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Datasheet for the decision of 31 August 2007

Case Number: T 1252/04 - 3.4.02

Application Number: 02002176.2

Publication Number: 1255136

IPC: G02B 6/122

Language of the proceedings: EN

Title of invention:
Phototonic crystal waveguide turnable by a resonant stub

Patentee:
Avago Technologies General IP (singapore) Pte. Ltd.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 52(1), 54, 56

Keyword:
"Decision based on the file as it stands"

Decisions cited:
-

Catchword:
-

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Case Number: T 1252/04 - 3.4.02

D E C I S I O N
of the Technical Board of Appeal 3.4.02
of 31 August 2007

Appellant: Avago Technologies General IP (Singapore) Pte. Ltd.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 22 June 2004 refusing European application No. 02002176.2 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: A. Klein
Members: F. Maaswinkel
C. Rennie-Smith

Summary of Facts and Submissions

I. European patent application No. 02002176.2 relating to a photonic crystal waveguide apparatus was refused in a decision, dispatched on 22 June 2004, of the examining division on the ground that the subject-matter of the claims then on file did not involve an inventive step (Art. 52(1) and 56 EPC) in view of the teachings in the following documents:

D1: Optical and Quantum Electronics, vol. 32, pages 947 - 961 (2000); R. Stoffer et al.: "Numerical Studies of 2D photonic crystals: Waveguides, coupling between waveguides and filters";

D2: Physical Review Letters, vol. 80, pages 960 - 963 (1998); S. Fan et al.: "Channel Drop Tunneling through Localized States";

D3: WO-A-98/26316.

II. Against this decision the applicant (appellant) lodged an appeal which was received on 8 July 2004 and paid the fee for the appeal on the same day. With the statement setting out the grounds of appeal filed on 14 October 2004 the appellant filed new claims according to a main and an auxiliary request. The appellant requested that the decision under appeal be set aside and the newly filed claims be allowed or, alternatively, oral proceedings. Furthermore, repayment of the appeal fee was requested.

III. The wording of claim 1 according to this main request reads as follows:

"A photonic crystal waveguide apparatus (40, 60, 70), comprising:
a photonic crystal (42) including a periodic lattice (46),
a waveguide (44) in said photonic crystal (42) which is capable of transmitting light having a frequency within a bandgap of said photonic crystal (42), and
a resonant stub (47) connected to said waveguide (44) to control light in the waveguide (44);
wherein said resonant stub (47) comprises a resonator region (48) and a connecting channel (50) connecting said resonator region (48) and said waveguide (44)".

IV. In support of the main request the appellant developed the following arguments in the letter of 14 October 2004:

The subject-matter of claim 1 is based on the features of original claims 1, 2 and 4, which defined a photonic crystal comprising a periodic lattice. The features of this claim are new over the disclosures of documents D1, D2 and D3. In particular, D1 discloses a two-dimensional photonic crystal having removed either a single rod directly adjacent a crystal waveguide, or three rods, in order to create a side branch, as shown in Fig. 11 of D1, or having a cavity of three rods moved down one rod and having introduced an extra rod (Fig. 14). This latter disclosure, however, may not be considered a resonant stub comprising a resonator region and a connecting channel as disclosed e.g. in Fig. 4 of the description of the present patent application, where the channel is defined by removed rods and the resonator comprises a width which is larger than the channel. Document D2 discloses an

analysis of a tunneling process through localized states between two waveguides in a photonic crystal structure. The coupling of the waveguides is achieved by introducing two distant rods between the waveguides having a reduced radius. In addition, the dielectric constant of four specific rods is reduced (Fig. 2). This document discloses neither a resonator region nor a connecting channel as a resonant stub but a coupling element between two waveguides consisting of a row of modified rods. D3 discloses a tunable micro-cavity using nonlinear materials in a photonic crystal. A waveguide or a resonant stub is not disclosed in this document. Therefore the invention as defined in claim 1 is new.

