**Internal distribution code:**

(A) [ - ] Publication in OJ
(B) [ - ] To Chairmen and Members
(C) [ - ] To Chairmen
(D) [ X ] No distribution

# Datasheet for the decision of 14 October 2015

**Case Number:** T 0385/11 - 3.4.02

**Application Number:** 97112357.5

**Publication Number:** 0859262

**IPC:** G02F1/03, G02F1/225

**Language of the proceedings:** EN

**Title of invention:**
Optical modulator

**Applicant:**
FUJITSU LIMITED

**Headword:**

**Relevant legal provisions:**
EPC 1973 Art. 56

**Keyword:**
Inventive step - (yes)

**Decisions cited:**

**Catchword:**

Europäisches Patentamt
European Patent Office
Office européen des brevets

**Beschwerdekammern**
**Boards of Appeal**
**Chambres de recours**

European Patent Office
D-80298 MUNICH
GERMANY
Tel. +49 (0) 89 2399-0
Fax +49 (0) 89 2399-4465

**Case Number: T 0385/11 - 3.4.02**

# D E C I S I O N
# of Technical Board of Appeal 3.4.02
# of 14 October 2015

| | |
|---|---|
| **Appellant:** (Applicant) | FUJITSU LIMITED<br>1-1, Kamikodanaka 4-chome,<br>Nakahara-ku<br>Kawasaki-shi,<br>Kanagawa 211-8588 (JP) |
| **Representative:** | Hoffmann Eitle<br>Patent- und Rechtsanwälte PartmbB<br>Arabellastraße 30<br>81925 München (DE) |
| **Decision under appeal:** | **Decision of the Examining Division of the European Patent Office posted on 13 September 2010 refusing European patent application No. 97112357.5 pursuant to Article 97(2) EPC.** |

**Composition of the Board:**

| | |
|---|---|
| **Chairman** | B. Müller |
| **Members:** | F. Maaswinkel |
| | A. Hornung |

## Summary of Facts and Submissions

I. The appellant lodged an appeal against the decision of the examining division refusing European patent application number 97112357.5. This patent application relates to an optical modulator.

In the decision it was held that the subject-matter of claim 1 according to the Main Request then on file did not comply with the provisions of Article 84 EPC and Article 123(2) EPC. The subject-matter of claim 1 according to the Auxiliary Request did not involve an inventive step within the meaning of Article 56 EPC having regard to the combined disclosures in documents D1 and D4:

D1: JP 03 145623 A
D4: JP 08 194195 A

II. With the letter setting out the grounds of appeal the appellant requested to set aside the decision and to grant a patent on the basis of the sets of claims according to the Main Request or of the claims according to the First or Second Auxiliary Request, all requests filed with this letter. The appellant also filed an auxiliary request for oral proceedings in the event that the board was not prepared to allow the Main Request. The Main Request comprises the following documents:

Claims: 1 to 8, filed on 20 January 2011 with the letter containing the grounds of appeal;
Description: pages 1 to 7, 15 to 25 and 28 to 40 as originally filed;
pages 8, 13 and 14, filed on 10 September 2008;
pages 9, 9a, 9b, 12 and 27, filed on

8 September 2009;
pages 10, 10a, 10b, 11, 25 and 26 filed on 20 January 2011 with the letter setting out the grounds of appeal;
Drawings: sheets 1/17 to 17/17, as originally filed.

III. The wording of independent claim 1 of the Main Request reads as follows:

"An optical modulator comprising:

a substrate (1a) having electro-optic effect; an optical waveguide (4) of a Mach-Zehnder type, including an input waveguide (4a) for receiving direct current light, an output waveguide (4b) for outputting modulated signal light and two intermediate waveguides (4c, 4d) connected to said input waveguide via a Y-shaped splitting portion (R1) and connected to said output waveguide via a Y-shaped recombining portion (R2), formed on said substrate (la);

an electrode (2) formed on said substrate (la) for varying a refractive index of the intermediate waveguides (4c, 4d) in accordance with the variation of voltage applied to said electrode (2) to control light propagated in said optical waveguide (4) in such a manner that the direct-current light is modulated;

