valued 1550 nm to above 1560 nm and violation of the inequation in Claim 1 with its lower limit of 0.1 would already start at 1555 nm. Such wavelengths are so close to the wavelength of the gain maximum that with a degree of certainty a skilled person will definitely use them in practice. In the only disclosed embodiment the signal wavelength is 1580 nm, which corresponds to an inequation value of 0.6.

(d) The lower limit 0.1 of the relationship claimed in Claim 1 is arbitrarily selected, since λ_{max} and λ_{upper} are dependent on a variety of parameters which are not indicated explicitly.

(e) A skilled person may conclude from the disclosure of the numerical values in document **D1** that this conventional method corresponds to that claimed in Claim 1: The gain maximum is at 854 nm, the signal wavelength is centered at 857 nm and the 3 dB-bandwidth is 8 to 10 nm. It may be assumed that the skilled person will admit at least the 3 dB-bandwidth when using an InP-laser for optical amplification. This opinion is supported by document **D8** wherein a 1 dB-bandwidth of 10 nm and more is indicated. Hence document D8 teaches a skilled person to generously dimension the bandwidth when using such semiconductor laser amplifiers.

(f) The feature added to the subject-matter of Claim 1 as granted, i.e. the relationship defining the claimed wavelength region does not imply an inventive step, also not in combination with the remaining claim features. There is no technical reason disclosed in the patent in suit why the lower limit of the quotient of the inequation shall be 0.1. Hence, the claimed relationship has no other purpose than a delimitation against the novelty destroying prior art. The attempt to delimit the subject-matter of a claim against the prior art is per se no substantial foundation for the existence of an inventive step.

(g) Having regard to the third aspect of the invention, the use of a control system monitoring an output signal in order to control an input signal is generally known. Such a feedback control loop cannot be regarded as an invention without any disclosure of a non-obvious loop development as in the present case.

VIII. In his response to the Statement of Grounds of Appeal the Respondent requested the appeal to be dismissed and the patent to be maintained as amended. Auxiliarily, he requested oral proceedings.

IX. In support of his request, the Respondent made essentially the following submissions:

(a) The Appellant's statement that operation of a semiconductor laser amplifier within the wavelength range claimed is not commonly excluded by a skilled person is not supported by any of the prior art cited, which repeatedly states that the input optical signal should be at the maximum of the gain.

(b) It is disputed that a skilled person would automatically work inside the scope of the present claims, since the physical basis for the first aspect of the present invention - the effect that the peak of the material gain of a semiconductor laser amplifier moves to longer wavelengths as the power of the input optical signal is increased - was not known at the priority date.

(c) The Appellant's statement that a skilled person with certainty would operate an amplifier within the wavelength range defined by the inequality in Claim 1 because its lower limit is so close to the

peak of the material gain, is unsubstantiated. Before the priority date of the present invention a skilled person had no reason to move the wavelength of the input signal 10% away from the peak of the material gain towards the longer wavelength giving zero gain.

(d) Before the priority date of the present patent sub-nanometre wavelength control of semicontrol lasers was easily achievable. The relationship in Claim 1 defines a wavelength difference of the lower limit of the wavelength region as claimed from the peak of the material gain in the order of magnitude of some nanometres. Thus, an accidental operation within the claimed wavelength range is ruled out by the numerical values claimed in Claim 1.

(e) Document D8, in a particularly clear manner, teaches that the wavelength of the input optical signal would be at the peak of the material gain of a semiconductor laser amplifier; see the abstract, page 8 lines 7 to 10, page 11 line 35 to page 12 line 5, and page 17 lines 20 to 36. Thus, document D8 provides very strong evidence that the skilled man - far from being sure to operate at greater that 10% away from the peak of the material gain, made great efforts to operate as close to the peak of the material gain as possible.

Reasons for the Decision

1. Though the Opposition Division introduced late-filed documents D5 and D7 into the proceedings, it decided that these documents have no influence on the decision to be taken; see paragraph IV-(a) above. The Board re-

examined these documents with the same result and, for this reason, disregards them in the appeal proceedings under Article 114(2) EPC. The finding of the Opposition Division that late-filed document D6 is not to be taken into consideration in accordance with Article 114(2) EPC, is confirmed. Furthermore, the Board considers that document D8 (cited for the first time in the Grounds of Appeal) has no influence on the outcome of the Board's decision (see also paragraph IX-(e) above) and is therefore disregarded under Article 114(2) EPC as well.

