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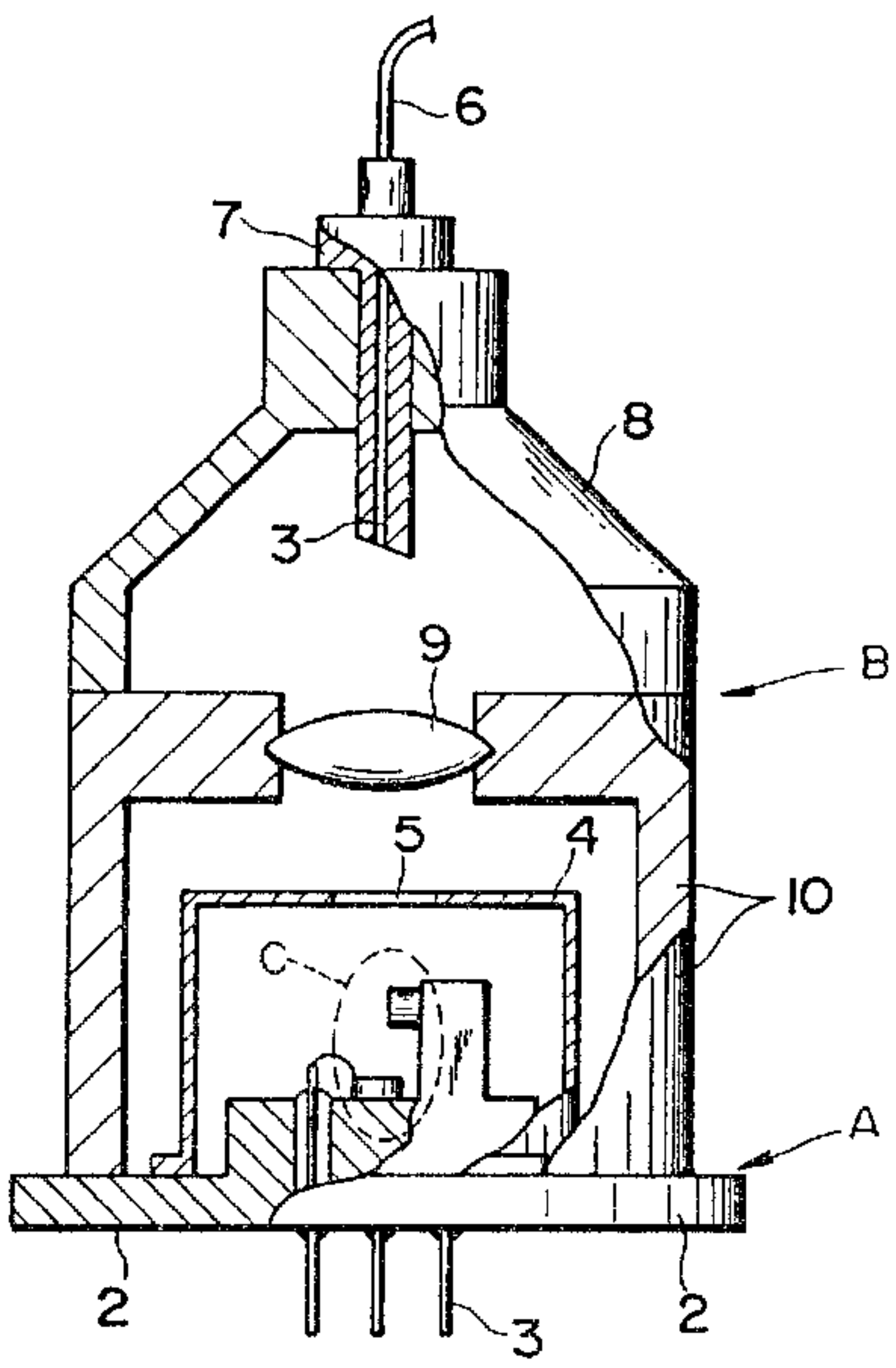

(57) Abrégé/Abstract:
A semiconductor laser device in which a housing with an optical fiber inserted in is secured to a header with a semiconductor laser chip mounted on is integrated, the light emitting surface of the semiconductor laser chip and the end surface of the optical fiber are opposed to each other, and there is provided a phododiode chip for detecting the signal light emitted from the backside (rear end surface) of the light emitting surface of the semiconductor laser chip, the photodiode chip including on the light detecting surface opposed to the rear end surface of the semiconductor laser chip a p-n junction for outputting a photocurrent in a detected signal and a region for capturing carriers generated in a peripheral area of the p-n junction. The semiconductor laser device can operate stably, and the positioning of the photodiode can be less strict. The potodiode can be easily mounted. Because the charge capturing region covered with an antireflection film absorbs an unnecessary component of the signal light, a semiconductor laser device which generates neither reflected light nor scattered light, which makes its operation unstable, and can stably operate.

ABSTRACT OF THE DISCLOSURE

A semiconductor laser device in which a housing with an optical fiber inserted in is secured to a header with a semiconductor laser chip mounted on is integrated, the light emitting surface of the semiconductor laser chip and the end surface of the optical fiber are opposed to each other, and there is provided a phododiode chip for detecting the signal light emitted from the backside (rear end surface) of the light emitting surface of the semiconductor laser chip, the photodiode chip including on the light detecting surface opposed to the rear end surface of the semiconductor laser chip a p-n junction for outputting a photocurrent in a detected signal and a region for capturing carriers generated in a peripheral area of the p-n junction. The semiconductor laser device can operate stably, and the positioning of the photodiode can be less strict. The potodiode can be easily mounted. Because the charge capturing region covered with an antireflection film absorbs an unnecessary component of the signal light, a semiconductor laser device which generates neither reflected light nor scattered light, which makes its operation unstable, and can stably operate.

SEI 92-33

TITLE OF THE INVENTION

Semiconductor Laser Device

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a semiconductor laser device used in transmission devices, etc. of the optical communication systems.

Related Background Art

The semiconductor laser device used in the optical communication using optical fibers is exemplified by the one as shown in FIG. 1 (a first prior art) which comprises a semiconductor laser chip 1A as a signal light source and a photodiode chip 1B as light detecting means for monitoring the light emitted from the rear end surface (lower end surface as viewed in FIG. 1) of the semiconductor laser chip 1A which is mounted on a header 2, and lead wires 3 connecting the photodiode chip 1B to a monitor circuit and connecting the semiconductor laser chip to an outside drive circuit (not shown).

