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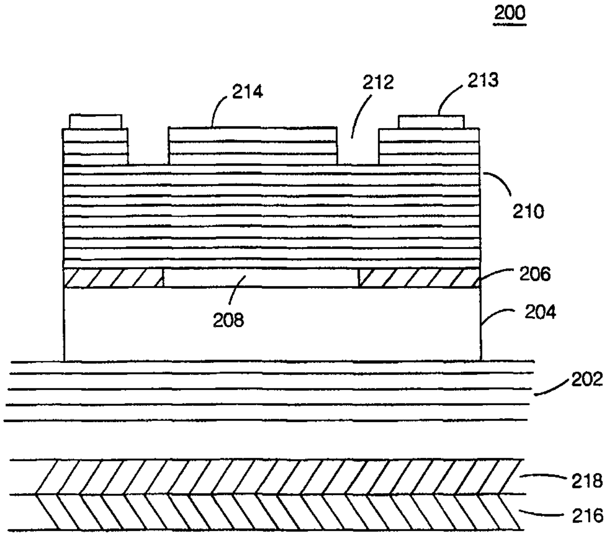

(57) Abstract

The present invention relates to an optical device (200) and method of manufacture. In particular the present invention provides an optical device for emitting light comprising first and second mutually facing mirrors (202, 210), the first mirror (210) comprising a surface window through which light can pass, an active region (204) disposed between the first and second mirrors for generating light and means for supplying a current to the active region. The device (200) being characterised by the first mirror (210) comprising a first reflective region (214) having a first reflectivity and a second region (212) having a second reflectivity, the first mirror comprising the first and second reflective regions being arranged to control the mode of operation of the device, and/or the mode of emission of light from the device.

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Optical Device and Method of manufacture

The present invention relates to an optical device and a method of manufacture thereof. More particularly, the present invention relates to a vertical cavity surface emitting laser.

Surface emitting semiconductor lasers are well known within the art and are commonly referred to as vertical cavity surface emitting lasers (VCSELs). A top emitting laser has top and bottom mirrors at either end of the resonant cavity. The top mirror has a lower reflectivity than that of the lower mirror. The converse is true for bottom emitting devices.

VCSELs have several advantages over laterally emitting semiconductor lasers, including the ease of producing arrays of lasers, the possibility of device testing early in the fabrication process, simpler integration into systems and a near circular optical output beam.

Single mode VCSELs have a single emission spectrum peak and a circular output beam and are therefore preferred to multi-mode devices in certain applications. For maximum efficiency, as much as possible of the current should be injected into the active region in the area of fundamental mode lasing. Current outside of this lasing area is generally wasted or generates light which is wasted. To achieve maximum efficiency and single mode operation, many devices employ a mesa of a size close to that of the fundamental optical mode. For both top and bottom emitting VCSELs, the injected current has to pass through this mesa, and its small area gives rise to an increased series resistance. For top emitting VCSELs, a window has to be provided in the top contact to allow optical emission. However, the window reduces the top contact area and increases the series resistance still further. To operate VCSELs at GHz frequencies with a conventional laser driver, it is desirable to reduce the series resistance as much as possible.

As the laser power is increased above a particular threshold, a surface emitting laser typically switches rapidly to a higher order optical mode which distorts its circular beam. This problem is addressed in US patent no 5,493,577. US patent no 5,493,577 discloses a VCSEL in which the laser efficiency has been improved and single mode operation achieved by forcing the injection current to flow close to the central axis of the device. An aluminium arsenide confinement layer is disposed between the active region and top-mirror. This layer may be transformed into an insulating material by exposure to wet nitrogen as is well known within the art. The aperture of the confinement layer is selected to confine the flow of injection current to the area of the active region that is responsible for the fundamental mode of operation. However, a very small aperture is necessary to obtain fundamental mode operation and it is difficult to achieve the desired accuracy, repeatability and uniformity of the aperture geometry. Further, the efficiency of such a device is reduced by the small aperture size due to increased scattering and diffraction losses at the aperture.

"Transverse mode control of vertical cavity top surface emitting lasers", by R A Morgan et al, IEEE Photonics Technology Letters, Vol 4, No 4, p374, 1993 (Morgan), discloses a single transverse mode top emitting VCSEL. Current is constrained to flow close to the central axis of the VCSEL by ion implantation of an annular region of the top mirror stack. An apertured electrical contact is provided on the top surface of the mirror which is aligned co-axially with the undoped region of the top mirror. The aperture in the electrical contact is sufficiently small to allow transmission of only the fundamental mode by using the exit window of a top surface emitter as a spatial filter. Morgan suffers from the significant disadvantage that the ion implantation reduces the electrical conductivity for the entire depth of the top mirror which leads to an undesirable increase in series resistance.

