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**D E C I S I O N**  
**of 4 December 1997**

**Case Number:** T 0982/96 - 3.4.2

**Application Number:** 91117657.6

**Publication Number:** 0482497

**IPC:** G02F 1/37, G02B 6/12

**Language of the proceedings:** EN

**Title of invention:**  
Light wavelength shifter

**Applicant:**  
Pioneer Electronic Corporation

**Opponent:**  
-

**Headword:**  
-

**Relevant legal provisions:**  
EPC Art. 54, 56, 84, 123(2)  
EPC R. 88

**Keyword:**  
"Inventive step - (no) main and auxiliary requests"

**Decisions cited:**  
-

**Catchword:**  
-



Case Number: T 0982/96 - 3.4.2

**D E C I S I O N**  
**of the Technical Board of Appeal 3.4.2**  
**of 4 December 1997**

**Appellant:** Pioneer Electronic Corporation  
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**Decision under appeal:** Decision of the Examining Division of the  
European Patent Office posted 3 July 1996  
refusing European patent application  
No. 91 117 657.6 pursuant to Article 97(1) EPC.

**Composition of the Board:**

**Chairman:** E. Turrini  
**Members:** S. V. Steinbrener  
L. C. Mancini

## Summary of Facts and Submissions

- I. The appellant lodged an appeal against the decision of the Examining Division to refuse European patent application 91 117 657.6 (publication No. EP-A-0 482 497).

In its decision, the Examining Division held that the subject matter of the single claim as filed with the applicant's letter dated 22 June 1995 did not involve an inventive step in the sense of Article 56 EPC having regard to the following documents:

D1: Optics Communications, vol. 48, No. 3, 1 December 1983, pages 215-220;

D2: IBM Technical Disclosure Bulletin, vol. 24, No. 3, August 1981, page 1472; and

D3: Applied Physics Letters, vol. 29, No. 9, 1 November 1976, pages 572-574.

- II. In the communication of 23 September 1997 pursuant to Article 11(2) of the Rules of Procedure of the Boards of Appeal, the Board pointed out that the subject matter of the amended claim as filed with the appellant's statement of grounds dated 4 November 1996 did not comply with Articles 123(2) and 84 EPC, respectively, and - if rectified - did not appear to involve an inventive step with respect to the above-cited prior art.

Reacting to the Board's objections, the appellant filed an amended claim with its letter dated 4 November 1997.

- III. Oral proceedings which had been appointed at the appellant's subsidiary request took place on 4 December 1997. At the end of the oral proceedings, the Chairman pronounced the decision of the Board.
- IV. The appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the amended claim according to the main request or on the basis of the amended claim and amended description and drawings according to the auxiliary request.
- V. The wording of the single claim according to the main request as submitted at the oral proceedings reads as follows:

"1. Method for generating a second harmonic wave by using a light wavelength shifter device for a lightbeam from a semiconductor laser of which a deviation of wavelength of output light is allowed, said device comprising:

an optical waveguide type light wavelength shifter element which comprises a core of a nonlinear optical crystal having a varying rate of a difference between effective refractive indices ( $N_w$ ,  $N_{2w}$ ) respectively for fundamental and second-harmonic wavelengths with respect to temperature equal to about or higher than  $10^{-4}/^{\circ}\text{C}$ , and a cladding in contact with the core so that a primary incident light on the core can be shifted to a second harmonic wave having a wavelength of a half the wavelength of said primary incident light; and a thermoelectric element consisting of a Peltier effect element in contact with said optical waveguide type light wavelength shifter element, wherein said different refractive indices ( $N_w$ ,  $N_{2w}$ ) of the nonlinear optical crystal due to a variation of the wavelength of

the output light from the semiconductor laser are made equal to each other by varying the temperature of the wavelength shifter element."

The single claim according to the auxiliary request as submitted at the oral proceedings is worded as follows:

"A light wavelength shifter device for a lightbeam from a semiconductor laser of which a deviation of wavelength of output light is allowed, said device comprising:

an optical waveguide type light wavelength shifter element which comprises a core (11) of a nonlinear optical crystal having a varying rate of a difference between effective refractive indices ( $N_{\omega}$ ,  $N_{2\omega}$ ) respectively for fundamental and second-harmonic wavelengths with respect to temperature equal to about or higher than  $10^{-4}/^{\circ}\text{C}$ , and a cladding (12) in contact with the core so that a primary incident light on the core can be shifted to a second harmonic wave having a wavelength of a half the wavelength of said primary incident light; and a thermoelectric element (20) in contact with said cladding (12) operative to place said nonlinear optical crystal at a temperature whereat said effective refractive indices ( $N_{\omega}$ ,  $N_{2\omega}$ ) are equal to each other, wherein said thermoelectric element (20) consists of a Peltier effect element and wherein a channel-type shifter device is provided, in which the core (11) is surrounded by the cladding (12)."

