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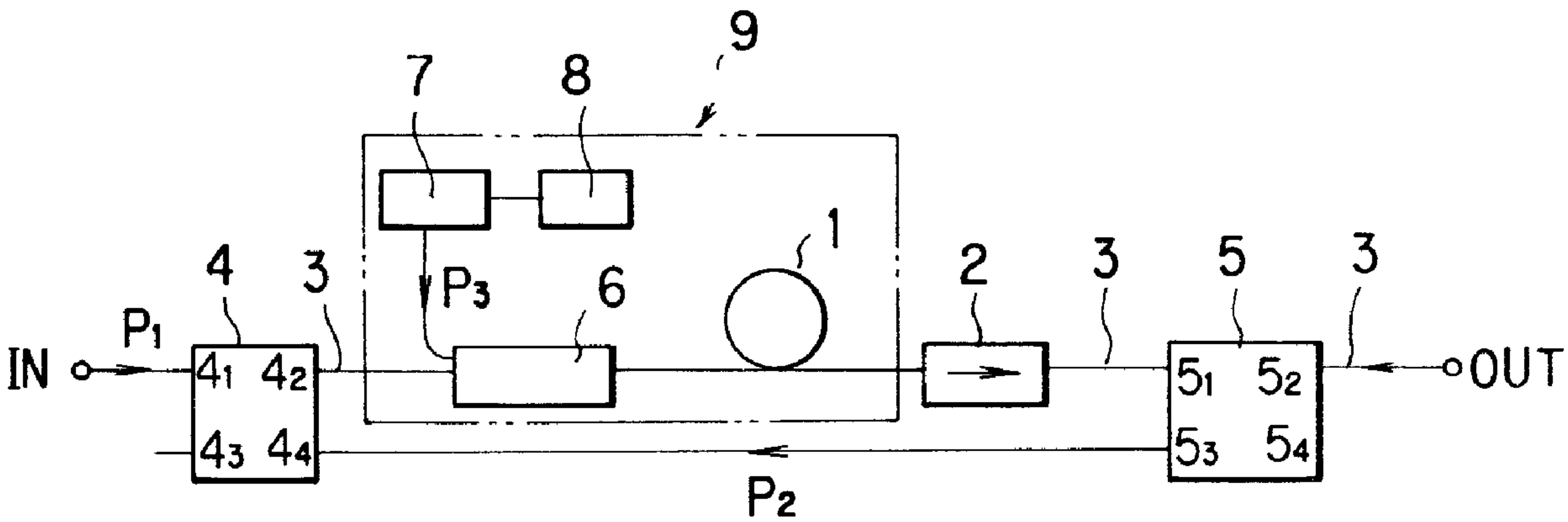

(57) Abrégé/Abstract:
There is provided an optical amplifying apparatus comprising an optical isolator and applicable for various measurement and monitoring of optical transmission systems involving bidirectional telecommunication and retrogressive light. Such an optical amplifying apparatus specifically comprises an optical transmission line 3 for conveying signal light p1, an optical amplifier 1 connected to an optical transmission line 2 for amplifying signal light p1 and an optical isolator 2 connected to the optical transmission line 3 for suppressing oscillation of the optical amplifier 1 caused by reflected signal light p1, to which optical devices 4, 5 connected to the optical transmission line 3 for isolating and combining signal light p1 and retrogressive light p2 are added. As signal light and retrogressive light can be independently isolated and combined together in an optical amplifying apparatus according to the invention, it can be used for bidirectional telecommunication, measurement and monitoring of various optical transmission systems utilizing retrogressive light and other applications.

ABSTRACT OF DISCLOSURE

There is provided an optical amplifying apparatus comprising an optical isolator and applicable for various measurement and monitoring of optical transmission systems involving bidirectional telecommunication and retrogressive light. Such an optical amplifying apparatus specifically comprises an optical transmission line 3 for conveying signal light p1, an optical amplifier 1 connected to an optical transmission line 2 for amplifying signal light p1 and an optical isolator 2 connected to the optical transmission line 3 for suppressing oscillation of the optical amplifier 1 caused by reflected signal light p1, to which optical devices 4, 5 connected to the optical transmission line 3 for isolating and combining signal light p1 and retrogressive light p2 are added. As signal light and retrogressive light can be independently isolated and combined together in an optical amplifying apparatus according to the invention, it can be used for bidirectional telecommunication, measurement and monitoring of various optical transmission systems utilizing retrogressive light and other applications.

