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(54) Title: VERTICAL CAVITY SURFACE EMITTING LASER COMPRISING A MODULATOR MONOLITHICALLY INTEGRATED ON TOP
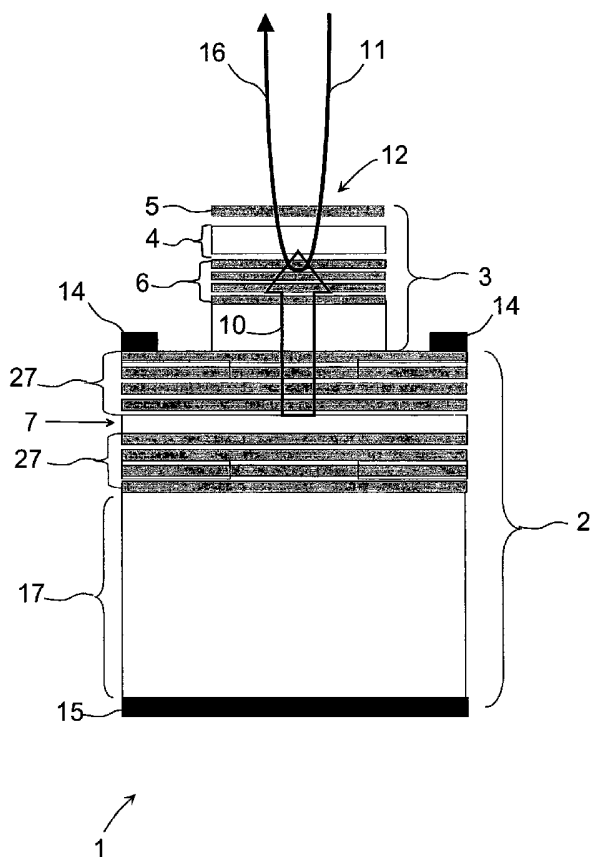
(57) Abstract: The optical modulator (1) according to the present invention includes vertical-cavity surface-emitting laser (2) integrated with surface-normal non-linear optical modulation section (3). The modulation section (3) of the device is driven by an intensity-modulated pump beam (10) generated by the laser (2). The modulation section (3) is formed on top of the emitting surface of the vertical-cavity surface-emitting laser (2). The modulation section (3) comprises a first (5) mirror, a second mirror (6), and an absorber region (4) between the first (5) and the second mirror (6), wherein at least one optical property of the absorber region (4) is arranged to be varied by varying the intensity of the pump optical beam (10). The optical modulator according to an advantageous embodiment of the present invention is a monolithic optically-controlled optoelectronic intensity modulator. The device has an integrated arrangement, in which optical intensity modulation of a saturable absorber (4) that acts as an intensity surface-normal modulator is pumped by applying current modulation to the surface-emitting laser (2).

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VERTICAL CAVITY SURFACE EMITTING LASER COMPRISING A MODULATOR MONOLITHICALLY INTEGRATED ON TOP

Field of the Invention

5   The present invention relates to modulation of optical light using semiconductor devices with surface-normal geometry, and more specifically, to enhancement of on/off ratio, or modulation contrast of surface-normal modulators. The present invention relates to a semiconductor modulator comprising a vertical-cavity surface-emitting

10   laser to produce a pump optical beam emitting substantially perpendicular to a surface of the laser, and a modulator element for modulating an optical signal to produce a modulated optical signal. The present invention also relates to a method for producing a semiconductor modulator comprising a vertical-cavity surface-emitting

15   laser to produce a pump optical beam emitting substantially perpendicular to a surface of the laser, and a modulator element for modulating an optical signal to produce a modulated optical signal.

Description of Related Art

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Optical modulators are key elements in optical technology used in such systems as optical interconnect systems. There is considerable interest in surface-normal modulators for high-speed, wide-band optical signal processing and interconnection technology. One attractive solution is

25   based on an epitaxially grown semiconductor modulator structure, consisting of multiple quantum wells with an optical mirror or mirrors to form a modulator.

In large-scale monolithic applications, where many components must

30   be fabricated on a single wafer, it is essential to minimize the size of each component. Semiconductor surface normal modulators appear to be a promising solution because of their low power consumption and small size. Therefore, in comparison with waveguide type modulators, surface-normal modulators are most useful in applications where a

35   fairly high density of outputs is desired. Another advantages of surface normal modulators are simplicity of the coupling of the light and fibre pigtailing and polarization insensitivity.

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A major problem with surface-normal modulators is low modulation contrast and efficiency, because the interaction length with an optical beam is limited to a few micrometers. To overcome shortcomings that arise due to the short interaction length, asymmetrical Fabry-Pérot (ASFP) structures have been used in surface-normal modulators. The ASFP modulator is composed of a pair of asymmetric mirrors separated by an active layer. The use of a resonant structures strongly influences the device characteristics such as achievable modulation in a cavity, spectral bandwidth, sensitivity to changing ambient temperature and optical saturation. For instance, the bandwidth of such Fabry-Pérot structures is reduced as the mirror reflectivity increases.

