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(54) Title: OPTICAL BOOSTING OF AMPLIFICATION AND ABSORPTION VIA MDM

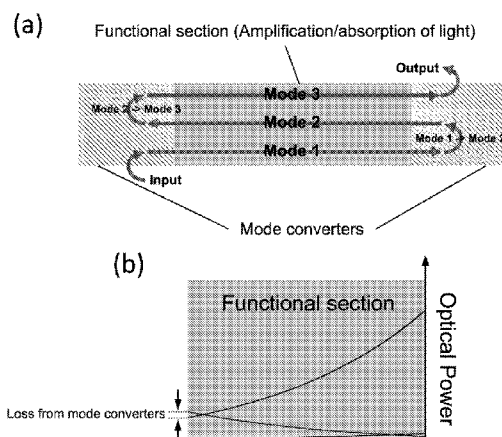


Fig. 1

(57) Abstract: The photonic device comprises a mode converter and a converter coupling means to offer a form of mode-division multiplexing (MDM), such that light interacting with the functional section may be converted into a different transversal mode by the mode converter, and may be multiplexed back into the functional section by the converter coupling means. The light may then interact with the functional section again, thus boosting the interaction length between the light and the functional section, thus boosting optical amplification or absorption as desired. Optionally, this process may be repeated several times, and each time the light passes through the functional section in a different transversal mode, a further boost may be experienced. Finally, the light may be converted back to the fundamental mode at the output.



Optical boosting of amplification and absorption via MDM

TECHNICAL FIELD

- 5 The present disclosure generally relates to a photonic device. Particular embodiments relate to a photonic device for light amplification and/or light absorption.

BACKGROUND

- 10 Optical amplification and absorption in waveguides can be used to make optical amplifiers and electro-absorption modulators. However, these devices are typically either long, inefficient, or cannot offer high optical extinction. This is because light only travels once through the functional section for light amplification or absorption, limiting the interaction strength.

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Many directions have been taken to improve light amplification and absorption:

1. Improved device design, such as optical confinement, better material, better heat sinking through thermal shunting, buried heterostructure, even using slow-light effect. These method works at device-level, so they are specific to certain technology
- 20 platforms. Besides, light still only passes through the functional material once.
2. Optical resonance such as ring and Fabry-Perot resonator-enhanced devices. They typically only work for selected wavelengths and can lead to uncontrolled oscillations and frequency selective circuit disturbances.
3. Reflective devices such as reflective optical amplifiers. However, an optical
- 25 circulator is needed to separate the input and output signal, which greatly limits their integrability. In addition, the device may become more sensitive to spurious reflections at the input/output side.

SUMMARY

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Disclosed herein are various generic circuit architectures for embodiments of a photonic device for optical amplification and absorption in waveguides using mode-division multiplexing (MDM). In these embodiments, the active medium can be used

more than one time, but without the disadvantages introduced in the prior art. For example, there is no inherent need for frequency-selective cavities or reflectors. In an example device for optical amplification, the operation may be described as follows, starting from the input: 1) light interacts with the functional section in mode 1; 2) light
5 get converted into another transversal mode by external mode converters, and get multiplexed back into the same functional section. The direction the light enters the functional section does not matter. 3) light interacts with the functional section again, boosting the interaction length. 4) The process 2) – 3) may be repeated, and each time light passes through the functional section in a different transversal mode. 5) Finally,
10 light may be converted back to the fundamental mode at the output.

In the context of optical amplification or absorption waveguides, a ‘functional section’ can be defined as a region of the waveguide where the desired optical function, such as amplification or absorption, takes place. This functional section can for example be
15 realized by incorporating an appropriate material, such as a rare-earth-doped fiber or a semiconductor quantum well, into the waveguide structure. The length and position of the functional section can be carefully designed and optimized to achieve the desired performance characteristics of the device. For example, in an erbium-doped fiber amplifier (EDFA), the functional section is typically a length of fiber doped with
20 erbium ions. When pumped with a suitable wavelength of light, the erbium ions absorb energy and then transfer that energy to other nearby erbium ions, resulting in amplification of the optical signal passing through the fiber.

In summary, the functional section of an optical waveguide can be considered as the
25 region where the desired optical function is performed, and it can for example be achieved through the use of specially designed materials and careful design of the waveguide structure.

Since optical amplification and absorption are inherently an exponential process as a
30 function of the interaction length, the total gain or loss gets exponentially boosted by the aforementioned device.