US patent no 5,778,018 describes single transverse optical mode device operation in which current flows from an electrical contact through a top mirror stack, an active region, a bottom mirror stack and a substrate to an electrical contact. Lasing occurs where there is current flow and light is emitted through the substrate. The cross sectional area of the entire top mirror stack is controlled so that only a single transverse mode is supported in the waveguide formed by the mirror stack. However, this technique is limited to use in manufacturing bottom emitting devices. The small cross-sectional area of the top mirror stack prevents a window being formed in the top mirror electrical contact. Further, as the area of the mirror stack is small, the series resistance is relatively high. Still further, the emitted light must pass through the substrate of the device which leads to a reduction in the maximum power output as compared to top surface emitting devices.

It is an object of the present invention to mitigate at least some of the problems associated with the prior art.

Accordingly, an embodiment of the present invention provides an optical device for emitting light comprising first and second mutually facing mirrors, the first mirror comprising a surface window through which light can pass, an active region disposed between the first and second mirrors for generating light in response to a current and means for supplying the current to the active region, the device being characterised by the first mirror comprising a first reflective region having a first reflectivity and a second region having a second reflectivity that are arranged to control the mode of lasing of the device, and/or the mode of emission of light from the device.

An advantage of an embodiment of the present invention is that the fundamental optical mode is closely coordinated with the current path, that is, the current path (or current confinement aperture) and the optical confinement aperture are concentrically disposed.

The reduction in the series resistance, following from having a larger current aperture, of the device enables the device to be operated at higher frequencies.

Advantageously, a top-emitting VCSEL according to an embodiment of the present invention has an increased resistance to degradation. The increased resistance to degradation follows from the increased distance between the air-semiconductor interface of the top surface and the active region.

The embodiments of the present invention have the advantage that the fine tuning of the optical mode characteristics of the devices can be made late in the fabrication process and multimode devices can be adjusted to produce single mode devices that, rather than being rejected, allow multimode devices to be converted to single mode devices thereby reducing wastage. The conversion process utilises an etching process during which the reflection coefficient is reduced for the regions of the top mirror that would but for the etching support higher order modes.

In an embodiment, an optical waveguide of reduced cross-section, for example, a reduced diameter, is formed by etching the top mirror, allowing optical mode control. A shallow etch gives rise to a smaller difference in effective refractive index between core and cladding compared to a deep etch. This in turn leads to a larger sized single mode in the shallow etched case and a correspondingly larger maximum output power.

The shallow trench is etched using a photolithographic pattern as the definition accuracy is superior to alternative techniques.

As the top mirror is only etched to a shallow depth, the active region is kept distant from the semiconductor/air interface. The increased distance between the air/semiconductor interface leads to a reduction in the oxidation of the device AlGaAs layers which results in an improved device lifetime.

Contacts can be made in the normal manner to the top of the device. A deeper top mirror etch increases the series resistance of the device considerably. Preferably, the etch depth should be kept to the minimum necessary to establish a sufficiently different change of effective refractive index to suppress the higher order modes. It will be appreciated that this etch depth will vary on a per batch basis. Care should be taken to avoid increasing the electrical resistance between the contact ring and the current confining aperture.

The lateral oxidation process is inherently less able to define accurately lateral dimensions. The larger oxide aperture in the present method of mode control relaxes the oxidation process tolerances. The larger aperture of the present invention reduces the series resistance.

Optical mode control and current confinement are separated in the devices disclosed in US 5,778,018. The top mirror is etched to provide fundamental mode optical emission, and the threshold current is reduced by ion implantation. The small transverse size of the mirror mesa forces the use of a top contact without a window and this in turn allows optical emission only through the substrate.

Accordingly, an embodiment of the present invention provides a top surface electrical contact with an aperture to allow top face light emission.

Further, Morgan describes an optical device in which the current path is defined by ion implantation and the optical output is spatially filtered by an aperture in the top contact to allow the passage of only the fundamental mode. The reflectivity of the contact-semiconductor interface is phase-mismatched to be less than the semiconductor-air interface. Embodiments according to the present invention can produce differences in reflectivities of at least 10% and often more than 90% and in some instances tending towards 100%.

An embodiment provides an optical device further comprising current confinement means for controlling the path of the current into the active region. Preferably, the current confinement means comprises an apertured oxide layer. In a preferred embodiment, the aperture oxide layer comprises an oxide of aluminium arsenide.

An embodiment is provided in which the current confinement means is a separate element to the first or second regions of reflectivity of the first mirror.

Preferably, the first mirror is arranged to urge the mode resonance of the device to the fundamental mode.

A preferred embodiment provides an optical device in which the second region of reflectivity has reduced reflectivity and increased transmissibility compared to the first region of reflectivity.