A variety of configurations of surface-normal modulators are being proposed to switch and modulate optical signals. Majority of the proposed surface-normal modulators are electrically-addressed devices whose operation is based on the Quantum-Confined Stark Effect (QCSE). They require the application of controlled amounts of electric field. This field is easily introduced by placing quantum wells in the intrinsic region of p-i-n diode. Several groups have realized hybrid optoelectronic ASFP devices by using the QCSE in multiple-quantum wells (MQWs). The device operation is based on the shift of excitonic absorption resonances in MQWs due to an applied electrical field. The changes in the device reflection (or transmission) then modulate the signal light. In all-optical modulator ultrashort pump pulses from the light source (possibly followed by an optical amplifier) irradiate the *saturable absorber optical gate, and open it by the bleaching of the* absorption. These devices use the strong non-linear absorption changes (i.e. absorption bleaching or saturation) in MQW structure, when excited optically with pump light. Signal light irradiates the same area of the device and, therefore, is encoded by the pump pulses. As a result, the data carried on the pump pulses are transferred to the signal light. Therefore, the method consists of modulating the saturable loss of the MQWs by optically pumping it above the bandgap by an external laser. This technique is attractive because it allows all-optical switching at ultrafast speed, however, *it requires ultrashort pulse laser producing pump light for modulation the reflection/transmission of the optical gate.*

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Some of the desirable characteristics of efficient optical modulators/switches are low chirp, low operation power, large contrast ratio, and high speed. In addition, modulators should ideally have desirable optical bandwidth.

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Vertical Cavity Surface Emitting Laser (VCSEL) diodes are semiconductor devices with light emission substantially perpendicular to the chip surface. They are highly attractive for applications in optoelectronics, since they offer several advantages compared to
10   conventional edge-emitting (in-plane) laser diodes, such as low electric power consumption, capability of on-wafer testing, simplified fibre coupling and packaging, single-longitudinal-mode spectra, and suitability for 2D-array integration.

15   Particular interest with respect to fibre-optical communication systems exists for those VCSELs that are able to emit at wavelengths around 1.31 μm or 1.55 μm because of minimum dispersion or absorption in silica fibres, respectively. Eligible material systems of compound semiconductors are (GaIn)(NAs) and GaInNAsSb(GaNAsSb) on GaAs
20   substrate and on InP there are (InGaAl)As, (InGa)(AsP) and (AlGa)(AsSb) potential for both 1.31μm and 1.55μm emitters.

The realization of VCSELs with reasonable characteristics, however, suffers from several technological challenges related to the required
25   materials, especially for InP-based devices in the 1.55 μm wavelength range:

-       Low refractive index-contrast of Distributed Bragg Reflector (DBR) mirrors;

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-       Poor thermal conductivity of ternary- (quaternary-) compound semiconductor DBRs;

-       Problematic light amplification performance at elevated
35   temperatures;

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- Selective Oxidation (of InAlAs) expected to cause material damage.

GaAs-based dilute nitride and antimonide alloys are seen to challenge now dominating InP-based semiconductors in the long-wavelength (1.3-1.5 μm) device markets. GaAs would offer many advantages over InP. It would be cost-effective and robust and have higher thermal conductivity than InP, and would allow for the manufacture of monolithic vertical-cavity surface-emitting lasers (VCSELs) in a single epitaxial growth run. Since the conventional InP-based material system has inherent disadvantages like poor thermal property and lack of proper mirror materials, long-wavelength laser diode constructed on GaAs substrate is highly desirable. A new material of GaInNAs, which could be realized by addition of small amount of nitrogen into GaInAs composition, is one of the best candidates for active layer of GaAs-based long-wavelength laser diodes. Due to large energy discontinuity in conduction band, the temperature characteristics of GaInNAs/Ga(Al)As quantum well is expected to be excellent. Moreover, well established GaAs/AlGaAs distributed Bragg reflectors provide enough reflectivity and conductivity for vertical-cavity surface-emitting lasers (VCSELs). Lateral confinement of carrier and optical mode by oxide layer is also applicable to improve the device performances.

The mixed group-III dilute nitrides, or substitutionally disordered $Ga_{1-x}In_xN_yAs_{1-y}$ possess intriguing physical properties and great potential for applications in optoelectronics. Long-wavelength GaInNAs / GaAs lasers have already been demonstrated. The development and optimization of GaAs-based VCSELs in the near infrared region (1.3 μm -1.55 μm) includes techniques for current confinement such as blocking layers and selective oxidation, and also VCSELs with quantum dots as active material.