In a first aspect, there is provided a photonic device for light amplification and/or light absorption, comprising:

- at least one functional section formed of an optical amplifier material and/or formed of an optical absorber material;

5 - at least one mode converter coupled to the at least one functional section and configured to:

- receive incoming light from the at least one functional section, wherein the incoming light is in a first mode;

10 - convert the received incoming light from the first mode to a second mode, the second mode being a different transversal mode than the first mode; and

- transmit the converted light towards the at least one functional section in the second mode, so as to allow the converted light to pass through the at least one functional section with reduced interference of the incoming light and the converted light within the functional section; and

15 - at least one converter coupling means configured to couple the at least one functional section to the at least one mode converter, in order to guide incoming amplified or partially absorbed light from the at least one functional section into the at least one mode converter, and in order to guide light transmitted from the at least one mode converter into the at least one functional section for further amplification and/or
20 absorption in the at least one functional section.

The at least one mode converter and the at least one converter coupling means offer a form of mode-division multiplexing (MDM), such that light interacting with the at least one functional section may be converted into a different transversal mode (i.e. a
25 sufficiently orthogonal mode) by the at least one mode converter, and may be multiplexed back into the at least one functional section by the at least one converter coupling means. The direction in which the light enters the at least one functional section does not matter. The light may then interact with the at least one functional section again, thus boosting the interaction length between the light and the at least
30 one functional section, thus boosting optical amplification or absorption as desired. Optionally, this process may be repeated several times, and a further boost may be experienced. Finally, the light may be converted back to the fundamental mode at the output.

In the context of light propagation through a waveguide, 'different transversal modes' (or, equivalently, 'different transverse modes') may refer to the different ways in which light can propagate through the waveguide. A transverse mode is a pattern of light propagation that is characterized by its optical field distribution across the transverse plane of the waveguide, perpendicular to the direction of propagation. Each transverse mode has a unique spatial distribution of electric and magnetic fields. In a waveguide, the electric and magnetic fields of light are confined within the waveguide structure and can be described in terms of their distribution along the transverse and longitudinal directions. The transverse direction is perpendicular to the direction of propagation, while the longitudinal direction is parallel to the direction of propagation.

In this context, TE and TM modes refer to the different distributions of the electric and magnetic fields along the radial and azimuthal directions in a waveguide. These modes can be excited and manipulated to achieve desired optical functions in the waveguide, and their specific characteristics depend on the geometry and material properties of the waveguide.

For example, in a circular waveguide, the fundamental mode is a transverse electric (TE) mode in which the electric field is perpendicular to the direction of propagation and has no radial variation, while in the transverse magnetic (TM) mode, the magnetic field is perpendicular to the direction of propagation and has no azimuthal variation. In a cylindrical waveguide, for example, the TE and TM modes refer to the different distributions of the electric and magnetic fields along the radial and azimuthal directions, respectively. In a TE mode, the electric field is perpendicular to the direction of propagation and has no radial variation, meaning that it has the same magnitude at all radial positions in the waveguide. However, the magnetic field has both radial and azimuthal variation, meaning that its magnitude varies both radially and circumferentially around the waveguide. In a TM mode, the magnetic field is perpendicular to the direction of propagation and has no azimuthal variation, meaning that it has the same magnitude at all azimuthal positions around the waveguide. However, the electric field has both radial and azimuthal variation, meaning that its magnitude varies both radially and circumferentially around the waveguide. These different modes can be excited by coupling light into the waveguide with a suitable

polarization and incident angle. The exact mode that is excited will depend on the geometry and material properties of the waveguide, as well as the wavelength of the incident light.

- 5 In waveguides with more complex geometries, such as rectangular, elliptical, multicore, and meta-material-based waveguides, there can be multiple transverse modes with different spatial distributions of fields. These different transverse modes can have different propagation constants, which determine the rate at which the mode decays as it propagates along the waveguide.

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In summary, different transverse modes in a waveguide refer to the different patterns of light propagation characterized by their unique spatial distribution of electric and magnetic fields. These modes can have different propagation constants and can be excited and manipulated to achieve desired optical functions in the waveguide.

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In an embodiment, the at least one converter coupling means comprises a plurality of tapered layers disposed on each other and arranged to evanescently couple light across the layers of the plurality of tapered layers, such that an effective volume of each layer of the plurality of tapered layers is reduced along a lateral dimension of the plurality of tapered layers. This may be done in order to reduce undesired mode conversions due to the evanescent coupling.