In FIG. 1, a cap 4 has a light transmitting window 5 which passes the signal light emitted from the semiconductor laser chip 1A and airtightly seals the semiconductor laser chip 1A and the photodiode chip 1B.

A condenser lens 9 secured to a lens holder 10 is used to cause the signal light emitted from the semiconductor laser chip 1A to effectively enter an optical fiber 6 inserted in a housing 8 through a ferrule 7. Especially the structure of FIG. 1 is called coaxial type.

On the other hand, the semiconductor laser device (a second prior art) shown in FIG. 2 is called butterfly type and has a housing 8 of rectangular section. This semiconductor laser device has basically the same function as the first prior art. But it is possible that an IC (integrated circuit) chip for the laser drive circuit and the monitor circuit is mounted on the header 2 secured in the housing 8.

The photodiode chip 1B as the light detecting means comprises, as shown in FIG. 3, an epitaxial layer 12 grown on a semiconductor substrate 11, and a diffusion region 13 formed on the surface of the epitaxial layer 12 by thermal diffusion of a metal element and having an opposite polarity to that of the epitaxial layer 12.

The interface between the epitaxial layer 12 and the diffusion region 13 have a p-n junction, so that the light radiated to the p-n junction contributes to the generation of a photocurrent. The generated photocurrent is taken outside for monitor through electrodes 14, 15.

But these conventional semiconductor laser devices have the following problems.

The above-described semiconductor laser devices have properties that the semiconductor laser chip 1A as the signal light source tends to have unstable emitted light intensities corresponding to temperature changes. The signal light emitted from the semiconductor laser chip 1A is monitored by the photodiode chip 1B to control an average current to be applied to the semiconductor laser chip 1A to be constant so that a level of the light monitored by the outside electronic circuit is maintained constant.

But to operate the semiconductor laser chip 1A more stably at a high speed above about 100 Mbps, the control of the average current is not sufficient. Actually it is also necessary to detect a minimum emitted light intensity and a maximum one and control a level of the emitted light intensity. But the conventional semiconductor laser devices, which use the photodiode chip 1B of the above-described common structure, cannot accurately detect a minimum and a maximum emitted light intensity, and it is difficult to put the conventional semiconductor laser devices to practical uses.

This is because a photocurrent generated by the light radiated to a part of the surface of the photodiode apart from the light detecting region (p-n junction) becomes a slow response component which does not follow a change of an emitted light intensity of a laser beam.

In FIG. 3 reference numeral 16 indicates a divergence of a light beam emitted from the semiconductor laser chip 1A. Carriers generated by those of the beams absorbed in the light detecting region 13 (a light detecting window) on the surface of the photodiode chip 1B and its very neighboring area (e.g., 3 ~ 5μm) are effectively isolated at high speed by an electric field applied to the p-n junction and contribute to the generation of a photocurrent. But the signal light absorbed outside the region and the area adversely generate a very slow response photocurrent because the electric field is not applied thereto.

Consequently, in monitoring digital signal light, signal waveform distortions occur (especially a rectangular pulse trails by μsec at the fall), and a maximum and a minimum values cannot be accurately detected. High-speed, stable modulation cannot be performed.

In the conventional semiconductor laser devices, because of this problem, a position of the photodiode chip 1B on the header is finely adjusted so that the signal light emitted from the rear end surface (the lower end surface in FIG 1) is incident only on the light detecting region of the photodiode chip 1B. A resultant problem is that it takes more time to mount a photodiode chip 1B on the header 2 because the mounting position of the photodiode chip 1B on the header 2 has to be finely adjusted. This problem is a neck to the massproduction.

Although the semiconductor laser device is essential to the optical communication, the device has such problems and cannot be put to all uses, which is a neck to the rapid prevalence of the optical communication systems.

SUMMARY OF THE INVENTION

This invention has been made to solve the above-described problems, and an object of this invention is to provide a semiconductor laser device having a structure which is easy to be fabricated.

This invention relates to a semiconductor laser device in which a housing with an optical fiber inserted in is secured to a header with a semiconductor laser chip mounted on is integrated, the light emitting surface of the semiconductor laser chip and the end surface of the optical fiber are opposed to each other, and there is provided a phododiode chip for detecting the signal light emitted from the backside (rear end surface) of the light emitting surface of the semiconductor laser chip, the photodiode chip including on the light detecting surface opposed to the rear end surface of the semiconductor laser chip a p-n junction for outputting a photocurrent in a detected signal and a region for capturing carriers generated in a peripheral area of the p-n junction.

Especially the photodiode chip is characterized in that a p-n junction as the light detecting region is formed by thermal diffusion of a metal element on an epitaxial layer grown on a substrate (the light detecting region and the epitaxial layer have opposite polarities to each other), and a charge capturing region is formed around the p-n junction by the same method.

According to this invention, the photodiode chip is provided for monitoring an intensity of emitted light from the semiconductor laser chip as the signal light source and includes the charge capturing region for unnecessary carriers. Such photodiode chip can be easily mounted.

The photodiode chip mounted on the semiconductor laser device has the region for capturing unnecessary carriers generated by signal light radiated to an area outside the light detecting region. Even when the signal light from the rear end surface of the semiconductor laser chip is radiated the peripheral area of the light detecting region, no slow response component is generated in the photocurrent signal.

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not to be considered as limiting the present invention.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art form this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a broken side view of a first example of the conventional semiconductor laser device.

FIG. 2 is a sectional view of a second example of the conventional semiconductor laser device.

FIG. 3 is a sectional view of a photodiode chip installed in the conventional semiconductor laser devices.

FIG. 4A is a broken side view of the semiconductor laser device according to a first embodiment of this invention.

FIG. 4B is a sectional view of major part of the semiconductor laser device according to the first embodiment of this invention.

FIG. 5 is a sectional view of a charge capturing photodiode chip used in this invention.

FIG. 6 is a broken side view of the semiconductor laser device according to second embodiment of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The semiconductor laser device according to a first embodiment of this invention will be explained with reference to FIGs. 4 to 6.