Summary of the invention

It is an object of the present invention to use a laser light of the semiconductor injection laser integrated with multiple-quantum wells

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saturable absorber used in surface-normal configuration to modulate the reflection of the optical gate.

It is another object of the invention to improve the modulation contrast of optically pumped surface-normal modulators.

It is another object of the invention to increase the modulation efficiency of the optically pumped surface-normal modulators.

Yet another object of this invention is to enable a number of applications, for example, the application of this technology in mode-locked lasers for repetition rate stabilization, in optical signal processing, in interconnection systems, etc.

The device according to an advantageous embodiment of the invention comprises optically-controlled vertical-cavity modulator integrated monolithically with pump vertical-cavity surface-emitting laser. Molecular beam epitaxy (MBE) or metalorganic chemical vapor deposition (MOCVD) grown quantum well optoelectronic modulators in the GaInNAs / GaAs and GaInNAsSb(GaNAsSb) materials system can be used to meet the criteria for long-wavelength optical modulators.

The device according to an advantageous embodiment of the present invention comprises a reflection-type modulator with surface-normal architecture in which the signal light propagates substantially perpendicular to the surface and exploiting pump optical beam from integrated vertical-cavity surface-emitting laser (VCSEL) for modulation/switching the signal light.

The device concept exploits the integration of the surface-emitting vertical-cavity laser diode and surface-normal optical gate on the same substrate.

More precisely, the semiconductor modulator according to the present invention is primarily characterized in that the modulator element is formed on top of the emitting surface of the vertical-cavity surface-

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emitting laser, and that the modulator element comprises a first mirror, a second mirror, and an absorber region between the first and the second mirror, wherein at least one optical property of the absorber region is arranged to be varied by varying the intensity of the pump optical beam. The method according to the present invention is primarily characterized in that the modulator element is formed on top of the emitting surface of the vertical-cavity surface-emitting laser, in which modulator element a first mirror, a second mirror, and an absorber region between the first and the second mirror are formed, wherein at least one optical property of the absorber region can be varied by varying the intensity of the pump optical beam.

The present invention shows remarkable advantages over solutions of prior art. The pump VCSEL is directly modulated by modulating the injection current. Saturable absorber region is positioned on the top of the VCSEL structure and it is not affected by the injection current. Therefore, modulated laser light crosses the absorber region and modulates its transmission by saturating optically the absorption.

There is no need for external light source to pump the absorption section of the modulator.

Brief description of the drawings

In the following, the invention will be described with reference to the appended drawings, in which

Fig. 1   discloses in cross-sectional view an absorber region with distributed Bragg reflector of a semiconductor according to an advantageous embodiment of the present invention,

Fig. 2   depicts a characteristic of an absorber region of a semiconductor modulator according to an advantageous embodiment of the present invention,

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Fig. 3   discloses in cross-sectional view a semiconductor
modulator according to an advantageous embodiment of
the present invention, and

5   Fig. 4   discloses an example of a transmission system in which the
semiconductor modulator of the present invention can
advantageously be implemented.

Detailed description of the invention

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The conceptual configuration of a semiconductor modulator 1
according to an advantageous embodiment of the present invention is
shown in Fig. 3. The basic parts of the semiconductor modulator 1
include a vertical-cavity surface-emitting laser 2, and a modulator

15   element 3 comprising an absorber region 4 with top and bottom mirrors
5, 6, preferably distributed Bragg reflectors shown in Fig. 1. The
absorber region 4 and the mirrors 5, 6 are preferably grown on a GaAs
substrate 23.

20   The pump laser 2 includes semiconductor gain medium 7 comprising
quantum wells and distributed Bragg reflectors (DBRs) 27 as cavity
mirrors. The pump laser 2 allows for high-speed amplitude modulation
of the laser beam by modulating the injection current of the laser 2.

25   The absorber region 4, which operates as an optical modulator, is
optically connected with the laser cavity; it situates in the optical path of
the output beam 10 of the laser.

The absorption rate of the absorber region 4 can be varied by varying

30   the intensity of the light that illuminates to the absorber region 4. The
characteristic curve of the absorber region 4 is non-linear. Fig. 2
depicts an example of a characteristic curve of an absorber region 4 of
a modulator 1 according to an advantageous embodiment of the
present invention. The x-axis depicts the light intensity directed to the

35   absorber region, and the y-axis depicts the transmission rate of the
absorber region as a function of the light intensity. It can be seen that
at low light intensities the transmission of the absorber is low, i.e.