OPTICAL AMPLIFYING APPARATUS

BACKGROUND OF THE INVENTION

[Field of the Invention]

This invention relates to an improvement to an optical amplifying apparatus comprising optical transmission lines, optical amplifiers, optical isolators and other components.

[Prior Art]

Optical amplifying apparatuses using optical fibers having an optical amplification capability and laser amplifiers have been known and utilized as means for switching optical transmission lines in optical CATV systems and other practical applications.

There has been reported that light of 1.55μm band can be effectively amplified by using a silica-type single mode optical fiber having an erbium (Er)-doped core in an optical amplification system of the above described type.

As illustrated in Fig. 6 of the accompanying drawings, an optical amplifying apparatus under consideration normally comprises a pumping source 11 for optical pumping, an optical combiner 12 for combining optical signals and pumped light and an optical fiber type optical amplifier 13 having an rare earth element-doped core 33 connected to an optical transmission line 14, to which an optical isolator 34 is added.

An optical transmission system comprising an optical amplifying apparatus as illustrated in Fig. 6 normally has a number of nodes connecting different optical transmission lines or those connecting optical transmission lines and various pieces of optical equipment.

Nodes of an optical transmission system can reflect signal light if mismatches of interfaces exist there and, consequently, certain optical amplifiers of the system can be caused to oscillate and malfunction by the reflected light.

Thus, it is of vital importance for an optical amplifying system as illustrated in Fig. 6 to be able to effectively avoid unstable operation and oscillation of any of its optical amplifiers due to reflection of light in order to achieve a large gain.

The optical isolator 15 of the apparatus of Fig. 15 is connected to an or both ends of the optical amplifier 13 in order to suppress any possible oscillation of the optical amplifier 13 due to reflection of light.

The optical isolator 15 typically comprises an optical device having no polarization dependency and shows a level of attenuation of retrogressive light between 20 and 60dB.

An optical transmission system comprising an optical isolator 15 connected to the optical transmission line 14 as illustrated in Fig. 6 has certain drawbacks as described below.

Firstly, it cannot be used for optical signal transmission in the reverse direction and therefore is not good for bidirectional telecommunication.

Secondly, it is not compatible with a so-called optical time domain reflection (OTDR) method for detecting any malfunctioning points in the optical transmission system and testing and monitoring its operation.

OTDR is a method with which pulsed signal light p1 is introduced into the optical transmission line 14 by way of its input terminal and the retrogressive light p2 generated by the signal light p1 such as backscattering light or backreflecting light is observed at the input terminal of the optical transmission line 14 for changes with time to detect any existing malfunctioning points in the optical transmission system. However, when an optical isolator 15 is connected in series with the optical amplifier 13 as illustrated in Fig. 6, the retrogressive light p2 is attenuated by the optical isolator to an extent of 20 to 60dB and cannot reach the input terminal of the optical transmission line 14.

Thus, various measuring methods that utilizes retrogressive light are not compatible with known optical transmission systems comprising optical isolators 15.

In view of the above technological problem, it is therefore an object of the present invention to provide an optical amplifying apparatus that comprises an optical isolator and can be used for bidirectional telecommunication and measurement and monitoring of various types utilizing retrogressive light.

SUMMARY OF THE INVENTION

According to the invention, the above object is achieved by providing an optical amplifying apparatus comprising an optical transmission line, an optical amplifier connected to the optical transmission line for amplifying signal light, an optical isolator connected to the optical transmission line for suppressing oscillation of the optical amplifier caused by reflected signal light and one or more than one optical devices connected to the optical transmission line for isolating and combining signal light and retrogressive light.

Said optical devices for isolating and combining signal light and retrogressive light may comprise optical circulators.

An optical pumping unit for pumping signal light for the purpose of the present invention may be connected upstream to the optical amplifier on the optical transmission line or to an optical device disposed on the output terminal side of the optical transmission line.

Said optical pumping unit for pumping signal light may comprise a pumping source for generating pumped light, a drive circuit for driving the pumping source and an optical combiner for feeding pumped light to the optical amplifier.