In the above text of both claims, an obvious mistake consisting in that after deletions the indefinite article "a" was left twice before the expression "Peltier effect element" has been corrected by the Board.

VI. The appellant's argumentation in support of its requests may be summarised as follows:

The present application imparts the teaching that a variation of the laser wavelength leads to a change in the refractive index of the nonlinear optical crystal which change may be compensated by a change in temperature of the crystal so that the refractive indices for the fundamental and second-harmonic wavelengths  $N_o$  and  $N_{2\omega}$ , respectively, remain equal. Such a teaching, in particular if formulated as a method for generating a second-harmonic wave, cannot be derived from the available prior art.

In this context, it must be born in mind that wave propagation in waveguides differs from that in bulk material. In particular, for waveguides the conventional refractive index of the bulk material has to be replaced by the so-called "effective" refractive index  $N_{eff}$  ( $N_{eff} = N_{film} \sin \Theta$ ,  $\Theta$  being the angle of incidence) not considered in the prior art.

Furthermore, the prior art which is rather old relates to experimental assemblies for demonstration purposes and does not disclose any practical solution for an optical recording apparatus.

Finally, there have been enormous difficulties in utilising potassium niobate for the present purpose. The strong dependency of the refractive index of this material on temperature normally considered as a drawback has been converted into a decisive advantage in accordance with the present application. Moreover, the application is not restricted to potassium niobate which is only an example. Rather, a clear teaching is given to search for materials having an even stronger dependency of the refractive index on temperature. In the prior art, there is no hint in this direction.

Having regard to the auxiliary request which is based on the embodiment of Figure 4, an additional important improvement in temperature control and homogeneity is achieved by completely surrounding the core with the cladding. This teaching cannot be derived from the prior art.

Thus, in order to arrive at the subject matter of the claim according to both requests several distinct steps would have to be added to the closest prior art. Therefore, the claimed subject matter cannot be regarded as obvious.

## **Reasons for the Decision**

### **1. Admissibility**

The appeal is admissible.

### **2. Articles 84 and 123(2) EPC**

The Board is also convinced that the requirements of Articles 84 and 123(2) EPC are met by the respective amended single claim according to the main and auxiliary requests.

In the claims now under consideration, the refractive index has been specified to be the "effective" refractive index. Although this term does not appear in the original application documents which constantly and consistently use "equivalent" refractive index instead (see pages 7 and 8 of the description), the Board considers the substitution of "effective" for "equivalent" as the correction of an obvious mistake under Rule 88 EPC since the expression "equivalent refractive index" does not exist in the technical field

concerned, and a skilled person would have no doubt that in case of optical waveguide structures the "effective refractive index" must have been meant, this modified refractive index normally replacing the bulk refractive index in a core surrounded by a cladding.

3. *Article 54 EPC*

The Board considers the subject matter of the claim according to both requests to be novel with respect to the available prior art as can be seen from the following discussion of inventive step.

4. *Article 56 EPC*

4.1 Main request

4.1.1 In the Board's view document D1 comes closest to the subject matter claimed in accordance with the main request since this document already relates to a method for frequency doubling the output of a semiconductor laser with the aid of potassium niobate as a nonlinear optical crystal.

4.1.2 In this prior art (see in particular Figure 1 and associated text), there is described

- a method for generating a second harmonic wave (see D1, page 215, left-hand column) by using a light wavelength shifter device (see Figure 1: optical arrangement including a KNbO<sub>3</sub> crystal and a temperature controller) from a semiconductor laser;
- the device comprising an optical light wavelength shifter element which comprises a nonlinear optical crystal having a varying rate of a

difference between refractive indices ( $N_{\omega}$ ,  $N_{2\omega}$ ) respectively for fundamental and second-harmonic wavelengths with respect to temperature equal to about or higher than  $10^{-4}/^{\circ}\text{C}$  (see D1, Figure 1: KNbO<sub>3</sub> crystal, this material also used in the present application necessarily having the claimed temperature dependencies of the refractive indices; see also TABLE 1 of the present application) so that a primary incident light can be shifted to a second harmonic wave having a wavelength of a half the wavelength of said primary incident light; and

- a thermoelectric element consisting of a Peltier effect element in contact with said optical light wavelength shifter element (see D1, page 216, last paragraph of right-hand column and Figure 1: temperature controller of Peltier type in contact with KNbO<sub>3</sub> crystal).