Preferably, the first and second regions of reflectivity are laterally or radially disposed relative to each other.

In a preferred embodiment, the second region of reflectivity has an annular shape. Preferably, the first region of reflectivity is seven μm wide.

Differences in reflectivity of the first mirror can be realised using regions of different thickness. Preferably, an optical device is provided in which the depth of the second region of reflectivity is less than the depth of the first region of reflectivity, preferably by one µm.

The first region of reflectivity can be defined using a photolithographic process.

It will be appreciated that the device is arranged to emit light from the mirror most remote from the substrate, that is, the device is arranged to be a top emitting device, whether or not the device remains mounted on its growth substrate or is mounted on some other substrate.

A second aspect of the present invention provides a method for manufacturing an optical device for emitting light, the method comprising the steps of producing on a substrate an optical device having first and second mutually facing mirrors, the first mirror comprising a window through which light can pass, an active region disposed between the first and second mirrors for generating light depositing on the substrate an electrical contact, depositing on an exposed upper surface of the optical device an electrical contact, producing within the first mirror a first reflective region and a second reflective region, the first and second reflective regions being arranged to control the mode of operation of the device and/or the mode of emission of light from the device.

Other aspects of the present invention are defined in the appended claims.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

figure 1 is a schematic sectional view of a conventional vertical cavity surface emitting laser;

figure 2 is a schematic sectional view of a top emitting vertical cavity surface emitting laser constructed in accordance with the present invention; and

figure 3 is a schematic sectional view of a top emitting vertical cavity surface emitting laser constructed with a dielectric second mirror stack; and

figure 4 shows the variation of light output power with drive current of a VCSEL according to a preferred embodiment.

Figure 1 of the accompanying drawings shows a schematic top emitting VCSEL 100. An optically emitting region 102 disposed between a first mirror stack 104 and a second mirror stack 106. The first mirror stack 104 is etched, or selectively deposited, to form a mesa like structure. The active region 102 comprises a first cladding layer 108, an active layer 110 (such as a quantum well or the like) and a second cladding layer 112. An electrical contact ring 114 is formed on at least the first mirror 104 and a broad area electrical contact 116 is formed on a substrate 118 of the device. The electrical contact 114 is apertured to define a window 120 for the emission of light from the VCSEL 100 through the first mirror 104. The substrate 118 is made of, for example, gallium arsenide, the first 104 and second 106 mirror stacks are, for example, made of a series of gallium arsenide and aluminium gallium arsenide layers and the electrical contacts are, for example, made of alloys containing gold. In this simple form the VCSEL is very inefficient as a single mode laser because light is emitted from the whole of the active region, typically in a mode other than the fundamental mode. When a voltage is applied between the electrical contacts 114 and 116, a current flows and lasing action occurs, as is well known within the art. The current flows throughout the first mirror stack 104 and lasing occurs wherever that current flows. Since current outside of the desired fundamental mode is wasted, the mirror stack mesa 104 must be reduced in size to achieve single mode operation. However, this leads to an increase in series resistance and prevents use of the VCSEL 100 at GHz frequencies.

Referring to figure 2, there is shown schematically a sectional view of a VCSEL 200 according to a first embodiment. The first embodiment comprises a first mirror stack 210, an active region 204, an annular low conductance region 206 surrounding a conducting region 208, and a second mirror stack 202. A trench 212 is etched in the first mirror stack 210. The etched trench 212 defines a first or central area 214 which controls the optical emission mode. It will be appreciated that as soon as one mode optical lasing mode becomes dominant, all other modes are suppressed. The trench etching makes the reflectivity, and consequently the gain, for the fundamental mode greater than for the higher order modes and therefore more likely to become dominant. A contact ring 213 is formed substantially co-axially with the etched trench 212. The complete device is formed on a substrate 218 and a back contact 216 is disposed on the substrate.

Preferably, the low conductance region 206 is produced by selective oxidation of a high aluminium content aluminium arsenide layer to leave the conducting region 208. The low conductance region 206 controls the current flow into the active region 204. The current flow is confined to flow at least within that portion of the active region responsible for producing lasing in the fundamental mode of the device.

Unlike US patent no 5,493,577, in which the optical and current confinement necessary for single mode operation are both controlled by the lateral oxidation of an aluminium arsenide layer, the first embodiment of the present invention relaxes the process tolerances at the oxidation stage by separating the current confinement and optical mode control aspects of the VCSEL design. Furthermore, the first embodiment, as a consequence of the larger aperture, has reduced scattering and diffraction optical losses and reduced series resistance.