Said optical pumping unit connected to the optical devices may comprise a pumping source for generating pumped light and a drive circuit for driving the pumping source.

As described above, an optical amplifying apparatus according to the invention comprises an optical amplifier, an optical isolator and optical devices for isolating and combining signal light and retrogressive light are connected to an optical transmission line.

If, optical devices comprising optical circulators are respectively disposed on the input and output terminal sides of the optical transmission line of such an optical amplifying apparatus, signal light transmitted from the input terminal to the output terminal of the optical transmission line is amplified by the optical amplifier after passing through the optical circulator on the input terminal side and then passes through that optical isolator and then through the optical circulator on the output terminal side.

On the other hand, retrogressive light passes through the optical circulator on the output terminal sides and then through the optical circulator on the input terminal side before getting to the input terminal of the optical transmission line without passing through the optical isolator.

Thus, it will be seen that signal light and retrogressive light can be independently isolated and combined together in an optical amplifying apparatus having a configuration as described above.

Now, the present invention will be described in greater detail by referring to the accompanying drawings that illustrate preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a preferred embodiment of the invention.

Fig. 2 is a schematic view of an optical device used in the embodiment of Fig. 1.

Fig. 3 is a graph showing the result of an experiment using the embodiment of Fig. 1 and a conventional optical amplifying apparatus along with an OTDR method.

Fig. 4 is a block diagram of another preferred embodiment of the invention.

Fig. 5 is a block diagram of still another preferred embodiment of the invention.

Fig. 6 is a block diagram of a conventional optical amplifying apparatus.

DETAILED DESCRIPTION OF THE INVENTION

A first preferred embodiment of the invention will be described by referring to Fig. 1.

As shown in Fig. 1, the embodiment comprises an optical amplifier 1, an optical isolator 2 for suppressing oscillation of the optical amplifier caused by reflected signal light, an optical transmission line 3 for conveying light signal, optical devices 4, 5 for independently isolating and combining signal light and retrogressive light, an optical combiner 6 for combining signal light and pumped light, a pumping source 7 for optical amplification and a drive circuit for driving the pumping source 8.

Of the above listed components, the optical amplifier 1, the optical combiner 6, the pumping source 7 and the drive circuit 8 constitute an optical amplifying unit.

The optical amplifier 1 may comprise an optical waveguide for optical amplification as illustrated in Fig. 1 or a known conventional laser amplifier (not shown).

An optical waveguide for optical amplification to be used for the optical amplifier 1 is typically a single mode optical fiber of a silica or fluoride-type comprising a core and a clad which are covered by a plastic layer.

The core of an optical waveguide to be used for the purpose of the invention is made of silica- or fluoride-type host glass which is doped with one ore more than one rare earth elements such as erbium (Er) and neodymium (Nd). Additionally, one ore more than one substances selected from a group of substances including alkaline earth elements such as beryllium (Be), oxides of yittrium-aluminum-garnet (YAG) alloys, oxides of yittrium-lanthanoid-fluorine (YLF) alloys, transition metal ions may be used for doping the host glass.

Alternatively, the core of the optical waveguide may be made of fluoride glass of an erbium- or neodymium-doped ZBLAN (ZrF_4-BaF_2-LaF_3-NaF) type or containing independently BaF_2, AlF_3 and/or NdF_3.

The clad of the optical waveguide is also made of silica- or fluoride type glass containing one or more than one doping substances as described above and obviously has a refractive index smaller than that of the core.

The optical isolator 2 is an optical device having no polarization dependency that can effectively suppress oscillation of the amplifier as described above.

The optical transmission line 3 may be an optical fiber of known type such as a silica- or fluoride type.

The optical devices 4, 5 are typically optical circulators comprising respectively a plurality of input/output ports 4_1-4_4 and 5_1-5_4 as illustrated in Fig. 2.

As seen from Fig. 2, the incident light that enters the optical device 4 through the port 4_1 goes out from the port 4_2 and the light that enters the device through the port 4_3 goes out from the port 4_4 whereas the light that enters the optical device 4 through the port 4_2 goes out from the port 4_3 and the light that enters the device through the port 4_4 goes out from the port 4_1.

