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(56) Documents Cited
WO 98/31080 A DE 019523267 A US 5754578 A
US 5513204 A

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(54) Abstract Title

Long wavelength vertical cavity laser with integrated short wavelength pump laser

(57) A short wavelength pump laser 20 has a long wavelength VCSEL laser 12 in overlying relation. The stimulated emission from the short wavelength laser acts to activate the long wavelength laser. Optically transparent glue fixes and mounts the lasers in vertical alignment. Alignment problems are not realized with the structure and no free carrier losses or other complexities typically associated with the prior art arrangements are realized. The laser 12 may be formed on an InP of GaAs substrate, and the laser 20, which may also be a VCSEL laser, may be formed on a GaAs substrate. The laser 12 may emit at 1300 nm or 1550 nm and the laser 20 at 850 nm or 980 nm. The lasers 12,20 may include air-gap or dielectric mirrors.

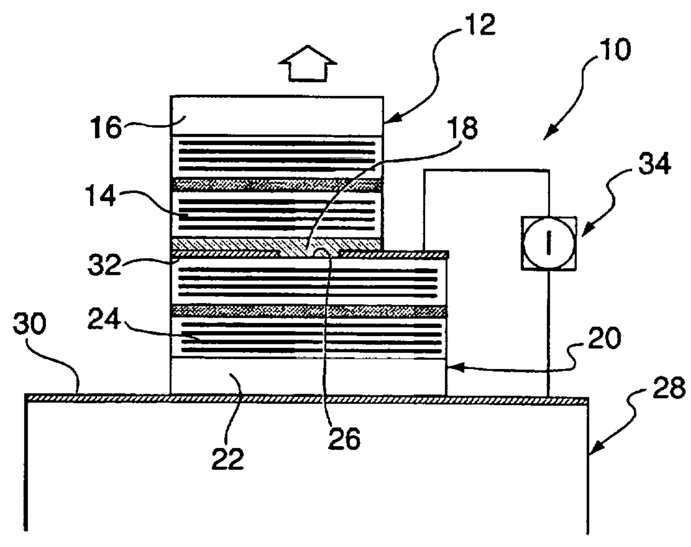

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

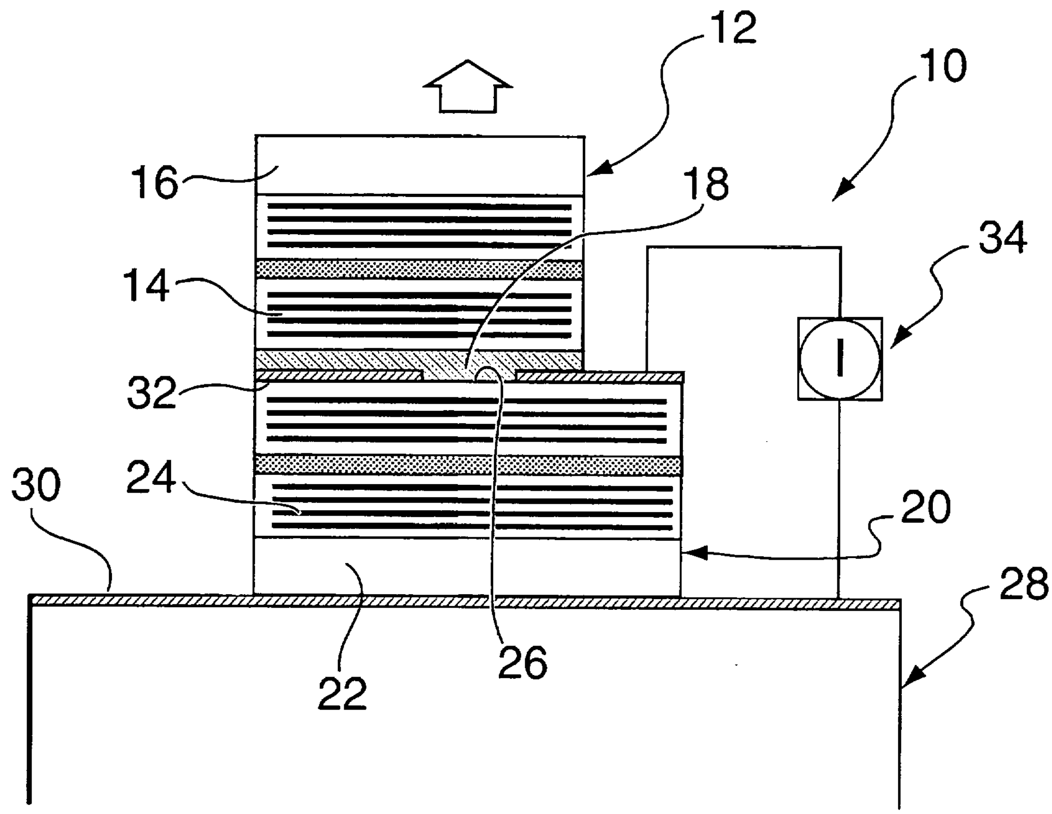

FIG. 1

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LONG WAVELENGTH VERTICAL CAVITY LASER WITH INTEGRATED SHORT WAVELENGTH PUMP LASER

The present invention relates to a long wavelength vertical cavity laser with integrated short wavelength pump laser and more particularly, the present invention relates to such a laser formed by the combination of two independent vertical cavity surface emitting laser (VCSEL) structures, which together form an electrically driven vertical cavity laser emitting at long wavelength.

As is known in the laser art, the development of long wavelength (1300-1550 nm) emitting vertical cavity lasers (VCLs) has been complicated by the lack of suitable epitaxial mirrors, high optical losses inside the laser cavity and a low and temperature sensitive optical gain in the active layer structure. Instead of injecting an electrical current, the lasing operation can be achieved much easier by exciting the active material optically using an external light source at a shorter wavelength ("optical pumping"). The free carrier losses in a optically pumped VCL structure are greatly reduced, because only nominally undoped semiconductor materials are employed. It is also possible to employ dielectric materials e.g. as high index-contrast layer pairs for highly reflective Bragg mirrors. The pump source is easier to fabricate using GaAs based VCL emitting at a wavelength in the 780-980 nm