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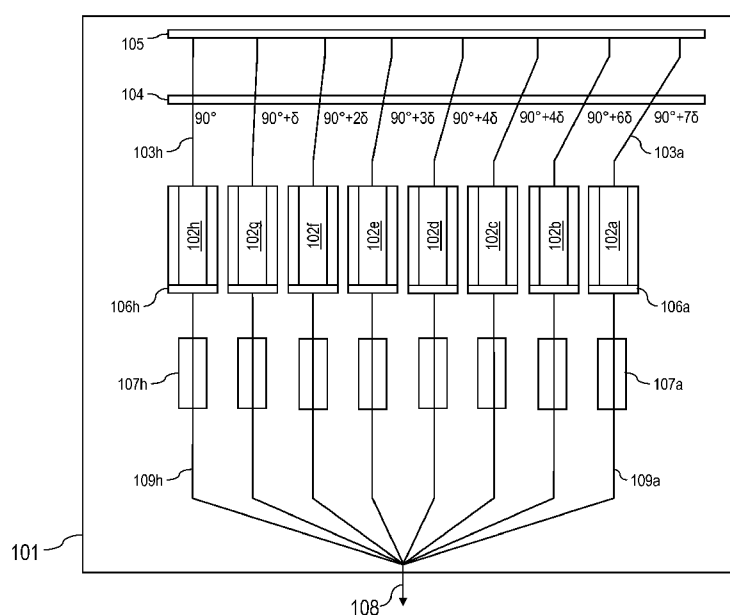
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(54) Title: OPTICAL NETWORK ELEMENT, PROCESS OF MANUFACTURE AND METHOD FOR GENERATING LIGHT
BEAMS

Fig.1



(57) Abstract: An optical network element is provided, comprising several lasers, wherein at least one dielectric filter is arranged within an least one resonator of the lasers, wherein for each laser, light in the resonator enters the at least one dielectric filter at a predetermined angle and wherein the light generated within each laser enters the at least one dielectric filter at a different angle. Furthermore, a process of manufacture and a method for generating several light beams by several lasers are suggested.

Description

Optical network element, process of manufacture and method for generating light beams

5

The invention relates to an optical network element, a process of manufacture and a method for generating light beams.

10 A passive optical network (PON) is a promising approach regarding fiber-to-the-home (FTTH), fiber-to-the-business (FTTB) and fiber-to-the-curb (FTTC) scenarios, in particular as it overcomes the economic limitations of traditional point-to-point solutions.

15

Several PON types have been standardized and are currently being deployed by network service providers worldwide.

Conventional PONs distribute downstream traffic from the optical line terminal (OLT) to optical network units (ONUs)
20 in a broadcast manner while the ONUs send upstream data packets multiplexed in time to the OLT. Hence, communication among the ONUs needs to be conveyed through the OLT involving electronic processing such as buffering and/or scheduling, which results in latency and degrades the throughput of the
25 network.

In fiber-optic communications, wavelength-division multiplexing (WDM) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using
30 different wavelengths (colors) of laser light to carry different signals. This allows for a multiplication in capacity, in addition to enabling bidirectional communications over one strand of fiber.

35 WDM systems are divided into different wavelength patterns, conventional or coarse and dense WDM. WDM systems provide, e.g., up to 16 channels in the 3rd transmission window (C-band) of silica fibers of around 1550 nm. Dense WDM uses the

same transmission window but with denser channel spacing. Channel plans vary, but a typical system may use 40 channels at 100 GHz spacing or 80 channels at 50 GHz spacing. Some technologies are capable of 25 GHz spacing. Amplification options enable the extension of the usable wavelengths to the L-band, more or less doubling these numbers.

Optical access networks, e.g., coherent Ultra-Dense Wavelength Division Multiplex (UDWDM) networks, could be used as a future data access.

Data transmission of spectrally densely spaced wavelengths is utilized by applications such as Next Generation Optical Access (NGOA) systems allowing high data rates of, e.g., 100 Gbit/s.

In these optical scenarios, a multitude of optical wavelengths is required in order to be individually modulated. Such optical wavelengths may have a spectral distance of a few gigahertz and can be used either for an ultra dense wavelength grid optical access system like NGOA where each user may be assigned a wavelength of his own or for a transmission of high data rates a multitude of wavelengths are bundled and transmitted over a small spectral range.

