EUROPEAN PATENT SPECIFICATION

Date of publication and mention of the grant of the patent: 25.06.2003 Bulletin 2003/26

Application number: 97306901.6

Date of filing: 05.09.1997

Semiconductor laser device
Halbleiterlaservorrichtung
Dispositif laser à semi-conducteur

Designated Contracting States:
DE FR GB NL

Priority: 06.09.1996 JP 23679896

Date of publication of application: 11.03.1998 Bulletin 1998/11

Divisional application: 03003559.6

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Description

[0001] The present invention relates generally to semiconductor laser devices, and more particularly, to a semiconductor laser device comprising an active layer having a quantum well structure and an optical recording medium drive using the same.

[0002] An AlGaInP system semiconductor laser device has been actively studied and developed as a semiconductor laser device having a lasing wavelength in a red band. The AlGaInP system semiconductor laser device can carry out lasing in a band of 630 to 680 nm, and the wavelength band is high in spectral luminous efficacy. Therefore, the semiconductor laser device is used for a laser pointer, a line marker, and the like. The semiconductor laser device has a shorter lasing wavelength than an AlGaAs system semiconductor laser device, whereby it is expected as a light source for high-density recording, for example, and is scheduled to be employed as a light source of a digital video disc (DVD) currently proposed.

[0003] In such a semiconductor laser device, the inventors of the present application have found that the maximum light output power can be improved to approximately 40mW by employing a strain compensation type multi quantum well structure for an active layer.

[0004] When the semiconductor laser device is used as a light source for a reloadable optical recording medium, however, it is desired to lengthen the life of the semiconductor laser device while increasing the maximum light output power.

[0005] EP-A-0437243 discloses a semiconductor laser device in which cladding layers of different conductivity type are formed on either side of an active layer with a quantum well structure, to define a cavity. The upper cladding layer has a flat part and a ridge. A current blocking layer is formed in the upper cladding layer, that current blocking layer having an opening in the direction of the length of the cavity, and from a predetermined distance from a cavity facet, to cover the flat part and the sides of the ridge of the upper cladding layer. Thus this document corresponds to the pre-characterising part of claim 1.

[0006] EP-A-0539162 discloses a semiconductor laser device of similar structure, except that the cladding layers are of the same conductivity type.

[0007] According to the present invention there is provided a semiconductor laser device comprising in the order listed:

a cladding layer of a first conductivity type:

an active layer having a quantum well structure including one or a plurality of quantum well layers; and

a cladding layer of a second conductivity type opposite to said first conductivity type,

said cladding layer of the first conductivity type, said active layer, and said cladding layer of the second conductivity type constituting a cavity, further compromising a current injection blocking structure for blocking the injection of current into a region, on the side of at least one of the facets of the cavity, of said active layer,

said current injection blocking structure compromising a current blocking layer formed on said cladding layer of the second conductivity type and having a stripe-shaped opening for injecting current,

said stripe-shaped opening being arranged along the cavity length direction from a position at a predetermined distance from at least one of the facets of the cavity,

said cladding layer of the second conductivity type comprising a flat portion formed on said active layer and a stripe-shaped ridge portion on said flat portion, and

said current blocking layer is formed on said flat portion so as to cover the side surface of said ridge portion and formed on a region on the upper surface of said ridge portion from at least one of said facets of the cavity to the position at said predetermined distance therefrom,

where in the total volume of said quantum well layer or layers directly below said stripe-shaped portion is not more than approximately $1 \times 10^{-16} m^3$.

[0008] Since the total volume of the quantum well layer or layers directly below the stripe-shaped ridge portion is not more than approximately $1 \times 10^{-16} m^3$, the characteristics of the threshold current and the maximum light output power are good.

[0009] It is more preferable that the total volume of the quantum well layer or layers directly below the stripe-shaped ridge portion is not more than approximately $9 \times 10^{-17} m^3$. Consequently, the characteristics of the threshold current and the maximum light output power are improved.

[0010] It is still more preferable that the total volume of the quantum well layer or layers directly below the stripe-shaped ridge portion is not more than approximately $8 \times 10^{-17} m^3$. Consequently, the characteristics of the threshold current and the maximum light output power are further improved.

[0011] It is preferable that the total volume of the quantum well layer or layers directly below the stripe-shaped ridge
portion is not less than approximately $4 \times 10^{-17} \text{m}^3$. Consequently, the characteristics of the threshold current and the maximum light output power are good.

It is more preferable that the total volume of the quantum well layer or layers directly below the stripe-shaped ridge portion is not less than approximately $4.5 \times 10^{-17} \text{m}^3$. Consequently, the characteristics of the threshold current and the maximum light output power are improved.

It is still more preferable that the total volume of the quantum well layer or layers directly below the stripe-shaped ridge portion is not less than approximately $6 \times 10^{-17} \text{m}^3$. Consequently, the characteristics of the threshold current and the maximum light output power are further improved.

Specifically, the total volume of the quantum well layer or layers directly below the ridge portion is preferably not less than approximately $4 \times 10^{-17} \text{m}^3$ nor more than approximately $1 \times 10^{-16} \text{m}^3$, more preferably not less than $4.5 \times 10^{-17} \text{m}^3$ nor more than approximately $9 \times 10^{-17} \text{m}^3$, and still more preferably not less than approximately $6 \times 10^{-17} \text{m}^3$ nor more than approximately $8 \times 10^{-17} \text{m}^3$.

It is preferable that the predetermined distance from at least one of the facets of the cavity is not less than approximately $10 \mu\text{m}$ nor more than approximately $40 \mu\text{m}$. Consequently, the characteristics of the threshold current and the maximum light output power are improved.