20

Due to the tapering, it is possible to engineer a gradual change of the refractive index of the material of the layers, because less material results in a lower index. The material density of the layers may be reduced along the longitudinal dimension by tapering them, i.e. reducing their effective volume along their lateral dimension. Preferably, the effect of the change in refractive index should result in sub-wavelength changes to the light waves, in order to avoid impact on the light waves.

25

- 30 In an embodiment, the at least one converter coupling means additionally or alternatively comprises a plurality of layers disposed on each other and arranged to evanescently couple light across the layers of the plurality of layers, wherein each layer of the plurality of layers has a diminishing material density along a longitudinal

dimension of the plurality of layers, such that an effective volume of each layer of the plurality of layers is reduced along the longitudinal dimension of the plurality of layers. This may be done in order to reduce undesired mode conversions due to the evanescent coupling.

5

Due to the material density (i.e. a filling factor) reduction, it is possible to engineer a gradual change of the refractive index of the material of the layers, because less material results in a lower index. The material density of the layers may be reduced along the longitudinal dimension by selectively removing more material on one side of the longitudinal dimension than on the other side of the longitudinal direction. In principle, it can also be considered to add metallic nanoparticles into the material using a different concentration along the longitudinal direction to achieve a similar effect (but by changing the imaginary part instead of the real part). Materials which have been subjected to such a material reduction are often called "meta-materials". Preferably, the effect of the change in refractive index should result in sub-wavelength changes to the light waves, in order to avoid impact on the light waves.

In an embodiment, the at least one mode converter is configured for converting the first mode of the received incoming light in the second mode by converting the first mode of the received incoming light into another mode that is a different transversal mode than the first mode.

In an embodiment, the device has a vertical architecture, and wherein the or each mode coupler is disposed on top of or below the at least one functional section along a vertical axis of the vertical architecture.

In an alternative embodiment, the device has a vertical architecture, and wherein the or each mode coupler is in juxtaposition to the at least one functional section along a horizontal axis of the vertical architecture.

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In an embodiment, the at least one mode converter comprises at least one of the following: a directional coupler; a multi-mode interference coupler; and a Y-branch.

In an embodiment, the photonic device comprises at least a first waveguide coupling means and a second waveguide coupling means, wherein the first waveguide coupling means is configured to couple the at least one functional section to a waveguide adapted for carrying light, and wherein the second waveguide coupling means is configured to couple the at least one functional section to the waveguide or to another waveguide adapted for carrying light.

In an embodiment, the at least one functional section is configured for generating light.

- 10 In an embodiment, the at least one mode converter comprises a plurality of mode converters and wherein the at least one converter coupling means comprises a plurality of converter coupling means.

In a second aspect, there is provided a method of light amplification and/or light absorption in a photonic device, comprising:

- 15 - guiding light into at least one functional section of the photonic device, wherein the at least one functional section is formed of an optical amplifier material and/or formed of an optical absorber material, wherein the guided light is in a first mode;
- 20 - converting the guided light from the first mode to a second mode, the second mode being a different transversal mode than the first mode; and
- guiding the converted light into the at least one functional section, wherein the converted light is in the second mode, so as to allow the converted light to pass through the at least one functional section with reduced interference of the converted light within the functional section.

25 In an embodiment, the method comprises at least one additional step of converting the light to another, different transversal mode and comprising at least one additional step of guiding into the at least one functional section the light thus converted to the other, different transversal mode.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1: Generic circuit architecture and an illustration of the optical power inside the functional section.

Figure 1 (a) in particular shows several passes of the optical signal through the functional section, via mode conversions in mode converters juxtaposed to the functional section, such that the different modes of the optical signal passing through the functional section do not interfere with each other, by using MDM.

Figure 1 (b) in particular shows such a process by illustrating the optical power inside the functional section. In each pass, there may be some additional optical loss from the mode converters.

Figure 2: Schematics of an example circuit that uses 2 modes (not-to-scale). a: Top-view circuit schematics. b: Cross-sectional structure of the passive waveguide forming the mode converters and the functional section for optical amplification or absorption. c: 3-D illustration of the coupling between the functional section and the mode converters/multiplexers. d: Zoom-in schematics of the mode converter/multiplexer in a.

Figure 3: Enhanced amplification and absorption measured from this implementation.

DETAILED DESCRIPTION

Figure 1 schematically illustrates an exemplary circuit architecture according to the present disclosure, and includes an exemplary illustration of the optical power inside the functional section.

Figure 1 (a) in particular shows several passes of the optical signal through the functional section, via mode conversions in mode converters coupled to the functional section, such that the different modes of the optical signal passing through the functional section do not interfere with each other, by using MDM.