range. In the art, good results have been demonstrated with monolithic 1300 nm VCL which has been fabricated together with a 850 nm pump VCL on top of the actual 1300 nm structure. This was generated by V. Jayaraman et al., *Uniform Threshold Current, Continuous-Wave, Single Mode, 1300 nm Vertical Cavity Lasers From 0 to 70°C*, Electron. Lett.,Vol. 34, No. 14, 1998, p.1405. The fabrication of this electrically/optically driven VCL (e/o-VCL) requires rather advanced processing such as two wafer fusion steps and the fabrication of a mesa-type pump-VCL with coplanar contacts.

It would be desirable to achieve the results in the prior art using two separate VCL structures which did not present any alignment problems and provided other advantages in terms of costs, etc. The present invention achieves this goal.

According to one aspect of the present invention, there is provided a long wavelength vertical cavity laser, comprising:

a short wavelength top emitting vertical cavity laser; and a long wavelength optically pumped vertical cavity surface emitting laser overlying the short wavelength laser and in optical communication with the short wavelength laser.

In accordance with a further aspect of one embodiment of the present invention, there is provided a method of forming a long wavelength vertical cavity laser, comprising:

a short wavelength top emitting vertical cavity laser;

a long wavelength optically pumped vertical cavity surface emitting laser;

positioning the short wavelength laser in overlying relation with the long wavelength laser;

passing electrical current into the short wavelength laser to generate light emission;

passing emitted light through a bottom mirror of the long wavelength laser; and

stimulating a long wavelength emission from the long wavelength laser through an upper mirror of the long wavelength laser.

In the instant invention, an e/o-VCL which operates in the same way as the device taught by Jayaraman et al. *supra*, but consists of two separate, planar VCL structures. The overall concept is to place an optically pumped long wavelength VCL in overlying relation with a planar, short wavelength VCL. Mechanical contact between the two VCLs is made by use of optically transparent glue. The glue may also be used to reduce the back-reflection of the pump light. The lateral dimensions of the optically pumped sample are smaller than those of the pump-VC in order to provide access to the top metal electrode. The lateral alignment between both lasers is not critical and could be facilitated by automated packaging equipment.