It is more preferable that the predetermined distance from at least one of the facets of the cavity is not less than approximately $20 \mu\text{m}$ nor more than approximately $30 \mu\text{m}$. Consequently, the characteristics of the threshold current and the maximum light output power are further improved.

It is preferable that the semiconductor laser device is composed of an AlGaInP system semiconductor in terms of a short wavelength. In the case of the AlGaInP semiconductor laser device, the cladding layers of the first and second conductivity types may be composed of $(\text{Al}_{x_1} \text{Ga}_{1-x_1})_y \text{In}_{1-y_1} \text{P}$, and the quantum well layer may be composed of $(\text{Al}_{p} \text{Ga}_{1-p})_q \text{In}_{1-q} \text{P}$, where $1 > x_1 > p > 0$, and $1 > q > 0$. It is preferable that the structures are formed on a GaAs semiconductor substrate of the first conductivity type.

The quantum well structure may be a multi quantum well structure constructed by alternately stacking a plurality of quantum well layers and a plurality of barrier layers. Particularly, it is preferable that the plurality of quantum well layers in the multi quantum well structure have tensile strain, and the plurality of barrier layers therein have compressive strain. In this case, the threshold current can be decreased and the maximum light output power can be increased while achieving a short wavelength, and the life of the semiconductor laser device can be lengthened.

In the case of the AlGaInP semiconductor laser device, the quantum well layer in the single quantum well structure may be composed of $(\text{Al}_{x_1} \text{Ga}_{1-x_1})_y \text{In}_{1-y_1} \text{P}$, where $x_1 > p > 0$, and $1 > q > 0$. It is preferable that the structures are formed on a GaAs semiconductor substrate of the first conductivity type.

The quantum well structure may be a single quantum well structure. In this case, the volume of the saturable light absorbing member in the active layer can be decreased, whereby the threshold current can be significantly prevented from being increased. Particularly, the quantum well layer in the single quantum well structure may have tensile strain. In this case, a shorter wavelength can be achieved.

In the case of the AlGaInP semiconductor laser device, the quantum well layer in the single quantum well structure may be composed of $(\text{Al}_{x_1} \text{Ga}_{1-x_1})_y \text{In}_{1-y_1} \text{P}$, where $x_1 > p > 0$ and $1 > q > 0$.

The active layer may further comprise optical guide layers provided on both surfaces of the quantum well structure. The quantum well layer may have tensile strain, and at least a region, on the side of the quantum well structure, of each of the optical guide layers may have compressive strain. In this case, the strain of the active layer can be sufficiently compensated for, whereby the life of the semiconductor laser device can be lengthened. Moreover, a short wavelength can be achieved.

In the case of the AlGaInP system semiconductor laser device, the optical guide layers may be composed of $(\text{Al}_{x_2} \text{Ga}_{1-x_2})_y \text{In}_{1-y_2} \text{P}$, where $x_1 > x_2 > 0$, and $1 > y_2 > 0$.

The current injection blocking structure may be provided in the vicinity of both facets of the cavity. In the case of the AlGaInP system semiconductor laser device or an AlGaAs system semiconductor laser device, a GaAs layer of the first conductivity type may be used as the current blocking layer. The cladding layers of the first and second conductivity types may have different compositions. The optical guide layers on both surfaces of the quantum well layer may have different compositions.

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

Fig. 1 is a schematic perspective view of a semiconductor laser device according to a first embodiment of the present invention;

Fig. 2 is a schematic cross-sectional view taken along a line A - A of the semiconductor laser device according to the first embodiment;

Fig. 3 is a schematic cross-sectional view taken along a line B - B of the semiconductor laser device according to the first embodiment;
An AlGaInP system semiconductor laser device according to a first embodiment of the present invention will be described with reference to the drawings. Fig. 1 is a schematic perspective view of the semiconductor laser device according to the first embodiment, Fig. 2 is a schematic cross-sectional view taken along a broken line A - A in Fig. 1, Fig. 3 is a schematic cross-sectional view taken along a broken line B - B in Figs. 1 and 2, and Fig. 4 is a diagram showing a schematic band structure on the side of a conduction band in the vicinity of an active layer of the semiconductor laser device shown in Fig. 1.

In Figs. 1 to 3, an n-type GaAs semiconductor substrate 1 has one main surface (crystal growth plane) mis-oriented at an angle $\theta$ from the (100) plane to the [011] direction. The angle $\theta$ is preferably 5 to 17°, and more preferably 7 to 13°, which is 13° in the present embodiment. A buffer layer 2 composed of n-type Ga$_{0.5}$In$_{0.5}$P having a thickness of 0.3 $\mu$m is formed on the one main surface of the n-type GaAs semiconductor substrate 1.

A cladding layer 3 composed of n-type (Al$_{x1}$Ga$_{1-x1}$)$_{y1}$In$_{1-y1}$P having a thickness of 1.5 $\mu$m and $q = 0.64$, and $r = 0.5$ and $s = 0.44$. In the present embodiment, $x1 = 0.7$ and $y1 = 0.5$. An undoped active layer 4 is formed on the cladding layer 3. As shown in detail in Fig. 4, the active layer 4 has a structure in which an optical guide layer 5, a multi quantum well structure 6 and an optical guide layer 7 are stacked in this order.

The multi quantum well structure 6 has a strain compensation type multi quantum well structure constructed by alternately stacking quantum well layers 6a composed of (Al$_{x2}$Ga$_{1-x2}$)$_{y2}$In$_{1-y2}$P having a thickness of 1.5 $\mu$m on the side of a p-type cladding layer 8 as described later, whereby the region 7b has no strain.