By providing a resonant stub comprising a resonator region and a channel connecting this region and the waveguide of the photonic crystal apparatus the resonant frequency (frequency of the transmission zero) of the resonator region can be controlled by controlling its parameters. In addition, by controlling the parameters of the connecting channel, the coupling (bandwidth of the transmission zero) between the resonator region and the waveguide can be controlled. This concept is not rendered obvious by any of the documents D1 to D3 alone or in combination. In particular, document D1 describes a simplified theoretical model of a 2D-photonic crystal not having any practical application purpose. It does not address the tuning of the frequency of the transmission zero which, according to the present invention, is controlled by the resonator parameters. Document D2 relates to a completely different system than the apparatus of the invention, since that system is based

on two waveguides and two cavities between the waveguides. That system is designed to accomplish a complete transfer between the waveguides by creating resonant states of different symmetry and by forcing an accidental degeneracy between them. Document D2 does not address any aspects with respect to a tunable waveguide apparatus. Since this document does not mention anything relevant going beyond the teaching of D1 with respect to a resonant stub comprising a resonator region and a connecting channel, a combination of D1 and D2 does not render obvious the subject-matter of claim 1 of the main request. Document D3 discloses a tunable micro-cavity using nonlinear materials in a photonic crystal and does not disclose a waveguide apparatus. Therefore the present invention may not be rendered obvious by D3 alone or in combination with D1 and/or D2.

V. In a communication pursuant to Article 11(1) RPBA, dated 11 January 2007 and accompanying the summons to oral proceedings on 23 March 2007, the board expressed the following provisional opinion:

i) *The request for refund of the appeal fee*:
The letter of 13 October 2004 does not contain any substantiation for this request. Furthermore the board could not find any indication of a substantial procedural violation in the proceedings. Therefore there appears to be no basis for reimbursement of the appeal fee.

ii) *Patentability*

Main request - Claim 1

Document D1, see Figure 14 and the associated description on page 959, discloses a photonic crystal waveguide comprising a photonic crystal including a periodic lattice (the regular arrangement of rods shown in Figure 14) and a waveguide capable of transmitting light having a frequency within the bandwidth of the photonic bandgap of the photonic crystal (see Figure 15). According to the appellant, the cavity shown in Figure 14 of D1 may not be considered as a resonant stub comprising a resonator region and a connecting channel as shown, for instance, in Figure 4 of the present patent application, where the connecting channel is defined by removing rods and the resonator comprises a width which is larger than the channel. However, claim 1 of the main request does not define any further restrictions in this respect: the resonant stub is defined as comprising a resonator region, which may be any cavity in which the electromagnetic waves may exhibit resonant behaviour, and a connecting channel, which in a generic sense is defined as enabling the connection/propagation of the electromagnetic waves from the waveguide to the resonator region (including via evanescent waves). Therefore it appears that the subject-matter of claim 1 is not new over the disclosure in document D1.

Dependent claims

The board does not concur with the opinion of the appellant that D1 would relate to only a numerical study "...not having any practical purpose" insofar as the plots shown in Figures 5 to 8 of the patent

application are also assumed to represent numerical (theoretical) results, which are of the same nature as the plots in D1 (see Figures 2, 4, 5, 6, 8, 9, 10, 12 and 15). Furthermore, as pointed out by the examining division in point 2.3 of the Communication of 22 July 2003, document D1 explicitly refers to document D2 for the concept of tuning and document D3 teaches to change the refractive index of nonlinear material in a resonant cavity of a photonic crystal in order to tune the frequency of the resonant mode (see page 5 of D3). Therefore, in order to adapt the filter characteristic shown in Figure 15 of D1 to his particular needs the skilled person would follow the teaching on page 956, second line, of this document and consider ways of tuning the cavity, as taught either by the explicit reference to document D2 ("Fan *et al*, 1998") or by other prior art in the field of photonic crystal such as document D3, which already mentions the tuning of a microcavity in its title. Since documents D2 and D3 show how various design parameters of a photonic crystal may be altered (D2: rods with different sizes and dielectric constants; D3: tuning of the resonant frequency by varying the refractive index) the skilled person would contemplate applying these teachings to the crystal waveguide in Figure 14 of document D1. Hence, the further features of the dependent claims do not appear to involve an inventive step.

iii) *Auxiliary request*

With respect to this request it is noted that claim 1 appeared to combine the features of claims 1 and 2 of the main request. The further claims 2 to 11 correspond to claims 3 to 12 of the main request. Therefore the

observations made for the claims of the main request apply similarly to the auxiliary request.