Figure 1 (b) in particular shows such a process by illustrating the optical power inside the functional section. In each pass, there may be some additional optical loss from the mode converters.

One purely exemplary implementation using two orthogonal modes may for example be realized on an InP membrane on a Si (IMOS) platform. In such an exemplary implementation, InGaAsP-based multi-quantum well (MQW) may be used as the functional material for light amplification and absorption. InP-based directional couplers may be used as mode converters and multiplexers.

Figure 2 schematically illustrates an exemplary circuit according to the present disclosure (not-to-scale).

a: Top-view circuit schematics. b: Cross-sectional structure of the passive waveguide forming the mode converters and the functional section for optical amplification or absorption. c: 3-D illustration of the coupling between the functional section and the mode converters/multiplexers. d: Zoom-in schematics of the mode converter/multiplexer in a.

Figure 2(a) shows top-view schematics of such an exemplary circuit according to the present disclosure. In this circuit, the light path is as follows: Input fiber grating coupler (FGC, TE_0) – mode converter (TE_0 passing through) – SOA (TE_0 amplification or absorption) – mode converter (TE_0 passing through) – U-bend (TE_0) – mode converter (TE_0 converted to TE_1) – SOA (TE_1 amplification or absorption) – mode converter (TE_1 converted back to TE_0) – output FGC (TE_0).

The functional section may preferably be based on a regrowth-free twin-guide scheme. The active functional layers including the n- and p-InP claddings, the InGaAsP Q1.25 core containing a compressively strained 4-MQW, and the metal contacting layers may be epitaxially grown on top of the 300 nm-thick i-InP layer, in which the passive waveguide and other photonic circuitries may be fabricated.

Note that the number of quantum wells given in this example (viz. four) is not intended to be limiting, and can in various embodiments be any other number (e.g. 1-100, or even more) of quantum wells. Moreover, in other embodiments, other dimensions and other compositions may be used instead. Furthermore, other types of light-emitting and/or light-absorbing material may be used instead, including doped fiber glass, or organic materials.

Halfway the fabrication, the whole layer stack may preferably be flipped and buried in the benzo-cyclobutene (BCB) bonding layer, as can be seen in Fig. 1(b). The whole wafer may also be planarized and buried in polyimide (PI). The Q1.25 layer immediately under the i-InP layer may preferably be a wet etch-stop layer. The width of the SOA may preferably be designed to be 2.2 mm, supporting both the TE_0 and TE_1 mode in the core region.

Figure 2(c) illustrates a plurality of tapered layers as a converter coupling means (or mode coupling), usable for coupling modes between the functional section (or functional layer) and the shown mode converter. The mode converter itself can for example be a dual-core directional coupler, as depicted in Fig. 2(a) and Fig. 2(d). However, it should be noted that the Fig. 2(d) is just one exemplary form of the mode converter, and that there are many other means to construct such a mode converter, such as by using Y-branches or MMIs. The principles underlying the present disclosure relate to a circuit that uses MDM for light amplification and absorption, and are not limited to the discrete components that are specifically illustrated in these examples.

A reason to use such a plurality of tapered layers for mode coupling is that, typically, the functional section may have a very different cross-section than that of the mode converter. This imposes a challenge on coupling multiple modes between the functional section and the mode converter. Therefore, careful design is needed, such as by tapering down separately different layers as shown in Fig. 2(c). Alternatively, use can be made of sub-wavelength structures, free-space coupling, or butt-joint coupling, to achieve the coupling.

It is noted that the specific semiconductor materials chosen in the examples in the present disclosure is not intended to be limiting, and that for example GaAs, SiGe, and/or GaN, or any other suitable semiconductor material, could be chosen as semiconductor material instead.

Moreover, other lateral or in-plane devices could also work, and the stacked layer architecture presented in the examples in the present disclosure is merely intended as an example. It is advantageous to use a tapered approach and/or an engineered

material approach for the converter coupling means (as was explained above) in the case of a stacked layer architecture as presented here, but if the device would be designed to have an abutted approach, wherein the relevant components would be situated on a same layer, next to each other, it could be conceived to reduce the need for tapers.

Furthermore, it may be considered to introduce free space coupling to mode converters situated more remotely from the function section, i.e. at a distance from the functional section.

In general, embodiments according to the present disclosure are not intended to limit the invention with respect to details of the coupling or the mode conversion, but are merely intended to provide possible examples.