In the optical guide layer 5, $y2 = 0.44$ is selected in a region 5a having a thickness of 40Å on the side of the quantum well structure 6 in close contact with the structure 6, whereby the region 5a has tensile strain. On the other hand, in the optical guide layer 7, $y2 = 0.5$ is selected in a region 7b having a thickness of 460Å on the side of the multi quantum well structure 6 in close contact with the structure 6, whereby the region 7b has compressive strain.

The optical guide layer 5 is composed of undoped (Al$_{x2}$Ga$_{1-x2}$)$_{y2}$In$_{1-y2}$P having a thickness of 500Å. In the present embodiment, $x2 = 0.5$. In the optical guide layer 5, $y2 = 0.44$ is selected in a region 5a having a thickness of 40Å on the side of the multi quantum well structure 6 in close contact with the structure 6, whereby the region 5a has compressive strain. On the other hand, in the optical guide layer 7, $y2 = 0.5$ is selected in a region 7b having a thickness of 460Å on the side of the p-type cladding layer 8 as described later, whereby the region 7b has no strain.

Fig. 11 is a schematic cross-sectional view taken along a line B - B of the semiconductor laser device according to the second embodiment; Fig. 12 is a diagram showing a schematic band structure in the vicinity of an active layer of the semiconductor laser device according to the second embodiment; Fig. 13 is a diagram showing the relationship between the total volume of quantum well layers directly below a stripe-shaped ridge portion, threshold current, and maximum light output power; Fig. 14 is a diagram showing the results of a reliability test; and Fig. 15 is a schematic view showing an optical pickup using the semiconductor laser device according to the present invention; and Fig. 16 is a block diagram showing the construction of an optical recording medium drive using the optical pickup shown in Fig. 15.
[0033] A stripe-shaped ridge portion 10 composed of p-type (Al_{x1}Ga_{1-x1})_{1-y1}In_{y1-P} having a width of W5 μm on its lower surface and having a thickness of 1.2 μm which extends along the cavity length direction and constituting a p-type cladding layer is formed on the p-type etching stop layer 9. In the present embodiment, x1 = 0.7 and y1 = 0.5. A contact layer 11 composed of p-type Ga_{0.5}In_{0.5}P having a thickness of 0.1 μm is formed on the upper surface of the ridge portion 10.

[0034] A current blocking layer 12 composed of n-type GaAs having a thickness of 0.8 μm is formed on the upper surface of the etching stop layer 9 so as to cover the side surface of the ridge portion 10 and the side surface of the contact layer 11, and is formed on a region on the upper surface of the contact layer 11 from one facet 13a, which outputs main laser light, of a cavity to a position at a predetermined distance L1 therefrom. In the present embodiment, L1 = 20 μm. Consequently, the n-type current blocking layer 12 has an opening 12a forming a current path on a region on the upper surface of the contact layer 11 at a distance m from the above-mentioned position at the predetermined distance L1 to the other facet 13b of the cavity, that is, on the upper surface of the ridge portion 10, as shown in Fig. 2.

[0035] A cap layer 14 composed of p-type GaAs having a thickness of 3 μm is formed on the current blocking layer 12 and the contact layer 11 in the opening 12a.

[0036] A p-side ohmic electrode 15 composed of Au - Cr is formed on the upper surface of the cap layer 14, and an n-side ohmic electrode 16 composed of Au - Sn - Cr is formed on the lower surface of the n-type GaAs semiconductor substrate 1.

[0037] In the semiconductor laser device, the current blocking layer 12 is formed on the region on the upper surface of the ridge portion 10 from the facet 13a outputting main laser light to the position at the predetermined distance L1 therefrom. Accordingly, a region of the active layer 4 below the current blocking layer 12 is a current injection blocking region into which current is blocked from being injected. The current blocking layer 12 is not formed on the region on the upper surface of the ridge portion 10 at a distance m from the above-mentioned position at the predetermined distance L1 to the other facet 13b. Accordingly, the active layer 4 below the region is a current injection region into which current is sufficiently injected. That is, the semiconductor laser device has a current injection blocking structure on the side of one of the facets of the cavity.

[0038] In the present embodiment, the total volume of the quantum well layers 6a having a width W directly below the stripe-shaped ridge portion 10 is 9.9 X 10^{-17} m^3.

[0039] The steps of fabricating the semiconductor device laser will be described using the drawings. As shown in Fig. 5, an n-type buffer layer 2, an n-type cladding layer 3, an undoped active layer 4, a p-type cladding layer 8, a p-type etching stop layer 9, a p-type cladding layer 10, and a p-type contact layer 11 are continuously grown in this order on an n-type GaAs semiconductor substrate 1 by MOCVD (Metal Organic Chemical Vapor Deposition).

[0040] As shown in Fig. 6, an SiO_2 film having a thickness of 0.2 μm is then formed on the p-type contact layer 11 by electron beam evaporation, and the SiO_2 film is patterned by a photolithographic technique and etching using a fluorine etchant, to produce a stripe-shaped mask 21. Thereafter, a region from the p-type contact layer 11 to the p-type etching stop layer 9 is subjected to wet etching with the mask 21 being used, to form the p-type cladding layer 10 in the shape of a stripe-shaped ridge portion.

[0041] Thereafter, the mask 21 from a facet 13a to a position at a predetermined distance L1 therefrom is etched away by a photolithographic technique and etching using a fluorine etchant, as shown in Fig. 7.

[0042] As shown in Fig. 8, an n-type current blocking layer 12 is then formed by MOCVD with the mask 21 whose portion on the side of the facet 13a is removed being used, after which the mask 21 is etched away by a fluorine etchant.

[0043] A p-type cap layer 14 is then formed by MOCVD, after which a p-side ohmic electrode 15 and an n-side ohmic electrode 16 are formed, to complete the semiconductor laser device shown in Fig. 1.