FIG. 4A is a broken side view of a major part of the semiconductor laser device according to a first embodiment of this invention. FIG. 4B is an enlarged view of the part C in FIG. 4A (the upper part of the header 2).

A difference of the conventional semiconductor laser device (FIG. 1) is that the photodiode chip 1B for monitoring the signal light emitted from the rear end surface of the semiconductor laser chip 1A as enlarged in FIG. 4B, is provided by a semiconductor of the type (called charge capturing photodiode chip) that a photocurrent generated by the signal light radiated to a peripheral area of the p-n junction as the light detecting region is made unreactive.

As shown in FIG. 4B, a semiconductor chip 1A is mounted on a header 2, and a semiconductor chip 1B is also mounted on the header 2 on the side of the rear end surface of the semiconductor chip 1A. A lens holder 10 and a housing 8 are integrated with the header 2.

An optical fiber 6 is inserted in the housing through a ferrule 7. The end surface of the optical fiber 5 is opposed to the light emitting surface of the semiconductor laser chip 1 across a lens 9 and a light transmitting window 5.

The photodiode chip 1B used in the semiconductor laser device according to this first embodiment of this invention can be provided by a charge capturing photodiode chip of the structure that the photocurrent generated by the light radiated in a peripheral area of the p-n junction, i.e., the light detecting region, is made unreactive. One example of the structure is shown in FIG. 5.

A region 17 having the same polarity as a light detecting region 13 is formed on an epitaxial layer on a substrate by thermal diffusion of a metal element, whereby the photocarriers generated in the region 17 do not flow to the light detecting region 13 but extinguish near the p-n junction between the epitaxial layer 12 and the region 17, or the p-n junction exposed on the end surfaces of the chip. This is specifically described in Japanese Patent Application No. 230206/1990.

By using such improved photodiode chip 1B in monitoring an emitted light intensity, no slow response component of a photocurrent is generated even in a state where a monitored beam from the semiconductor laser chip 1A is divergent. The photodiode chip 1B can be easily mounted, and resultantly semiconductor laser devices can be easily fabricated and can be accordingly inexpensive.

The inventors have fabricated the semiconductor laser device having the structure of FIG. 4A.

A 1.3 μm-wavelength InGaAsP semiconductor laser chip 1A and the improved photodiode chip of InGaAs 1B are mounted on a header 2 of Fe for CD lasers. The photodiode chip 1B is electrically connected to a lead 3 with a Au wire.

The photodiode chip 1B is provided by a charge capturing type photodiode chip 1B comprising a p-n junction as a light detecting region 13 of 300 μm in diameter formed by thermal diffusion of Zn on an InGaAs epitaxial layer 12, and a charge capturing region 17 formed thereon by the same method. Needless to say, the p-n junction of this photodiode chip 1B is passivated with a SiN film, and the entire surfaces of the light detecting region 13 and of the charge capturing region 17 are covered with an antireflection film.

Then the semiconductor laser chip 1A and the photodiode chip 1B are airtightly sealed by a cap 4 with a light transmitting window 5, and the interior of the cap is filled with nitrogen gas. The condenser lens 9 is provided by a spherical lens. The spherical lens is secured to a stainless holder 10. And this lens is so set by monitoring from above with a TV monitor that the light emitting portion of the semiconductor laser chip 1A is seen at the center of the lens, and next is YAG welded to each other at the part A in FIG. 4A by YAG laser.

Then a housing with an optical fiber 7 inserted through a ferrule 7, and the lens holder 10 are brought nearer to be welded to each other by YAG laser at the part B by monitoring intensities of the incident light on the end surface of the optical fiber 6 for a maximum light intensity.

Next, the semiconductor laser device according to a second embodiment of this invention will be explained with reference to FIG. 6.

In this embodiment, a 1.55 μm-wavelength InGaAs semiconductor laser chip 1A is mounted on a Si submount 20 with an AuSn eutectic solder. In the case where the header 2 is provided by a metal package, the Si submount 20 secures the electric insulation between the semiconductor laser chip 1A and the metal package. The Si submount 20 as the header is mounted at a set position on the metal package by an SnPb solder. A photodiode chip 1B is mounted on a position on the header 2 (metal package) where the photodiode chip 1B can detect the light emitted from the rear end surface (lower end surface as view in FIG. 6) of the semiconductor laser chip 1A.

This photodiode chip 1B used in this embodiment has the same structure as that of the photodiode chip 1B used in the embodiment of FIG. 4A that the charge generated by the light radiated to a peripheral area of the light detecting region is captured. Accordingly the positioning of the photodiode chip 1B can be less strict than that of the conventional photodiode chips. This contributes to raise a degree of design freedom of the metal package 2. This photodiode chip 1B is mounted on a submount 21 of alumina ceramics mounted on the metal package with an AuSn eutectic solder. The electrodes of the semiconductor laser chips 1A and of the photodiode chip 1B are electrically connected to set outside electrodes through Au wires.

A metal cap 19 with a spherical lens 5 for coupling the signal light emitted from the forward end surface of the semiconductor laser chip 1A with the optical fiber 6 is, by projection welding, secured to the metal package 2 with the semiconductor laser chip 1A mounted on. Then a holder 8 with the optical fiber 6 inserted in is secured to the metal package 2 similarly with projection welding. In securing the cap 19 and the holder 8, aligning means is used so that the light emitted form the semiconductor laser chip 1A is effectively incident on the optical fiber 6. The space airtightly closed by the metal package 2 and the cap 19 and accommodating the semiconductor laser chip 1A is filled with an inert gas, e.g., nitrogen gas, in its dry state, so that even in low temperature conditions the inert gas does not bedew the surfaces of the semiconductor devices. The materials of the semiconductors, the packages and the submounts are one examples, and other different materials can be selected depending on applications.

The improved semiconductor laser device using the thus-improved photodiode chip for monitoring can accurately monitor the state of an emitted laser beam, and resultantly can be stably driven up to high speeds and high temperatures. Furthermore, the positioning of the photodiode can be less strict, and resultantly the photodiode can be mounted easily. The charge capturing region with an antireflection film formed on can absorb unnecessary component of signal light, and resultantly no reflected light or scattered light, which makes the operation of the semiconductor laser unstable are generated, and resultantly the operation of the semiconductor laser device can be stable.