The light coupling between the SOA and the passive waveguide may be done via a multi-layered taper, for example an evanescent taper as seen in Fig. 2(c). In this context, the term “evanescent” may be taken to refer to a gradual coupling of light energy from layer to layer, in this example layout from the active core layer to the i-InP layer. It is noted that an evanescent taper may also be introduced into various other embodiments that are structurally different from the exemplary embodiment illustrated in this figure.

In this exemplary evanescent taper, by preferably separately tapering down the p-InP layer first, unwanted mode conversions may surprisingly be suppressed, by first shrinking down the waveguide in the functional section in the vertical direction, reducing the number of supported modes, because mode conversion is dependent on the number of supported modes. It is noted that this point is not trivial and that using a taper in this manner here serves to avoid mode conversion, whereas conventionally tapers have been used to actually perform mode conversion, so not to avoid it.

Therefore, this taper is capable of coupling both the TE_0 and TE_1 modes between the mode converters and the functional section.

Fig. 2(d) shows exemplary zoom-in schematics of the dual-core adiabatic tapers used as a mode converter. This mode converter may contain a multimode bus connecting directly to the functional section, and a TE_0 access waveguide for converting from/to the TE_1 mode in the bus waveguide.

5

Mode converters can be used in semiconductor light amplification and/or absorption devices to convert the mode of the light from one transverse mode to another. This can be useful, for example, when coupling light into or out of the device, or when manipulating the light within the device to achieve desired optical functions. One type of mode converter usable in semiconductor devices is the tapered waveguide. A tapered waveguide is a waveguide that changes in width gradually along its length, causing the transverse mode of the light to change as it propagates through the waveguide.

10

In an optical amplifier, for example, the tapered waveguide can be used to convert the fundamental mode of the input light into a higher-order mode that is better matched to the active region of the amplifier. This can increase the overlap between the light and the gain medium, leading to more efficient amplification. In an absorption device, such as a photodetector, the tapered waveguide can be used to convert the mode of the light from a higher-order mode to the fundamental mode, which is more efficiently detected by the detector.

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Other types of mode converters usable in semiconductor devices include photonic crystals and grating structures. These structures can manipulate the propagation of light through the device by selectively reflecting or transmitting certain modes of the light.

25

In summary, mode converters in semiconductor light amplification and/or absorption devices can be used to convert the transverse mode of the light to achieve desired optical functions. Tapered waveguides, photonic crystals, and metaphotonic and subwavelength grating structures are examples of mode converters usable in these devices.

30

Figure 3 illustrates the enhanced amplification and absorption that may be observed from a circuit according to the present disclosure, compared to a conventional single-pass circuit. In the wavelength range of 1520-1540 nm, up to 5 dB more absorption is achieved (100% more); In the wavelength range of 1540 nm – 1600 nm, up to 5.4 dB
5 more amplification is achieved (87% more).

CLAIMS

1. A photonic device for light amplification and/or light absorption, comprising:

- at least one functional section formed of an optical amplifier material and/or formed
5 of an optical absorber material;

- at least one mode converter coupled to the at least one functional section and
configured to:

- receive incoming light from the at least one functional section, wherein the
incoming light is in a first mode;

10 - convert the received incoming light from the first mode to a second mode, the
second mode being a different transversal mode than the first mode; and

- transmit the converted light towards the at least one functional section in the
second mode, so as to allow the converted light to pass through the at least
one functional section with reduced interference of the incoming light and the
15 converted light within the functional section; and

- at least one converter coupling means configured to couple the at least one functional
section to the at least one mode converter, in order to guide incoming amplified or
partially absorbed light from the at least one functional section into the at least one
mode converter, and in order to guide light transmitted from the at least one mode
20 converter into the at least one functional section for further amplification and/or
absorption in the at least one functional section.

2. The photonic device of claim 1, wherein the at least one converter coupling means
comprises a plurality of tapered layers disposed on each other and arranged to
25 evanescently couple light across the layers of the plurality of tapered layers, such that
an effective volume of each layer of the plurality of tapered layers is reduced along a
lateral dimension of the plurality of tapered layers.

3. The photonic device of claim 1 or claim 2, wherein the at least one converter
30 coupling means comprises a plurality of layers disposed on each other and arranged
to evanescently couple light across the layers of the plurality of layers, wherein each
layer of the plurality of layers has a diminishing material density along a longitudinal

dimension of the plurality of layers, such that an effective volume of each layer of the plurality of layers is reduced along the longitudinal dimension of the plurality of layers.