[0044] The following Table 1 shows a threshold current and maximum light output power in each of the semiconductor laser devices in the present embodiment, a comparative example 1, a comparative example 2 and a comparative example 3. The semiconductor laser device in the comparative example 1 is constructed similarly to the semiconductor laser device in the embodiment except that an active layer 4 composed of an undoped (Al_{0.5}Ga_{0.85}In_{0.5})P layer having a thickness of 800Å which has no quantum well structure, and there is provided no facet vicinity current injection blocking structure. The semiconductor laser device in the comparative example 2 is constructed similarly to the semiconductor laser device in the comparative example 1 except that the above-mentioned facet vicinity current injection blocking layer is provided. The semiconductor laser device in the comparative example 3 is constructed similarly to the semiconductor laser device in the embodiment except that the above-mentioned facet vicinity current injection blocking structure is not provided.

[0045] The cavity length L is 600 μm. A coating having reflectivity of 5 % is applied to the facet 13a of the cavity, and a coating having reflectivity of 95 % is applied to the facet 13b of the cavity.
[0046] As can be seen from Table 1, in the semiconductor laser device in the comparative example 3 comprising an active layer having a multi quantum well structure, the maximum light output power can be increased, and the threshold current can be decreased, as compared with those in the semiconductor laser device in the comparative example 1 comprising an active layer having no quantum well structure. That is, the formation of the active layer in the quantum well structure is effective in increasing the maximum light output power and decreasing the threshold current.

[0047] On the other hand, as can be seen from comparison between the comparative example 1 and the comparative example 2, it is considered that the introduction of the facet vicinity current injection blocking structure increases the threshold current. In the present embodiment, however, it is found that the threshold current is hardly increased, and the maximum light output power can be increased, as compared with those in the semiconductor laser device in the comparative example 3 comprising an active layer having a quantum well structure in which no facet vicinity current injection blocking layer is provided. Moreover, the semiconductor laser device in the present embodiment has a longer life than the semiconductor laser device in the comparative example 3.

[0048] Specifically, in the semiconductor laser device according to the present embodiment, the current injection blocking structure for blocking the injection of current into the active layer 4 is provided in the vicinity of the facet 13a outputting main laser light, and the active layer 4 has the strain compensation type quantum well structure 6 constructed by alternately stacking quantum well layers 6a having tensile strain and quantum barrier layers 6b having compressive strain. Therefore, the maximum light output power can be increased while decreasing the threshold current, and the life of the semiconductor laser device is long.

[0049] An AlGaInP system semiconductor laser device according to a second embodiment of the present invention will be described with reference to the drawings. Fig. 9 is a schematic perspective view of the semiconductor laser device according to the second embodiment, Fig. 10 is a schematic cross-sectional view taken along a broken line A - A in Fig. 9, Fig. 11 is a schematic cross-sectional view taken along a broken line B - B in Figs. 9 and 10, and Fig. 12 is a diagram showing a schematic band structure in the vicinity of an active layer of the semiconductor laser device.

[0050] The semiconductor laser device according to the second embodiment differs from the semiconductor laser device according to the first embodiment in that the active layer 4 in the first embodiment is replaced with an active layer 24 having a single quantum well structure. Therefore, the same reference numerals are assigned the same portions as those in the first embodiment and hence, the description thereof is not repeated.

[0051] In Figs. 9 to 11, an undoped active layer 24 is formed on an n-type cladding layer 3. As shown in detail in Fig. 12, the active layer 24 has a structure in which an optical guide layer 25, a single quantum well structure 26 and an optical guide layer 27 are stacked in this order.

[0052] The optical guide layer 25 is composed of undoped \( \text{Al}_2 \text{Ga}_1 \text{x}, \text{Al}_2 \text{Ga}_1 \text{y}, \text{Al}_2 \text{Ga}_1 \text{z} \text{In}_1 \text{y}, \text{Al}_2 \text{Ga}_1 \text{z} \text{P} \) having a thickness of 500Å. In the present embodiment, \( x = 0.5 \). In the optical guide layer 25, \( y = 0.44 \) is selected in a region 25a having a thickness of 100Å on the side of the single quantum well structure 26 in close contact with the structure 26, whereby the region 25a has compressive strain. On the other hand, in the optical guide layer 25, \( y = 0.5 \) is selected in a region 25b having a thickness of 400Å on the side of the n-type cladding layer 3, whereby the region 25b has no strain.

[0053] The single quantum well structure 26 is composed of only \( \text{Al}_1 \text{y}, \text{Ga}_1 \text{p}, \text{Al}_1 \text{q} \text{In}_1 \text{q}, \text{Al}_1 \text{q} \text{P} \) having a thickness of 250Å which has tensile strain, where \( 1 > p \geq 0 \) and \( 1 > q > 0.51 \). In the present embodiment, \( p = 0 \) and \( q = 0.67 \).

[0054] The optical guide layer 27 is composed of undoped \( \text{Al}_2 \text{Ga}_1 \text{x}, \text{Al}_2 \text{Ga}_1 \text{y}, \text{Al}_2 \text{Ga}_1 \text{z} \text{In}_1 \text{y}, \text{Al}_2 \text{Ga}_1 \text{z} \text{P} \) having a thickness of 500Å. In the present embodiment, \( x = 0.5 \). In the optical guide layer 27, \( y = 0.44 \) is selected in a region 27a having a thickness of 40Å on the side of the single quantum well structure 26 in close contact with the structure 26, whereby the region 27a has compressive strain. On the other hand, in the optical guide layer 27, \( y = 0.5 \) is selected in a region 27b having a thickness of 460Å on the side of a p-type cladding layer 8, whereby the region 27b has no strain.