Similarly, the incident light that enters the optical device 5 through the port 5_1 goes out from the port 5_2 and the light that enters the device through the port 5_3 goes out from the port 5_4 whereas the light that enters the optical device 5 through the port 5_2 goes out from the port 5_3 and the light that enters the device through the port 5_4 goes out from the port 5_1.

The optical combiner 6 comprises an optical coupler such as a wave division module (WDM) for combining signal light and pumped light.

The pumping source 7 typically comprises a semiconductor laser capable of oscillating to emit light with a required frequency band such as a 0.8μm band, 0.98μm band or 1.48μm band.

The optical amplifying apparatus as illustrated in Fig. 1 comprises a transmission route for signal light p1 from the input terminal (shown at the leftmost end) to the output terminal (shown at the rightmost end) of an optical transmission line 3 by way of ports 4_1 and 4_2 of an optical device 4, an optical combiner 6, an optical amplifier 1, an optical isolator 2 and two ports 5_1 and 5_2 of another optical device 5 and a transmission route for retrogressive light p2 from the output terminal (shown at the rightmost end) to the input terminal (shown at the leftmost end) of the optical transmission line 3 by way of ports 5_2 and 5_3 of an optical device 5 and two ports 4_4 and 4_1 of the optical device 4.

With an optical amplifying apparatus as illustrated in Fig. 1, signal light p1 entering from the input terminal of the optical transmission line 3 proceeds through the port 4_1, the inside of the optical device 4, the port 4_2, the optical combiner 6, the optical amplifier 1, the optical isolator 2, the port 5_1, the inside of the optical device 5 and the port 5_1 and goes out from the output terminal of the optical transmission line 3.

As signal light p1 passes through these components of the optical transmission line 3, pumped light p3 coming from the pumping source 7 which is driven (lit) by the drive circuit 8 enters the optical transmission line 3 by way of the optical combiner 6 to excite the optical amplifier 1 so that the signal light p1 passing through the optical amplifier is amplified by the latter.

On the other hand, retrogressive light p2 that proceeds in a direction opposite to that of signal light p1 passes the output terminal of the optical transmission line 3, the port 5_2, the inside of the optical device 5, the port 5_3, the port 4_4, the inside of the optical device 4 and the port 4_2 before it enters the input terminal of the optical transmission line 3 without passing through the optical isolator 2.

Consequently, signal light p1 and retrogressive light p2 can be independently isolated and combined by an optical amplifying apparatus as illustrated in Fig. 1.

Figs. 3(a) and 3(b) are graphs showing the result of an experiment using the embodiment of Fig. 1 and a conventional optical amplifying apparatus as illustrated in Fig. 5 along with an OTDR method.

In Figs. 3(a) and 3(b), the axis of ordinate represents the amount of returned light (dB) and that of ordinate represents the distance by which light is transmitted (km).

The unit of the ordinate (1 bit: 5dB) is a certain reference value.

For the experiment, an OTDR apparatus, a 17km long single mode optical fiber (having a core with a refractive index of 1.463000), an optical amplifying apparatus and a 20 km long single mode optical fiber (having a core with a refractive index same as that of the first optical fiber) were connected in the described order and ordinary procedures of measurement were followed.

The incoming light used for the experiment had a wavelength of 1.5μm and a distance of transmission of approximately 64km.

When the OTDR method was used with an optical amplifying apparatus of Fig. 1, the condition of the optical fiber connected downstream to the optical amplifying apparatus could be determined as illustrated in Fig. 3(a).

This is because the optical amplifying apparatus of Fig. 1 comprises optical devices 4, 5 and therefore retrogressive light p2 can be transmitted to the input terminal of the optical transmission line 3 regardless of the existence of an optical isolator 2.

When the OTDR method was used with an optical amplifying apparatus of Fig. 6, the condition of the optical fiber connected downstream to the optical amplifying apparatus could not be determined as illustrated in Fig. 3(b).

This is because the optical amplifying apparatus comprising an optical isolator is not provided with an optical circulator.

In an optical amplifying apparatus as shown in Fig. 1, an optical isolator 2 may be connected downstream to the optical device 1 and/or the optical amplifier 1 in order to reduce reflection of signal light p1 as much as possible.

