

DESCRIPTION

TITLE OF INVENTION: COOLING DEVICE

TECHNICAL FIELD

5 [0001]

The present disclosure relates to a cooling device.

Priority is claimed on Japanese Patent Application No. 2023-171320, filed
October 2, 2023, the content of which is incorporated herein by reference.

BACKGROUND ART

10 [0002]

Patent Document 1 discloses a cooling jacket. The cooling jacket includes first
and second tubular portions through which a refrigerant flows, and a body portion
connected to side surfaces of the first and second tubular portions. The body portion
defines a flow path portion through which the refrigerant flows by a single member, and
15 cools a cooling target object.

Citation List

Patent Document

[0003]

Patent Document 1: Japanese Patent No. 5533215

20 SUMMARY OF INVENTION

Technical Problem

[0004]

Meanwhile, for example, in a network rack of a data center, small heat-
generating bodies are densely arranged. The heat-generating body is cooled by air
25 supplied thereto. For example, when the heat-generating body is an optical module,

small optical modules of about several centimeters are densely arranged. Therefore, in an air cooling method of supplying air to the optical module to cool the optical module, a large amount of power is required. With the recent needs for decarbonization, reduction of power consumption is also an important issue.

5 [0005]

As a cooling method of suppressing power consumption, there is an immersion cooling method of cooling a heat-generating body by immersing the heat-generating body in a refrigerant. However, when the heat-generating body is an optical module, light is used as a medium for information transmission. Therefore, the immersion
10 cooling method of immersing the optical module in the refrigerant of which a refractive index of light changes cannot be adopted as the cooling method of the optical module, and the above-described air-cooled type has to be adopted.

[0006]

The present disclosure has been made to solve the above-described problems,
15 and an object of the present disclosure is to provide a cooling device capable of improving cooling efficiency and reducing power consumption.

Solution to Problem

[0007]

In order to achieve the above-described object, the present disclosure provides a
20 cooling device including: a housing including a space formed inside and a recess portion recessed inward from an outer surface; a server provided in the housing and including a terminal protruding into the recess portion; an optical module provided in the recess portion and connected to the terminal; a refrigerant supply section configured to supply a refrigerant into the housing; and a refrigerant discharge section configured to discharge
25 the refrigerant from the housing.

Advantageous Effects of Invention

[0008]

According to the cooling device of the present disclosure, it is possible to improve the cooling efficiency and reduce the power consumption.

5 BRIEF DESCRIPTION OF DRAWINGS

[0009]

[FIG. 1] A perspective view of a cooling device according to a first embodiment of the present disclosure.

[FIG. 2] A cross-sectional view of the cooling device according to the first
10 embodiment of the present disclosure taken along a depth direction.

[FIG. 3] A cross-sectional view of the cooling device according to the first embodiment of the present disclosure taken along a width direction.

[FIG. 4] A perspective view of a cooling device according to a second embodiment of the present disclosure.

15 [FIG. 5] A cross-sectional view of the cooling device according to the second embodiment of the present disclosure taken along a depth direction.

[FIG. 6] A cross-sectional view of the cooling device according to the second embodiment of the present disclosure taken along a width direction.

[FIG. 7] A cross-sectional view of a cooling device according to a third
20 embodiment of the present disclosure taken along a width direction.

[FIG. 8] A cross-sectional view of a cooling device according to a fourth embodiment of the present disclosure taken along a width direction.

[FIG. 9] A cross-sectional view of a cooling device according to a fifth embodiment of the present disclosure taken along a width direction.

25 [FIG. 10] A cross-sectional view of a cooling device according to a sixth

embodiment of the present disclosure taken along a width direction.

[FIG. 11] A cross-sectional view of a cooling device according to a seventh embodiment of the present disclosure taken along a width direction.

[FIG. 12] A perspective view of a cooling device according to an eighth
5 embodiment of the present disclosure.

[FIG. 13] A cross-sectional view of the cooling device according to the eighth embodiment of the present disclosure taken along a depth direction.

[FIG. 14] A cross-sectional view of the cooling device according to the eighth embodiment of the present disclosure taken along a width direction.

10 [FIG. 15] A cross-sectional view of a cooling device according to a ninth embodiment of the present disclosure taken along a depth direction.

[FIG. 16] A cross-sectional view of the cooling device according to the ninth embodiment of the present disclosure taken along a width direction.

[FIG. 17] A perspective view of a cooling device according to another
15 embodiment of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0010]

<First Embodiment>

(Configuration of Cooling Device)

20 Hereinafter, a cooling device 1 according to an embodiment of the present disclosure will be described with reference to FIGS. 1 to 3.

As shown in FIGS. 1 to 3, the cooling device 1 includes a housing 10, a server 2, an optical module 20, a refrigerant supply section 3, a refrigerant discharge section 4, a refrigerant line 5, and a heat exchanger 6.

25 [0011]

(Housing)

The housing 10 accommodates electronic devices such as the server 2 described later. The housing 10 is formed, for example, by additive manufacturing (AM) molding. The housing 10 includes a housing body 11 and a jacket 12.

5 [0012]

(Housing Body)

The housing body 11 is formed, for example, in a rectangular parallelepiped shape. The housing body 11 includes a lower wall 13 extending in a horizontal direction, an upper wall 14 disposed above the lower wall 13 at an interval, and a
 10 plurality of side walls 15 connecting an outer edge of the lower wall 13 and an outer edge of the upper wall 14 in an up-down direction D_v . The lower wall 13 is formed in a rectangular plate shape. The upper wall 14 is formed in a rectangular plate shape having the same shape as the lower wall 13. Each side wall 15 is formed in a rectangular plate shape extending in the up-down direction D_v . A sealed space S is
 15 formed inside the housing body 11 by the lower wall 13, the upper wall 14, and the side walls 15. The housing body 11 is disposed to extend in the up-down direction D_v and to extend in the horizontal direction. The housing body 11 is made of, for example, a metal material.

[0013]

20 Hereinafter, in the horizontal direction orthogonal to the up-down direction D_v , one direction will be referred to as a width direction D_w . In addition, in the horizontal direction orthogonal to the up-down direction D_v , a direction orthogonal to the width direction D_w will be referred to as a depth direction D_s .