VI. In a reply of 22 February 2007 the appellant submitted new sets of claims according to a main and a first and second auxiliary requests.

The wording of claim 1 according to this new main request is as claim 1 according to the former main request (see point III supra) with, at the end of the new claim, the additional features:

"...wherein an extension of the resonator region (48) in a light transmission direction in which light is transmitted through said waveguide (44) is larger than an extension of said connecting channel (50) in said light transmission direction".

The wording of claim 1 according to the first auxiliary request is as claim 1 according to the former main request (see point III supra) with at the end of the new claim the additional features:

"...wherein said periodic lattice (46) comprises an array of posts (46) or gas-filled holes or evacuated holes, and
wherein the resonator region (48) extends across a length corresponding to a first number of posts or holes in a light transmission direction in which light is transmitted through said waveguide (44), wherein the connecting channel (50) extends across a length corresponding to a second number of posts or holes in said light transmission direction, and wherein the first number is larger than the second number".

The wording of claim 1 according to the second auxiliary request is as claim 1 according to the former main request (see point III supra) with at the end of the new claim the additional features:

"...wherein said periodic lattice (46) comprises an array of posts (46) or gas-filled holes or evacuated holes, and
wherein the resonator region (48) extends across a length corresponding to three posts or holes in a light transmission direction in which light is transmitted through said waveguide (44) and wherein the connecting channel (50) extends across a length corresponding to one post or hole in said light transmission direction".

VII. The further arguments of the appellant in this letter in support of its new requests can be summarised as follows:

The support for the additional features of claim 1 of the new requests is in Figure 4 and in the paragraph on page 13, lines 8 - 21 of the original description, where it is disclosed that the number of posts comprising the resonator region can be controlled in defining the resonance frequency and that the number of posts omitted from the channel can be controlled in defining the bandwidth of the transmission zero.

Claim 1 of the main request defines the extension of the resonator region in the light transmission direction as being larger than an extension of the connecting channel in the light transmission direction. This feature is not disclosed in the prior art. For

instance, the wavelength filter in Fig. 14 of D1 comprises a crystal waveguide with a three-rods-deep side branch with higher reflection coefficients at the junction to the waveguide. If, for sake of argument, one considers the extra rod as representing the connecting channel, the extensions of the connecting channel and the resonator region would be identical, so that this document does not anticipate the subject-matter of claim 1 of the main request. Documents D2 and D3 are totally silent about a combination of a waveguide, a connecting channel and a resonator region as defined in claim 1. By the features of this claim it is possible to adjust the frequency and the width of the transmission zero in a somehow separate manner, see, for example, page 4, line 25 to page 5, line 10, and page 13, lines 8 - 21. These arguments also apply to claim 1 of the auxiliary requests.

VIII. In a letter of 6 March 2007 the appellant withdrew its request for oral proceedings and requested that a decision be issued based on the file as it stands. In consequence the board by a notice of 13 March 2007 cancelled the oral proceedings.

Reasons for the Decision

1. The appeal is admissible.

2. *Main request*

2.1 *Amendments*

The board is satisfied that the additional features in claim 1 of the main request are fairly supported by the

passages in original description referred to by the appellant and in particular by Figure 4. This equally holds for claim 1 of the first and second auxiliary requests. Therefore these claims are not objectionable under Art. 123(2) EPC.

2.2 *Novelty*

2.2.1 According to the appellant, document D1 does not disclose the additional feature that an extension of the resonator region in a light transmission direction in which the light is transmitted through the waveguide is larger than an extension of the connecting channel.

2.2.2 However, in the communication of 11 January 2007 (*see point V.ii supra*) the board had expressed its opinion that that the cavity shown in Fig. 14 of document D1 represents a resonant stub (for this terminology see also the second sentence on top of page 959), including a resonator region and a connecting channel, which, in case of the embodiment in Fig. 14, is a channel in a generic sense, based on evanescent coupling. Therefore in this embodiment the extension of the resonator region in the light transmission direction has a length of one rod, and the extension of the connecting channel is zero, from which it follows that the embodiment in Fig. 14 of D1 anticipates the subject-matter of claim 1 of this request (Art. 52(1) and 54 EPC).