a driver (11) for varying the voltage applied to said electrode (2) to cause the direct current light to propagate in the intermediate waveguides (4c, 4d) in different modes, comprising:

a first mode in which direct-current light received from the input waveguide (4a) in an input mode is propagated in the intermediate waveguides (4c, 4d) in the same mode as the input mode, recombined at the Y-shaped recombining portion (R2) and input to the output waveguide (4b) as signal light in the same mode;

a second mode in which direct-current light received from the input waveguide (4a) in an input mode is propagated in the intermediate waveguides (4c, 4d) as lights with different phases, the lights with different phases are recombined at the Y-shaped recombining portion (R2) into light having a mode that differs from the input mode, and the light is radiated as radiation light to the inside of the substrate (1a);

an interference light generating means for making the radiation light radiated from said Y-shaped recombining portion (R2) into said substrate (1a) and signal light leaking from said optical waveguide (4) into the substrate (1a) interfere with each other in said substrate (1a) to generate interference light and outputting said interference light from an end surface of said substrate (1a) to space, wherein the interference light generating means comprises the Y-shaped recombining portion (R2) and the substrate (1a) in the vicinity of the Y-shaped recombining portion or the output waveguide (4b) and the substrate (1a) in the vicinity of the output waveguide (4b);

a photo-detector (5) for monitoring the interference light input from said interference light generating means via said space, the photo-detector (5) being disposed in a position to which the interference light is emitted, said position being about 550 to 750 µm lower than an end position of the output waveguide (4b), said end position being on the end surface of the substrate (1a); and a signal controlling circuit (10) for varying direct-current bias to be applied to said electrode (2) according to a change of the interference light monitored by said photo-detector (5) to control an operating point of said optical modulator ".

Claims 2 to 8 are dependent claims.

The claims of the Auxiliary Requests are not relevant for the purpose of the present decision.

IV. The appellant's arguments may be summarised as follows:

The Main Request comprises Claims 1 to 8 as filed during the Oral Proceedings on May 21, 2010 (whose compliance with Art. 123(2) was recognized at first instance), wherein Claim 1 has been amended to specify that the photodetector is disposed in a position that is about 550 to 750 µm lower than an end position of the output waveguide. Basis for this amendment is at lines 20 - 25 on page 26 of the patent application as filed. No other changes have been made. The claims of the Main Request are therefore considered to fulfill the requirements of Article 123(2) EPC.

The present invention as claimed concerns a Mach-Zehnder (MZ) type optical modulator comprising an input waveguide for inputting DC signal light; an output waveguide for outputting the modulated signal light; and two intermediate waveguides with electrodes for varying the refractive index of the intermediate waveguides. Such modulators are known from the prior art documents D1, D3 (= JP04024610A) and D4. The operating point of MZ modulators is controlled by the DC component of the bias applied to the modulator electrodes, resulting in outputting the modulated signal light (if the light modes propagating in the intermediate waveguides are in phase) or in outputting so-called radiation light (if the light modes are out of phase). The radiation light (or "leaking light") originates in the periodic scattering at the modulator’s Y-shaped recombining portion, see document D1 and paragraph [0003] of D4. The radiation light can be monitored and used to control the operating point of the optical modulator, but it is

scattered out of the plane of the Y-shaped coupler at a very small angle of typically 1°-2° (see the upper right hand column on page 4 of document D3). As a consequence of the limitation of the length of the output waveguide that is imposed by practical requirements, it was expected by those working in the field that the positions at which the radiation light and the signal light (from the output waveguide) would emerge on the surface of the substrate would be separated by a very small distance, thus requiring the optical fibers and/or detectors for collecting these lights to be positioned very close to one another. This requirement led to difficulties in fabricating a system for detecting both the signal light output from the output waveguide and the radiation light output from the substrate, particularly as the photodetector fibers are typically spaced apart by only 80 µm.