In the present embodiment, four side walls 15 are provided. Two side walls 15
 25 among the four side walls 15 are disposed to face each other in the width direction D_w .

The other two side walls 15 among the four side walls 15 are disposed to face each other in the depth direction Ds.

[0014]

(Jacket)

5 The jacket 12 is provided on one side wall 15 disposed perpendicular to the depth direction Ds. The jacket 12 is provided to protrude inward from an outer surface 10a of the housing 10. The jacket 12 has a recess portion 16.

[0015]

(Recess Portion)

10 In the jacket 12, the recess portion 16 is formed to be recessed inward from the outer surface 10a of the housing 10.

[0016]

In the present embodiment, the jacket 12 is integrally made of the same material as the housing body 11. The jacket 12 is made of, for example, a metal material and has
15 predetermined rigidity.

The shape or disposition of the jacket 12 (the shape or disposition of the recess portion 16) will be described in detail later.

[0017]

(Server)

20 The server 2 is provided in the space S in the housing 10. In the shown example, the server 2 is schematically shown, and the electronic devices other than the server 2 are omitted. The server 2 includes a terminal 2a protruding into the recess portion 16. In the present embodiment, the server 2 includes a plurality of terminals 2a. At least one terminal 2a is provided for each recess portion 16.

25 [0018]

(Optical Module)

One optical module 20 is provided in each recess portion 16. In the shown example, the optical module 20 is schematically shown. The optical module 20 is inserted into the recess portion 16 from the outside of the housing 10. The optical module 20 is connected to the terminal 2a of the server 2. An optical fiber 22 is connected to an end portion of the optical module 20 on a side opposite to the terminal 2a. The optical module 20 transmits and receives information to and from another device via the optical fiber 22.

[0019]

10 (Refrigerant Supply Section)

The refrigerant supply section 3 supplies a refrigerant R into the housing 10. The refrigerant supply section 3 is provided in a central portion of the lower wall 13 of the housing body 11. The refrigerant supply section 3 is a supply pipe that communicates with the space S in the housing 10 and extends downward from the lower wall 13. The housing 10 is filled with the refrigerant R supplied from the refrigerant supply section 3 in a liquid phase state. All the jackets 12 are immersed in the refrigerant R in the housing 10.

[0020]

(Refrigerant Discharge Section)

20 The refrigerant discharge section 4 discharges the refrigerant R from the housing 10. The refrigerant discharge section 4 is provided in a central portion of the upper wall 14 of the housing body 11. The refrigerant discharge section 4 is a discharge pipe that communicates with the space S in the housing 10 and extends upward from the upper wall 14.

25 [0021]

(Refrigerant Line)

The refrigerant line 5 is a pipe that connects an upstream end of the refrigerant supply section 3 and a downstream end of the refrigerant discharge section 4. The refrigerant line 5 guides the refrigerant R, which is discharged from the refrigerant discharge section 4, to the refrigerant supply section 3 again.

[0022]

(Heat Exchanger)

The heat exchanger 6 is provided in the refrigerant line 5. The heat exchanger 6 cools the refrigerant R that has exchanged heat with the optical module 20. The heat exchanger 6 may be of an air-cooled type or a liquid-cooled type.

[0023]

(Detailed Structure around Jacket)

Hereinafter, a detailed structure around the jacket 12 will be described.

Here, as an example, a case will be described in which the shape of the optical module 20 is simplified and the optical module 20 is formed in a rectangular parallelepiped shape extending in one direction.

[0024]

As shown in FIGS. 2 and 3, an outer shape of the jacket 12 is formed in a rectangular parallelepiped shape extending in one direction according to the shape of the optical module 20. A plurality of the jackets 12 are provided on one of the side walls 15. The plurality of jackets 12 are arranged in the up-down direction D_v and the width direction D_w and are disposed in a rectangular grid pattern as viewed in the depth direction D_s . The plurality of jackets 12 are disposed at intervals in the up-down direction D_v and the width direction D_w . In the shown example, three rows each including the four jackets 12 arranged in the width direction D_w are provided in the up-

down direction Dv. In each row, the jackets 12 are disposed at equal intervals in the width direction Dw. Further, the rows of the jackets 12 are disposed at equal intervals in the up-down direction Dv.

[0025]

5 The recess portion 16 is formed in each jacket 12 to extend in one direction according to the shape of the optical module 20. In the present embodiment, each jacket 12 is provided such that the recess portion 16 is recessed in the depth direction Ds.

In the present embodiment, the optical module 20 is in contact with an inner surface 16a of the recess portion 16. More specifically, the inner surface 16a of the
10 recess portion 16 and the optical module 20 are in contact with each other without a gap in the width direction Dw and the up-down direction Dv. Further, a heat generation surface 21 having a relatively large heat generation amount as another region among the surfaces of the optical module 20 is in contact with the inner surface 16a of the recess
15 portion 16. In the shown example, the heat generation surface 21 of the optical module 20 is disposed to face upward and is in contact with an upper surface of the inner surface 16a of the recess portion 16. The heat generation surface 21 is a horizontal plane extending in the width direction Dw and the depth direction Ds.

[0026]

The jacket 12 includes a heat transfer promoting section 17. The heat transfer
20 promoting section 17 is a portion of a wall portion constituting the jacket 12 with which the optical module 20 is in contact. In the present embodiment, the heat transfer promoting section 17 constitutes an upper wall of the jacket 12. The heat transfer promoting section 17 includes a heating surface 18. The heating surface 18 constitutes a portion of an outer surface of the jacket 12. The heating surface 18 faces a side
25 opposite to the inner surface 16a of the recess portion 16 in contact with the heat

generation surface 21 of the optical module 20. The heating surface 18 heats the refrigerant R by transferring heat from the heat generation surface 21 to the refrigerant R in the housing 10. In the present embodiment, the heating surface 18 is a horizontal plane facing upward and extending in the width direction Dw and the depth direction Ds.

5 [0027]

(Circulation of Refrigerant)

Subsequently, the circulation of the refrigerant R in the cooling device 1 will be described.