3. *First auxiliary request*

3.1 *Novelty*

3.1.1 Claim 1 according to this request defines the additional features that the lattice comprises an array of posts or gas-filled holes or evacuated holes; and that the resonator length in the direction of light transmission of the waveguide comprises a larger number of posts or holes in the light transmission direction than the length of the connecting channel in this direction.

3.1.2 With respect to the first feature, the device in document D1 comprises an array of silicon rods which is a special form of "posts" (see, for instance, page 8, line 19 of the original description of the present patent application). Furthermore, as discussed in point 2.2.2 supra, the length of the resonator region in the device of Fig. 14 in document D2 is one rod or posts, the length of the connecting channel is zero posts, therefore that device anticipates the subject-matter of claim 1 of this request as well.

4. *Second auxiliary request*

4.1 *Novelty*

4.1.1 Compared to claim 1 of the first auxiliary request, in claim 1 of this request it is further specified that the length of the resonator region in the direction of light transmission of the waveguide is three posts or holes; and that the connecting channel extends across a length corresponding to one post or hole. Since the

respective lengths in the device in Fig. 14 of D1 are one and zero, the subject-matter of claim 1 of this request is novel over the disclosure in D1.

4.1.2 A device with the features of claim according to this request is also not known from the other prior art documents, in particular D2 and D3. Therefore this subject-matter is new.

4.2 *Inventive step*

4.2.1 The subject-matter of claim 1 differs from the waveguide apparatus in Fig. 14 of document D1 in the number of posts of the resonator region in the direction of light transmission of the waveguide (three, compared to one post in the device of D1); and the length of the connecting channel (one post, compared to zero in D1). According to the appellant, by virtue of the features of this claim it is possible to adjust the frequency of the transmission zero and the width of the transmission zero in a somehow separate manner.

4.2.2 However, the board observes that the prior art already discloses that the transmission properties of a photonic crystal waveguide apparatus can be influenced by modifying the position and numbers of the posts: Section 5 of document D1 discloses different embodiments of a tunable notch filter (see page 956, line 5 of D1), which falls within the definition of a photonic crystal waveguide apparatus (see page 6, line 21 of the original description of the patent application). In the embodiment of Fig. 10 of D1 the notch filter is realised by removing a single rod or post directly adjacent the waveguide. As can be seen by

inspection of Fig. 10, the transmission minimum or zero wavelength lays at approximately 1.45 μm and the transmission width of the filter is still appreciable. In the last two lines on page 956 with reference to Fig. 11 it is disclosed that the free spectral range (and thus the position of the zero transmission frequency) can be modified by increasing the cavity depth to three rods, see also Fig. 12. Furthermore, by modifying the cavity in shifting the three-rod-deep, one-rod-wide cavity one layer away from the waveguide, thus establishing the coupling to the waveguide by evanescent coupling (Fig. 14), it is possible to modify the filter characteristic of Fig. 12 by reducing the width of the transmission zero frequency.

4.2.3 In the opinion of the board, this shows that document D1 gives a clear teaching to the skilled person that the filter properties, in particular the width and position of the transmission zero, of notch filters based on photonic crystal waveguide apparatuses can be tuned by modifying the position and number of posts in the waveguide and cavity. As already pointed out in the board's communication of 11 January 2007, in document D2, explicitly referred to on page 956, line 3 of D1, the filter properties can also be modified by reducing the radius of the rods or their dielectric constant. Document D3 discloses further tuning possibilities.

4.2.4 The subject-matter of claim 1 of this request differs therefore from the prior art notch filter in the selection of the extension of the resonator region and connecting channel. However, in the original application documents there is no information that this selection would result in a particular advantage in

comparison with other notch filters, such as those disclosed in D1.

4.2.5 Furthermore, as pointed out in paragraph 4.2.3, the idea of tuning the notch filter transmission zero position and width by selecting the position and size of the resonance cavity and the coupling to the waveguide was known from the prior art (D1).

4.2.6 Therefore the board finds that the subject-matter of claim 1 of this request does not involve an inventive step (Art. 52(1) and 56 EPC).

5. In summary, none of the independent claims according to the requests on file are allowable. Furthermore the board had pointed out in its previous communication that also the features of the dependent claims did not appear to involve an inventive step. Consequently, the appellant's requests must be refused.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

M. Kiehl A. G. Klein