As described above, according to this invention, the photodiode chip as the monitoring light detecting means is provided by a photodiode chip having the structure having a region for capturing unnecessary carriers, and resultantly the photodiode chip can accurately detect waveforms of laser beams and stably operate even at high speed and at high temperature conditions. In addition, the positioning of the photodiode can be less strict, and resultantly the photodiode can be easily mounted. The charge capturing region with the antireflection film formed on can collect an unnecessary component of signal light, and resultantly no reflection light and scattered light, which makes the operation of the semiconductor laser unstable with signal light, are not generated, and a stable operative semiconductor laser device can be provided.

The semiconductor laser device according to this invention is essential as a component to the machines and instruments especially for the high-speed data transfer and the optical communication subscribers among the communication networks in which the optical communication is being advanced.

From the invention thus described, it will be obvious that the invention may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A semiconductor laser device comprising:

a housing with an optical fiber as an transmission path inserted in:

a header for securing the housing integrally therewith;

a semiconductor laser chip mounted on the header for emitting signal light to an incident end surface of the optical fiber through a lens optical system; and

a photodiode chip mounted on the header, and including a p-n junction for outputting a photocurrent generated by the signal light emitted from a backside of the semiconductor laser chip, and a region for capturing carriers generated in a peripheral area of the p-n junction, the p-n junction and the region being formed on a light detecting surface.

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

the photodiode chip includes a charge capturing region formed by thermal diffusion of a metal element on an epitaxial layer grown on a substrate, said charge capturing region having the same polarity as the light detecting region, and the light detecting region and the charge capturing region having the same polarity.

3. A semiconductor laser device according to claim 1, wherein

the optical fiber and the semiconductor laser chip are incontiguously optically coupled with each other through a lens optical system, the incident end surface of the optical fiber and the light emitting surface of the semiconductor laser being opposed to each other.

4. A semiconductor laser device according to claim 1, wherein

the semiconductor laser chip and the photodiode chip are incontiguously optically coupled with each other, and the backside of the light emitting surface of the semiconductor laser chip and the light detecting surface of the photodiode chip being opposed to each other.

5. A semiconductor laser device according to claim 1, wherein

the semiconductor laser chip and the photodiode chip both mounted on the header is airtightly sealed with a cap, and the interior of the cap is filed with an inert element.

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

the cap has a light transmitting window for passing the signal light emitted from the emitting surface of the semiconductor laser chip.

7. A semiconductor laser device comprising:

a housing with an optical fiber as an optical transmission path inserted in;

a header securing the housing integrally therewith

a semiconductor laser chip mounted on the header through an Si submount for emitting signal light to an incident end surface of the optical fiber through a lens optical system; and

a photodiode chip including a p-n junction mounted on the header for outputting a photocurrent generated by a signal light emitted from the backside of a light emitting surface of the semiconductor laser chip, and a region for capturing carriers generated by a peripheral area of the p-n junction, the p-n junction and the region being formed on a light detecting surface.

8. A semiconductor laser device according to claim 7, wherein the lens optical system is provided by a spherical lens.

9. A semiconductor laser device according to claim 7, wherein

the header securing the semiconductor laser chip through the Si submount is provided by a metal package.

10. A semiconductor laser device according to claim 7, wherein

the photodiode chip includes a charge capturing region formed by thermal diffusion of a metal element on epitaxial layer grown on a substrate and having the same polarity as the light detecting region, the light detecting region and the charge capturing region having the same polarity.

11. A semiconductor laser device according to claim 7, wherein

the optical fiber and the semiconductor laser chip are incontiguously optically coupled with each other through a lens optical system, and the incident end surface of the optical fiber and the light emitting surface of the semiconductor laser chip are opposed to each other.

12. A semiconductor laser device according to claim 7, wherein

the semiconductor laser chip and the photodiode chip are incontiguously optically coupled with each other, and the backside of the light emitting surface of the semiconductor laser chip and the light detecting surface of the photodiode chip are opposed to each other.

13. A semiconductor laser device according to claim 7, wherein

the semiconductor laser chip and the photodiode chip both mounted on the header is airtightly sealed by a cap, and the interior of the cap is filled with an inert element.

14. A semiconductor laser device according to claim 13, wherein

the cap has a light transmitting window for passing the signal light emitted from the light emitting surface of the semiconductor laser chip.