The present inventors have found that the radiation light radiated from the Y-shaped recombining portion interferes significantly with a component of the signal light leaking from the output waveguide to produce an interference light, which can be detected by a photo-detector at a surprisingly large distance below the end position of the output waveguide, namely by disposing the photodetector at a distance of 550 to 750 µm lower than an end position of the output waveguide, which distance was previously believed to be too great to permit the radiation light to be detected effectively.

Present Claim 1 differs from Claim 1 of the Auxiliary Request filed on May 21, 2010 in that it requires that the photo-detector is positioned about 550 to 750 µm lower than an end position of the output waveguide in order to detect the emitted interference light (c.f. the previously recited single value of "about 750 µm").

Claim 1 of the aforementioned Auxiliary Request was considered by the examining division to lack an inventive step over the combination of documents D4 and D1, for the reasons set out in sections 4 - 8 of the reasons for the decision. In the following, reference is made to the computer-generated English language translation of D4, which is available from the Japanese Patent Office.

Firstly, it is noted in connection with the comments in sections 4.2 and 6 of the decision that although the two loss mechanisms identified by the examining division (namely, the radiation of light from the Y-junction 16 and the leakage of signal light caused by the curvature of the output waveguide 17 shown in Fig. 1) can indeed be considered to operate in the optical modulators of D4, it does not follow that the so-called "break-through light" (labeled 19, 31 and B in Figs. 2, 5 and 8) represents the interference of the lights generated by these loss mechanisms. In this regard, it is observed that the core teaching of D4 is to remove the symmetry in the conventional arrangement of a Y-junction 6 and an output waveguide 7 of an optical modulator (as shown in Fig. 7), by either introducing a curvature of some form into the output waveguide (as in Fig. 1) or by skewing the direction of the output waveguide with respect to the Y-junction (as in Fig. 6), and thereby in either case allow the signal light to be guided by the output waveguide to a location further removed from where the radiation light (i.e. the "break-through light") emerges on the end surface of the substrate. However, destroying the symmetry of the conventional arrangement also removes the symmetry in the conventional radiation patterns caused by the above-mentioned loss mechanisms, and would thus be expected to diminish or destroy any interference effect that might have been inherent in the

conventional arrangement. Thus, in this respect D4 teaches away from the subject-matter of Claim 1.

As regards the existence of such interference in the optical modulators described in D4, it is firstly noted that Figs. 2, 5 and 8 show essentially identical break-through light distributions (see 19, 31 and B), suggesting that the loss mechanisms introduced in the examples of Figs. 5 and 8 do no affect the observed intensity distribution of the radiation light. In this context, the appellant also observed that contrary to the assertion in section 6 of the reasons, the beam waist of the break-through light B shown in Fig. 9 is not noticeably different from the waists of beams 19 and 31 in Figs. 3 and 6. This assertion appears to follow from an interpretation of Fig. 9 that overlooks the disclosure in Fig. 8 of the "output ray" A being emitted from a position above the region where the break-through light B emerges on the end surface 1A of the substrate 1. In other words, the output ray A overlies the break-through light B in plan view of the device (as shown in Fig. 9), such that a part of the breakthrough light B is obscured in this view by the output ray A. Thus, Fig. 9 does not disclose two break-through light beams each having a smaller beam waist than beams 19 and 31, as the remarks in section 6 of the decision would appear to suggest.

Accordingly, D4 provides no explicit or implicit disclosure of the break-through light being a product of the interference between the light radiated from the Y-junction and light leaking from the output waveguide, and discloses nothing at all that would cause the skilled person to dispose a detector in a position to which the interference light is emitted, much less a position which is about 550 to 750 µm lower than the end

position of the output waveguide, as required by Claim 1.

Section 4.2.2 of the reasons for the decision alleges that the skilled person would solve the objective technical problem of "sufficiently separating the photodetector from the output position of the signal light by a predetermined, desired distance" in the manner formerly claimed (thus disposing the photo-detector about 750 µm from the output position of signal light) simply by following the teachings of D4. In particular, the equation in par. [0022] and a knowledge of trigonometry are alleged to enable the skilled person to determine the required position of the photo-detector in relation to the end of the output waveguide on the end surface on the substrate.