Although the laser wavelength is stabilised in D1 by additional measures (i.e. by operating the laser at constant drive current and constant temperature; see D1, page 216, right-hand column, last paragraph and page 217, left-hand column, last paragraph), the known light wavelength shifter device would also be **suitable for** a lightbeam from a semiconductor laser of which a deviation of wavelength of output light is allowed since the phase matching condition  $N_{\omega} = N_{2\omega}$  can be preserved in the case of laser wavelength changes by controlling the temperature of the nonlinear optical crystal as can be seen from Figures 1 and 4 of D1. In Figure 4 of D1, it is demonstrated that phase matching can be achieved over a broad range of fundamental wavelengths by tuning the temperature of the KNbO<sub>3</sub> crystal.

4.1.3 Thus, the claimed method differs from the closest prior art in substance only in that

(i) the optical light wavelength shifter element is of waveguide type having a core of said nonlinear optical crystal and a cladding in contact with the core whereas a bulk nonlinear optical crystal is used in D1; and in that

(ii) said different refractive indices ( $N_x$ ,  $N_{2x}$ ) of the nonlinear optical crystal due to a variation of the wavelength of the output light from the semiconductor laser are made equal to each other by varying the temperature of the wavelength shifter element whereas - as has been pointed out above - the wavelength of the semiconductor laser which normally fluctuates (and could also be temperature tuned; see D1, page 216, right-hand column, last paragraph) is expressly stabilised in D1. Therefore, in D1 for preserving the phase matching condition in case of a stable wavelength of the semiconductor laser, the temperature of the nonlinear crystal must also be kept stable, i.e. at  $-34^{\circ}\text{C}$  under the specific conditions of D1.

4.1.4 In consequence, the technical problem solved by these differences could be seen in achieving highly efficient second harmonic generation in case of a non-stabilised semiconductor laser wavelength (see the present application, page 3, second and third paragraphs).

In the Board's view, the formulation of this problem cannot contribute to patentability since - without any additional measures - the wavelength of a conventional semiconductor laser must be expected to vary (as can be seen from D1) and therefore will inevitably affect an

efficient second harmonic generation under phase matching conditions which are met for a particular wavelength only (see also page 3, second paragraph of the present application in this respect).

- 4.1.5 Although document D1 uses a stabilised semiconductor laser source, it gives a clear hint as to how efficient second harmonic generation can be achieved in case of a variation of the fundamental input wavelength: with the aid of a tunable dye laser it is demonstrated in D1 that the phase matching condition may be preserved over a broad range of input wavelengths by varying the temperature of the nonlinear optical crystal so that  $N_w$  remains equal to  $N_{2w}$  (see D1, Figure 4 and associated text).

Therefore, it cannot be considered inventive to maintain efficient second harmonic generation by temperature tuning of the nonlinear crystal in case of a change in the fundamental wavelength. This general possibility would also readily occur to a skilled person in the more particular case of wavelength variations of a semiconductor laser if laser stabilisation is not considered desirable or feasible. In consequence, feature (ii) relates to an obvious application of the general teaching of document D1.

Having regard to feature (i), a skilled person would have expected an enhancement of second harmonic generation by incorporating a waveguide structure comprising a core and a cladding in contact with the core, in nonlinear optical crystals as suggested in document D3 (see D3, page 572, left-hand column, paragraphs 1 and 2, and the paragraph bridging the left-hand and right-hand columns on this page). Therefore, in order to further improve the efficiency of second harmonic generation, use of a waveguide configuration for the light wavelength shifter element

would be obvious to an expert as an additional fully independent measure. The fact that such waveguide structures are feasible with nonlinear optical materials having the claimed temperature dependencies of the refractive indices can be seen from document D2 disclosing a potassium niobate waveguide for second harmonic generation with semiconductor lasers.