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Fig. 1

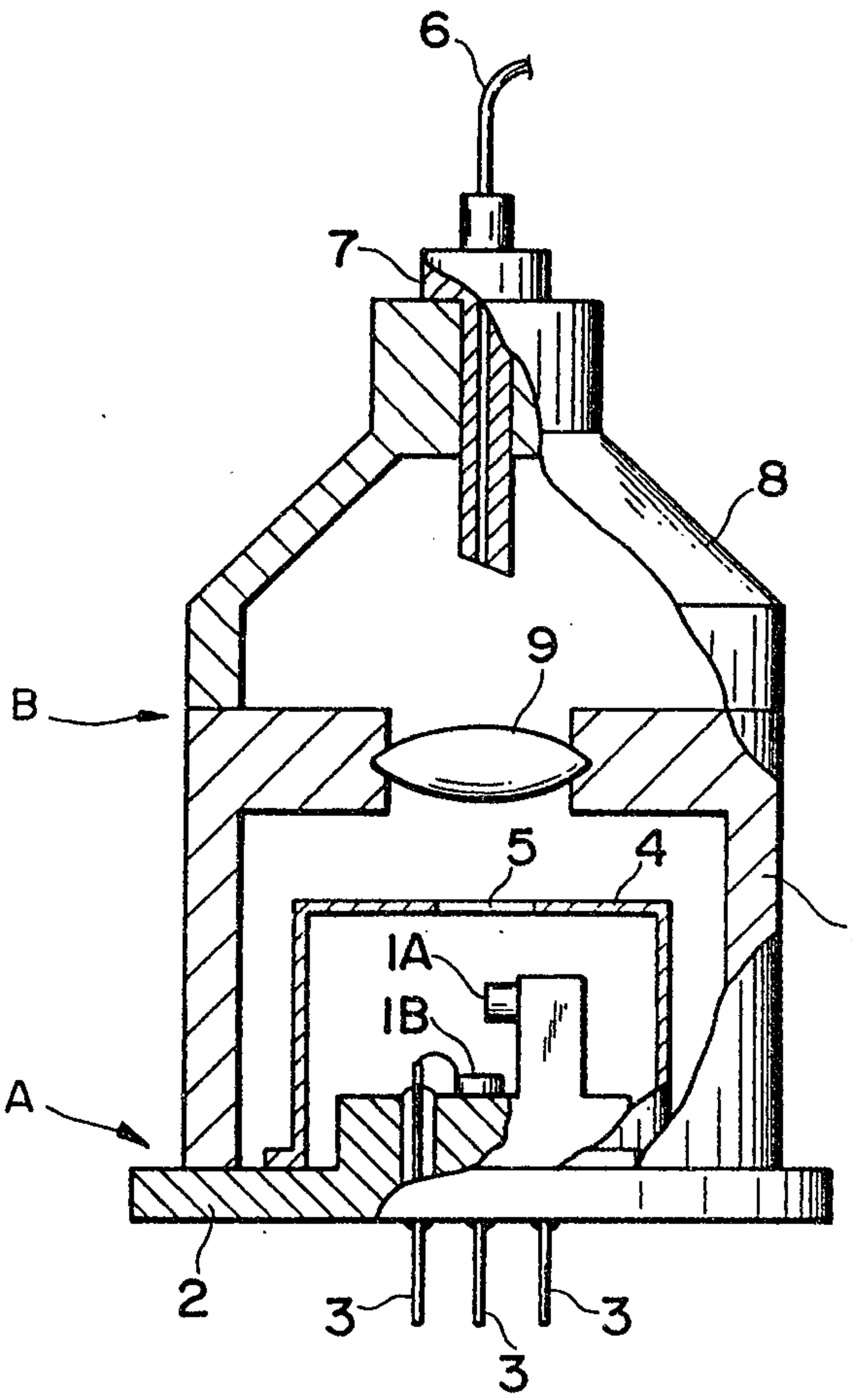

Fig. 2

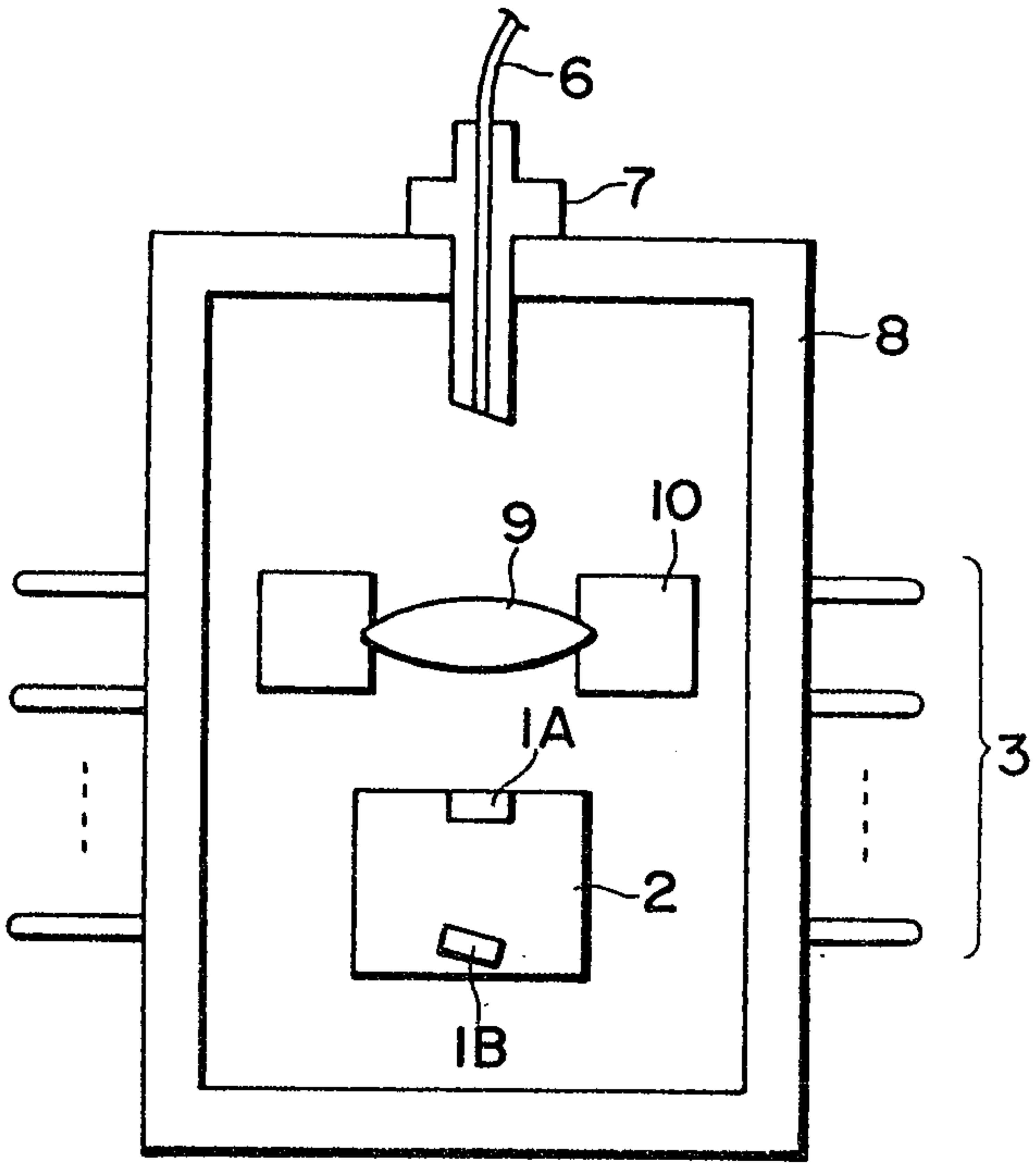

Fig. 3