Having thus generally described the invention, reference will now be made to the accompanying drawing illustrating a preferred embodiment and in which:

Figure 1 is a schematic illustration of the laser structure according to one embodiment of the present invention.

Referring now to the drawing, Figure 1 schematically illustrates an embodiment of the present invention, globally denoted by numeral 10. As illustrated, a long wavelength optically pumped VCSEL 12 comprises an optically pumped long wavelength laser having an active layer 14 and an InP or GaAs substrate 16. All of the elements of such VCSELs are well known in the art. In the embodiment shown, the long wavelength VCSEL 12 includes an opening 18 which is in optical communication with a short wavelength VCSEL, the latter being globally denoted by numeral 20. Laser 20 includes a GaAs substrate 22 and the typical active layers 24. Laser 20 further includes an opening 26 for passage of light emission therethrough and into communication with laser 12 positioned in overlying relation. Laser 20 is mounted to sub-mount 28 which serves as a metal contact 30 together with metal contact 32 on laser 20. A source of electrical current 34 is applied to the short wavelength laser 20 in order to induce emission.

In operation, an electrical current is injected across the pump VCL 20. This generates a stimulated emission (e.g. at 850 nm) above the laser threshold. The mirror reflectivities (not shown) are chosen such that most of the lasing light is coupled upwardly through an opening in the p-electrode 32, the transparent glue and the bottom mirror of the long wavelength VCL 12. The short-wavelength pump light is absorbed in the active region 14 of the upper VCL structure 12 where it generates a long wavelength stimulated emission. The long wavelength emission is removed via the upper mirror (not shown) and the transparent InP or GaAs substrate 16. This is generally denoted by the arrow in the figure.

In view of the fact that the optically pumped VCL cavity does not have to be electrically conductive, it may also involve air-gap structures, where sacrificial layers are removed by selective etching which is taught by Streubel et al., in 1.26 μm *Vertical Cavity Laser with Two InP/Air-Gap Reflectors*, <u>Electron. Lett.</u>, Vol. 32, 1996, p.1369. The epitaxial structure of a long wavelength VCL, which involves one or two air-gap mirrors can be easily grown by standard epitaxial technologies. The air-gap structure offers the additional advantage of external wavelength tuning, e.g. by electrostatic forces.

The structure of the present invention combines all the advantages of an e/o-VCL with a low-cost standard processing and packaging technology. The fundamental advantages of an e/o-VCL are:

i) reduced free carrier losses in the long wavelength VCL due to the lack of doping; and

ii) current injection and resistive heating only in the short-wavelength pump VCL.

The e/o-VCL structure set forth herein offers the following advantages:

i) design flexibility in the choice of the optically pumped structure (see Table 1);

ii) the pump source and the optically pumped VCL can be fabricated, tested and optimized independently;

iii) the short wavelength pump-VCL can be developed from commercially available devices, all necessary technology is available;

iv) the emitted wavelength is defined only by the optically pumped structure. A standard pump VCL mounted on header can serve as basic building block for different long wavelength VCLs; and

v) the package of the present invention provides a low-cost product.

The following combinations of VCLs are possible:

Pump VCL	➪ 850 nm top emitting VCL ➪ 980 nm top or bottom emitting VCL ➪ VCLs with H-implanted current aperture ➪ VCLs with Al-oxide current aperture ➪ Mesa-type VCLs
Optically Pumped 1300 nms VCLs	➪ VCL with two air-gap mirrors ➪ VCL with one air-gap mirror and one dielectric mirror ➪ VCL with two wafer-fused GaAs/AlGaAs mirrors ➪ VCLs with one wafer-fused GaAs/AlGaAs and one dielectric mirror ➪ VCLs with two dielectric mirrors ➪ VCLs with two GaAs/AlGaAs mirrors and lattice matched GaInNAs-active layer
Optically Pumped 1550 nm VLs	➪ VCL with two air-gap mirrors ➪ VCL with one air-gap mirror and one dielectric mirror ➪ VCL with one air-gap mirror and one epitaxially grown mirror (GaAs/AlGaAs or GaInAsP/InP) ➪ VCLs with one wafer-fused GaAs/AlGaAs and one InP/GaInAsP mirror ➪ VCLs with two wafer-fused GaAs/AlGaAs mirrors ➪ VCLs with one wafer-fused GaAs/AlGaAs and one dielectric mirror ➪ VCL with two dielectric mirrors ➪ VCLs with two GaAs/AlGaAs mirrors and lattice matched GaInNAs-active layer