The housing 10 is filled with the refrigerant R in a liquid phase. Hereinafter,
10 the refrigerant R in a liquid phase will be described as a liquid refrigerant RL, and the refrigerant R in a gas phase will be described as a gaseous refrigerant RG.

When the optical module 20 generates heat, the heat of the optical module 20 is transferred to the jacket 12 in which the optical module 20 is accommodated. The heat transfer mainly occurs in the heat transfer promoting section 17 of the jacket 12 in
15 contact with the heat generation surface 21 of the optical module 20. The heat of the optical module 20 is transferred to the liquid refrigerant RL present around the jacket 12 via the jacket 12. In particular, the refrigerant R in contact with the heating surface 18 of the jacket 12 is heated and boiled by the heat transferred from the heating surface 18. As a result, the gaseous refrigerant RG (vapor of the refrigerant R) is generated on the
20 heating surface 18 and moves upward. The gaseous refrigerant RG that has reached the upper wall 14 is discharged to the outside of the housing 10 from the refrigerant discharge section 4. Thereafter, the gaseous refrigerant RG is cooled by the heat exchanger 6. The cooled gaseous refrigerant RG is condensed to become the liquid refrigerant RL. The liquid refrigerant RL is guided to the refrigerant supply section 3,
25 and is supplied again into the housing 10.

In this way, the refrigerant R circulates in the cooling device 1 due to the thermal convection caused by the heat generated by the optical module 20.

[0028]

(Operation and Effect)

5 In the present embodiment, the cooling device 1 includes the housing 10, the server 2, the optical module 20, the refrigerant supply section 3, and the refrigerant discharge section 4. The housing 10 includes the space S formed inside and the recess portion 16 that is recessed inward from the outer surface 10a. The server 2 is provided in the housing 10 and includes the terminal 2a that protrudes into the recess portion 16.

10 The optical module 20 is provided in the recess portion 16 and is connected to the terminal 2a. The refrigerant supply section 3 supplies the refrigerant R into the housing 10. The refrigerant discharge section 4 discharges the refrigerant R from the housing 10.

[0029]

15 As a result, the refrigerant R can circulate around the recess portion 16 in which the optical module 20 is accommodated. Therefore, the heat of the optical module 20 can be efficiently transferred to the refrigerant R without directly bringing the optical module 20 into contact with the refrigerant R. Accordingly, the same cooling efficiency as that of immersion cooling can be obtained. Therefore, the power consumption can be

20 reduced as compared with an air-cooled type that requires a large amount of power for blowing. Therefore, with the above-described configuration, the cooling efficiency can be improved, and the power consumption can be reduced.

[0030]

 In the present embodiment, the optical module 20 is in contact with an inner

25 surface 16a of the recess portion 16.

[0031]

As a result, the heat transfer between the optical module 20 and the refrigerant R can be promoted. Accordingly, the cooling efficiency can be further improved.

[0032]

5 In the present embodiment, the housing 10 includes the jacket 12 that is provided to protrude inward from the outer surface 10a and is formed with the recess portion 16. The heat generation surface 21 having a relatively large heat generation amount among the surfaces of the optical module 20 is in contact with the inner surface 16a of the recess portion 16. The jacket 12 includes the heating surface 18 that faces a
10 side opposite to the inner surface 16a of the recess portion 16 in contact with the heat generation surface 21 and that transfers heat from the heat generation surface 21 to the refrigerant R in the housing 10 to heat the refrigerant R.

[0033]

Therefore, the heat of the optical module 20 can be efficiently transferred to the
15 refrigerant R via the heating surface 18. Therefore, the refrigerant R is likely to be boiled on the heating surface 18, and a large amount of heat of the optical module 20 can be dissipated as latent heat of vaporization of the refrigerant R. Accordingly, the cooling efficiency can be further improved.

[0034]

20 <Second Embodiment>

Hereinafter, a cooling device 201 according to the second embodiment of the present disclosure will be described with reference to FIGS. 4 to 6. The same configurations as those in the above-described embodiment are denoted by the same names and the same reference numerals, and the description thereof will be omitted as
25 appropriate. The present embodiment is different from the first embodiment in that the

heat generation surface 21 and the heating surface 18 are vertical surfaces extending in the up-down direction Dv.

[0035]

In the present embodiment, as shown in FIG. 4, the refrigerant supply section 3 is provided in the vicinity of a corner portion of the lower wall 13 of the housing body 11, and the refrigerant discharge section 4 is provided in the vicinity of a corner portion of the upper wall 14 of the housing body 11. When viewed from above, the refrigerant supply section 3 and the refrigerant discharge section 4 are disposed on a diagonal line of the upper wall 14.

[0036]

In the present embodiment, as shown in FIGS. 5 and 6, the plurality of jackets 12 are arranged in the up-down direction Dv and the width direction Dw and are disposed in a rectangular grid pattern when viewed from the depth direction Ds. The plurality of jackets 12 are disposed at intervals in the up-down direction Dv and the width direction Dw. In the shown example, two rows each including the six jackets 12 arranged in the width direction Dw are provided in the up-down direction Dv. In each row, the jackets 12 are disposed at equal intervals in the width direction Dw.

[0037]

Two jackets 12 arranged in the up-down direction Dv are integrally formed by sharing a lower wall of an upper jacket 12 and an upper wall of a lower jacket 12.

[0038]

The heat generation surface 21 of the optical module 20 is disposed to face one side in the width direction Dw, and is in contact with a side surface of the inner surface 16a of the recess portion 16 that faces the width direction Dw. The heat generation surface 21 is a vertical surface extending in the up-down direction Dv and the depth

direction Ds.

[0039]

In the present embodiment, the heat transfer promoting section 17 constitutes a side wall of the jacket 12. The heating surface 18 of the heat transfer promoting section 17 is a vertical surface facing the one side in the width direction Dw and extending in the up-down direction Dv and the depth direction Ds, similarly to the corresponding heat generation surface 21. Two jackets 12 arranged in the up-down direction Dv are provided such that the heating surfaces 18 of the two jackets 12 are flush with each other. The two heating surfaces 18 are continuous with each other.