The optical device 4 connected to the input terminal of an optical amplifying apparatus of Fig. 1 may be omitted. Then, a given measuring means is connected to the port 5_4 of the optical device arranged near the output terminal of the apparatus.

Fig. 4 illustrates another preferred embodiment of the present invention.

While the optical amplifying apparatus of Fig. 4 substantially similar to that of Fig. 1, the former differs from the latter in that an optical pumping unit 9 is connected to the port 5_4 of the optical device 5 of the former.

The optical pumping unit 9 of this embodiment does not comprise an optical combiner 6.

With an optical amplifying apparatus as illustrated in Fig. 4, signal light p1 entering from the input terminal of the optical transmission line 3 proceeds through the port 4_1, the inside of the optical device 4, the port 4_2, the optical amplifier 1, the optical isolator 2, the port 5_1, the inside of the optical device 5 and the port 5_2 and goes out from the output terminal of the optical transmission line 3 in the same way as described earlier by referring to the first embodiment.

As signal light p1 passes through these components of the optical transmission line 3, pumped light p3 coming from the pumping source 7 which is driven (lit) by the drive circuit 8 enters the optical transmission line 3 by way of the port 5_4, the inside of the optical device 4 and the port 5_1 to excite the optical amplifier 1 so that the signal light p1 passing through the optical amplifier is amplified by the latter.

On the other hand, retrogressive light p2 that proceeds in a direction opposite to that of signal light p2 passes the output terminal of the optical transmission line 3, the port 5_1, the inside of the optical device 5, the port 5_3, the optical transmission line 3', the port 4_4, the inside of the optical device 4 and the port 4_1 before it enters the input terminal of the optical transmission line 3 without passing through the optical isolator 2.

Consequently, signal light p1 and retrogressive light p2 can be independently isolated and combined by an optical amplifying apparatus as illustrated in Fig. 4.

It will be apparent that the embodiment of Fig. 4 may be modified in various ways as in the case of the first embodiment of Fig. 1.

Finally, a preferred embodiment illustrated in Fig. 5

will be described.

This embodiment is realized by adding an optical amplifying means between the ports 4_4 and 5_3 of the respective optical devices 4 and 5 of the embodiment of Fig. 4 in order to give it a bidirectional amplifying capability for accommodating bidirectional telecommunication.

In the embodiment of Fig. 5, an optical amplifier 1' and an optical isolator 2' are inserted into an optical transmission path comprising the ports optical 4_4 and 5_3 of respective optical devices 4 and 5 and optical pumping units 9_1 and 9_2 of the above described type are connected to the ports 4_3 and 5_4 of the respective optical devices 4 and 5 to form the optical amplifying means.

With an optical amplifying apparatus as illustrated in Fig. 5, signal light p1 entering from the leftmost terminal of the optical transmission line 3 proceeds through the port 4_1, the inside of the optical device 4, the port 4 , the optical amplifier 1, the optical isolator 2, the port 5_1, the inside of the optical device 5 and the port 5_2 and goes out from the rightmost terminal of the optical transmission line 3.

Concurrently, pumped light p3 coming from the optical pumping unit 9_1 enters the optical transmission line 3 by way of the port 5_4, the inside of the optical device 4 and the port 5_1 to excite the optical amplifier 1 so that the signal light p1 passing through the optical amplifier is amplified by the latter.

With an optical amplifying apparatus as illustrated in Fig. 5, signal light p2 entering from the rightmost terminal of the optical transmission line 3 proceeds through the port 5_2, the inside of the optical device 5, the optical transmission line 3', the optical isolator 2', the optical amplifier 1', the port 4_4, the inside of the optical device 4 and the port 4_1 and goes out from the leftmost terminal of the optical transmission line 3.

Concurrently, pumped light p4 coming from the optical pumping unit 9_2 enters the optical transmission line 3' by way of the port 4_3, the inside of the optical device 4 and the port 4_4 to excite the optical amplifier 1' so that the signal light p2 passing through the optical amplifier is amplified by the latter.

Thus, an optical amplifying apparatus as shown in Fig. 5 has a bidirectional amplifying capability to accommodate bidirectional telecommunication.

Additionally, an optical amplifying apparatus according to the invention can be appropriately used with widely known backward and double side excitation techniques.