It is, however, a disadvantage that several discrete laser sources providing such wavelengths may interfere with each other or are not at a constant frequency distance from each other (e.g., due to temperature effects). This situation becomes even more critical in case the laser sources are closely spaced to each other (e.g., separated by a frequency range amounting to 3 GHz).

The **problem** to be solved is to improve an existing optical system and in particular to efficiently provide optical wavelengths at a spectral distance of, e.g., a few GHz and at

the same time allow for a precise adjustment of such optical wavelengths.

This problem is solved according to the features of the
5 independent claims. Further embodiments result from the depending claims.

In order to overcome this problem, an optical network element is provided

- 10 - comprising several lasers, wherein at least one dielectric filter is arranged within at least one resonator of the lasers,
- wherein for each laser, light in the resonator enters the at least one dielectric filter at a predetermined
15 angle,
- wherein the light generated within each laser enters the at least one dielectric filter at a different angle.

20 The optical network element may be any system, device or optical component or a portion thereof. The optical network element may be a substrate with an arrangement as suggested.

Advantageously, this concept allows that the laser (or any
25 comparable light source) provides light beams at different wavelengths, wherein the wavelengths are separated by, e.g., a few gigahertz. The spectral distance between the light beams is substantially unsusceptible against temperature variation, because any change of temperature applies to the
30 whole arrangement, e.g., the photonic motherboard on which the several lasers and/or the dielectric filter are deployed.

It is noted that several dielectric filters could be provided, wherein each dielectric filter is entered by light
35 of a resonator or cavity of at least one laser. Each dielectric filter may thus be a frequency (or wavelength) defining element for several lasers.

The approach presented can be used as a device to provide several light beams of different frequencies. Hence, for example, long haul DWDM laser arrays can be provided in an efficient manner.

5

In an embodiment, the angles for the several lasers (substantially) differ by a predetermined angle or a multiple thereof.

10 Hence, each of the several lasers has a resonator and a gain medium, wherein light generated by the gain medium enters the dielectric filter at a different angle compared to the angle that is applied to the resonator of the other lasers.

15 It is in particular noted that a single laser may not utilize the dielectric filter and thus provides a light beam without any deviation or impact by such dielectric filter.

The predetermined angle can be regarded as an offset angle
20 resulting in an offset frequency (wavelength). Thus, the lasers via the coupling with the dielectric filter provide light beams that are spectrally separated from each other by a frequency that is determined by the different angles.

25 In a further embodiment, the at least one dielectric filter is arranged within a cavity of the lasers.

The cavity of the laser can also be regarded as resonator comprising a gain medium and is in particular arranged
30 between a mirror and a semi-transparent mirror.

In a next embodiment, each laser comprises

- a gain medium, wherein one side of the gain medium is connected to a semi-transparent mirror, and
- 35 - a waveguide that is connected to the other side of the gain medium and to a mirror via the dielectric filter.

Thus, each laser via its gain medium and the angle at which its light enters the dielectric filter provides an outgoing light beam of a given frequency.

- 5 The gain medium of the laser generates light that is fed via the dielectric filter to the mirror and reflected back to the gain medium. The light generated leaves the laser via the semi-transparent mirror.
- 10 The laser gain media may be realized as semiconductor optical amplifiers (SOAs).

It is also an embodiment that the light of the gain medium is conveyed to the dielectric filter by a waveguide.

- 15 Pursuant to another embodiment, said waveguide is an etched waveguide within a layer.

- According to an embodiment, said layer can be a layer on a motherboard, in particular a photonic motherboard.
- 20

According to another embodiment, the mirror and/or the semi-transparent mirror is/are arranged in an etched or milled slot of the motherboard.

- 25 In yet another embodiment, the mirror is used for several lasers.

- A single mirror can be used for several waveguides, i.e. the light passing the dielectric filter can be conveyed via several waveguides to this mirror and back via the dielectric filter to the gain media. This may be applicable for several lasers in parallel.
- 30

- 35 According to a next embodiment, the dielectric filter is used for several lasers.

Hence, the light from the gain medium can be fed to the dielectric filter via the waveguide and enter the dielectric filter at a predefined angle, wherein a single dielectric filter can be used for being connected via several waveguides to several gain media.