4. The photonic device of any preceding claim, wherein the at least one mode converter is configured for converting the first mode of the received incoming light in the second mode by converting the first mode of the received incoming light into another mode that is a different transversal mode than the first mode.

5. The photonic device of any of claims 1-4, wherein the device has a vertical architecture, and wherein the or each converter coupling means is disposed on top of or below the at least one functional section along a vertical axis of the vertical architecture.

6. The photonic device of any of claims 1-4, wherein the device has a vertical architecture, and wherein the or each converter coupling means is in juxtaposition to the at least one functional section along a horizontal axis of the vertical architecture.

7. The photonic device of any preceding claim, wherein the at least one mode converter comprises at least one of the following: a directional coupler; a multi-mode interference coupler; and a Y-branch.

8. The photonic device of any of claims 1-7, comprising at least a first waveguide coupling means and a second waveguide coupling means, wherein the first waveguide coupling means is configured to couple the at least one functional section to a waveguide adapted for carrying light, and wherein the second waveguide coupling means is configured to couple the at least one functional section to the waveguide or to another waveguide adapted for carrying light.

9. The photonic device of any of claims 1-7, wherein the at least one functional section is configured for generating light.

10. The photonic device of any preceding claim, wherein the at least one mode converter comprises a plurality of mode converters and wherein the at least one converter coupling means comprises a plurality of converter coupling means.

- 5 11. A method of light amplification and/or light absorption in a photonic device, comprising:
- guiding light into at least one functional section of the photonic device, wherein the at least one functional section is formed of an optical amplifier material and/or formed of an optical absorber material, wherein the guided light is in a first mode;
 - 10 - converting the guided light from the first mode to a second mode, the second mode being a different transversal mode than the first mode; and
 - guiding the converted light into the at least one functional section, wherein the converted light is in the second mode, so as to allow the converted light to pass through the at least one functional section with reduced interference of the converted
 - 15 light within the functional section.

12. The method of claim 11, comprising at least one additional step of converting the light to another, different transversal mode and comprising at least one additional step of guiding into the at least one functional section the light thus converted to the other,
- 20 different transversal mode.

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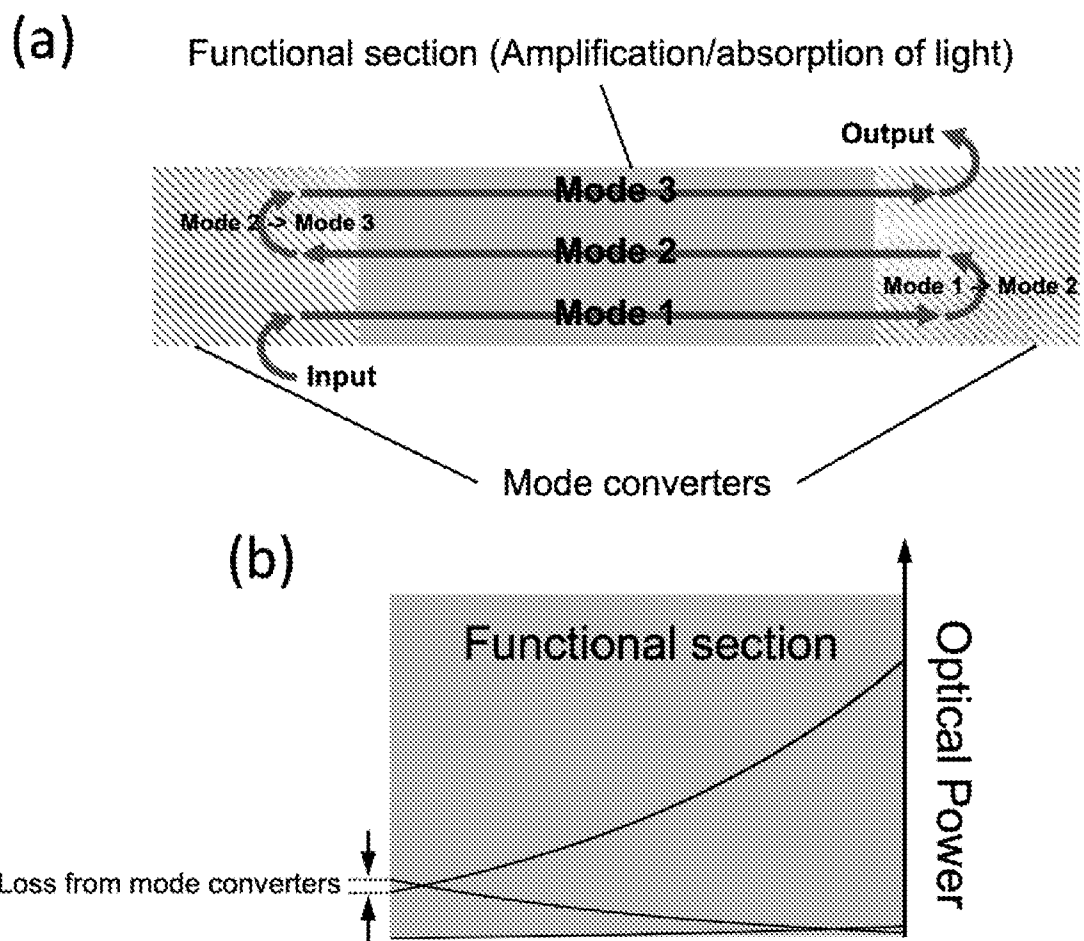