10 [0040]

(Operation and Effect)

In the present embodiment, a plurality of the jackets 12 are provided to be arranged in the up-down direction Dv. The heating surface 18 is a vertical surface extending in the up-down direction Dv.

15 [0041]

Therefore, it is possible to reduce inhibition of the flow of vapor of the refrigerant R generated at the heating surface 18 of the lower jacket 12 by the upper jacket 12. Accordingly, the cooling efficiency can be further improved.

[0042]

20 <Third Embodiment>

Hereinafter, a cooling device 301 according to the third embodiment of the present disclosure will be described with reference to FIG. 7. The same configurations as those in the above-described embodiment are denoted by the same names and the same reference numerals, and the description thereof will be omitted as appropriate.

25 The present embodiment is different from the second embodiment in that the optical

module 20 and the jacket 12 in which the optical module 20 is accommodated are offset from each other in the up-down direction Dv.

[0043]

In the present embodiment, as shown in FIG. 7, two jackets 12 arranged in the up-down direction Dv are provided at an interval. The two jackets 12 arranged in the up-down direction Dv are provided such that the heating surfaces 18 thereof are located on the same vertical surface.

[0044]

(Operation and Effect)

In the present embodiment, the jackets 12 arranged in the up-down direction Dv are provided at an interval.

[0045]

As a result, the refrigerant R can flow between the jackets 12 arranged in the up-down direction Dv. Accordingly, the heat transfer area of the jacket 12 in contact with the refrigerant R is increased, and thus the cooling efficiency can be further improved.

[0046]

<Fourth embodiment>

Hereinafter, a cooling device 401 according to the fourth embodiment of the present disclosure will be described with reference to FIG. 8. The same configurations as those in the above-described embodiment are denoted by the same names and the same reference numerals, and the description thereof will be omitted as appropriate. The present embodiment is different from the third embodiment in that the jacket 12 further includes a surface area increasing member 19 on the heating surface 18.

[0047]

(Surface Area Increasing Member)

In the present embodiment, as shown in FIG. 8, the surface area increasing member 19 is provided on the heating surface 18 of each jacket 12. The surface area increasing member 19 is a member that is thermally connected to the heating surface 18 and that increases the surface area of the heating surface 18. The surface area increasing member 19 according to the present embodiment is a plurality of fins protruding from the heating surface 18 in the width direction Dw. The surface area increasing member 19 is not limited to the fins, and may be, for example, a lattice or a porous material.

[0048]

10 (Operation and Effect)

In the present embodiment, the jacket 12 further includes the surface area increasing member 19 that increases the surface area of the heating surface 18 on the heating surface 18.

[0049]

15 Accordingly, the contact area between the refrigerant R and the heating surface 18 can be increased. Therefore, the heat exchange between the optical module 20 and the jacket 12 can be promoted. Further, the contact area between the refrigerant R and the heating surface 18 is increased, so that the critical heat flux is increased.

Accordingly, it is possible to suppress a sudden transition from nucleate boiling, which has high heat transfer efficiency, to film boiling on the heating surface 18.

[0050]

<Fifth embodiment>

Hereinafter, a cooling device 501 according to the fifth embodiment of the present disclosure will be described with reference to FIG. 9. The same configurations as those in the above-described embodiment are denoted by the same names and the

same reference numerals, and the description thereof will be omitted as appropriate.

The present embodiment is different from the second to fourth embodiments in that the heat generation surface 21 of the optical module 20 and the heating surface 18 of the jacket 12 are inclined with respect to the horizontal plane.

5 [0051]

In the present embodiment, as shown in FIG. 9, the plurality of jackets 12 are arranged in the up-down direction D_v and the width direction D_w and are disposed in a rectangular grid pattern when viewed in the depth direction D_s . The plurality of jackets 12 are disposed at intervals in the up-down direction D_v and the width direction D_w , as
10 in the second embodiment. In the shown example, two rows each including the six jackets 12 arranged in the width direction D_w are provided in the up-down direction D_v . In each row, the jackets 12 are disposed at equal intervals in the width direction D_w .

[0052]

The two jackets 12 arranged in the up-down direction D_v are provided such that
15 the lower end of the upper jacket 12 and the upper end of the lower jacket 12 are in contact with each other when viewed in the depth direction D_s .

[0053]

In the present embodiment, the heating surface 18 is an inclined surface inclined with respect to the horizontal plane. More specifically, a plurality of heating surfaces
20 18 all face the same direction, and each heating surface 18 faces upward and one side in the width direction D_w . Each heating surface 18 is inclined at approximately 45 degrees with respect to the horizontal plane. An angle of inclination of each heating surface 18 with respect to the horizontal plane can be changed as appropriate.

[0054]

25 (Operation and Effect)

In the present embodiment, a plurality of the jackets 12 are provided in the up-down direction Dv, and the heating surface 18 is the inclined surface inclined with respect to the horizontal plane.

[0055]

5 Therefore, the bubbles of the refrigerant R generated on the heating surface 18 are easily separated from the heating surface 18. Accordingly, the vapor of the refrigerant R easily escapes upward without being stagnant. Therefore, it is possible to suppress the deterioration of the slow heat performance of each jacket 12 and to further improve the cooling efficiency.

10 [0056]

<Sixth Embodiment>

Hereinafter, a cooling device 601 according to the sixth embodiment of the present disclosure will be described with reference to FIG. 10. The same configurations as those in the above-described embodiment are denoted by the same names and the
15 same reference numerals, and the description thereof will be omitted as appropriate. The present embodiment is different from the fifth embodiment in that the optical module 20 and the jacket 12 in which the optical module 20 is accommodated are offset from each other in the up-down direction Dv.

[0057]

20 In the present embodiment, as shown in FIG. 10, two jackets 12 arranged in the up-down direction Dv are provided at an interval.

[0058]

(Operation and Effect)

In the present embodiment, the jackets 12 arranged in the up-down direction Dv
25 are provided at an interval.

[0059]

As a result, the refrigerant R can flow between the jackets 12 arranged in the up-down direction D_v . Accordingly, the heat transfer area of the jacket 12 in contact with the refrigerant R is increased, and thus the cooling efficiency can be further improved.