As signal light and retrogressive light can be independently isolated and combined together in an optical amplifying apparatus according to the invention, it can be used for bidirectional telecommunication, measurement and monitoring of various optical transmission systems utilizing retrogressive light and other applications.

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

1. An optical amplifying apparatus comprising an optical transmission line, an optical amplifier connected to the optical transmission line for amplifying signal light, an optical isolator connected to the optical transmission line for suppressing oscillation of the optical amplifier caused by reflected signal light and at least one optical device connected to the optical transmission line for isolating and combining signal light and retrogressive light such that retrogressive light can bypass the optical isolator and optical amplifier.

2. An optical amplifying apparatus according to claim 1, wherein said optical device for isolating and combining signal light and retrogressive light comprises an optical circulator.

3. An optical amplifying apparatus according to claim 1 or 2, wherein an optical pumping unit for pumping signal light is connected upstream to the optical amplifier on the optical transmission line.

4. An optical amplifying apparatus according to claim 1 or 2, wherein an optical pumping unit for pumping signal light is connected to an optical device disposed on the output terminal side of the optical transmission line.

5. An optical amplifying apparatus according to claim 3, wherein said optical pumping unit for pumping signal light comprises a pumping source for generating pumped light, a drive circuit for driving the pumping source and an optical combiner for feeding pumped light to the optical amplifier.

6. An optical amplifying apparatus according to claim 4,

wherein said optical pumping unit comprises a pumping source for generating pumped light and a drive circuit for driving the pumping source.

7. An optical amplifying apparatus according to any one of claims 1 to 6 including two of the optical devices, one of the optical devices being connected upstream to the optical amplifier and the optical isolator on the optical transmission line, and one of the optical devices being connected downstream to the optical amplifier and the optical isolator on the optical transmission line.

