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# D E C I S I O N
**of 19 May 1999**

**Case Number:** T 0368/94 - 3.4.1

**Application Number:** 90301850.5

**Publication Number:** 0385643

**IPC:** H01S 3/085

**Language of the proceedings:** EN

**Title of invention:**
Quantum well vertical cavity laser

**Applicant:**
AT & T Corp.

**Opponent:**
-

**Headword:**
-

**Relevant legal provisions:**
EPC Art. 56

**Keyword:**
"Inventive step (no)"

**Decisions cited:**
-

**Catchword:**

**Case Number:** T 0368/94 - 3.4.1

**D E C I S I O N**
**of the Technical Board of Appeal 3.4.1**
**of 19 May 1999**

**Appellant:** AT & T Corp.
32 Avenue of the Americas
New York, N.Y. 10013-2412 (US)

**Representative:** Watts, Christopher Malcolm Kelway, Dr.
Lucent Technologies (UK) Ltd.
5 Mornington Road
Woodford Green
Essex IG8 0TU (GB)

**Decision under appeal:** **Decision of the Examining Division of the European Patent Office posted 14 December 1993 refusing European patent application No. 90 301 850.5 pursuant to Article 97(1) EPC.**

**Composition of the Board:**

**Chairman:** G. Davies
**Members:** M. G. L. Rognoni
U. G. O. Himmler

**Summary of Facts and Submissions**

I. The appellant (applicant) lodged an appeal, received on 26 January 1994, against the decision of the Examining Division, dispatched on 14 December 1993, refusing the application No. 90 301 850.5 (publication No. 0 385 643). The fee for the appeal was paid on 24 January 1994. The statement setting out the grounds of appeal was received on 13 April 1994.

In the decision under appeal, the Examining Division held that the application did not meet the requirements of Articles 52(1) and 56 EPC, having regard, inter alia, to the following documents:

D1: Conference on Lasers and Electro-Optics 1988, Technical Digest Series, vol. 7, Conference edition, Summaries of papers presented at the conference, 25-29 April 1988, Anaheim, California; R. Geels et al.:"Semiconductor diode lasers";

D3: P. L. Gourley and T. J. Drummond: "Single crystal, epitaxial multilayers of AlAs, GaAs and $Al_xGa_{1-x}As$ for use as optical interferometric elements", Applied Physics Letters, vol. 49, No. 9, 1 September 1986, pages 489 to 491.

II. In a communication to the appellant, the Board introduced the following documents:

D5: Y.Arakawa et al.: "Theory of Gain, Modulation Response, and Spectral Linewidth in AlGaAs Quantum Well Lasers", IEEE Journal of Quantum Electronics, October 1985, vol. QE-21, No. 10, pages 1666 to

1674;

D6: Wei Hsin et al.: "GaAs/AlGaAs Surface Emitting Laser Diode with Vertical Distributed Feedback Optical Cavity and Transverse Junction Buried Heterostructure", IEDM-87, 1987, pages 792 to 795;

and expressed the preliminary opinion that the appeal was likely to be dismissed.

III. In reply to the Board's communication, the appellant declared that they did not wish to make any further observations, but relied on the arguments presented in the statement of grounds of appeal.

IV. The appellant requested that the decision under appeal be set aside and a patent be granted on the basis of the following documents:

**Claims:**
No. 1 to 21 as filed with a letter dated 15 July 1993, received on 21 July 1993;

**Description:**
Pages 1 to 13 as originally filed;

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

V. The wording of claim 1 reads as follows:

"1. Apparatus comprising quantum well laser vertical cavity structure for lasing in a direction non-parallel to the major dimensions of a quantum well, such laser consisting essentially of an active element containing one or two quantum wells and a cavity dependent upon reflectance as between two distributed Bragg reflector mirrors."

VI. The appellant's arguments can be summarised as follows:

Surface emitting lasers using multiple quantum well (MQW) active regions and distributed Bragg reflector (DBR) mirrors formed the state of the art. The objective problem addressed in the present application was to reduce the threshold power of such lasers with a view to achieving higher integration density. No prior art showed that using only one or two quantum wells had been recognized as a useful thing to try and to do. In fact, D1 confirmed the general belief that a laser with a DBR cavity required at least three quantum wells. Though D3 showed a DBR reflector with a peak reflectivity of very nearly 100%, it did not disclose that DBR mirrors could have the properties required to make a laser with one or two quantum wells. In fact, mirrors with 100% reflectance would not be of any use at all, because, though the laser would probably generate light, it would not actually emit any. Reducing the number of pairs in the DBR reflector would eventually produce a mirror which was not totally opaque, but in which the loss was high compared with the transmittance. A laser made with such mirrors would have very low efficiency, because more light would be lost than emitted. There was nothing in D3 to suggest to a person seeking a practical solution to the problem of reducing threshold power that using only one or two quantum wells would be a possible practical approach. There was no advantage to having a low threshold, if , due to the low efficiency of the DBR mirrors of the cavity, the laser had to be run above threshold to give an acceptable output. In summary, D3 did not disclose anything which would contradict the belief that a MQW laser required at least three quantum wells, or which would point towards the present invention.