A 850nm single mode VCSEL was realised according to the present invention. The VCSEL was fabricated from an epitaxial structure comprising many gallium arsenide (GaAs) and aluminium gallium arsenide ($Al_xGa_{1-x}As$) layers deposited sequentially on a single crystal n-type gallium arsenide substrate. The layer sequence for the particular device was as shown in table 1 below. In table 1, Al_x represents ($Al_xGa_{1-x}As$) i.e. Al 0.2 is shorthand for $Al_{0.2}Ga_{0.8}As$.

Repeats	Thickness(Å)	Material	Dopant	Type
1	50	GaAs	C	p
27	424	Al0.2	C	p
27	200	Al0.5	C	p
27	471	Al0.78	C	p
27	200	Al0.5	C	p
1	424	Al0.2	C	p
1	200	Al0.5	C	p
1	350	AlAs	UD	
1	240	Al0.78	UD	
1	975	Al0.3	UD	
1	100	GaAs	UD	
1	100	Al0.3	UD	
1	100	GaAs	UD	
1	100	Al0.3	UD	
1	100	GaAs	UD	
1	990	Al0.3	UD	
1	580	Al0.78	Si	n
1	200	Al0.52	Si	n
15	424	Al0.2	Si	n
15	200	Al0.52	Si	n
15	471	Al0.78	Si	n
15	200	Al0.52	Si	n
27	424	Al0.78	Si	n
27	200	Al0.52	Si	n
27	471	Al0.2	Si	n

27	200	Al0.52	Si	n
1	10000	GaAs	Si	n
1	5000	Al0.5	Si	n
1	500	GaAs	Si	n

Table 1

The VCSEL was fabricated using six processing steps. The bottom surface of the substrate wafer was first metallised with n-type electrical contact material comprising a gold/nickel/germanium alloy. Gold/zinc/gold annular p-type electrical contact rings were deposited on the top surface of the epitaxial layer. The sample was annealed at 430°C and individual devices were trench isolated by wet etching. The current confinement aperture was defined by oxidation in wet nitrogen at 400°C. The current confinement aperture diameter was greater than that of the unetched mirror but not so greater as to unduly increase the threshold current. In an embodiment, the current confinement aperture had a diameter of 10 μm. The laser was completed by etching a shallow annular trench in the top surface of the top mirror. The trench was within the top electrical contact ring to produce a small mirror mesa that is co-axial with the current confinement aperture. A typical small mirror diameter may be of the order of 6 μm. The small mirror diameter is governed by the need to be sufficiently large to support fundamental optical mode lasing but sufficiently small to suppress the higher order lasing modes.

Although the above embodiments describes a substantially circular contact ring, the embodiments of the present invention could equally well be realised using contacts that are other than circular.

Although the embodiment realised above had a structure as depicted in table 1, the present invention is not limited thereto. Embodiments can equally well be realised in which the top mirror comprises between five to fifty pairs of different layers of optical thickness equal to one quarter of the operating wavelength with relatively high and low respective refractive indices, the bottom mirror comprises between five to one hundred pairs, the diameter of the etched top mirror may be between four and eight microns, the depth of the trench may be between 0.25 and 2.0 microns or 2-15 pairs and the current confinement aperture diameters may be between 4 and 15 microns.

Several hundred devices have been made using the above process and have been found to have the desired single mode characteristics. Figure 4 shows the variation of a etched top mirror VCSEL light emission according to the present invention with drive current characteristic. The upper curve represents the intensity of light emitted with polarisation along the (110) direction and the lower curve represents the intensity of light emitted with polarisation in a perpendicular direction.

By separating the current confining and optical mode control aspects, the present invention relaxes the manufacturing tolerances imposed upon the lateral oxidisation of the AlAs layer and increases the manufacturing tolerances imposed upon the production of the top mirror which is the element that may, without wishing to be bound by any particular theory, define the optical mode of resonance. It will be appreciated that to avoid the current confinement layer performing or contributing to the optical confinement function, the diameter or dimensions of the current confinement layer must exceed those of the optical confinement means.

Referring to figure 3 there is shown a second embodiment of an optical device 300 according to the present invention. The optical device comprises a first mirror 304, a second mirror 309, mounted on a substrate 318. The device also comprises a centrally disposed conducting region 308 surrounding by an annular low conductance region 306. The active region 307 is disposed on top of the second mirror 309. Electrical contacts 301 and 316 are disposed on the top surface of the first mirror 304 and the substrate 318 respectively. It can be seen that the optical device 300 has a Distributed Bragg Reflector or mirror stack 302 disposed on the top surface of the partial mirror 304. The dimensions of the stack are selected so that only the fundamental mode of lasing is supported. Table 2 below illustrates a preferred embodiment of a device according to figure 3.