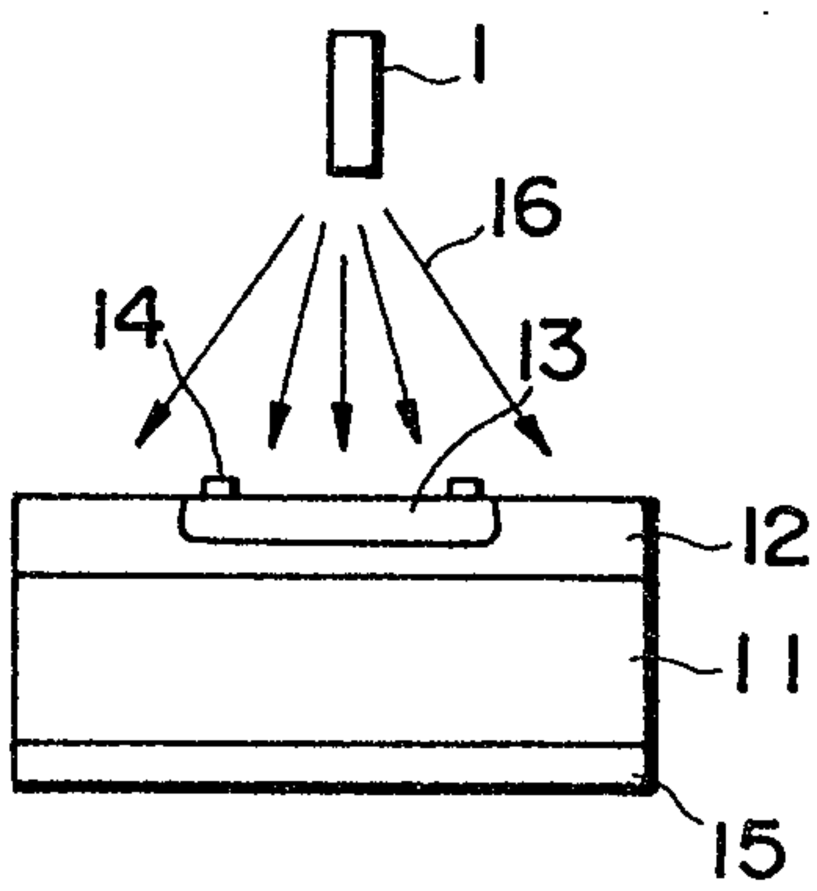

Fig. 4A

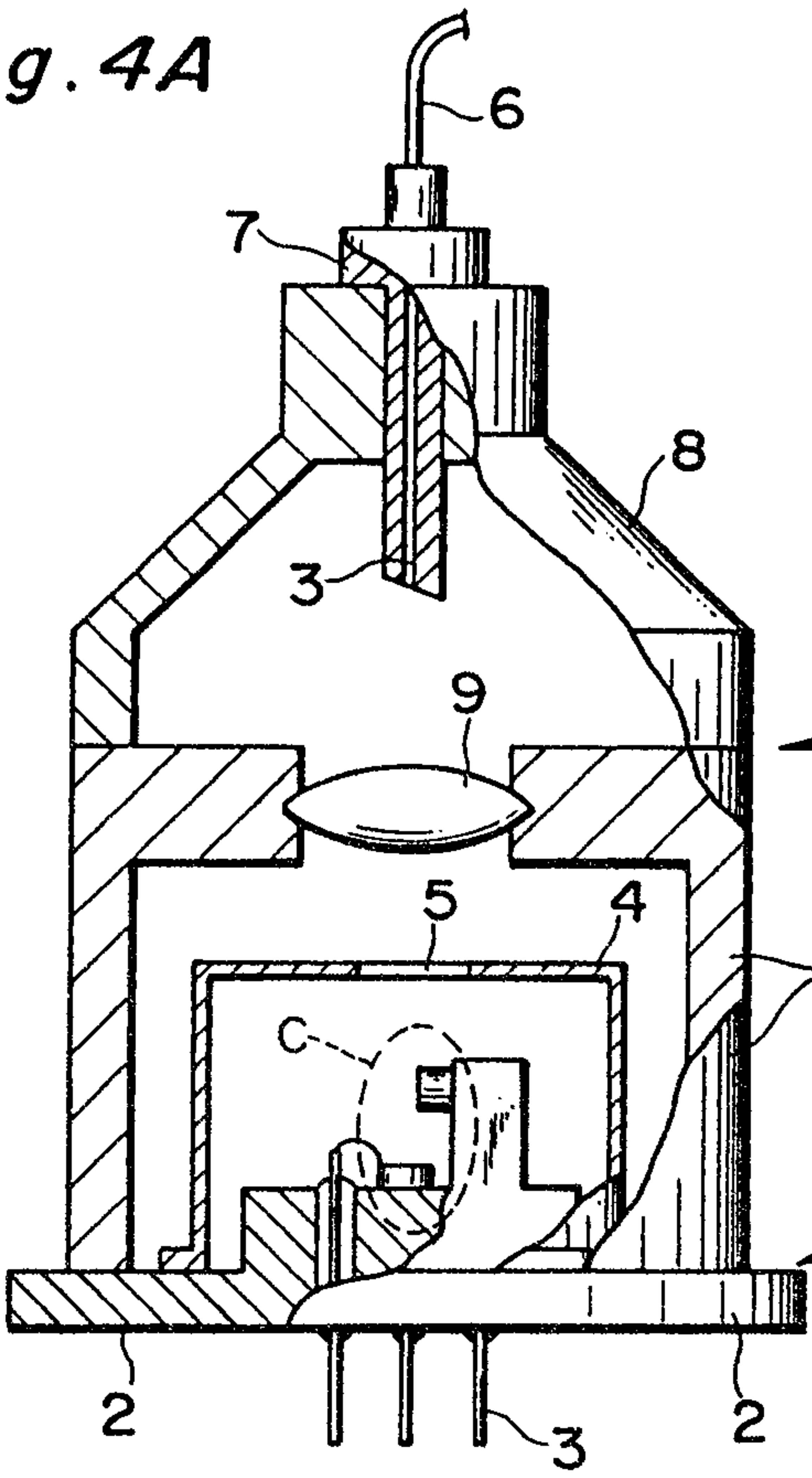

Fig. 4B

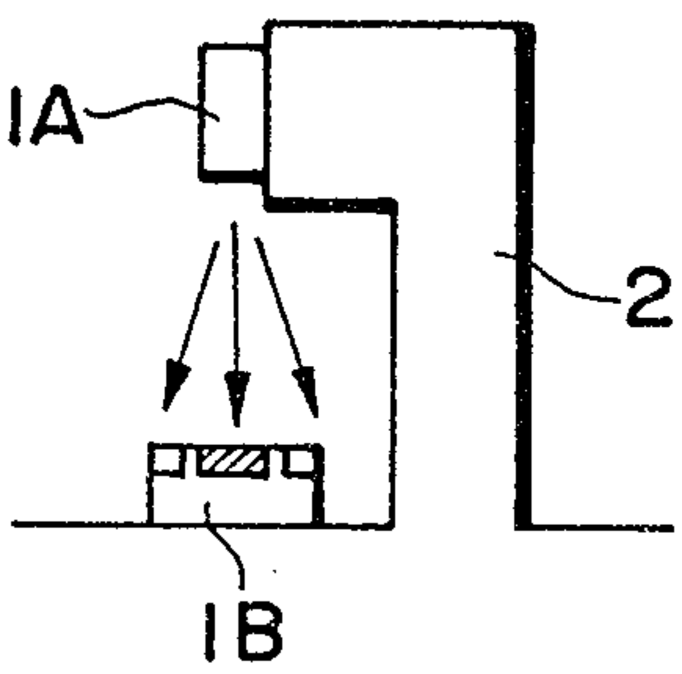