Although embodiments of the invention have been described above, it is not limited thereto and it will be apparent to those skilled in the art that numerous modifications form part of the present invention insofar as they do not depart from the spirit, nature and scope of the claimed and described invention.

CLAIMS:

1. A long wavelength vertical cavity laser, comprising:

a short wavelength top emitting vertical cavity laser; and

a long wavelength optically pumped vertical cavity surface emitting laser overlying said short wavelength laser and in optical communication with said short wavelength laser.

2. The laser as set forth in claim 1, wherein said long wavelength laser has a wavelength of 1300 nanometers.

3. The laser as set forth in claim 1, wherein said short wavelength laser has a wavelength comprising a laser of a wavelength of 850 nanometers.

4. The laser as set forth in claim 3, wherein said laser is a top emitting laser.

5. The laser as set forth in claim 4, wherein said laser has a hydrogen implanted current aperture.

6. The laser as set forth in claim 4, wherein said laser has an aluminum oxide current aperture.

7. The laser as set forth in claim 3, wherein said laser comprises a mesa-type laser.

8. The laser as set forth in claim 1, wherein said long wavelength laser has a wavelength of 1550 nanometers.

9. The laser as set forth in claim 2 or 8, wherein said laser includes two air-gap mirrors.

10. The laser as set forth in claim 2 or 8, wherein said laser includes one air-gap mirror and one dielectric mirror.

11. The laser as set forth in claim 2 and 8, wherein said laser includes two wafer fused GaAs/AlGaAs mirrors.

12. The laser as set forth in claim 2 and 8, wherein said laser includes one wave fused GaAs/AlGaAs mirror and one dielectric mirror.

13. The laser as set forth in claim 2 and 8, wherein said laser includes two dielectric mirrors.

14. The laser as set forth in claim 2 and 8, wherein said laser includes two GaAs/AlGaAs mirrors and lattice matched GaInNAs active layer.

15. The laser as set forth in claim 8, wherein said laser includes one air-gap mirror and one epitaxially grown mirror.

16. The laser as set forth in claim 8, wherein said laser includes one wafer fused GaAs/AlGaAs and one InP/GaInAsP mirror.

17. The laser as set forth in claim 1, wherein said optical communication and fixture between said lasers is maintained by optically transparent glue.

18. A method of forming a long wavelength vertical cavity laser, comprising:

a short wavelength top emitting vertical cavity laser;

a long wavelength optically pumped vertical cavity surface emitting laser;

positioning said short wavelength laser in overlying relation with said long wavelength laser;

passing electrical current into said short wavelength laser to generate light emission;

passing emitted light through a bottom mirror of said long wavelength laser; and

stimulating a long wavelength emission from said long wavelength laser through an upper mirror of said long wavelength laser.

19. The method as set forth in claim 18, further including the step of selecting mirror reflectivity such that lasing light is directed upwardly through an opening in said short wavelength laser.

20. The method as set forth in claim 18, wherein emitted light from said short wavelength laser is absorbed in an active region of said long wavelength laser.

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Claims searched: all
Examiner: Martyn Dixon
Date of search: 25 January 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H1K (KEAP,KPADL)

Int Cl (Ed.6): H01S (3/025,3/085,3/094,3/0941,3/25)

Other: Online: EPODOC,WPI,JAPIO,INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	WO 98/31080 A	(Gore)	
X,Y	US 5754578 A	(Gore) see especially fig 3	X:1,18-20 at least Y:11,16
X	US 5513204 A	(Optical Concepts) the whole document	1-4,7,8, 12,13, 17-20
A	DE 19523267 A	(Bosch) see abstract	

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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