Pursuant to yet an embodiment, the dielectric filter is movable or rotatable.

By moving or rotating, the angle at which light enters the dielectric filter can be adjusted. Thus, the frequency of the light beam supplied by the laser(s) can be adjusted.

The problem stated above is also solved by a process of manufacture of the optical network element as described herein, wherein the dielectric filter is applied using a hybrid photonic integration technology.

According to an embodiment, the dielectric filter is realized by coating a substrate with alternating films of material of at least partially different refraction indices.

The problem mentioned above is also solved by a method for generating several light beams by several lasers,

- wherein for each laser light is conveyed via a dielectric filter within the resonator of this laser,
- wherein said light enters the dielectric filter at a predetermined angle,
- wherein the light generated within each laser enters the at least one dielectric filter at a different angle.

Hence, the light beam's frequency generated by each laser depends on the angle at which the light enters the dielectric filter. Each laser may provide a light beam of different frequency, because the light within the respective laser's resonator enters the dielectric filter at a different angle.

It is noted that one or several dielectric filters could be provided for said several lasers.

5 The remaining aspects disclosed herein apply to the method in an according manner.

Also, the problem stated above is solved by a communication system comprising in particular at least one of said optical network elements.

10

Embodiments of the invention are shown and illustrated in the following figure:

Fig.1 shows a schematic diagram of a photonic motherboard
15 comprising an array of laser gain media, wherein waveguides are etched on the motherboard and a dielectric filter is arranged in an etched or precision milled slot of the motherboard.

20 The solution provided herein in particular suggests using a multitude of lasers (also referred to as laser sources or light sources) to provide spectrally separated light beams. Advantageously, the approach works well even in case the light beams are separated only by a small frequency band,
25 e.g., 3 GHz. It is another advantage that the spectral distance between the different (adjacent) light beams can be maintained without any additional active locking mechanism to be provided.

30 Hence, it is suggested using a small band dielectric filter as a frequency selective element provided in the laser cavity. The transmission window (which is identical to the laser's wavelength in case the dielectric filter is arranged within a laser resonator) depends on an angle at which the
35 light beam enters and/or passes the filter. Hence, the transmission wavelength (and therefore the laser wavelength) can be adjusted if the dielectric filter is moved or rotated.

A single dielectric filter can be provided as a frequency defining element for several lasers. Light generated at each laser impinges on the dielectric filter at a different angle. In particular, the angle at which a particular light beam enters the dielectric filter is (slightly) different from the angle(s) at which its adjacent laser(s) enter(s) the dielectric filter.

A photonic motherboard or layer can be used for conveying the light beams. A cavity in the photonic motherboard may comprise a waveguide structure, wherein light is conveyed via separate waveguides, and wherein each waveguide intersects with the dielectric filter at a different angle.

Fig.1 shows a schematic diagram of a photonic motherboard (e.g., a silicon motherboard) comprising an array of laser gain media 102a to 102h, which may be realized each as a semiconductor optical amplifier (SOA). Waveguides 103a to 103h are etched on the motherboard 101. A dielectric filter 104 is arranged in an etched or precision milled slot of the motherboard 101. Also, a mirror 105 is located in an etched or precision milled slot of the motherboard 101.

The gain medium 102a generates light that is fed by the waveguide 103a via the dielectric filter 104 to the mirror 105 and back to the gain medium 102a. The amplified light passes a semi-transparent mirror 106a as a light beam and is fed by a waveguide 109a to a modulator 107a, where an electrical signal can be used for modulating data onto the optical signal. The modulated light beam is then conveyed via said waveguide 109a to a single output fiber 108. This applies accordingly for the other laser arrangements accordingly, wherein the light generated by each of the laser's gain medium enters the dielectric filter 104 at a different angle. The modulated light beams of the lasers are combined onto said optical fiber 108. The modulators 107a to 107h can be arranged as a modulator array.

The waveguides 103a to 103h pass the dielectric filter 104 each at a slightly different angle. An angle offset δ corresponds to a frequency offset $\Delta\nu$. Hence, the configuration shown in Fig.1 is arranged for generating light
5 beams at the frequencies ν_0 , $\nu_0+\Delta\nu$, $\nu_0+2\Delta\nu$, ..., $\nu_0+7\Delta\nu$.