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Fig. 5

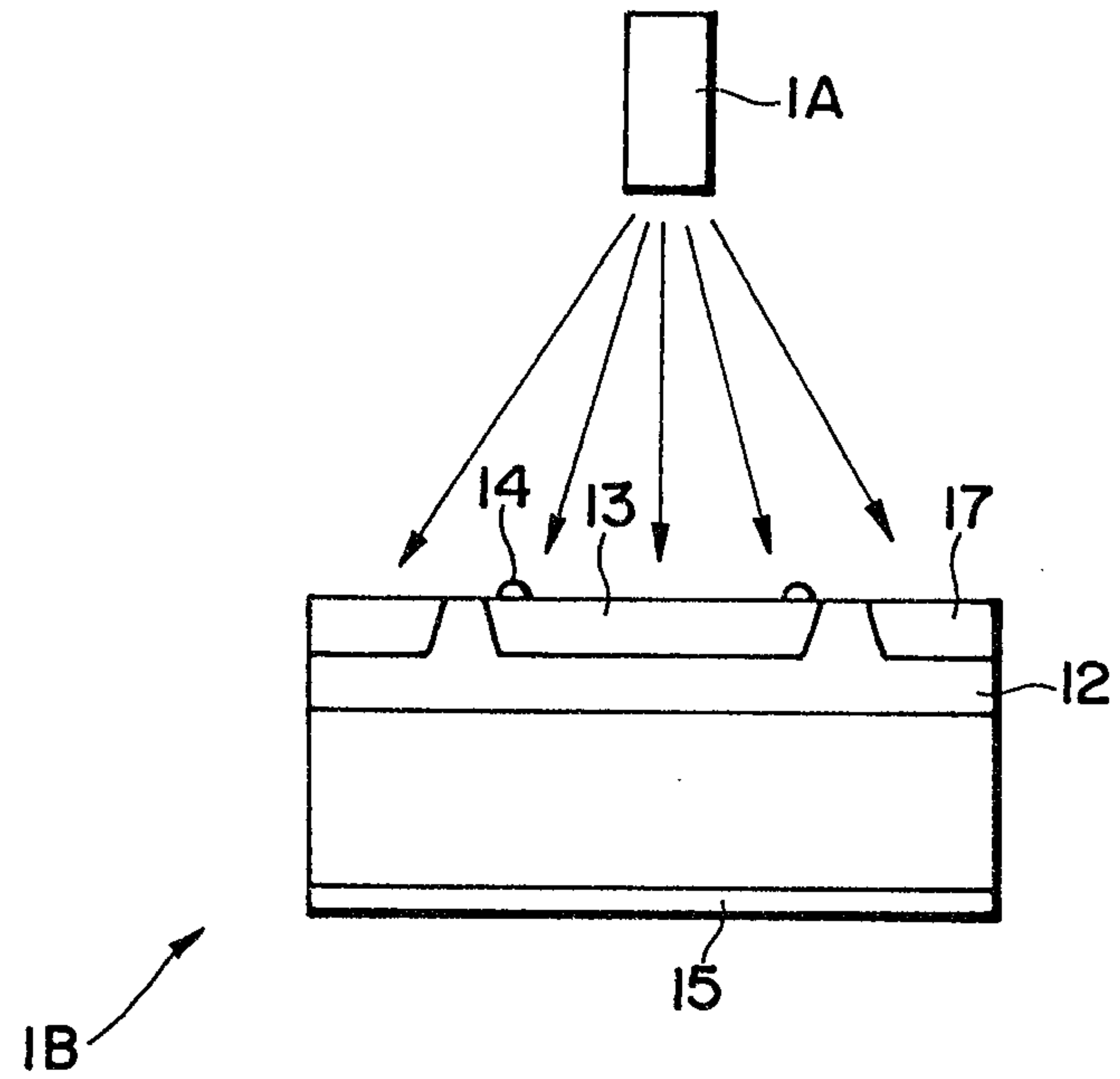

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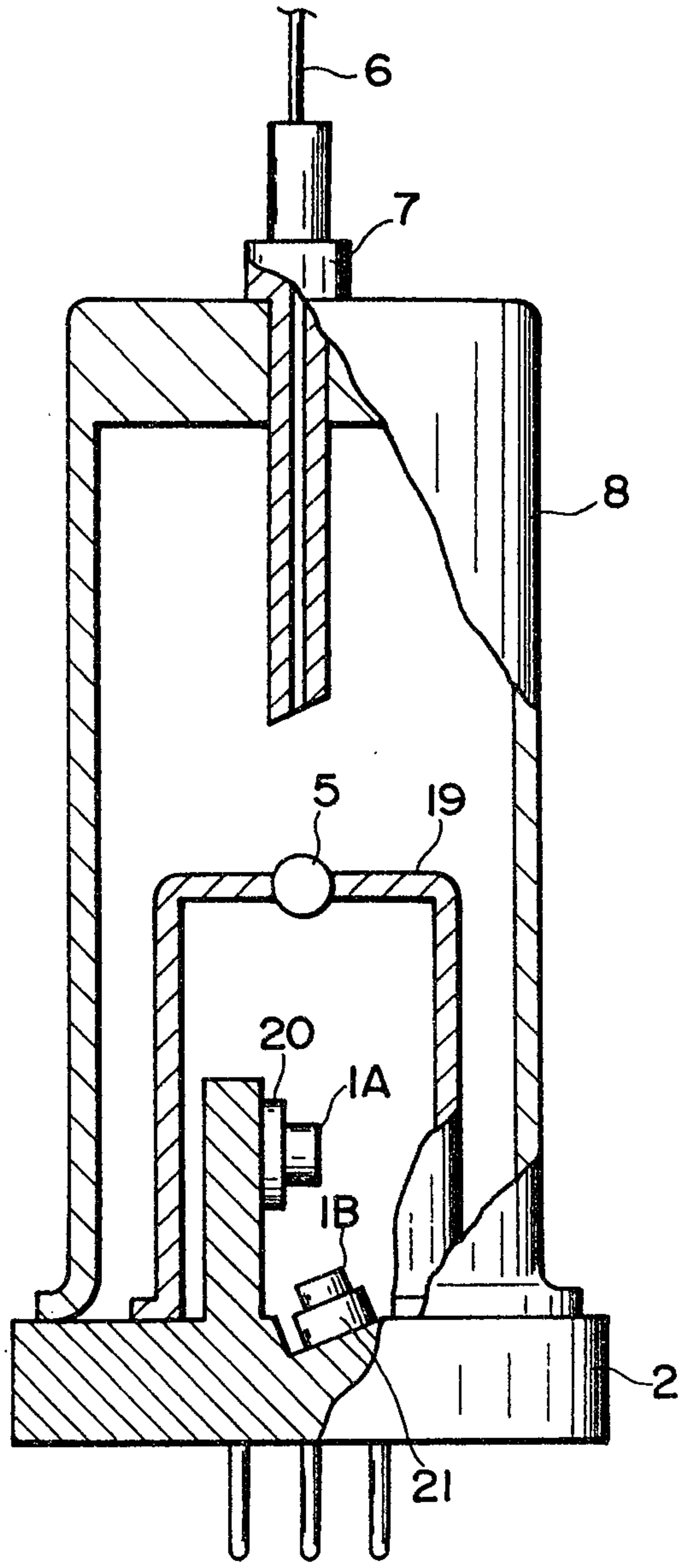