Regarding the equation in par. [0022], it is noted that although the variable "y" has been correctly identified in section 4.2.2 as "the displacement of the output waveguide from the longitudinal axis passing along the output Y-junction 16", it appears that this displacement can be equated with "the separation between the light 19 to be monitored and the signal light 18" (as the remarks in the 4th paragraph of section 4.2.2 appear to suggest) only if the light to be monitored (i.e. the break-through light) is assumed to be emitted from a location on the end surface of the substrate that is independent of the length of the output waveguide and directly below the aforementioned longitudinal axis. This, however, would be contrary to the division's allegation that the monitored light can be regarded as the interference light of present Claim 1, as well as the disclosure in Figs. 2 and 8. Furthermore, the statement that the "...effect of the choice of the length Z on the separation [y] between the light 19 to be monitored and

the signal light 18 can be appreciated by comparing the light distribution (shown in figure 2) achieved in the device of figure 1 with that achieved by the device of figure 4 (the corresponding distribution is shown in figure 5)" cannot be followed also because Figs. 1 and 4 relate to modulators having differently shaped output waveguides (the shape of the former being given by the equation in par. [0022], and the latter being described in par. [0029] as an arc of a circle), with no indication being given of the length Z in the description of Fig. 1.

In summary, document D4 only discloses a lateral separation of the break-through light from the signal light on the end surface of the substrate of 300 µm in the example shown in Fig. 1 (see par. [0023]), and 350 µm for the Fig. 4 example (see par. [0030]). However, D4 does not teach the skilled reader how to achieve other values of the lateral separation.

In connection with the comments in section 4.2.2 of the decision concerning the determination of the separation "Y" of the signal and break-through lights in the depth direction of the substrate, the appellant notes that the discussion in D4 focuses on various means of modifying the lateral separation of the lights (i.e. in the "y"-direction), with no mention being made of the separation along the "Y"-direction (i.e. in depth direction of the substrate). It therefore appears that the statement "...and spreads in the angle of divergence of about 3 times focusing on the multiplexing part 16" (which the applicant notes is more accurately translated as "...spreads from the coupler 16 as the center so as to have a 3° angle with respect to the coupler 16") in par. [0020] would be understood by the skilled reader to refer, in the context of D4, to the divergence in the

aforementioned lateral "y"-direction of the two light beams constituting the "break-through light", for example as shown in Figs. 2, 5 and 8.

As a more general point, a skilled person tasked with overcoming the fabrication problems that are inherent in known optical modulators, for example as disclosed in D4, is provided with a number of possible solutions in the cited documents D1, D3 and D4. For example, D3 suggests the use of a reflecting element (see 4 or 40 in Fig. 2 of D3) to allow a photo-detector (5) to be disposed on the back of the device substrate (1). However, none of the documents discloses or provides any hint at overcoming the aforementioned drawbacks of the prior art in the simple and elegant way taught in the present application; namely, by exploiting the interference between the leaking signal light and the radiation light in the substrate. Therefore the claimed subject-matter is novel and involves an inventive step.

## Reasons for the Decision

1. The appeal is admissible.

2. Amendments

The claims of the present Main Request are based on the set of claims of the prior Auxiliary Request, against which the examining division had not raised any objections under Article 123(2) EPC. The added feature concerning the position of the photodetector finds its basis at page 26, l. 20 - 25 of the patent application as filed. Therefore the application documents comply with the provisions of Article 123(2) EPC.