Repeats	Thickness(Å)	Material	Dopant	Type
	Post	Exitaxial	Growth	
1	half wavelength	SiO_2		
4	quarter wavelength	TiO_2		
4	quarter wavelength	SiO_2		
	Epitaxial	Growth		
10	424	Al0.2	C	p
10	200	Al0.5	C	p
10	471	Al0.78	C	p
10	200	Al0.5	C	p
1	424	Al0.2	C	p
1	200	Al0.5	C	p
1	350	AlAs	UD	
1	240	Al0.78	UD	
1	975	Al0.3	UD	
1	100	GaAs	UD	
1	100	Al0.3	UD	
1	100	GaAs	UD	
1	100	Al0.3	UD	
1	100	GaAs	UD	
1	990	Al0.3	UD	
1	580	Al0.78	Si	n

1	200	Al0.52	Si	n
15	424	Al0.2	Si	n
15	200	Al0.52	Si	n
15	471	Al0.78	Si	n
15	200	Al0.52	Si	n
27	424	Al0.78	Si	n
27	200	Al0.52	Si	n
27	471	Al0.2	Si	n
27	200	Al0.52	Si	n
1	10000	GaAs	Si	n
1	5000	Al0.5	Si	n
1	500	GaAs	Si	n

Table 2

It will be appreciated that the GaAs/AlGaAs mirror alone has too low a reflectivity for lasing to occur. The additional dielectric mirror stack increases the reflectivity in the central region enabling lasing to occur on application of the appropriate device voltage. The dielectric mesa diameter is sufficient to support the fundamental lasing mode but not large enough to support higher order lasing modes. The dimensions of the top stack would be as follows: diameter between four and eight microns and height between one to five pairs. The epitaxial part of the top mirror would contain between five and fifteen pairs.

It will be appreciated that the growth time of a device as illustrated in figure 3 will be less than the growth time of a device which requires a trench to be etched to define the regions of differing reflectivity.

In the above embodiments, the relative areas of the optical confinement mode stack and the aperture in the current confinement AlAs oxidised layer are in the ratio of approximately 1:2.

Within the context of the present invention, a substrate can be either a growth substrate upon which a device is fabricated or a mounting substrate upon which a fabricated device can be or is mounted.

CLAIMS

1. An optical device for emitting light comprising first and second mutually facing mirrors, the first mirror comprising a surface window through which light can pass, an active region disposed between the first and second mirrors for generating light and means for supplying a current to the active region, the device being characterised by the first mirror comprising a first reflective region having a first reflectivity and a second region having a second reflectivity, the first mirror comprising the first and second reflective regions being arranged to control the mode of operation of the device, and/or the mode of emission of light from the device.

2. An optical device as claimed in claim 1, further comprising current confinement means for controlling the path of the current into the active region.

3. An optical device as claimed in claim 2, wherein the current confinement means comprises an apertured oxide layer.

4. An optical device as claimed in claim 3, wherein the aperture oxide layer comprises an oxide of aluminium arsenide.

5. An optical device as claimed in any of claims 2 to 4, wherein the current confinement means is a separate element to the first or second regions of reflectivity of the first mirror.

6. An optical device as claimed in any preceding claim, wherein the first mirror is arranged to urge the mode resonance of the device to the fundamental mode.

7. An optical device as claimed in any preceding, wherein the second region of reflectivity has reduced reflectivity and

increased transmissibility compared to the first region of reflectivity.

8. An optical device as claimed in any preceding claim, wherein the first and second regions of reflectivity are laterally or radially disposed relative to each other.

9. An optical device as claimed in any preceding claim, wherein the second region of reflectivity has an annular shape.

10. An optical device as claimed in any preceding claim, where the first region of reflectivity is seven µm wide.

11. An optical device as claimed in any preceding claim, wherein the thickness of the second region of reflectivity is less than the thickness of the first region of reflectivity, preferably by one µm.

12. An optical device as claimed in any preceding claims, wherein the first region of reflectivity is defined using a photolithographic process.

13. An optical device as claimed in any preceding claim, the device is arranged to emit light from the mirror most remote from the substrate.

14. An optical device substantially as described herein with reference to and/or as illustrated in the accompanying drawings.

15. A method for manufacturing an optical device for emitting light, the method comprising the steps of

producing on a substrate an optical device having first and second mutually facing mirrors, the first mirror comprising a window through which light can pass, an active region disposed between the first and second mirrors for generating light depositing on the substrate an electrical contact,

depositing on an exposed upper surface of the optical device an electrical contact,

producing within the first mirror a first reflective region and a second reflective region, the first and second reflective regions being arranged to control the mode of operation of the device and/or the mode of emission of light from the device.

16. A method as claimed in claim 15, further comprising the step of annealing the device at a predetermined temperature to reduce the series resistance of the device.