Fig. 6



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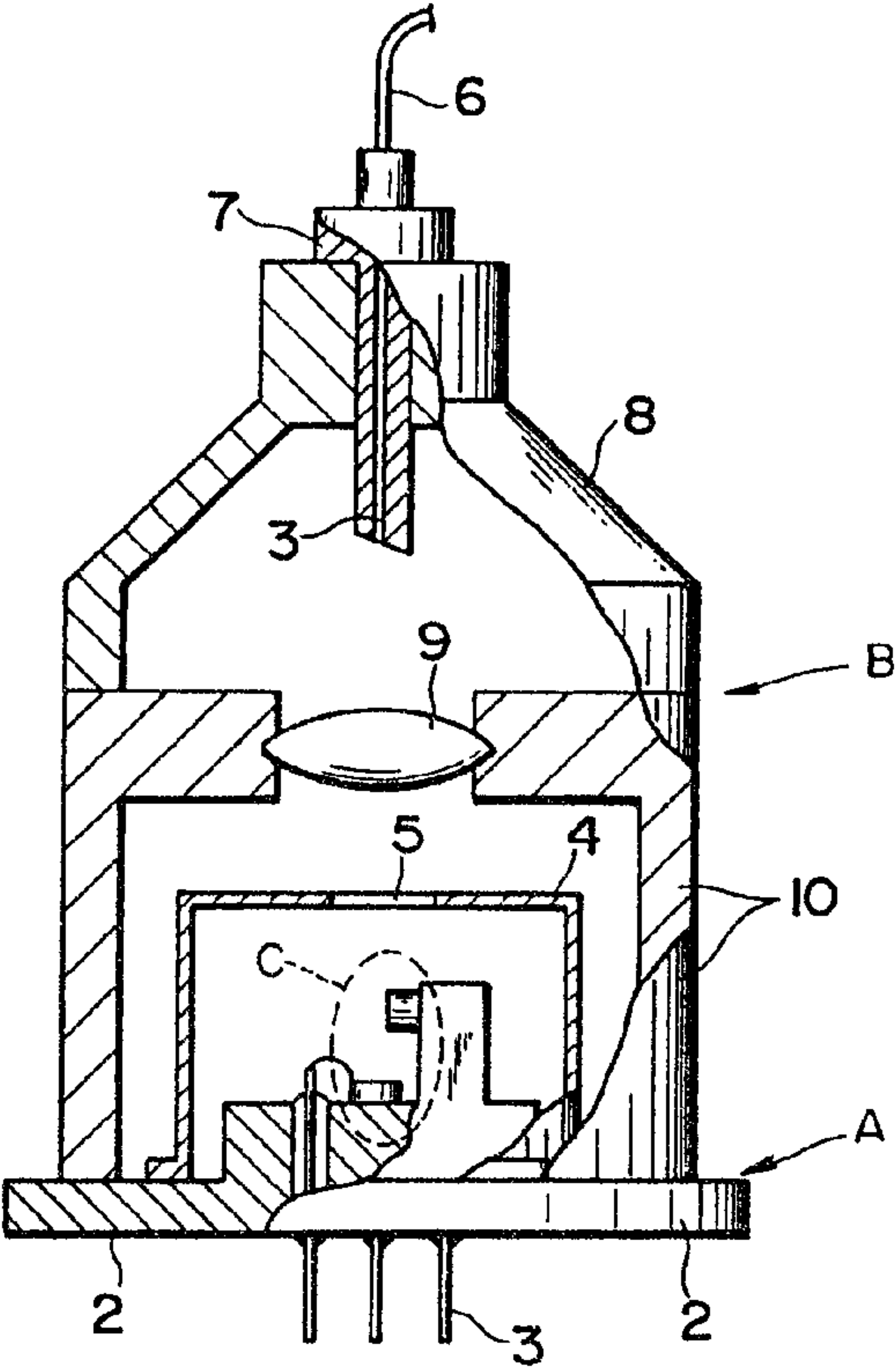
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