3. Patentability

3.1 Novelty - Claim 1

3.1.1 Claim 1 defines a Mach-Zehnder (MZ) type optical modulator. As recognised by the appellant such modulators are disclosed in prior art documents D1, D3 and D4. Prior art MZ-modulators comprise optical waveguides and electrodes on a substrate having an electro-optical effect as defined in Claim 1. A driver applies voltages on the electrodes to modulate the incident DC light beam in order that the light beam is output as a signal light in a first mode if the applied voltage is such that the light beams in the intermediate waveguides are in phase; and in a second mode if the applied voltage is such that the light beams in the intermediate waveguides are out of phase. In the latter case these beams, upon recombination at the Y-shaped recombining portion, propagate to the inside of the substrate as radiation modes. These features are common to this type of modulators. For instance, in document D4 the signal light A and the radiation mode B (also designed as "leakage light") are illustrated in Fig. 8 in the context of a prior art device shown in Fig. 7. The temporal behaviour of the signal light and the radiation light is shown as curves M and N in Fig. 9 of the patent application; and, similarly, as curves (1) and (2) in Fig. 1(c) of document D3.

3.1.2 Claim 1 defines that the MZ-modulator comprises "interference light generating means" by which, in addition to the modulated signal light and the radiation mode, a further light signal is generated. This signal is generated by the interference of the radiation mode propagating in the substrate and signal light leaking from the output waveguide. According to Claim 1, the

interference light generating means comprises the Y-shaped recombining portion and the substrate in the vicinity of the Y-shaped recombining portion or the output waveguide and the substrate in the vicinity of the output waveguide.

3.1.3 Since all prior art MZ-modulators comprise substrates having a Y-shaped recombining portion and an output waveguide, basically prior art MZ-modulators should also show the interference phenomenon described in the present patent application.

3.1.4 Document D4 does not explicitly address a photodetector. In the prior art, see e.g. document D1, a photodetector is commonly used for detecting the radiation mode light in a feedback loop for detecting drift and stabilising the working point of the modulator. Document D4 explicitly refers to D1 for using the radiation mode or leakage light as feedback light (see par. [0006]), see also par. [0027] of D4).

3.1.5 Document D4 does not disclose the feature that the photodetector is disposed in a position to which the interference light is emitted, said position being about 550 to 750 µm lower than an end position of the output waveguide, said end position being on the end surface of the substrate.

3.1.6 Hence, the subject-matter of Claim 1 is novel over the disclosure in document D4. The feature addressing the particular position of the photodetector is also not known from the further documents in the proceedings.

3.1.7 It is concluded that the subject-matter of Claim 1 is novel (Art. 54 EPC 1973).

3.2 Inventive step

3.2.1 The feature of the positioning of the photodetector about 550 to 750 µm lower than an end position of the output waveguide in order to detect the interference light solves the technical problem of overcoming the disadvantage of prior art MZ-modulators, discussed in the context of Figures 29 - 31 of the patent application: in the prior art a shift or drift of the operating point was detected by using the radiation mode light signal, which exits the device at a distance of typically less than 150 µm (Figure 4 of document D1 discloses a required distance between the cores of fibres 5 and 6 of 130 - 150 µm; according to page 8, line 20, of the original patent application, in the prior art show in Figure 29, the optical fibre 106 and the waveguide 104 are spaced only about 80 µm apart).

3.2.2 The finding in the patent application that the radiation mode couples coherently with the leaking light signal and generates an interfering signal in the vicinity of the Y-shaped recombining portion and along the output waveguide is not disclosed in the available prior art documents, nor is it known that the interference signal is emitted at a position being about 550 to 750 µm lower than an end position of the output waveguide.

3.2.3 It is also not known from the prior art that this interference signal may be used in the signal controlling circuit for varying the bias applied to the electrodes in order to control the operation point of the modulator. In fact it appears from the data in Figure 6 of the patent application that the normalised interference signal $R_{DC}$ is typically only 1% of the amplitudes of the modulated light signal and the radiation mode signal (cf. Fig. 9 of the patent

application). This may be the reason that this signal is not disclosed in the prior art.

3.2.4 In paragraph 2 at page 10 of the decision the examining division had argued that the light 19 at the output face 11A (shown in Fig. 2 of document D4) was a result of interference between the radiation mode and the signal light leaking into the substrate, therefore the light 19 was the "interference light".