2. *Novelty-Claims 1 and 11*

2.1 The subject-matter defined by the wording of Claims 1 and 11 differs from the method and apparatus disclosed in document D1 in that this nearest prior art neither explicitly discloses nor implicitly satisfies the relationship:

$$(\lambda - \lambda_{max})/(\lambda_{upper} - \lambda_{max}) \geq 0.1,$$

wherein:

λ: is the wavelength of the optical signal to be amplified,

λ_{max}: is the wavelength of the gain maximum at the driving current for the low power limit of optical power input, and

λ_{upper}: is the longer of the two wavelengths of zero gain at the driving current for the low power limit of optical power input.

The Appellant admits that document D1 discloses only numerical values for λ (857 nm) and λ_{max} (854 nm) but not for λ_{upper}. However, the denominator of the above relationship cannot be determined on the basis of the explicit disclosure of document D1.

2.2 The Board does not follow the Appellant's implicit submission in paragraph VIII-(e) that a 3 dB-bandwidth of 8 to 10 nm as disclosed in document D1, allows per se to extrapolate a 0 dB-bandwidth and thus an estimation of the eventual λ_{upper} - value in the nearest prior art. Any extrapolation would necessarily need a reliable second bandwidth-value for a second dB-value. Such a value is not derivable from document D1 and thus a skilled person is unable to determine - on the basis of Document D1 and its background knowledge - the slope for an extrapolation towards 0 dB. The Appellant admits that in practice bandwidths are generously dimensioned. As the bandwidth determines the denominator of the relationship set out in Claim 1, its generous dimensioning diminishes the resulting value, i.e. moves a conventional method and apparatus out of the claimed region and therefore - contrary to the Appellant's opinion - creates a reliable distance from the conventional operation at λ_{max}, so that the possibility of an inherent or accidental infringement in the Board's view appears negligible. Hence, the subject-matter of Claim 1 must be regarded to stay outside any implicit disclosure which a skilled person derives from document D1.

2.3 A second bandwidth-value which allows to estimate λ_{upper} is missing in all cited prior art documents, in particular in document D7. Document D7 does not disclose a bandwidth at 1 dB above zero gain but at 1 dB below maximum gain and thus represents the bandwidth for an approximately constant maximal amplification. Hence, the bandwidth-value of 10 nm on which the Appellant relies (see para. VIII-(e)) is situated on the wrong end of the curve to be extrapolated and therefore not relevant. A vague orientation about realistic values of the denominator $\lambda_{upper} - \lambda_{max}$ is only possible on the basis of Figure 2 of the patent under appeal, showing that λ_{upper} -

λ_{max} about 50 nm and that the 0 dB-bandwidth is about 25 nm wider than the 3 dB-bandwidth. For the above reasons, the Board doubts that in the case of document D1 it is realistic to assume that $\lambda_{upper} - \lambda_{max}$ equals or is smaller than 30 nm. Therefore, the Board is unable to follow the Appellant's submission in paragraph VIII (a) and (e), that for the value $\lambda - \lambda_{max} = 3$ nm as disclosed in document D1 the relationship distinguishing the subject-matter of Claim 1 from its nearest prior art, is automatically satisfied when the method and apparatus disclosed in document D1 are operated in practice.

2.4 According to the physical law disclosed in Figure 3.7-7 of document D5 the wavelength of the gain maximum is shifted with increasing minority carries to higher **energies E**. This means physically a shift to higher optical frequencies and thus to **shorter** not longer **optical wavelengths**. Hence, contrary to the Appellant's submission in paragraph VIII-(b), a skilled person who operates a semiconductor laser amplifier above the low power limit and selects - according to the conventional rule - the signal wavelength at that of the gain maximum, moves with increasing driving current from λ_{max} as defined in Claim 1, into a wavelength direction which is opposite to the claimed one. Therefore, whatever driving current a skilled person applies, he would automatically work outside the claimed wavelength region.