Fig. 1

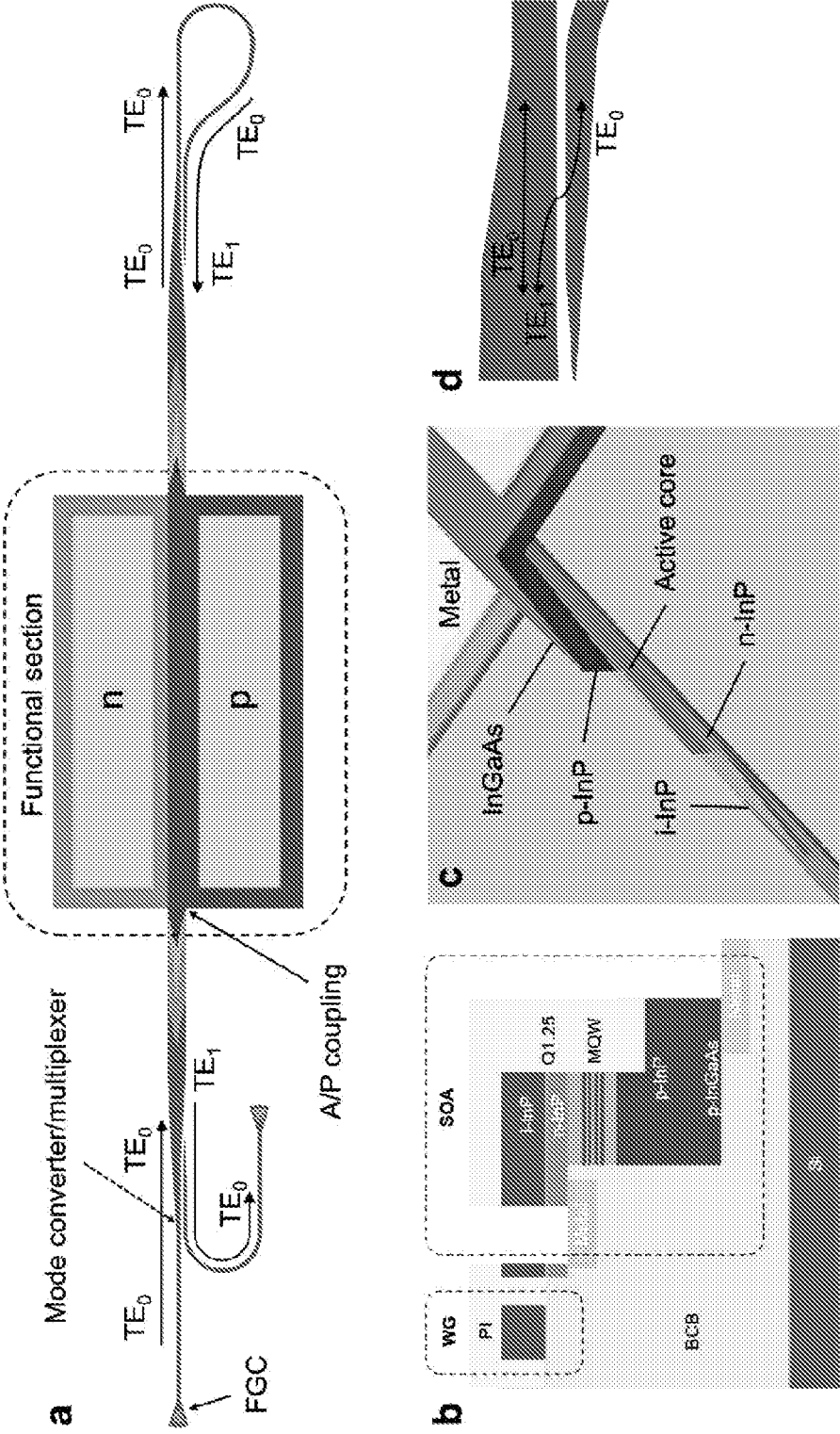


Fig. 2

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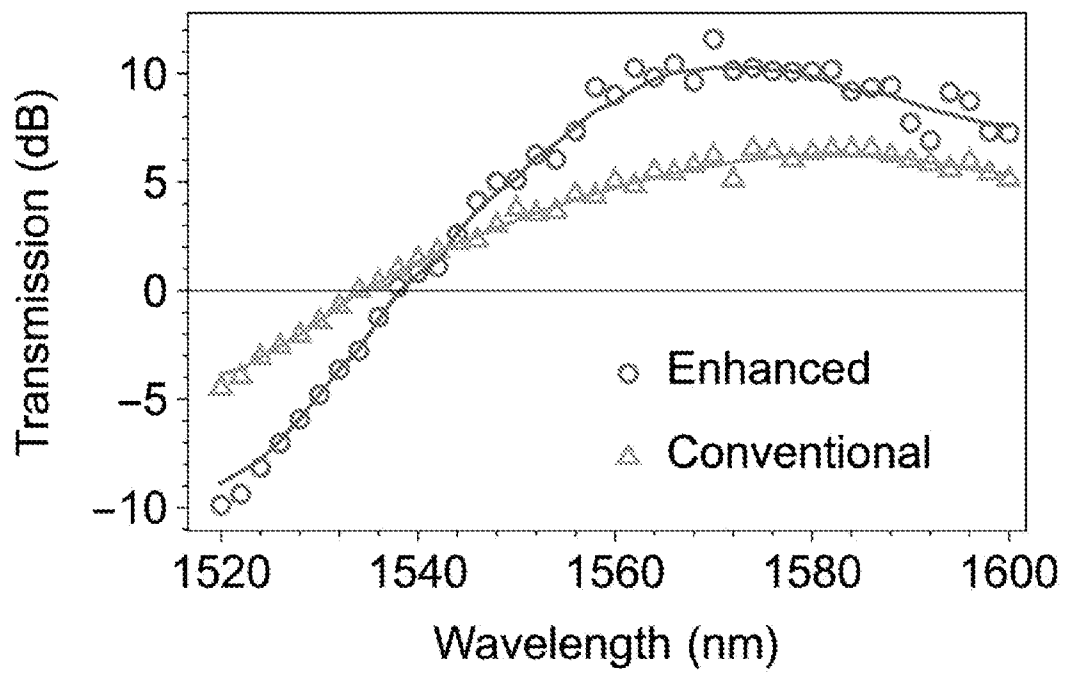


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2024/050096

A. CLASSIFICATION OF SUBJECT MATTER							
INV.	H01S5/00	H01S5/10	H01S5/50				
ADD.	H01S5/02	H01S5/0225	H01S5/02251	H01S5/0234	H01S5/343		
According to International Patent Classification (IPC) or to both national classification and IPC							
B. FIELDS SEARCHED							
Minimum documentation searched (classification system followed by classification symbols) H01S							
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched							
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, COMPENDEX, INSPEC, WPI Data							
C. DOCUMENTS CONSIDERED TO BE RELEVANT							
Category*	Citation of document, with indication, where appropriate, of the relevant passages				Relevant to claim No.		
X	CN 107 065 072 A (UNIV ZHEJIANG) 18 August 2017 (2017-08-18) paragraphs [0044] - [0106]; figures 3-9 -----				1-12		
A	JIAO YUQING ET AL: "InP membrane integrated photonics research", SEMICONDUCTOR SCIENCE TECHNOLOGY, vol. 36, no. 1, 3 December 2020 (2020-12-03), page 013001, XP093079622, GB ISSN: 0268-1242, DOI: 10.1088/1361-6641/abcadd page 0130012, left-hand column, paragraph 5 - page 01300114, right-hand column, paragraph 1; figures 2-7,13 ----- --/--				1, 9, 11		
<table><tr><td>☒ Further documents are listed in the continuation of Box C.</td><td>☒ See patent family annex.</td></tr></table>						☒ Further documents are listed in the continuation of Box C.	☒ See patent family annex.
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INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2024/050096

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