It is an advantage of this solution that in case of a temperature change, such change applies to all lasers of the motherboard 101 and to the dielectric filter, thus
10 maintaining the spectral distances between the respective light beams. Hence, adjacent light beams maintain their spectral distance even in case of a temperature change without the requirement of providing additional locking mechanisms.

15

It is also an advantage that the solution can be implemented by using hybrid photonic integration technologies. The frequency selective dielectric filter can be realized by coating a substrate with alternating films of material with
20 different refraction indices. Such a dielectric filter can be produced of a 2 or 3 inch wafer and many hundreds can be cut out of a single waver.

List of Abbreviations:

	DWDM	Dense WDM
	FTTB	Fiber-to-the-Business
5	FTTC	Fiber-to-the-Curb
	FTTH	Fiber-to-the-Home
	NGOA	Next Generation Optical Access
	OLT	Optical Line Terminal
	ONU	Optical Network Unit
10	PON	Passive Optical Network
	SOA	Semiconductor Optical Amplifier
	UDWDM	Ultra Dense WDM
	WDM	Wavelength Division Multiplexing

Claims:

1. An optical network element
 - comprising several lasers, wherein at least one dielectric filter is arranged within at least one resonator of the lasers,
 - 5 - wherein for each laser, light in the resonator enters the at least one dielectric filter at a predetermined angle,
 - wherein the light generated within each laser enters
 - 10 the at least one dielectric filter at a different angle.
2. The optical network element according to claim 1, wherein the angles for the several lasers differ by a predetermined angle or a multiple thereof.
- 15 3. The optical network element according to any of the preceding claims, wherein the at least one dielectric filter is arranged within a cavity of the lasers.
4. The optical network element according to any of the preceding claims, wherein each laser comprises
 - 20 - a gain medium, wherein one side of the gain medium is connected to a semi-transparent mirror, and
 - a waveguide that is connected to the other side of the gain medium and to a mirror via the dielectric filter.
- 25 5. The optical network element according to claim 4, wherein the light of the gain medium is conveyed to the dielectric filter by a waveguide.
6. The optical network element according to claim 5, wherein said waveguide is an etched waveguide within a
- 30 layer.
7. The optical network element according to claim 6, wherein said layer can be a layer on a motherboard, in particular a photonic motherboard.

8. The optical network element according to claim 7,
wherein the mirror and/or the semi-transparent mirror
is/are arranged in an etched or milled slot of the
motherboard.

5 9. The optical network element according to any of claims 4
to 8, wherein the mirror is used for several lasers.

10. The optical network element according to any of the
preceding claims, wherein the dielectric filter is used
for several lasers.

10 11. The optical network element according to any of the
preceding claims, wherein the dielectric filter is
movable or rotatable.