[0055] The semiconductor laser device is constructed similarly to the semiconductor laser device in the first embodiment except for the structure of the active layer. In the semiconductor laser device, therefore, a current blocking layer 12 is formed on a region on the upper surface of a ridge portion 10 from a facet 13a, which outputs main laser light, of a cavity to a position at a predetermined distance \( L \) therefrom. Accordingly, a region of the active layer 24 below the current blocking layer 12 is a current injection blocking region into which current is blocked from being injected. The
current blocking layer 12 is not formed on a region on the upper surface of the ridge portion 10 at a distance m from the above-mentioned position at the predetermined distance L1 to the other facet 13b of the cavity. Accordingly, the active layer 24 below the region is a current injection region into which current is sufficiently injected. That is, the semiconductor laser device according to the present embodiment has a current injection blocking structure in the vicinity of one of facets of the cavity.

**[0056]** In the present embodiment, the total volume of quantum well layer 26a having a width W directly below the stripe-shaped ridge portion 10 is $7.5 \times 10^{-17}$ m$^3$.

**[0057]** The following Table 2 shows threshold current and maximum light output power in each of the semiconductor laser devices in the second embodiment 2 and a comparative example 4. The semiconductor laser device in the comparative example 4 is constructed similarly to the semiconductor laser device in the second embodiment except that the above-mentioned facet vicinity current injection region is not provided. The cavity length L is 600 µm. A coating having reflectivity of 5 % is applied to the facet 13a of the cavity, and a coating having reflectivity of 95 % is applied to the facet 13b of the cavity.

<table>
<thead>
<tr>
<th>embodiment</th>
<th>threshold current (mA)</th>
<th>maximum light output power (mW)</th>
</tr>
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<tbody>
<tr>
<td>comparative example 4</td>
<td>38 ~ 41</td>
<td>~ 55</td>
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</table>

**[0058]** As can be seen from Table 2, in the semiconductor laser device in the comparative example 4 comprising an active layer having a single quantum well structure, the maximum light output power can be increased, and the threshold current can be decreased, as compared with those in the semiconductor laser device in the comparative example 3 comprising an active layer having a multi quantum well structure. That is, the formation of the active layer in the single quantum well structure is significantly effective in increasing the maximum light output power and decreasing the threshold current.

**[0059]** On the other hand, in the semiconductor laser device in the second embodiment, the threshold current is approximately the same, and the maximum light output power can be increased, as compared with those in the semiconductor laser device in the comparative example 4. This shows that in the case where the active layer has a single quantum well structure, the threshold current can be decreased, and the maximum light output power can be significantly increased by introducing the facet vicinity current injection blocking structure, as compared with those in the case where the active layer has a multi quantum well structure.

**[0060]** Moreover, the semiconductor laser device in the second embodiment has a longer life than those of the semiconductor laser devices in the comparative example 3 and the comparative example 4.

**[0061]** The relationship between the total volume of the quantum well layers having a width W directly below the ridge portion 10 on the active layer 4 having the facet vicinity current injection blocking structure in the first embodiment, the threshold current, and the maximum light output power is shown in Fig. 13. The maximum light output power is measured in a semiconductor laser device in which the reflectivity of a front facet coating of a cavity is 5 % and the reflectivity of a rear facet coating of the cavity is 55 %, and the threshold current is measured in a semiconductor laser device in which both facets of a cavity are uncoated.

**[0062]** As can be seen from Fig. 13, the total volume of the quantum well layers directly below the ridge portion 10 is preferably not more than approximately $1 \times 10^{-18}$ m$^3$, more preferably not more than approximately $9 \times 10^{-17}$ m$^3$, and still more preferably not more than approximately $8 \times 10^{-17}$ m$^3$.

**[0063]** If the total volume of the quantum well layers directly below the ridge portion 10 is too small, the characteristics of the threshold current and the maximum light output power are degraded, whereby it is preferably not less than approximately $4 \times 10^{-17}$ m$^3$, more preferably not less than approximately $4.5 \times 10^{-17}$ m$^3$, and still more preferably not less than approximately $6 \times 10^{-17}$ m$^3$.

**[0064]** A reliability test of the semiconductor laser devices in the second embodiment and the comparative example 4 is carried out. In this test, the reflectivity of the front facet coating of the cavity is taken as 5 %, the reflectivity of the rear facet coating of the cavity is taken as 95 %, the cavity length L is taken as 600 µm, and the light output power is taken as 30 mW, to measure the change in an operating current at a temperature of 50°C.

**[0065]** As shown in Fig. 14, in the semiconductor laser device in the comparative example 4, the operating current is raised beyond 100 hours. On the other hand, in the semiconductor laser device in the second embodiment 2, the operating current is hardly raised even beyond 1000 hours. It is thus found that the semiconductor laser device in the second embodiment has a longer life than the semiconductor laser device in the comparative example 4.

**[0066]** Although description was made of an example in which the distance L1 is 20 µm, approximately the same superior characteristics are obtained when the distance L1 is 20 to 30 µm, and a good effect is also obtained if it is in
the range of approximately 10 to approximately 40 μm.

[0067] Although description was made of a case where the active layer has the strain compensation type quantum well structure, the active layer may have a quantum well structure having tensile strain or compressive strain, or may have a quantum well structure having no strain. However, it is preferable that the active layer has the strain compensation type quantum well structure in order that the threshold current is low and the maximum light output power is high in a short wavelength region, and the life of the semiconductor laser device is long.

[0068] Furthermore, n-type Ga_{0.5}In_{0.5}P buffer layer 2 provided between the n-type GaAs semiconductor substrate 1 and the n-type cladding layer 3 may be replaced with an n-type GaAs buffer layer. Alternatively, no buffer layer may be provided. A structure in which the etching stop layer 9 is not used can be also realized.