5 [0060]

<Seventh Embodiment>

Hereinafter, a cooling device 701 according to the seventh embodiment of the present disclosure will be described with reference to FIG. 11. The same configurations as those in the above-described embodiment are denoted by the same names and the
10 same reference numerals, and the description thereof will be omitted as appropriate. The present embodiment is different from the sixth embodiment in that the optical module 20 and each row of the jacket 12 in which the optical module 20 is accommodated, extending in the width direction D_w , are offset from each other in the horizontal direction.

15 [0061]

In the present embodiment, as shown in FIG. 11, a plurality of the jackets 12 are arranged in the up-down direction D_v and the width direction D_w when viewed from the depth direction D_s . The jackets 12 arranged in the up-down direction D_v are disposed to offset from each other in the width direction D_w such that the heating surfaces 18
20 thereof are shifted from each other in the width direction D_w . As a result, among two rows of the jackets 12 extending in the width direction D_w , the row of the upper jacket 12 is disposed to approach the side wall 15 on one side in the width direction D_w , and the row of the lower jacket 12 is disposed to approach the side wall 15 on the other side in the width direction D_w .

25 [0062]

(Operation and Effect)

In the present embodiment, a plurality of the jackets 12 are arranged in the width direction Dw. The jackets 12 arranged in the up-down direction Dv are disposed to offset from each other in the width direction Dw such that the heating surfaces 18 thereof are shifted from each other in the width direction Dw.

[0063]

Therefore, it is possible to reduce inhibition of the flow of vapor of the refrigerant R generated at the heating surface 18 of the lower jacket 12 by the upper jacket 12. Accordingly, the vapor of the refrigerant R is more likely to smoothly escape upward. Therefore, it is possible to suppress the deterioration of the slow heat performance of each jacket 12 and to further improve the cooling efficiency.

[0064]

<Eighth Embodiment>

Hereinafter, a cooling device 801 according to the eighth embodiment of the present disclosure will be described with reference to FIGS. 12 to 14. The same configurations as those in the above-described embodiment are denoted by the same names and the same reference numerals, and the description thereof will be omitted as appropriate. The present embodiment is different from the first embodiment in that a plurality of optical modules 20 are installed in one recess portion 16.

[0065]

In the present embodiment, as shown in FIGS. 12 to 14, two jackets 12 are arranged in the up-down direction Dv. Each jacket 12 is formed to extend in the depth direction Ds and to extend long in the width direction Dw. Further, one recess portion 16 is formed in each jacket 12. The recess portion 16 is formed to extend in the depth direction Ds and to extend long in the width direction Dw according to the outer shape of

the jacket 12.

[0066]

A plurality of optical modules 20 are accommodated in one recess portion 16.

The heat generation surfaces 21 of the plurality of optical modules 20 are disposed to

5 face upward and are in contact with the upper surface of the inner surface 16a of the recess portion 16. The heat generation surface 21 is a horizontal plane extending in the width direction Dw and the depth direction Ds. In the present embodiment, the plurality of optical modules 20 are installed in the recess portion 16 without a gap in the width direction Dw.

10 [0067]

Further, in the present embodiment, the heat transfer promoting section 17 constitutes an upper wall of the jacket 12. The heating surface 18 of the heat transfer promoting section 17 is a horizontal plane facing upward and extending in the width direction Dw and the depth direction Ds, similarly to the corresponding heat generation

15 surface 21.

[0068]

(Operation and Effect)

In the present embodiment, a plurality of optical modules 20 are accommodated in one recess portion 16.

20 [0069]

Accordingly, a partition wall that separates the adjacent optical modules 20 can be eliminated in one recess portion 16. Therefore, it is possible to reduce the size of the cooling device 1 while the number of optical modules 20 mounted is maintained. In the present embodiment, the recess portion 16 is formed to be long in the width direction Dw, and the plurality of optical modules 20 are arranged in the width direction Dw

25

without a gap in one recess portion 16. As a result, the cooling device 1 can be reduced in size in the width direction Dw as compared with when the optical modules 20 are installed one by one in the recess portion 16 and the optical modules 20 are arranged in the width direction Dw by the same number as in the present embodiment.

5 [0070]

In the present embodiment, the recess portion 16 is provided to extend long in the width direction Dw, but the present disclosure is not limited to this. For example, the recess portion 16 may be provided to extend long in the up-down direction Dv.

[0071]

10 In the present embodiment, the plurality of optical modules 20 are installed in the recess portion 16 without a gap in the width direction Dw, but the present disclosure is not limited to this. The plurality of optical modules 20 accommodated in the same one recess portion 16 may be installed at intervals in the width direction Dw.

[0072]

15 <Ninth Embodiment>

Hereinafter, a cooling device 901 according to the ninth embodiment of the present disclosure will be described with reference to FIGS. 15 and 16. The same configurations as those in the above-described embodiment are denoted by the same names and the same reference numerals, and the description thereof will be omitted as appropriate. The present embodiment is different from the eighth embodiment in that the cooling device 901 further includes the cooling plate 30 that directly cools the heat-generating body.

[0073]

25 In the present embodiment, as shown in FIGS. 15 and 16, the recess portion 16 is formed to extend long in the width direction Dw, and the plurality of optical modules

20 are accommodated in one recess portion 16, as in the eighth embodiment. The plurality of optical modules 20 are installed in the recess portion 16 without a gap in the width direction Dw.

The cooling device 1 according to the present embodiment further includes the cooling plate 30, the second refrigerant supply section 31, the second refrigerant discharge section 32, the second refrigerant line 33, and the second heat exchanger 34, in addition to the configuration of the eighth embodiment.

[0074]

(Cooling Plate)

The cooling plate 30 is provided in the recess portion 16. The cooling plate 30 is in contact with the optical module 20. In the present embodiment, the cooling plate 30 is disposed between the optical module 20 and the heat transfer promoting section 17 of the jacket 12. The cooling plate 30 is formed to extend in the width direction Dw and is in direct contact with the heat generation surfaces 21 of the plurality of optical modules 20. A space in which the second refrigerant R2 can be stored is formed in the cooling plate 30. The optical module 20 is cooled by performing heat exchange between the optical module 20 and the second refrigerant R2 via the cooling plate 30. The second refrigerant R2 may be the same medium as the refrigerant R.