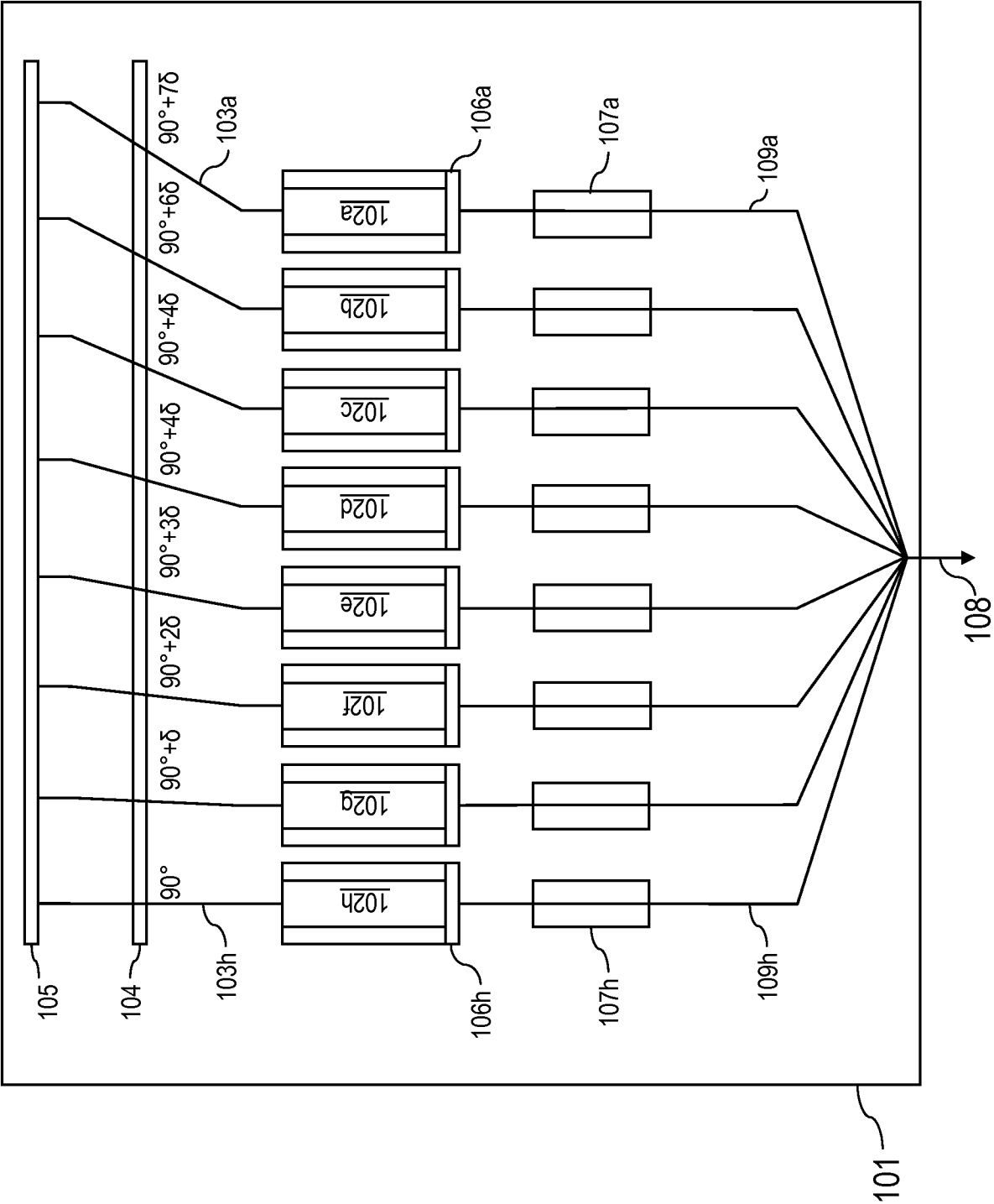
12. A process of manufacture of the optical network element
according to any of the preceding claims, wherein the
15 dielectric filter is applied using a hybrid photonic
integration technology.

13. The process of manufacture according to claim 12,
wherein the dielectric filter is realized by coating a
substrate with alternating films of material of at least
20 partially different refraction indices.

14. A method for generating several light beams by several
lasers,
– wherein for each laser light is conveyed via a
dielectric filter within the resonator of this laser,
25 – wherein said light enters the dielectric filter at a
predetermined angle,
– wherein the light generated within each laser enters
the at least one dielectric filter at a different
angle.

30

Fig.1



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
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 ADD.

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B. FIELDS SEARCHED

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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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 02/43202 A1 (LIU ZHONGSHAN [US]) 30 May 2002 (2002-05-30) page 3, line 22 - page 4, line 5 page 10, line 26 - page 11, line 7 page 12, line 8 - page 13, line 16; figures 2b,5,7	1-14
Y	----- US 6 876 679 B1 (BOWLER DENNIS [US] ET AL) 5 April 2005 (2005-04-05) paragraph [0035] paragraph [0049]; figure 2	1-14
A	----- US 5 216 680 A (MAGNUSSON ROBERT [US] ET AL) 1 June 1993 (1993-06-01) * abstract; figures 3a-3h ----- -/-	1-14



Further documents are listed in the continuation of Box C.



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International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RONEN E ET AL: "Passive phase locking of 169 lasers", LASERS AND ELECTRO-OPTICS, 2009 AND 2009 CONFERENCE ON QUANTUM ELECTRONICS AND LASER SCIENCE CONFERENCE. CLEO/QELS 2009. CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 2 June 2009 (2009-06-02), pages 1-2, XP031520978, ISBN: 978-1-55752-869-8 * abstract; figure 1 -----	1-14
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Information on patent family members

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