[0069] Furthermore, although in each of the above-mentioned embodiments, the current injection blocking structure is provided in the vicinity of one of the facets of the cavity, the current injection blocking structure may be provided in the vicinity of both the facets of the cavity.

[0070] Although (Al_{x}Ga_{1-x})_{y}In_{1-y}P (x \approx 0) crystals are accurately in lattice matching with the GaAs semiconductor substrate when y = 0.51 and cause no strain, they cause almost no strain if the composition ratio y of (Al_{x}Ga_{1-x})_{y}In_{1-y}P is in the vicinity of 0.51. Accordingly, in crystals abbreviated as (Al_{x}Ga_{1-x})_{y}In_{1-y}P or y = 0.5, for example, a value of 0.51 or its vicinity is sufficient as the composition ratio y of (Al_{x}Ga_{1-x})_{y}In_{1-y}P. Particularly in the present invention, it is preferable that the cladding layer and the current blocking layer have almost no strain.

[0071] Furthermore, although in each of the above-mentioned embodiments, the GaAs semiconductor substrate 1 has one main surface (crystal growth plane) misoriented from the (100) surface to the [011] direction, it is desirable that the GaAs semiconductor substrate has one main surface (crystal growth plane) in an equivalent relation therewith. Specifically, one main surface (crystal growth plane) of the GaAs semiconductor substrate may be a plane misoriented from the (100) surface to the [011] direction, a plane misoriented from the (010) surface to the [101] or [011] direction, or a plane misoriented from the (001) surface to the [110] or [110] direction, that is, a plane misoriented from the (100) plane to the <011> direction.

[0072] Although description was made of the semiconductor laser device having the stripe-shaped ridge portion, the present invention is applicable to a semiconductor laser device comprising a current blocking layer having a stripe-shaped opening, for example, a self-alignment type semiconductor laser device. Further, although description was made of the AlGaNP type semiconductor laser device, the present invention is also applicable to a semiconductor device of another material system, for example, an AlGaAs system, GaAlAsP system, GaInAs system, ZnMgSSe system, and AlInGaN system semiconductor laser devices.

[0073] Fig. 15 is a schematic view of an optical pickup 100 using the semiconductor laser device according to the present invention. In Fig. 15, laser light emitted from a semiconductor laser device 31 passes through a diffraction grating 32, a beam splitter 33, and a collimator lens 34, and is converged on the surface of an optical disk LD by an objective lens 36 having an aperture stop 35. Returned light from the optical disk LD passes through the objective lens 36 and the collimator lens 34, is reflected by the beam splitter 33, and is incident on a photodiode 39 through a concave lens 37 and a cylindrical lens 38.

[0074] Fig. 16 is a block diagram showing the construction of an optical recording medium drive 200 using the optical pickup 100 shown in Fig. 15. The optical recording medium drive 200 shown in Fig. 16 is an optical disk drive for reading information from an optical disk LD.

[0075] The optical recording medium drive 200 comprises an optical pickup 100, a motor 101, a rotation control system 102, a coarse motor 103, a coarse motor control system 104, a pickup control system 105, a signal processing system 106, and a drive controller 107.

[0076] The motor 101 rotates the optical disk LD at a predetermined speed. The rotation control system 102 controls a rotating operation of the motor 101. The coarse motor 103 moves the optical pickup 100 along the radius of the optical disk LD. The coarse motor control system 104 controls operations performed by the coarse motor 103. The optical pickup 100 irradiates laser light onto the optical disk LD, and receives returned light from the optical disk LD. The pickup control system 105 controls a projecting and receiving operation of the optical pickup 100.

[0077] The signal processing system 106 calculates a reproduction signal, a focus error signal and a tracking error signal upon receipt of an output signal from a photodiode 39 in the optical pickup 100, and feeds the reproduction signal to the drive controller 107, while feeding the focus error signal and the tracking error signal to the pickup control system 105. The drive controller 107 controls the rotation control system 102, the coarse motor control system 104, the pickup control system 105 and the signal processing system 106 in conformity to a command given through a drive interface 108, and outputs the reproduction signal through the drive interface 108.

[0078] In the optical recording medium drive shown in Fig. 16, the semiconductor laser device according to the present invention is used, whereby reliable and high-density recording and reproduction of information are possible with low power consumption, and the life of products is lengthened.

[0079] The semiconductor laser device of the present invention can be used for optical pickups having different structures from the optical pickup shown in Fig. 15 and optical recording medium drives having different structures from
the optical recording medium drive shown in Fig.16.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation.

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Claims

1. A semiconductor laser device comprising in the order listed:

   a cladding layer (3) of a first conductivity type:

   an active layer (4) having a quantum well (6) structure including one or a plurality of quantum well layers; and

   a cladding layer (8,10) of a second conductivity type opposite to said first conductivity type,

   said cladding layer (3) of the first conductivity type, said active layer (4), and said cladding layer (8,10) of the second conductivity type constituting a cavity, further comprising a current injection blocking structure for blocking the injection of current into a region, on the side of at least one of facets of the cavity, of said active layer,

   said current injection blocking structure comprising a current blocking layer (12) formed on said cladding layer (8) of the second conductivity type and having a stripe-shaped opening (12a) for injecting current,

   said stripe-shaped opening (12a) being arranged along the cavity length direction from a position at a predetermined distance from at least one of the facets of the cavity,

   said cladding layer of the second conductivity type comprising a flat portion (8) formed on said active layer and a stripe-shaped ridge portion (10) on said flat portion, and

   said current blocking layer (12) is formed on said flat portion (8) so as to cover the side surface of said ridge portion (10) and formed on a region on the upper surface of said ridge portion (10) from at least one of said facets of the cavity to the position at said predetermined distance therefrom,

   characterised in that:

   the total volume of said quantum well layer or layers directly below said stripe-shaped ridge portion (10) is not more than approximately \(1 \times 10^{-16} \text{m}^3\).