2.5 The Appellant is followed in his view according to paragraph VIII-(c) above that - taking Figure 2 of the patent in suit as evidence - a skilled person who follows the conventional rule and adapts experimentally the wavelength of the gain maximum to that of the signal to be amplified, falls clearly into the claimed wavelength region, if he realises this experimental adaptation at signal input energies above 10^{-5} W (λ_{max}

being 1550 nm; λ_{upper} being 1600 nm; $\lambda_{upper} - \lambda_{max}$ is thus 50 nm, so that for the 0.1-limit of the relationship the claimed wavelength region begins with 1555 nm and the 10^{-5} W value at 1560 nm is within it). However, the Appellant has filed no evidence that such an experimental adaptation was disclosed in a prior art document or was realised in practice before the priority date of the patent under appeal. A hypothetical possibility of operating within the claimed region per se is legally not sufficient to destroy the novelty of this region, particularly if the skilled person has no technical motive and there exists no practical necessity to work within this region. Since the signal input power interval from 10^{-6} W to 10^{-10} W allows to achieve an amplifier gain about 12 dB and for this signal power interval an experimental adaptation of the wavelength of the gain maximum to that of the signal to be amplified falls outside the claimed region, an inevitable operation within the claimed wavelength region at each practical use of a semiconductor laser amplifier is not evidenced by Figure 2 of the patent in suit.

2.6 The Appellant's argument in paragraph VIII-(d) attacks not novelty but clarity. In the Board's view, a dependence on a multitude of apparatus parameters gives no rise to an ambiguity, if the property claimed - as in the present case - can be measured with sufficient precision.

2.7 Documents D2 to D4 are further away from the subject-matter of Claims 1 and 11 than document D1; see paragraphs IV (a) and (b) above.

2.8 For the reasons stated above in pages 2.1 to 2.7, the subject-matter of Claims 1 and 11 is considered novel within the meaning of Article 54(2) EPC.

3. *Claims 1 and 11 - inventive step*

3.1 There is no hint in the cited prior art that the objective problem underlying the present invention, i.e. to improve the linearity of the amplification of signals with largely varying input energies in a semiconductor laser amplifier can be solved by working within the wavelength region as defined by the inequity which distinguishes the subject-matter of Claim 1 from the nearest prior art; see paragraph 2.1 above. The property of a semiconductor laser amplifier with a hetero-structure that its gain values get less dependent on signal input energies in a certain wavelength-region, in the Board's opinion could not be foreseen by a skilled person on the basis of his general knowledge; see also paragraph IV-(a) above.

3.2 Figure 2 of the patent demonstrates that already at the lower limit of the claimed wavelength region at 1555 nm the dashed curves for the material amplifier gain have less distance from each other than at 1550 nm. This fact evidences that an increased linearity of the amplification is present at the claimed lower limit. Hence - contrary to the Appellant's view in paragraph VIII-(d) and (f) - the claimed limit

$$(\lambda - \lambda_{max})/(\lambda_{upper} - \lambda_{max}) \geq 0.1$$

is not arbitrary but a technical teaching defining the region within the desired effect is experimentally present and usable.

3.3 Hence, Claims 1 and 11 are considered to imply an inventive step within the meaning of Article 56 EPC.

4. For the above reasons, Claims 1 and 11 which represent the **first** aspect of the present invention, are allowable. Dependent Claims 2 to 5, 7, 9, 10, 12 to 15, 17 and 19 to 22 concern particular embodiments of the method according to Claim 1 or of the apparatus according to Claim 11 respectively and are therefore likewise allowable.

5. *Claims 6 and 16*

Claims 6 and 16 representing the **second** aspect of the present invention, are allowable for the reasons set out by the first instance in paragraph IV-(b) above. The Appellant has not argued against these reasons in his grounds of appeal.

6. *Claims 8 and 18*

6.1 Claims 8 and 18 representing the **third** aspect of the present invention, are allowable for the reasons set out by the first instance in paragraph IV-(b) above.

6.2 The Appellant's opinion according to paragraph VIII-(g) is not followed. No prior art document on file hints that a skilled person should control the driving current of a semiconductor laser amplifier by monitoring the amplifier output power at a wavelength which is distinct from the wavelength of the amplified signal. Conventional control loops monitor the output signal which is used for the desired technical application. In the present case this would be the amplified signal. Therefore, the Board sees in the deviation from the above conventional principle a non-obvious technical development of the generally known prior art.

7. Under these circumstances, the Respondent's auxiliary request for oral proceedings can be disregarded as inapplicable.

Order

For these reasons it is decided that:

The Appeal is dismissed.

The Registrar: The Chairman:

M. Beer G. D. Paterson