[0075]

(Second Refrigerant Supply Section)

The second refrigerant supply section 31 supplies the second refrigerant R2 into the cooling plate 30. The second refrigerant supply section 31 is a supply pipe that communicates with the space in the cooling plate 30.

[0076]

(Second Refrigerant Discharge Section)

The second refrigerant discharge section 32 discharges the refrigerant R from the cooling plate 30. The second refrigerant discharge section 32 is a discharge pipe that communicates with the space in the cooling plate 30.

[0077]

5 (Second Refrigerant Line)

The second refrigerant line 33 is a pipe that connects an upstream end of the second refrigerant supply section 31 and a downstream end of the second refrigerant discharge section 32. The second refrigerant line 33 guides the refrigerant R, which is discharged from the second refrigerant discharge section 32, to the second refrigerant supply section 31 again.

[0078]

(Second Heat Exchanger)

The second heat exchanger 34 is provided in the second refrigerant line 33. The second heat exchanger 34 cools the second refrigerant R2 that has performed heat exchange with the optical module 20. The second heat exchanger 34 may be of an air-cooled type or a liquid-cooled type.

[0079]

(Operation and Effect)

In the present embodiment, the cooling device 1 further includes the cooling plate 30, the second refrigerant supply section 31, and the second refrigerant discharge section 32. The cooling plate 30 is provided in the recess portion 16 and is in contact with the optical module 20. The second refrigerant supply section 31 supplies the second refrigerant R2 into the cooling plate 30. The second refrigerant discharge section 32 discharges the second refrigerant R2 from the cooling plate 30.

[0080]

Therefore, the optical module 20 and the second refrigerant R2 can be subjected to heat exchange, and the optical module 20 can be further cooled by the cooling plate 30. Accordingly, the optical module 20 can be cooled in a short time as compared with when the optical module 20 is cooled only with the refrigerant R.

5 [0081]

In the present embodiment, a plurality of optical modules 20 are accommodated in one recess portion 16. The cooling plate 30 is in contact with the plurality of optical modules 20.

[0082]

10 Therefore, the plurality of optical modules 20 can be collectively cooled by one cooling plate 30. Accordingly, the cooling efficiency can be further improved.

[0083]

In the present embodiment, the cooling plate 30 is provided in the recess portion 16 extending in the width direction Dw of the eighth embodiment, and the embodiment
15 has been described using an example in which the plurality of optical modules 20 are cooled, but the present disclosure is not limited to this. The cooling plate 30 may be provided in the recess portion 16 of the first to seventh embodiments, and one cooling plate 30 may cool one optical module 20. In this case, the cooling plate 30 is disposed to extend in the depth direction Ds.

20 [0084]

In the present embodiment, the cooling plate 30 is disposed between the optical module 20 and the heat transfer promoting section 17 of the jacket 12, but the present disclosure is not limited to this. The cooling plate 30 can be changed as appropriate in disposition in the recess portion 16. For example, the cooling plate 30 may be disposed
25 at a position in contact with a surface of the optical module 20 opposite to the heat

generation surface 21.

[0085]

(Other Embodiments)

The embodiments of the present disclosure have been described in detail with
5 reference to the accompanying drawings, but the specific configuration is not limited to
the embodiments, and design changes and the like within the concept of the present
disclosure are also included.

In the above-described embodiments, the housing body 11 is formed in a
rectangular parallelepiped shape, but the present disclosure is not limited to this. For
10 example, the housing body 11 may be formed in a polygonal tubular shape or a
cylindrical shape, and the shape of the housing body 11 can be changed as appropriate
according to the installation conditions of the cooling devices 1, 201, 301, 401, 501, 601,
701, 801, and 901.

[0086]

15 In the above-described embodiments, the jacket 12 is formed integrally with the
housing body 11, but the present disclosure is not limited to this. For example, the
jacket 12 may be formed separately from the housing body 11 and attached to the
housing body 11.

[0087]

20 In the above-described embodiments, the jacket 12 is made of, for example, a
metal material and has predetermined rigidity, but the present disclosure is not limited to
this. For example, the jacket 12 may be made of a material having flexibility. In this
case, the jacket 12 can change the shape according to the surrounding structures such as
the shape of the housing body 11, the disposition of the electronic device inside the
25 housing body 11, and the shape of the optical module 20.

[0088]

In the above-described embodiments, each jacket 12 is disposed such that the recess portion 16 is recessed in the horizontal direction, but the present disclosure is not limited to this. The jacket 12 can be installed at a portion other than the side wall 15 of the housing body 11, such as the lower wall 13 or the upper wall 14. That is, the recess portion 16 may be provided to be recessed inward from the outer surface 10a of the housing 10 in a direction other than the horizontal direction, such as the up-down direction Dv.

[0089]

10 In the above-described embodiments, a case has been described in which a plurality of the jackets 12 are provided in one housing 10, but the present disclosure is not limited to this. Only one jacket 12 may be provided in one housing 10. That is, only one recess portion 16 may be provided in one housing 10.

[0090]

15 In the above-described embodiments, a case where the shape of the optical module 20 is simplified and the optical module 20 is formed in a rectangular parallelepiped shape extending in one direction has been described as an example, but the present disclosure is not limited to this. The shape of the optical module 20 can be changed as appropriate, and the shape of the jacket 12 can be changed as appropriate in accordance with the shape of the optical module 20.

[0091]

In the above-described embodiments, the embodiment has been described using an example in which the inner surface 16a of the recess portion 16 and the optical module 20 are in contact with each other without a gap in the width direction Dw and the up-down direction Dv, but the present disclosure is not limited to this. The inner

25

surface 16a of the recess portion 16 and the optical module 20 may be spaced apart from each other in the width direction Dw or the up-down direction Dv.

[0092]

In the above-described embodiments, a case has been described in which the refrigerant R boils and evaporates on the heating surface 18, but the present disclosure is not limited to this. The refrigerant R may circulate in the cooling device 1 in a liquid phase without evaporating on the heating surface 18.