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absorption is high . The transmission increases gradually with the increase in the light intensity. With light intensities near saturation intensity of the absorber (I_s), the transmission rate begins to increase more rapidly with the increase in the light intensity. Eventually, at high
5   light intensities, the absorber 4 is saturated, wherein the transmission rate is at its maximum and further increase in light intensity does not substantially affect the transmission rate. Therefore, by modulating the pump laser 2 by a modulating signal 8 generated by a modulating signal source 24 (Fig. 4) the light intensity of the pump laser 2 is
10   changed according to changes in the modulating signal 8. When the variations in the light intensity of the pump laser 2 are selected to vary around the abrupt part of the characteristic curve, the modulation effectiveness (or contrast ratio) is very high.

15   The non-linearity of the quantum-well absorptive material is a function of the intensity of the incident radiation, pump wavelength, the absorption cross-section and material volume.

The saturable absorber 4 can be included as an intrinsic region, into
20   asymmetric Fabry-Pérot (ASFP) structure to further enhance the non-linear response of the modulator 1. The ASFP saturable absorber 4 operates as a resonant or antiresonant absorber at a particular wavelength. By taking appropriate values for the reflectivity of the top reflector 5 of the ASFP, it is feasible to optimise the non-linearity and
25   losses. The saturation intensity of a saturable absorber 4 is regulated by positioning absorber element (e.g. quantum wells) within the absorber cavity and by optimising the absorber volume (e.g. number of quantum wells).

30   An exemplary realization of the saturable absorber (modulation element) 3 is shown in cross-sectional view in Fig. 1. The absorber section 4, wherein said Fabry-Pérot étalon has a free spectral range and finesse that can be optimised by adjusting thickness of the spacer layer 9 (Fig. 1) and reflectivity of the top mirror 5, e.g. distributed Bragg
35   reflector.

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The reflectivity of the bottom mirror 6 of the absorber has ideally 100 percent reflectivity for the signal light and transparent for the VCSEL pump light. However, in practice the reflectivity is slightly less than 100 percent.

Preferably, the modulator element 3 comprises a non-linear optical element 4 pumped optically by the radiation produced by the pump laser 2.

Preferably, the modulator element 3 is monolithically integrated with the pump laser 2 using vertical cavity configuration, which makes the coupling of the laser light into the modulator region 4 be efficient. The integration improves the important figures of merit of the intensity modulators, e.g., the "on/off" ratio and the transmission in the "on" state.

Preferably, the modulator comprises two optical beams: A first pump optical beam 10 carries the modulating signal in optical form for modulation/switching the signal light. A second optical beam 11 carries optical signal to be modulated; the signal light propagates substantially perpendicular to the surface of the device 1.

In the present invention, the semiconductor modulator 1 includes VCSEL section 2 with a multiple quantum well design of the active region and a non-linear optical element 3 connected to the first pump optical beam 10 with surface-normal architecture in which the signal light 11, 16 propagates substantially perpendicular to the surface.

Preferably, the non-linear optical medium 4 of modulation element 3 is multiple quantum-well structure.

Preferably, the nonlinear element 3 of the modulator 1 is a surface reflection saturable absorber.

The modulator region 4 includes a stack of semiconductor layers acting as Bragg reflector for signal beam 11.

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The signal wave to be modulated is injected through the input device aperture 12, passed the saturable absorber region 4 and reflected back by the Bragg reflector 6.

5   The VCSEL 2 is a forward-biased diode. It comprises a gain medium 7, wherein an optical axis is defined between DBR mirrors 27. An exemplary realization of the electrically pumped VCSEL is shown in cross-sectional view in Fig. 3.

10   It should be understood that the VCSEL structure 2 of the present invention is not limited by the design presented in the description but other electrically pumped VCSELs having different electrical contact structure and modal guiding can also be implemented in the modulator. VCSEL technology has been researched for years as an alternative
15   and less-costly light source for use in short-distance applications. Their smaller size, lower power, lower cost, and good reliability enabled their popularity to soar over the years. Commercial VCSELs run at 850 nm, although the market also began in the 980-nm range. Examples of the electrically pumped VCSEL can be found in opened literatures (for
20   example E. Hall et al., "Electrically-pumped, single-epitaxial VCSELs at 1.55 μm with Sb-based mirrors", Electron. Lett., vol. 35, pp. 1337-1338, 1999, or Tchang-Hun et al.,"Vertical resonator surface emission laser used in optical data communications systems comprises mirror structures, a light producing region, a semiconductor section", PATENT
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Fig. 4 presents an example of an optical transmission system in which the semiconductor modulator 1 can be used for light modulation. The pump laser 2 receives an electrical pump signal and generates optical
30   pump beam 10. The electrodes 14, 15 of the laser section is supplied with a modulating signal 8, which allows the laser section 2 to produce modulated laser emission. The modulated laser light passes through the absorber region 4 and modulates its transmission by saturating the absorption. The reflection of the modulator element 3 is increased or
35   decreased by increasing or decreasing the intensity of the pump laser light 10. The modulator element 3 is exposed with an optical signal 11 to be modulated. This optical signal is generated by an optical signal

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source 18 from which the optical signal is coupled to an optical circulator 19 via an input fibre 20. The optical circulator directs the optical signal to the modulator 1 via a coupling fibre 21 for modulation. The modulated optical signal is reflected from the modulator element 3.