17. A method as claimed in claim 16, wherein the predetermined temperature is between 200°C and 600°, preferably 430°C.

18. A method as claimed in any of claims 15 to 17, further comprising the step of producing a current confinement means.

19. A method as claimed in claim 18, wherein the step of producing the current confinement means comprises the step of producing an apertured oxide layer.

20. A method as claimed in claim 19, wherein the step of producing the apertured oxide layer comprises the step of oxidising the device in wet nitrogen at a predeterminable temperature, preferably between 300°C and 500°C, still more preferably at 400°C.

21. A method as claimed in any of claims 15 to 20, wherein the substrate is a single crystal n-type gallium arsenide substrate.

22. A method as claimed in any of claims 16 to 21, wherein current confinement aperture and the mesa mirror are substantially co-linear.

23. A method for manufacturing an optical device substantially as described herein with reference to and/or as illustrated in the accompanying drawings.

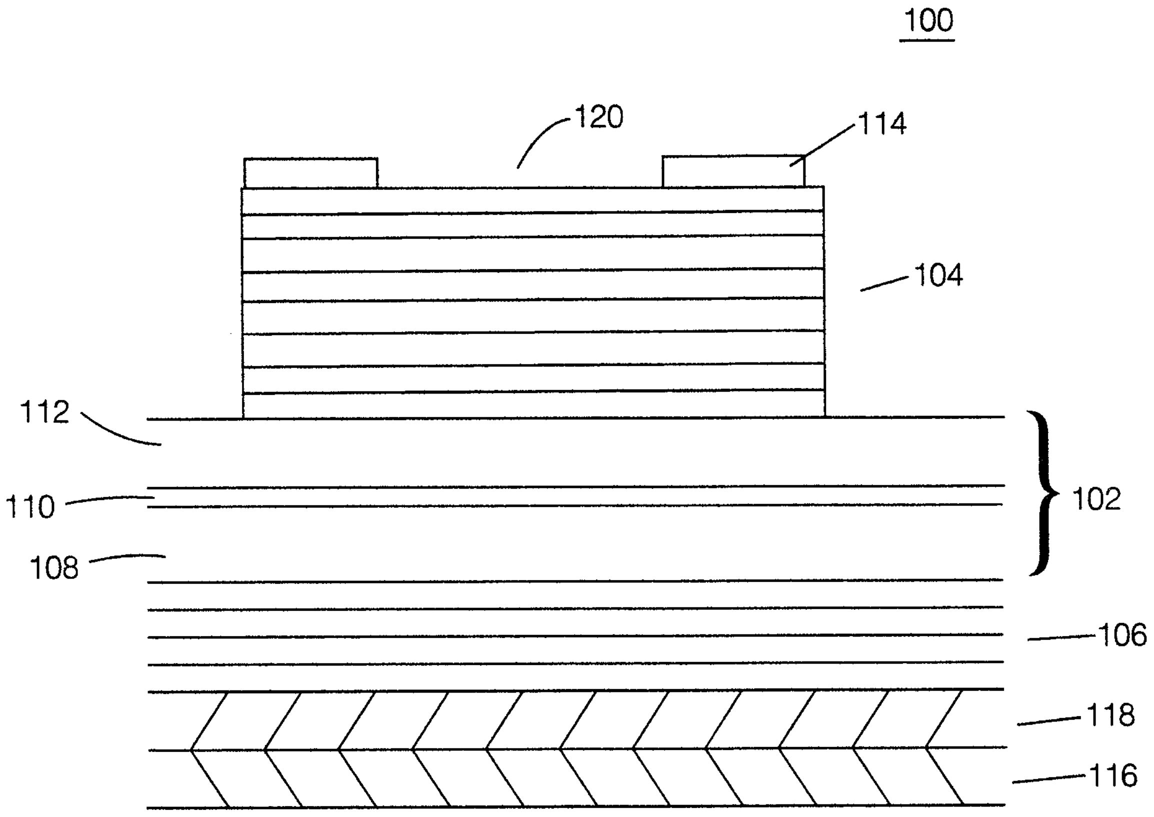

Fig. 1

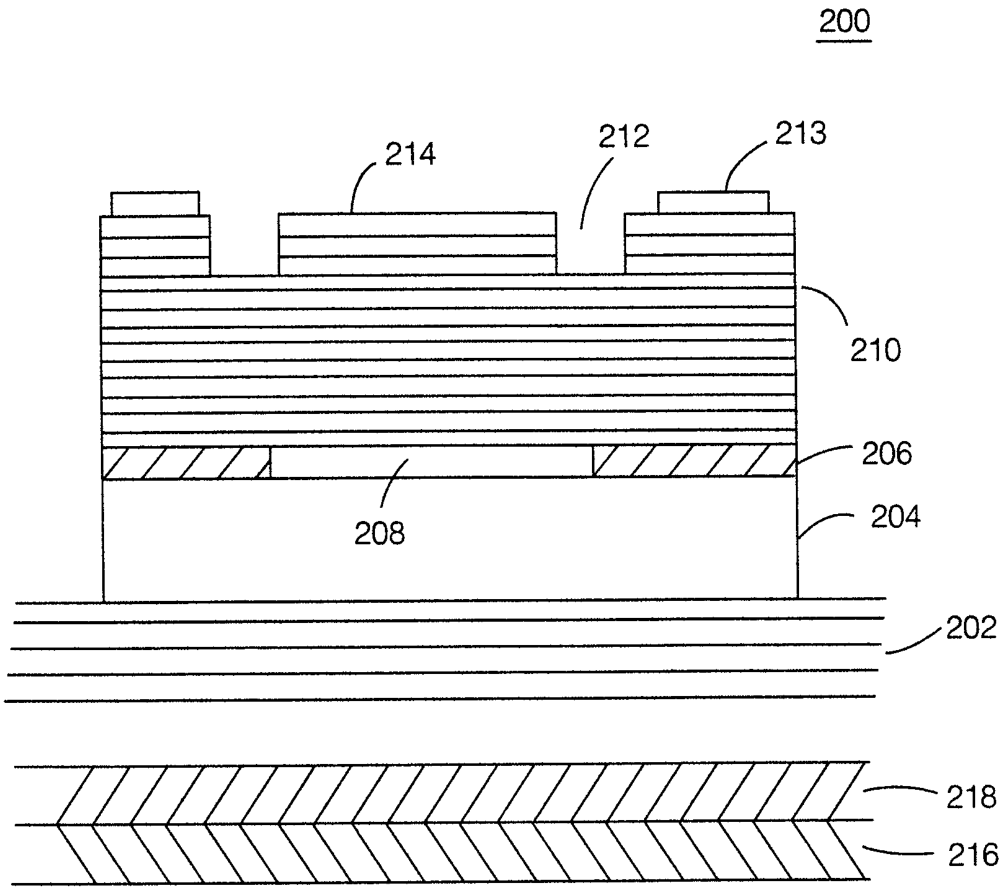

Fig. 2

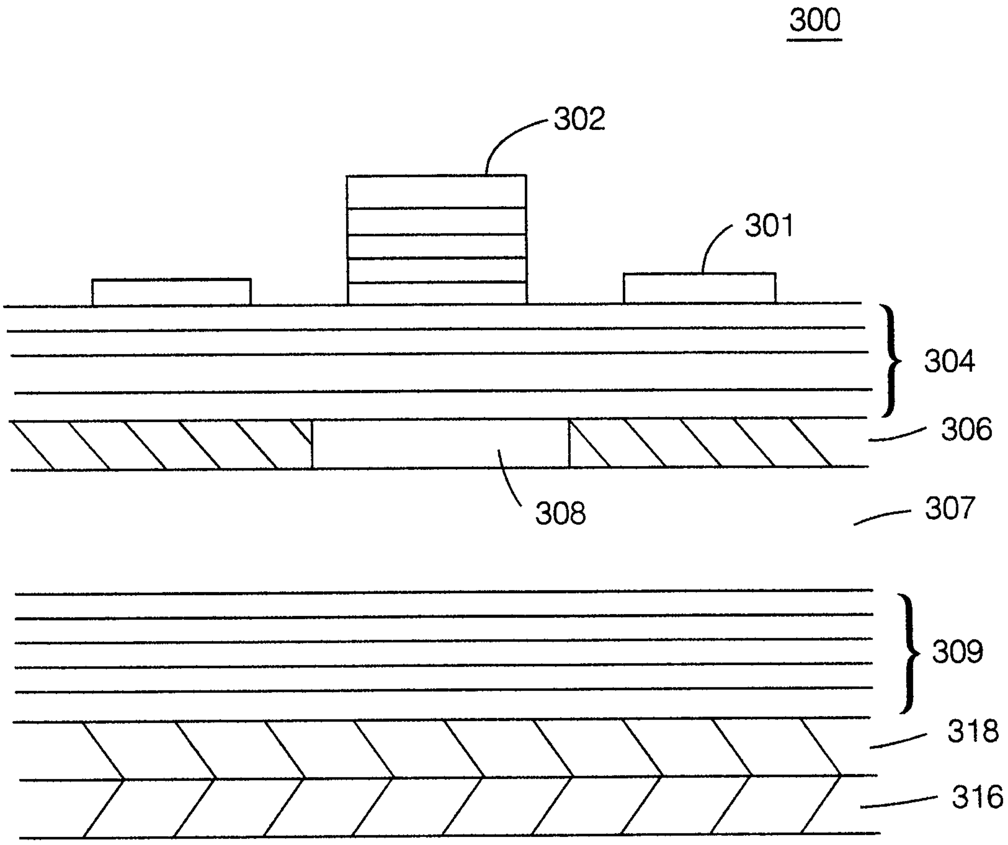

Fig. 3

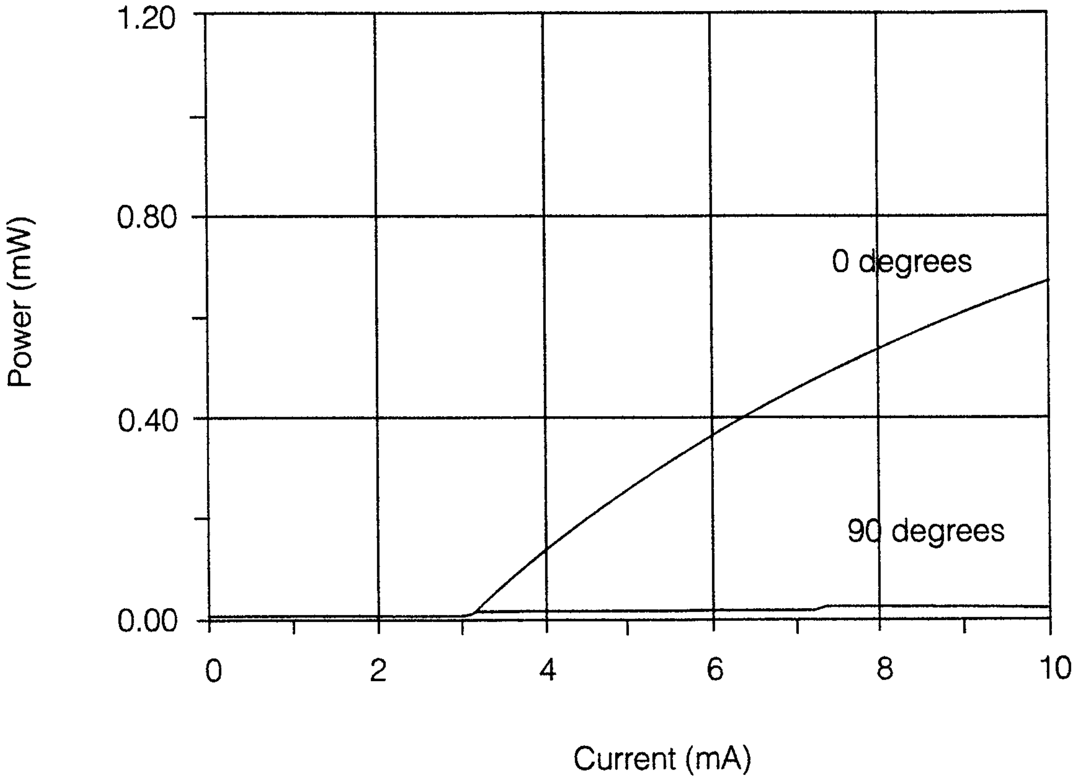
1.20
0.80
0.40
0.00
Power (mW)
0 degrees
90 degrees
0
2
4
6
8
10
Current (mA)

Fig. 4

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 00/00223

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01S5/183

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)
IPC 7 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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 812 577 A (DAWSON MARTIN DAVID ET AL) 22 September 1998 (1998-09-22)	1,7-9, 13-15,23
Y	column 1, line 25 -column 1, line 57 column 5, line 2 -column 5, line 18; claim 4; figure 4	1-4,15, 18,19
X	US 5 256 596 A (ACKLEY DONALD E ET AL) 26 October 1993 (1993-10-26) column 1, line 19 -column 1, line 39 column 2, line 62 -column 3, line 11 column 3, line 52 -column 3, line 55 column 4, line 50 -column 4, line 62; figures 1-3	1,2,5, 7-15,18, 21-23

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search 9 March 2000	Date of mailing of the international search report 17/03/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Gnugesser, H

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INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 00/00223

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 444 731 A (PFISTER JEAN-CLAUDE) 22 August 1995 (1995-08-22) column 1, line 14 -column 1, line 17 column 2, line 5 -column 2, line 37; figures 1,2	1,7-11, 13-15,23
X	US 5 388 120 A (ACKLEY DONALD E ET AL) 7 February 1995 (1995-02-07) column 3, line 58 -column 5, line 22; figures 1,2	1,2,14, 15,18,23
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A	US 5 568 499 A (LEAR KEVIN L) 22 October 1996 (1996-10-22) column 8, line 53 -column 8, line 67	15,18-20
A	US 5 577 064 A (SWIRHUN STANLEY E ET AL) 19 November 1996 (1996-11-19) column 8, line 56 -column 9, line 7	15-17
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