[0093]

In the above-described embodiments, a case has been described in which the refrigerant supply section 3 is provided on the lower wall 13 and the refrigerant discharge section 4 is provided on the upper wall 14, but the present disclosure is not limited to this. The dispositions of the refrigerant supply section 3 and the refrigerant discharge section 4 can be changed as appropriate. For example, each of the refrigerant supply section 3 and the refrigerant discharge section 4 may be provided on the side wall 15.

[0094]

In the above-described embodiments, a case has been described in which the refrigerant R is circulated by natural circulation using the phase change of the refrigerant R, but the present disclosure is not limited to this. For example, as shown in FIG. 17, a pump 8 may be provided in the refrigerant line 5, and the refrigerant R may be forcibly circulated by the pump 8. In this case, even when the refrigerant R does not evaporate on the heating surface 18, the refrigerant R can smoothly circulate in a liquid phase.

[0095]

In the above-described embodiments, the heat exchanger 6 may be of an air-cooled type or a liquid-cooled type. When the heat exchanger 6 is of an air-cooled type, for example, as shown in FIG. 17, a tubular member 9 may be provided above the heat

exchanger 6, and air may be naturally introduced into the heat exchanger 6 by a draft force generated by an upward flow of air warmed by the heat exchanger 6.

In addition, the form in which the refrigerant R circulates in a liquid phase by the pump 8 and the form in which the tubular member 9 is provided have been described
5 as an example of the cooling device 1 of the first embodiment, but these forms can also be applied to the cooling devices 201, 301, 401, 501, 601, 701, 801, and 901 according to the second to ninth embodiments.

[0096]

<Additional Notes>

10 The cooling devices 1, 201, 301, 401, 501, 601, 701, 801, and 901 described in each of the embodiments are understood as follows, for example.

[0097]

(1) Cooling devices 1, 201, 301, 401, 501, 601, 701, 801, and 901 according to a first aspect include a housing 10 including a space S formed inside and a recess portion
15 16 recessed inward from an outer surface 10a; a server 2 provided in the housing 10 and including a terminal 2a protruding into the recess portion 16; an optical module 20 provided in the recess portion 16 and connected to the terminal 2a; a refrigerant supply section 3 configured to supply a refrigerant R into the housing 10; and a refrigerant discharge section 4 configured to discharge the refrigerant R from the housing 10.

20 [0098]

As a result, the refrigerant R can circulate around the recess portion 16 in which the optical module 20 is accommodated. Therefore, the heat of the optical module 20 can be efficiently transferred to the refrigerant R without directly bringing the optical module 20 into contact with the refrigerant R. Accordingly, the same cooling efficiency
25 as that of immersion cooling can be obtained. Therefore, the power consumption can be

reduced as compared with an air-cooled type that requires a large amount of power for blowing.

[0099]

(2) Cooling devices 1, 201, 301, 401, 501, 601, 701, 801, and 901 according to a
5 second aspect are the cooling devices 1, 201, 301, 401, 501, 601, 701, 801, and 901
according to the first aspect, in which the optical module 20 may be in contact with an
inner surface 16a of the recess portion 16.

[0100]

As a result, the heat transfer between the optical module 20 and the refrigerant R
10 can be promoted.

[0101]

(3) Cooling devices 1, 201, 301, 401, 501, 601, 701, and 801 according to a third
aspect are the cooling devices 1, 201, 301, 401, 501, 601, 701, and 801 according to the
second aspect, in which the housing 10 may include a jacket 12 provided protruding
15 inward from the outer surface 10a and formed with the recess portion 16, a heat
generation surface 21 having a relatively large heat generation amount among surfaces of
the optical module 20 may be in contact with the inner surface 16a of the recess portion
16, and the jacket 12 may include a heating surface 18 facing a side opposite to the inner
surface 16a of the recess portion 16 in contact with the heat generation surface 21 and
20 configured to heat the refrigerant R by transferring heat from the heat generation surface
21 to the refrigerant R in the housing 10.

[0102]

Therefore, the heat of the optical module 20 can be efficiently transferred to the
refrigerant R via the heating surface 18. Therefore, the refrigerant R is likely to be
25 boiled on the heating surface 18, and a large amount of heat of the optical module 20 can

be dissipated as latent heat of vaporization of the refrigerant R.

[0103]

(4) Cooling devices 201, 301, and 401 according to a fourth aspect are the cooling devices 201, 301, and 401 according to the third aspect, in which a plurality of the jackets 12 may be arranged in an up-down direction Dv, and the heating surface 18 may be a vertical surface extending in the up-down direction Dv.

[0104]

Therefore, it is possible to reduce inhibition of the flow of vapor of the refrigerant R generated at the heating surface 18 of the lower jacket 12 by the upper jacket 12.

[0105]

(5) A cooling device 301 according to a fifth aspect is the cooling device 301 according to the fourth aspect, in which the jackets 12 arranged in the up-down direction Dv may be provided at intervals.

[0106]

As a result, the refrigerant R can flow between the jackets 12 arranged in the up-down direction Dv.

[0107]

(6) A cooling device 401 according to a sixth aspect is the cooling device 401 of any one according to the third to fifth aspects, in which the jacket 12 may further include, on the heating surface 18, a surface area increasing member 19 configured to increase a surface area of the heating surface 18.

[0108]

Accordingly, the contact area between the refrigerant R and the heating surface 18 can be increased. Therefore, the heat exchange between the optical module 20 and

the jacket 12 can be promoted.

[0109]

(7) Cooling devices 501, 601, and 701 according to a seventh aspect are the cooling devices 501, 601, and 701 according to the third aspect, in which a plurality of the jackets 12 may be arranged in an up-down direction Dv, and the heating surface 18 may be an inclined surface inclined with respect to a horizontal plane.

[0110]

Therefore, the bubbles of the refrigerant R generated on the heating surface 18 are easily separated from the heating surface 18. Therefore, the vapor of the refrigerant R is likely to escape upward.

[0111]

(8) Cooling devices 601 and 701 according to an eighth aspect are the cooling devices 601 and 701 according to the seventh aspect, in which the jackets 12 arranged in the up-down direction Dv are provided at intervals.