5   The reflected signal acquires amplitude/intensity modulation since it is assumed that the absorption of the modulator element 3 is strongly saturated by the modulated laser light. The modulated light beam is directed back to the coupling fibre 21 in which the optical signal propagates back to the optical circulator 19. By the optical circulator 19

10   the modulated optical signal is directed to the output port fibre 22 for transmission.

The quantum well structures of the laser 2 and modulator element 3 have the different parameters (e.g., bandgap). Generally, if the laser 2

15   wavelength is shorter than the bandgap wavelength of the modulator element 3, i.e. $\lambda_{pump} < \lambda_{modulator}$, the laser light provides strong saturation of the absorption in the modulator element 3.

For example, for modulator operating near $\lambda_{modulator} = 1.55$ μm, the pump

20   wavelength can conveniently be chosen in a range $\lambda_{pump} = 0.9-1.3$ μm.

In another aspect, the invention features a method for modulating an optical input 11, e.g., a laser beam, to provide a modulated optical output 16. First, the modulating VCSEL 2 generates a modulating

25   beam 10 configured to strike the surface-normal saturable absorber 4. Second, a surface-normal semiconductor saturable absorber 4 is irradiated with the optical input 11. In the optically-pumped modulator, a saturation intensity I_S of the saturable absorber 4 and optical intensity of the integrated laser 2, can be selected such that the saturable

30   absorber 4 is above the saturation intensity I_S for the "ON" state, and it is below the saturation intensity I_S for "OFF" state. When the modulating optical beam carriers a constant pump signal, either "ON" or "OFF", the modulator operates as an optical switch. When the modulating beam carries a modulating optical beam, the output beam

35   16, reflected from the modulator section substantially perpendicularly to the DBR mirror 5, is modulated according to the modulating pump beam 10. The optimum overlap of the modulating beam 10 and output

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modulated beam 16 is determined by the monolithic structure of the device 1 which incorporates pump laser 2 and the absorption section 4 of the surface normal modulator 3 on the same substrate 17. Therefore, the modulating laser beam overlaps in the absorber region, where the modulation of the signal beam takes place, thus providing high modulation efficiency.

In another aspect, the recovery time of the saturable absorber section 4 may be altered by using ion implantation.

The modulator section 3 is constituted by the saturable absorption section 4, and the bottom mirror (distributed Bragg reflector) 6 having a high reflectivity for a wavelength of the signal modulated light formed on the top of said vertical-cavity surface-emitting pump laser 2.

An electrically-pumped VCSEL is provided for converting an electrical signal into optical pump signal for modulation of the transmission of the modulator section in accordance with the amplitude of the converted electrical signal. In place of the optically-pumped modulator section, a non-linear reflection-type saturable absorber is used for modulation/switching the optical signal in accordance with the amplitude of the electrical signal.

The modulator section may comprise a top mirror 5 to exploit cavity effect for enhancing the modulation efficiency.

In an advantageous embodiment of the present invention the distributed Bragg reflector 6 of the modulator section 3 may be doped to conduct the injection current used for modulation of VCSEL 2.

It is obvious that the present invention is not limited solely to the above-presented embodiments, but it can be modified within the scope of the appended claims.

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Claims:

1. A semiconductor modulator (1) comprising a vertical-cavity surface-emitting laser (2) to produce a pump optical beam (10) emitting substantially perpendicular to a surface of the laser (2), and a modulator element (3) for modulating an optical signal (11) to produce a modulated optical signal (16), **characterized** in that the modulator element (3) is formed on top of the emitting surface of the vertical-cavity surface-emitting laser (2), and that the modulator element (3) comprises a first (5) mirror, a second mirror (6), and an absorber region (4) between the first (5) and the second mirror (6), wherein at least one optical property of the absorber region (4) is arranged to be varied by varying the intensity of the pump optical beam (10).

2. A semiconductor modulator (1) according to claim 1, **characterized** in that the at least one optical property is transmission rate of the absorber region (4).

3. A semiconductor modulator (1) according to claim 2, **characterized** in that the transmission rate of the modulator element (3) is non-linearly dependent on the intensity of the pump optical beam (10).

4. A semiconductor modulator (1) according to claim 1, 2 or 3, **characterized** in that the first mirror (5) is a Distributed Bragg Reflector mirror having a high reflectivity at the wavelength of the modulated optical signal (16).