3.2.5 In the opinion of the board the available data does not offer any basis for such a hypothesis: rather the output distribution of the radiation mode is as shown in Fig. 8 of the patent application (symbol "S"); or as shown in Fig. 8 of document D4 as "B"; and more in detail as in Figs. 12, 15, 18 and 21 of the patent application, where the maximum of the radiation mode pattern is between 100 and 200 µm below the substrate surface. It is also observed that in all prior art documents similar values for the distance or angle of the radiation mode below the substrate surface are disclosed: see Figures 2 and 4 of D1, in which the distance between the cores is 130 - 150 µm; document D3, page 4, indicating an angle between the emitted radiation mode and the waveguide of 1-2°; and Figures 2, 5 and 8 of document D4, in which the radiation mode 19, 31 or B is close below the substrate surface (to be compared with the horizontal distance between the radiation modes and the output waveguide, which in case of Figure 2 in D4 is 300 µm, see [0023], and in case of Figure 5 is 350 µm, see [0030]).

In comparison the interference light has its maximum at 550 to 750 µm below the substrate surface (Figs. 13, 16, 19 and 22).

3.2.6 In this respect the board concurs with the appellant that the teaching of document D4 is to obtain a larger - horizontal - separation between the modulated output signal and the radiation mode by introducing a curvature or by skewing the direction of the output waveguide. Such a design has the direct consequence that the overlap distance between the propagating leaking signal in the waveguide and the radiation mode at which a coherent coupling and thereby interference is possible is reduced. Hence document D4 rather teaches away from the idea of using the interference signal for the photodetector.

3.3 Therefore the subject-matter of Claim 1 involves an inventive step.

4. Claims 2 to 8 are dependent claims and therefore their subject-matter is equally inventive.

5. For the above reasons, the board finds that the appellant's Main Request meets the requirements of the EPC and that a patent can be granted on the basis of the Main Request.

**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 based on the following documents:

Claims: 1 to 8, filed on 20 January 2011 with the

letter setting out the grounds of appeal;
Description: pages 1 to 7, 15 to 25 and 28 to 40
as originally filed;
pages 8, 13 and 14, filed on
10 September 2008;
pages 9, 9a, 9b, 12 and 27, filed on
8 September 2009;
pages 10, 10a, 10b, 11, 25 and 26 filed on
20 January 2011 with the letter setting
out the grounds of appeal;
Drawings: sheets 1/17 to 17/17, as originally filed.

The Registrar: The Chairman:

M. Kiehl B. Müller

Decision electronically authenticated

Europäisches Patentamt
European Patent Office
Office européen des brevets

**Beschwerdekammern**
**Boards of Appeal**
**Chambres de recours**

European Patent Office
D-80298 MUNICH
GERMANY
Tel. +49 (0) 89 2399-0
Fax +49 (0) 89 2399-4465

**Case Number: T 0385/11 - 3.4.02**

# D E C I S I O N
# of Technical Board of Appeal 3.4.02
# of correcting an error in the decision
# of 14 October 2015

| | |
|---|---|
| **Appellant:** (Applicant) | FUJITSU LIMITED<br>1-1, Kamikodanaka 4-chome,<br>Nakahara-ku<br>Kawasaki-shi,<br>Kanagawa 211-8588 (JP) |
| **Representative:** | Hoffmann Eitle<br>Patent- und Rechtsanwälte PartmbB<br>Arabellastraße 30<br>81925 München (DE) |
| **Decision under appeal:** | **Decision of the Examining Division of the European Patent Office posted on 13 September 2010 refusing European patent application No. 97112357.5 pursuant to Article 97(2) EPC.** |

**Composition of the Board:**

**Chairman** B. Müller
**Members:** F. Maaswinkel
A. Hornung

In application of Rule 140 EPC the decision given on 14 October 2015 is corrected as follows:

- On page 16, change "pages 1 to 7, 15 to 25" into "pages 1 to 7, 15 to 24"

The Registrar: The Chairman

M. Kiehl B. Müller

Decision electronically authenticated