2. The semiconductor laser device according to claim 1, wherein

   the total volume of said quantum well layer or layers directly below said stripe-shaped ridge portion (10) is not more than approximately \(9 \times 10^{-17} \text{m}^3\).

3. The semiconductor laser device according to claim 2, wherein

   the total volume of said quantum well layer or layers directly below said stripe-shaped ridge portion (10) is not more than approximately \(8 \times 10^{-17} \text{m}^3\).

4. The semiconductor laser device according to claim 1, wherein the total volume of said quantum well layer or layers directly below said stripe-shaped ridge portion (10) is not less than approximately \(4 \times 10^{-17} \text{m}^3\).

5. The semiconductor laser device according to claim 4, wherein

   the total volume of said quantum well layer or layers directly below said stripe-shaped ridge portion (10) is not less than approximately \(4.5 \times 10^{-17} \text{m}^3\).

6. The semiconductor laser device according to claim 5, wherein

   the total volume of said quantum well layer or layers directly below said stripe-shaped ridge portion (10) is not less than approximately \(6 \times 10^{-17} \text{m}^3\).

7. The semiconductor laser device according to claim 1, wherein

   the total volume of said quantum well layer or layers directly below said stripe-shaped ridge portion (10) is not less than approximately \(4.5 \times 10^{-17} \text{m}^3\) nor more than approximately \(9 \times 10^{-17} \text{m}^3\).

8. The semiconductor laser device according to claim 1, wherein

   the total volume of said quantum well layer or layers directly below said stripe-shaped ridge portion (10) is
not less than approximately $6 \times 10^{-17}\text{m}^3$ nor more than approximately $8 \times 10^{-17}\text{m}^3$.

Patentansprüche

1. Halbleiter-Laservorrichtung, in der angeführten Reihenfolge umfassend:
   
   eine Mantelschicht (3) eines ersten Leitfähigkeitstyps;
   
   eine aktive Schicht (4) mit Quantentopfstruktur (6), die eine oder eine Vielzahl von Quantentopfschicht(en) umfasst; und
   
   eine Mantelschicht (8, 10) eines zweiten Leitfähigkeitstyps, der dem ersten Leitfähigkeitstyp entgegengesetzt ist,

   wobei die Mantelschicht (3) des ersten Leitfähigkeitstyps, die aktive Schicht (4) und die Mantelschicht (8, 10) des zweiten Leitfähigkeitstyps einen Hohlraum bilden, weiters umfassend eine Strominjektions-Blockierungsstruktur zum Blockieren der Strominjektion in einen Bereich der aktiven Schicht, der sich auf der Seite zumindest einer der Flächen des Hohlraums befindet,

   wobei die Strominjektions-Blockierungsstruktur eine Strom-Blockierungsschicht (12) umfasst, die auf der Mantelschicht (8) des zweiten Leitfähigkeitstyps ausgebildet ist und eine streifenförmige Öffnung (12a) zum Injizieren von Strom aufweist,

   wobei die streifenförmige Öffnung (12a) entlang der Hohlraum-Längsrichtung aus einer Position in einem vorbestimmten Abstand von zumindest einer der Flächen des Hohlraums angeordnet ist,

   wobei die Mantelschicht des zweiten Leitfähigkeitstyps einen ebenen Abschnitt (8), der auf der aktiven Schicht ausgebildet ist, und einen streifenförmigen Rippenabschnitt (10) auf dem ebenen Abschnitt umfasst, und

   die Stromblockierungsschicht (12) auf dem ebenen Abschnitt (8) so ausgebildet ist, dass sie die Seitenfläche des Rippenabschnitts (10) bedeckt und auf einem Bereich der Deckfläche des Rippenabschnitts (10) von zumindest einer der Flächen des Hohlraums bis zur Position im vorbestimmten Abstand von diesem ausgebildet ist,

   dadurch gekennzeichnet, dass

   das Gesamtvolumen der Quantentopfschicht oder -schichten direkt unterhalb des streifenförmigen Rippenabschnitts (10) nicht mehr als etwa $1 \times 10^{-16}\text{m}^3$ beträgt.

2. Halbleiter-Laservorrichtung nach Anspruch 1, worin das Gesamtvolumen der Quantentopfschicht oder -schichten direkt unterhalb des streifenförmigen Rippenabschnitts (10) nicht mehr als etwa $9 \times 10^{-17}\text{m}^3$ beträgt.

3. Halbleiter-Laservorrichtung nach Anspruch 2, worin das Gesamtvolumen der Quantentopfschicht oder -schichten direkt unterhalb des streifenförmigen Rippenabschnitts (10) nicht mehr als etwa $8 \times 10^{-17}\text{m}^3$ beträgt.

4. Halbleiter-Laservorrichtung nach Anspruch 1, worin das Gesamtvolumen der Quantentopfschicht oder -schichten direkt unterhalb des streifenförmigen Rippenabschnitts (10) nicht weniger als etwa $4 \times 10^{-17}\text{m}^3$ beträgt.

5. Halbleiter-Laservorrichtung nach Anspruch 4, worin das Gesamtvolumen der Quantentopfschicht oder -schichten direkt unterhalb des streifenförmigen Rippenabschnitts (10) nicht weniger als etwa $4,5 \times 10^{-17}\text{m}^3$ beträgt.