5. A semiconductor modulator (1) according to any of claims 1 to 4, **characterized** in that the second mirror (6) of the modulator section (3) is doped to conduct the injection current used for modulation of pump laser (2).

6. A semiconductor modulator (1) according to any of claims 1 to 5, **characterized** in that the modulator element (3) comprises GaInNAs / GaAs materials.

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7. A semiconductor modulator (1) according to any of claims 1 to 5, **characterized** in that the modulator element (3) comprises GaInNAsSb(GaNAsSb)/GaAs materials.

5   8. A semiconductor modulator (1) according to any of claims 1 to 7, **characterized** in that it is arranged to be operating at wavelengths $\lambda>1.3\ \mu m$.

9. A semiconductor modulator (1) according to any of claims 1 to 8,
10   **characterized** in that the first (5) mirror, the second mirror (6), and the absorber region (4) form a Fabry-Pérot étalon having a predetermined optical resonance frequency, and that the predetermined optical frequency is arranged to be occurred either at resonance or anti-resonance of said Fabry-Pérot étalon.

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10. A semiconductor modulator (1) according to any of claims 1 to 9, **characterized** in that the vertical-cavity surface-emitting laser (2) and the modulator element (3) are monolithically integrated onto a same substrate.

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11. A method for producing a semiconductor modulator (1) comprising a vertical-cavity surface-emitting laser (2) to produce a pump optical beam (10) emitting substantially perpendicular to a surface of the laser (2), and a modulator element (3) for modulating an optical
25   signal (11) to produce a modulated optical signal (16), **characterized** in that the modulator element (3) is formed on top of the emitting surface of the vertical-cavity surface-emitting laser (2), in which modulator element (3) a first (5) mirror, a second mirror (6), and an absorber region (4) between the first (5) and the second mirror (6) are
30   formed, wherein at least one optical property of the absorber region (4) can be varied by varying the intensity of the pump optical beam (10).

12. A method according to claim 11,   **characterized** in that in the production of the modulator element (3) GaInNAs / GaAs materials are
35   used.

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13. A method according to claim 11, **characterized** in that in the production of the modulator element (3) GaInNAsSb(GaNAsSb)/GaAs materials are used.