## Reasons for the Decision

1. The appeal is admissible.

2.1 D1 relates to an apparatus comprising the following features recited in claim 1:

- a quantum well laser vertical cavity structure for lasing in a direction non-parallel to the major dimensions of a quantum well,

- such laser consisting essentially of an active element containing a cavity dependent upon reflectance as between two distributed Bragg reflector mirrors.

The laser according to D1 has an active region containing "at least three quantum wells".

2.2 Hence, the subject-matter of Claim 1 is new and differs from the apparatus known from D1 in that the active region of the claimed laser contains:

"one or two quantum wells".

2.3 The Board agrees with the appellant that, in the light of D1, the objective problem addressed by the present application is to reduce the threshold power with a view to achieving higher integration density.

The present invention solves the above problem by means of a laser consisting essentially of an active element with one or two quantum wells.

3.1 According to the appellant, the significance of D1 is that it explicitly states (col. 2, first paragraph) that at least three quantum wells are required. In the appellant's opinion, D1 confirms that the general belief in the art prior to the present application was that Multiple Quantum Well (MQW) surface emitting lasers needed at least three quantum wells in the active layer (cf. D1, middle col., first paragraph).

3.2 It is indeed pointed out in D1 that "to avoid moving into the n = 2 quantum-well state and excessive leakage currents, at least three quantum wells are required in each diode junction of the surface-normal case" (D1, col. 2, first paragraph). In this context, D1 refers to D5 which is a theoretical investigation into the performance of AlGaAs quantum well semiconductor lasers.

3.3 D5 (cf. page 1668, first and second paragraphs) teaches, inter alia, the following:

- the gain of a quantum well (QW) laser shows a marked flattening ("saturation") at high injected currents (D5, cf. fig. 1);

- the maximum gain available with n QW's is n times larger that the maximum gain available with one QW since each well can provide its saturation gain, which is equal to that of a Single Quantum Well (SQW) laser;

- the saturation effect can be avoided by increasing the number of QW's although the injected current to achieve this maximum gain also increases by n times;

- owing to this saturation effect there exists an optimum number of QW's for minimizing the threshold current for a given total loss;

- for low losses, the injected **threshold current** is minimum in the case of n = 1.

In other words, it is clearly stated in D5 that the lowest threshold current can be achieved with a SQW laser **provided that the total losses are low.**

3.4 The statement in D1 that "at least three quantum wells are required" confirms, therefore, the teaching of D5 that, in a laser with **high internal losses**, a multiple quantum well active region should be used to avoid saturation effects that would increase the threshold current (cf. D1, middle col. "Note that a higher internal loss is assumed for the surface-normal laser to account for the higher doping levels"). In other words, D1 should not be interpreted as reflecting a general technical prejudice against single quantum well lasers.

3.5 Hence, in the opinion of the Board, the skilled person was aware before the priority date of the present application that using only one or two quantum wells was a viable solution to the problem of reducing the threshold current **as long as the laser's total losses were limited.**

4.1 According to the appellant, the general belief in the art prior to the present application was that reflectivity versus loss characteristics of DBR mirrors, such as were used in D1 for a laser with three or more quantum wells, was not good enough to make a low loss cavity suitable for a laser with just one or two quantum wells.

4.2 In this respect, the contested decision refers to D3 which shows a reflector formed by AlAs/GaAs with a peak reflectivity of very nearly 100%. According to the appellant, however, this document implies that a large number of periods produce a reflector which is useful as a single mirror, but not as a partially transmissive mirror for a laser with low threshold power, since the transmittance (if any) will be small compared with the loss.

4.3 The Board agrees with the appellant that, although D3 shows quarter-wave high reflectors (HR's) having 30 to 22 periods, the mirrors used in the described embodiment of a Fabry-Perot cavity suitable for a laser, have fewer layers (8 to 10) and thus a reflectivity which could not sustain lasing in an active layer comprising only one or two quantum wells. However, in the opinion of the Board, this does not reflect the general belief that it would not be possible to produce a quarter-wave high reflector with high reflectivity (i.e. more layers) and sufficient transmittance (i. e. low loss) to be used in a laser cavity. In fact, D6 proves that a "vertical distributed feedback surface emitting laser diode" comprising an optical cavity formed by 20 AlGaAs/GaAs pairs at the top and 60 pairs at the bottom was known before the priority date of the present application (cf. D6, page 792, col. 1 last paragraph and col. 2, first paragraph). As shown in Fig. 6 of D6, the reflectivity of the top surface is close to 1 (cf. page 793, "Computer Simulation Results").

4.4 As a result, a person skilled in the art, wishing to reduce the threshold power of a MQW (Multiple Quantum Well) laser according to D1, would realize from the teaching of D5 that the lowest threshold current could be obtained with a single quantum well (SQW) laser, provided that cavity losses were kept low. As it was known in the art (cf. D6) to make a high reflective distributed feedback mirror with sufficient transmittance to sustain lasing in a low-gain active layer, it would be obvious to the skilled person to try and **optimize** known DBR mirror structures so as to make them suitable for the cavity of a SQW laser. In so doing, the skilled person would arrive at an apparatus falling within the terms of claim 1 of the present application without the exercise of any inventive activity.

4.5 Hence, the subject-matter of claim 1 does not involve an inventive step within the meaning of Article 56 EPC.

**Order**

**For these reasons it is decided that:**

The appeal is dismissed.

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| The Registrar: | The Chairman: |
| M. Beer | G. Davies |