6. Halbleiter-Laservorrichtung nach Anspruch 5, worin das Gesamtvolumen der Quantentopfschicht oder -schichten direkt unterhalb des streifenförmigen Rippenabschnitts (10) nicht weniger als etwa $6 \times 10^{-17}\text{m}^3$ beträgt.

7. Halbleiter-Laservorrichtung nach Anspruch 1, worin das Gesamtvolumen der Quantentopfschicht oder -schichten direkt unterhalb des streifenförmigen Rippenabschnitts (10) weder weniger als etwa $4,5 \times 10^{-17}\text{m}^3$ noch mehr als etwa $9 \times 10^{-17}\text{m}^3$ beträgt.

8. Halbleiter-Laservorrichtung nach Anspruch 1, worin das Gesamtvolumen der Quantentopfschicht oder -schichten direkt unterhalb des streifenförmigen Rippenabschnitts (10) nicht weniger als etwa $4,5 \times 10^{-17}\text{m}^3$ noch mehr als etwa $9 \times 10^{-17}\text{m}^3$ beträgt.
schnitts (10) weder weniger als etwa $6 \times 10^{-17} \text{m}^3$ noch mehr als etwa $8 \times 10^{-17} \text{m}^3$ beträgt.

Revendications

5. Dispositif formant laser à semi-conducteur comprenant dans l’ordre indiqué:

une couche de placage (3) d’un premier type de conductivité;
une couche active (4) ayant une structure à puits quantique (6) comportant une ou plusieurs couches de puits quantique; et
une couche de placage (8, 10) d’un deuxième type de conductivité opposé audit premier type de conductivité, ladite couche de placage (3) du premier type de conductivité, ladite couche active (4) et ladite couche de placage (8, 10) du deuxième type de conductivité constituant une cavité, comprenant en outre une structure de blocage d’injection de courant pour bloquer l’injection du courant dans une région, sur le côté d’au moins d’une des facettes de la cavité, de ladite couche active,

ladite structure de blocage d’injection de courant comprenant une couche de blocage de courant (12) formée sur ladite couche de placage (8) du deuxième type de conductivité et présentant une ouverture en forme de bande (12a) pour injecter le courant,

ladite ouverture en forme de bande (12a) étant agencée dans la direction longitudinale de la cavité à partir d’une position à une distance prédéterminée d’au moins l’une des facettes de la cavité,

ladite couche de placage du deuxième type de conductivité comprenant une portion plate (8) formée sur ladite couche active et une portion de nervure en forme de bande (10) sur ladite portion plate et ladite couche de blocage de courant (12) est formée sur ladite portion plate (8) de manière à couvrir la surface latérale de ladite portion de nervure (10) et formée sur une région sur la surface supérieure de ladite portion de nervure (10) à partir d’au moins l’une desdites facettes de la cavité à la position à ladite distance prédéterminée de celle-ci,

caractérisé en ce que:

le volume total de la ou des couches de puits quantique précitées directement en dessous de ladite portion de nervure en forme de bande (10) n’est pas plus grand qu’approximativement $1 \times 10^{-16} \text{m}^3$.

2. Dispositif formant laser à semi-conducteur selon la revendication 1, où

le volume total de la ou des couches de puits quantique précitées directement en dessous de ladite portion de nervure en forme de bande (10) n’est pas plus grand qu’approximativement $9 \times 10^{-17} \text{m}^3$.

3. Dispositif formant laser à semi-conducteur selon la revendication 2, où

le volume total de la ou des couches de puits quantique précitées directement en dessous de ladite portion de nervure en forme de bande (10) n’est pas plus grand qu’approximativement $8 \times 10^{-17} \text{m}^3$.

4. Dispositif formant laser à semi-conducteur selon la revendication 1, où

le volume total de la ou des couches de puits quantique précitées directement en dessous de ladite portion de nervure en forme de bande (10) n’est pas plus petit qu’approximativement $4 \times 10^{-17} \text{m}^3$.

5. Dispositif formant laser à semi-conducteur selon la revendication 4, où

le volume total de la ou des couches de puits quantique précitées directement en dessous de ladite portion de nervure en forme de bande (10) n’est pas plus petit qu’approximativement $4,5 \times 10^{-17} \text{m}^3$.

6. Dispositif formant laser à semi-conducteur selon la revendication 5, où

le volume total de la ou des couches de puits quantique précitées directement en dessous de ladite portion de nervure en forme de bande (10) n’est pas plus petit qu’approximativement $6 \times 10^{-17} \text{m}^3$.

7. Dispositif formant laser à semi-conducteur selon la revendication 1, où

le volume total de la ou des couches de puits quantique précitées directement en dessous de ladite portion de nervure en forme de bande (10) n’est pas plus petit qu’approximativement $4,5 \times 10^{-17} \text{m}^3$ ni plus grand qu’approximativement $9 \times 10^{-17} \text{m}^3$.

8. Dispositif formant laser à semi-conducteur selon la revendication 1, où
le volume total de la ou des couches de puits quantique précisées directement en dessous de ladite portion de nervure en forme de bande (10) n'est pas plus petit qu'approximativement $6 \times 10^{-17} \text{m}^3$ ni plus grand qu'approximativement $8 \times 10^{-17} \text{m}^3$. 

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FIG. 2

CURRENT INJECTION BLOCKING REGION

L
m
L1

11 12a 14 13b

10 9 8 4 3 1 2

B B
FIG. 13

TOTAL VOLUME OF QUANTUM WELL LAYERS DIRECTLY BELOW RIDGE PORTION 
\((\times 10^{-16} \text{ m}^3)\)

THRESHOLD CURRENT (mA) [UNCOATED]

MAXIMUM LIGHT OUTPUT (mW) [5%-95% COATED]