[0112]

As a result, the refrigerant R can flow between the jackets 12 arranged in the up-down direction Dv.

[0113]

(9) A cooling device 701 according to a ninth aspect is the cooling device 701 according to the seventh or eighth aspect, in which a plurality of the jackets 12 may be arranged in a horizontal direction, and the jackets 12 arranged in the up-down direction Dv may be disposed offset from each other in the horizontal direction such that the heating surfaces 18 of the jackets 12 are shifted from each other in the horizontal direction.

[0114]

Therefore, it is possible to reduce inhibition of the flow of vapor of the refrigerant R generated at the heating surface 18 of the lower jacket 12 by the upper jacket 12.

[0115]

- 5 (10) Cooling devices 801 and 901 according to a tenth aspect are the cooling devices 801 and 901 according to any one of the first to ninth aspects, in which a plurality of optical modules 20 may be accommodated in one recess portion 16.

[0116]

- Accordingly, a partition wall that separates the adjacent optical modules 20 can
10 be eliminated in one recess portion 16.

[0117]

- (11) A cooling device 901 according to an eleventh aspect is the cooling device 901 according to any one of the first to ninth aspects, that may further include: a cooling plate 30 provided in the recess portion 16 and being in contact with the optical module
15 20; a second refrigerant supply section 31 configured to supply a second refrigerant R2 into the cooling plate 30; and a second refrigerant discharge section 32 configured to discharge the second refrigerant R2 from the cooling plate 30.

[0118]

- Therefore, the optical module 20 and the second refrigerant R2 can be subjected
20 to heat exchange, and the optical module 20 can be further cooled by the cooling plate 30.

[0119]

- (12) A cooling device 901 according to a twelfth aspect is the cooling device 901 according to the eleventh aspect, in which a plurality of optical modules 20 may be
25 accommodated in one recess portion 16, and the cooling plate 30 may be in contact with

the plurality of optical modules 20.

[0120]

Therefore, the plurality of optical modules 20 can be cooled by one cooling plate 30.

5 INDUSTRIAL APPLICABILITY

[0121]

According to the cooling device of the present disclosure, it is possible to improve the cooling efficiency and reduce the power consumption.

REFERENCE SIGNS LIST

10 [0122]

1 Cooling device

2 Server

2a Terminal

3 Refrigerant supply section

15 4 Refrigerant discharge section

5 Refrigerant line

6 Heat exchanger

8 Pump

9 Tubular member

20 10 Housing

10a Outer surface

11 Housing body

12 Jacket

13 Lower wall

25 14 Upper wall

	15 Side wall
	16 Recess portion
	16a Inner surface
	17 Heat transfer promoting section
5	18 Heating surface
	19 Surface area increasing member
	20 Optical module
	21 Heat generation surface
	22 Optical fiber
10	30 Cooling plate
	31 Second refrigerant supply section
	32 Second refrigerant discharge section
	33 Second refrigerant line
	34 Second heat exchanger
15	201 Cooling device
	301 Cooling device
	401 Cooling device
	501 Cooling device
	601 Cooling device
20	701 Cooling device
	801 Cooling device
	901 Cooling device
	Dv Up-down direction
	Dw Width direction
25	Ds Depth direction

R Refrigerant

R2 Second refrigerant

RL Liquid refrigerant

RG Gaseous refrigerant

5

S Space

CLAIMS

[Claim 1] A cooling device comprising:

a housing including a space formed inside and a recess portion recessed inward from an outer surface;

5 a server provided in the housing and including a terminal protruding into the recess portion;

an optical module provided in the recess portion and connected to the terminal;

a refrigerant supply section configured to supply a refrigerant into the housing;

and

10 a refrigerant discharge section configured to discharge the refrigerant from the housing.

[Claim 2] The cooling device according to Claim 1,

wherein the optical module is in contact with an inner surface of the recess portion.

15 [Claim 3] The cooling device according to Claim 2,

wherein the housing includes a jacket provided protruding inward from the outer surface and formed with the recess portion,

a heat generation surface having a relatively large heat generation amount among surfaces of the optical module is in contact with the inner surface of the recess

20 portion, and

the jacket includes a heating surface facing a side opposite to the inner surface of the recess portion in contact with the heat generation surface and configured to heat the refrigerant by transferring heat from the heat generation surface to the refrigerant in the housing.

25 [Claim 4] The cooling device according to Claim 3,

wherein a plurality of the jackets are arranged in an up-down direction, and
the heating surface is a vertical surface extending in the up-down direction.

[Claim 5] The cooling device according to Claim 4,

wherein the jackets arranged in the up-down direction are provided at intervals.

5 [Claim 6] The cooling device according to any one of Claims 3 to 5,

wherein the jacket further includes, on the heating surface, a surface area
increasing member configured to increase a surface area of the heating surface.

[Claim 7] The cooling device according to Claim 3,

wherein a plurality of the jackets are arranged in an up-down direction, and
10 the heating surface is an inclined surface inclined with respect to a horizontal
plane.

[Claim 8] The cooling device according to Claim 7,

wherein the jackets arranged in the up-down direction are provided at intervals.

[Claim 9] The cooling device according to Claim 7 or 8,

15 wherein a plurality of the jackets are arranged in a horizontal direction, and
the jackets arranged in the up-down direction are disposed offset from each
other in the horizontal direction such that the heating surfaces of the jackets are shifted
from each other in the horizontal direction.

[Claim 10] The cooling device according to any one of Claims 1 to 5,

20 wherein a plurality of optical modules are accommodated in one recess portion.

[Claim 11] The cooling device according to any one of Claims 1 to 5, further
comprising:

a cooling plate provided in the recess portion and being in contact with the
optical module;

25 a second refrigerant supply section configured to supply a second refrigerant

into the cooling plate; and

a second refrigerant discharge section configured to discharge the second refrigerant from the cooling plate.

[Claim 12] The cooling device according to Claim 11,

5 wherein a plurality of optical modules are accommodated in one recess portion,
and

the cooling plate is in contact with the plurality of optical modules.