5   14. A method according to claim 12 or 13, **characterized** in that the speed of the absorber region (4) is controlled by controlling density of defects by selecting material composition and growth condition.
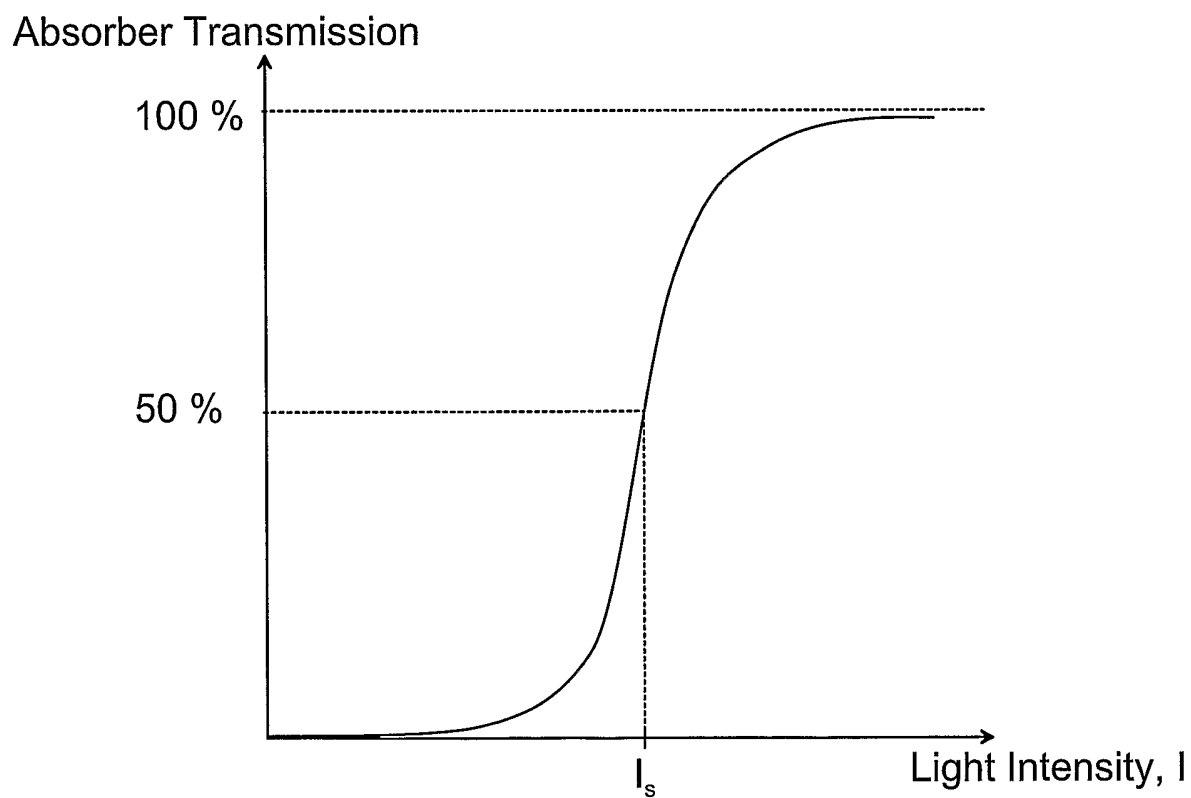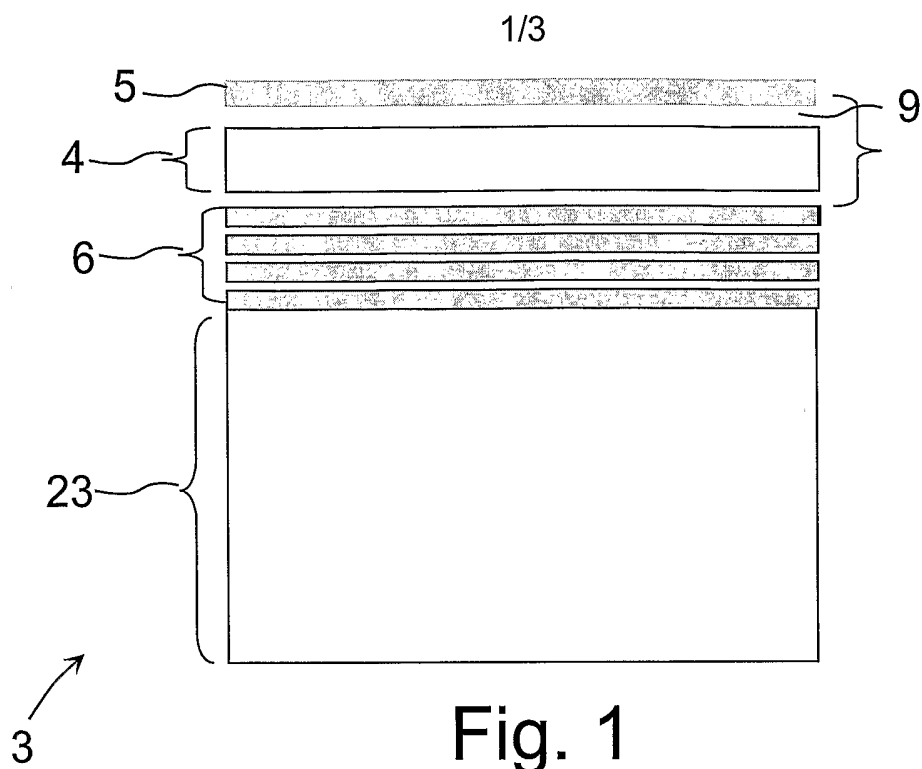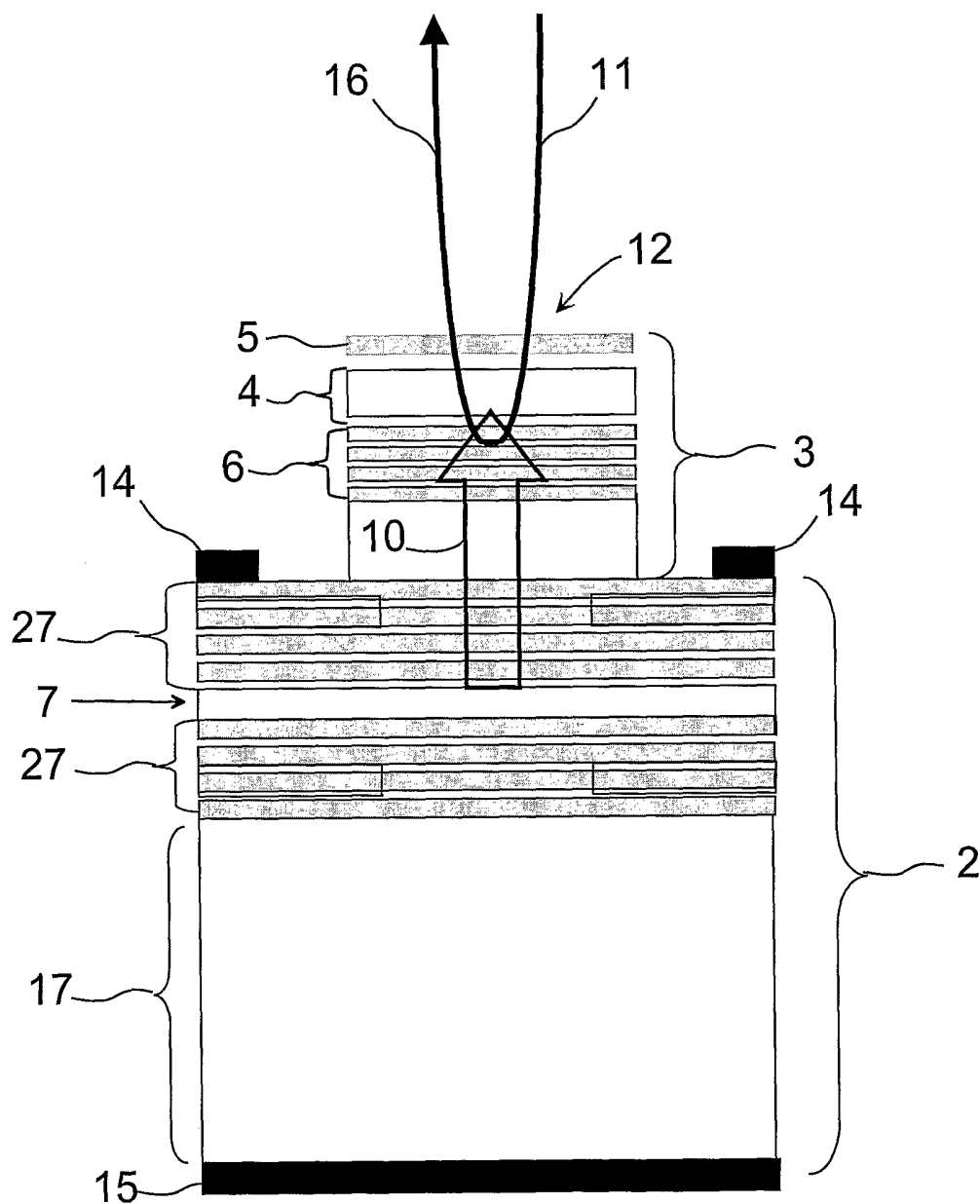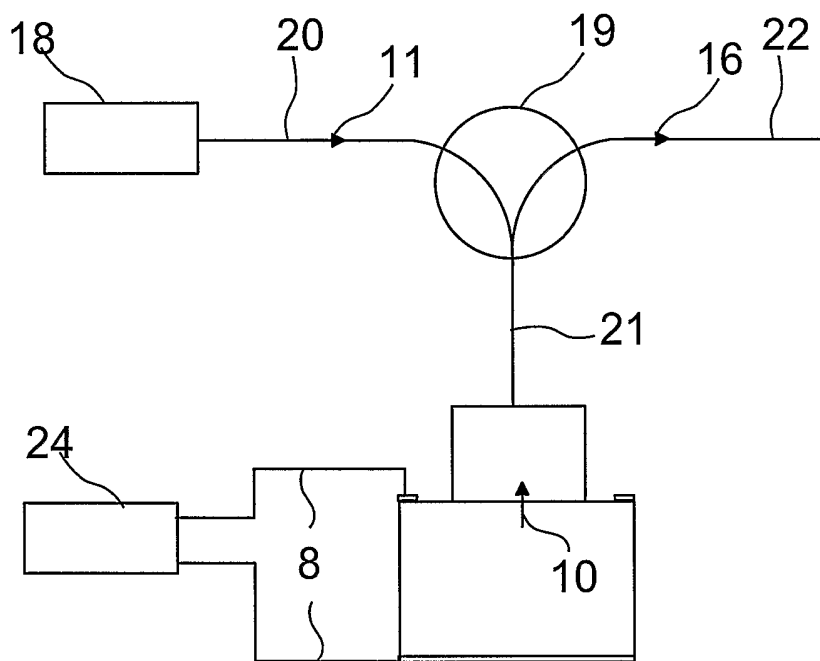
1/3

Fig. 1

Absorber Transmission

100 %

50 %

I_s

Light Intensity, I

Fig. 2

Fig. 3

Fig. 4

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H01S 5/183, H01S 5/026

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)

IPC7: H01S, G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI DATA, EPO-INTERNAL, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 0157977 A1 (INFINEON TECHNOLOGIES AG), 9 August 2001 (09.08.01), see description of figure 2	1,4,5,9,10, 11
Y		2,3,6-8, 12-14
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Y	Shimizu,H., et al "Nonlinear gain factor of 1,26µm GaInNAs-based SQW lasers" In: Lasers and Electro-Optics, 2001. CLEO/ Pacific Rim, 4th Pacific Rim Conference, 2001, On pages II-598-II599 vol. 2, INSPEC Accession number: 7373360 see whole document	6-8,12,13
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X	Further documents are listed in the continuation of Box C.	X	See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 November 2003	2 5 -11- 2003

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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International application No.
PCT/FI 03/00623

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