- 4.1.6 The appellant's view that the effect of a variation of the laser wavelength on the refractive index of the nonlinear optical crystal was not disclosed in the prior art, cannot be shared since this effect is fundamental and relates to the well-known phenomenon of dispersion, i.e. the dependency of the refractive index of an optical material on the wavelength of light leading *inter alia* to the familiar spectral splitting of white light by prisms (see also D1, page 215, middle of right-hand column in this context).

Although the "effective" refractive index is not explicitly referred to in documents D2 and D3 dealing with waveguide structures, the Board is convinced that an average practitioner is well aware of the fact that the conventional refractive index of bulk material is to be replaced by the effective refractive index in waveguides. This conviction led the Board to the conclusion that the initially used term "equivalent refractive index" may be corrected to read "effective refractive index" (see item 2 above; otherwise, i.e. if a skilled person were not fully aware of this fact, the said amendment would offend against Article 123(2) EPC and would therefore not be admissible).

Even if the cited documents are rather old and relate to experimental arrangements, these documents would be reconsidered by an average practitioner in case of need for recent applications, as e.g. optical recording

apparatus, and there are no grounds apparent why the subject matter **as claimed** should be more "practical" than those "experimental arrangements".

Finally, potassium niobate has already been used in the prior art in a waveguide configuration (see D2) and as a nonlinear optical material having an advantageously high temperature dependency of the refractive indices for broad range phase matching (see D1, Figure 4).

Although the claim refers to nonlinear optical materials having an even higher  $\Delta n_T$ , it is neither apparent from the present application nor from the available prior art that such materials exist. Therefore, this reference in the claim would be a mere invitation to a search programme with unknown prospects of success, and thus cannot be used as a basis for proving the existence of an inventive step.

4.1.7 In consequence, the subject matter of the claim according to the main request lacks the inventive step required by Articles 52(1) and 56 EPC, and the claim cannot be considered allowable for this reason.

#### 4.2 Auxiliary request

4.2.1 As can be readily derived from the discussion in items 4.1.1 - 4.1.3 above, the subject matter of the claim according to the auxiliary request differs from the closest prior art, i.e. document D1, in substance by

- feature (i);
- by the Peltier effect element being in contact with the cladding; and
- by providing a channel-type shifter element, in which the core is surrounded by the cladding.

In this context, attention is drawn to the fact that in D1 the thermoelectric element is already operative to place said nonlinear optical crystal at a temperature ( $-34^{\circ}\text{C}$ ) whereat said refractive indices ( $N_{\omega}$ ,  $N_{2\omega}$ ) are equal to each other.

- 4.2.2 Hence, the technical problem to be solved by these differences may be seen in providing a highly efficient light wavelength shifter device suitable for a lightbeam from a non-stabilised semiconductor laser (see page 3, third paragraph of the present application).

Again, the formulation of this problem is not supporting patentability for reasons analogous to those given in item 4.1.4 above.

- 4.2.3 As has also been pointed out in detail above, use of a waveguide structure (feature (i)) would be obvious to a skilled person from document D3 in view of the problem posed.

Moreover, from the fabrication process of the three-dimensional  $\text{LiNbO}_3$  waveguide structure described in D3 (see the paragraph bridging the left-hand and right-hand columns of page 572: Ti in-diffusion into a c plate at  $1050^{\circ}\text{C}$  for 20h), it must be assumed that a channel-type shifter element having a core (dimension about  $5\ \mu\text{m}$ ) surrounded by the cladding is provided in D3 as well. Since the prior art waveguide is mounted on a copper block whose temperature is controlled with a thermoelectric element (see D3, page 572, left-hand column, third paragraph), the thermoelectric element must also be in contact with said cladding.

Moreover, attention is drawn to document D2 disclosing potassium niobate waveguide structures resulting *inter alia* from in-diffusion or out-diffusion or ion implantation processes, and therefore - without the indication of any particular additional measures - must also be of channel-type having a central core surrounded by a cladding.

Thus, by directly employing a standard configuration for optical waveguides as described in the available prior art, a skilled person would arrive at the subject matter of the claim in accordance with the auxiliary request without exercising inventive skill.

4.2.4 The appellant referred to an advantage of the channel-type waveguide structure having regard to temperature control and homogeneity in this context. However, such an advantage has not been disclosed in the original application documents, and even if it were taken into account would be automatically achieved by merely following the teaching of the prior art.

4.2.5 In consequence, the single claim according to the auxiliary request is also not allowable (Articles 52(1) and 56 EPC).

**Order**

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

The appeal is dismissed.

The Registrar:

The Chairman:

P. Martorana

E. Turrini