FIG.1

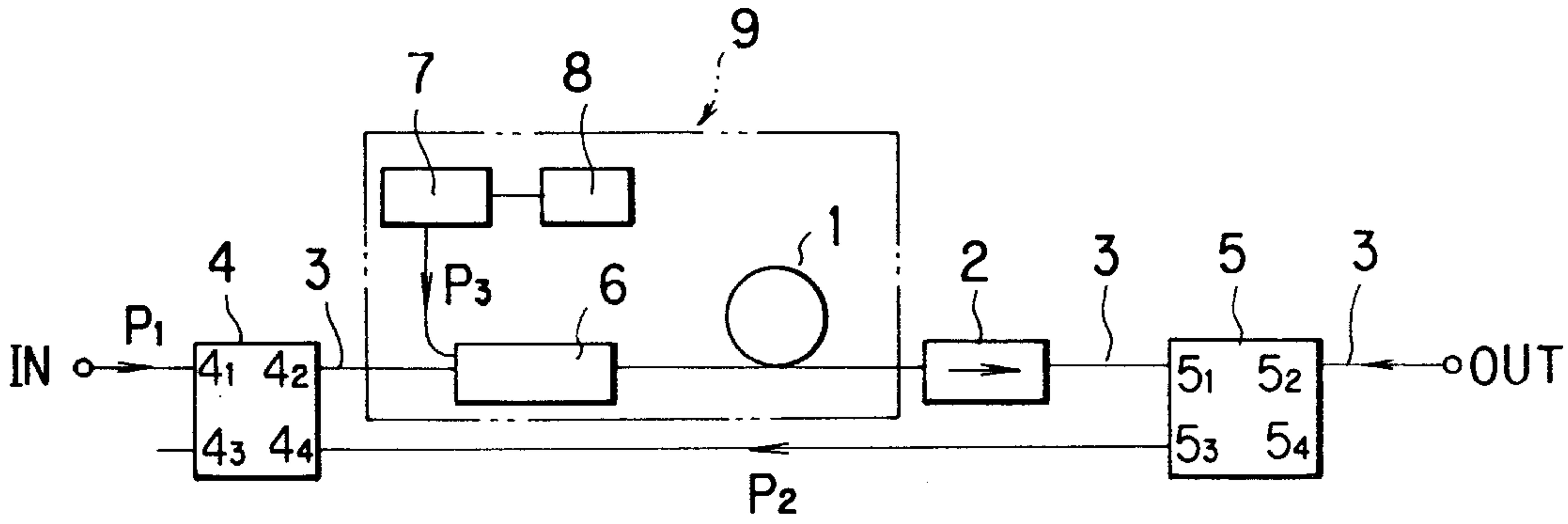

FIG.2

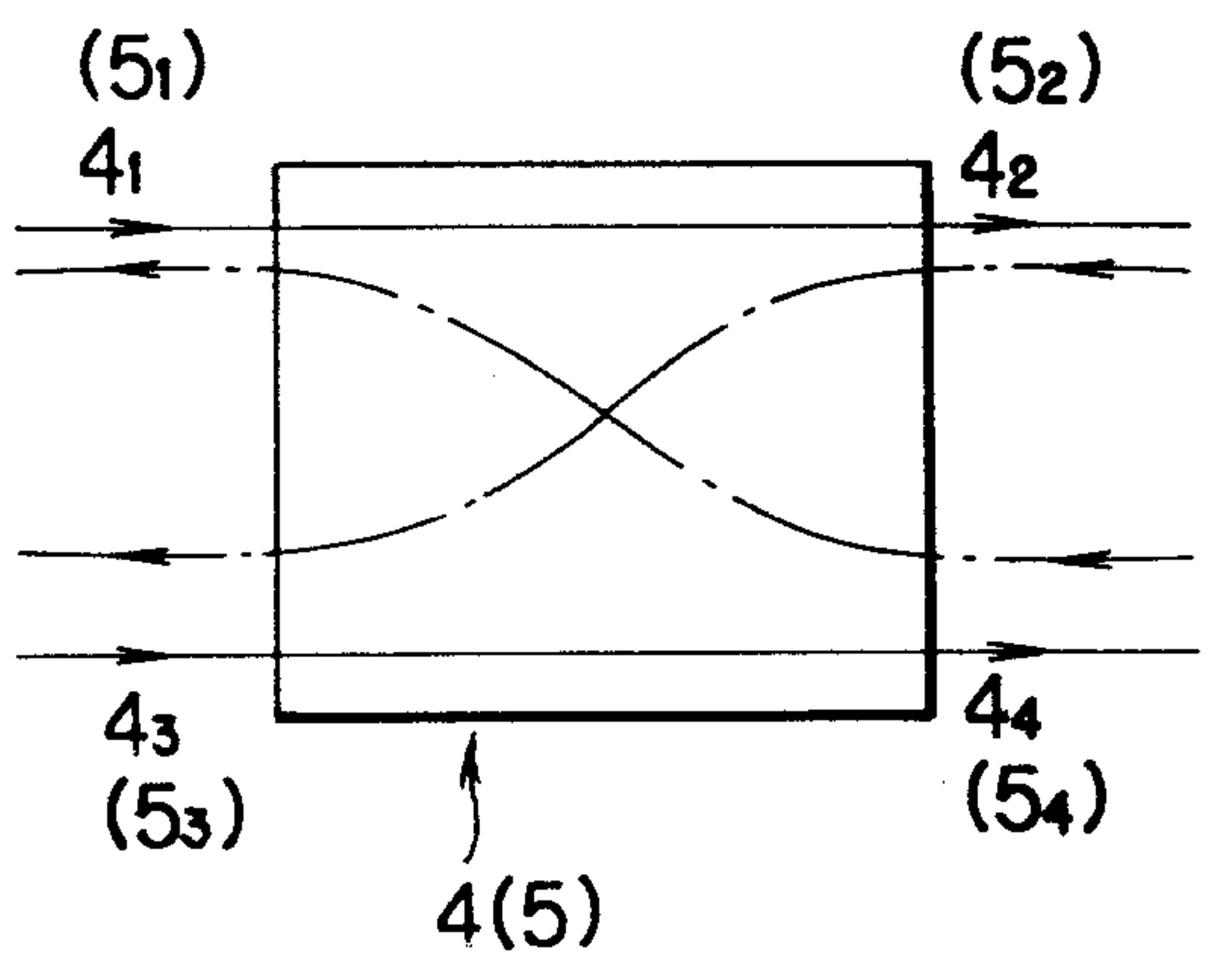

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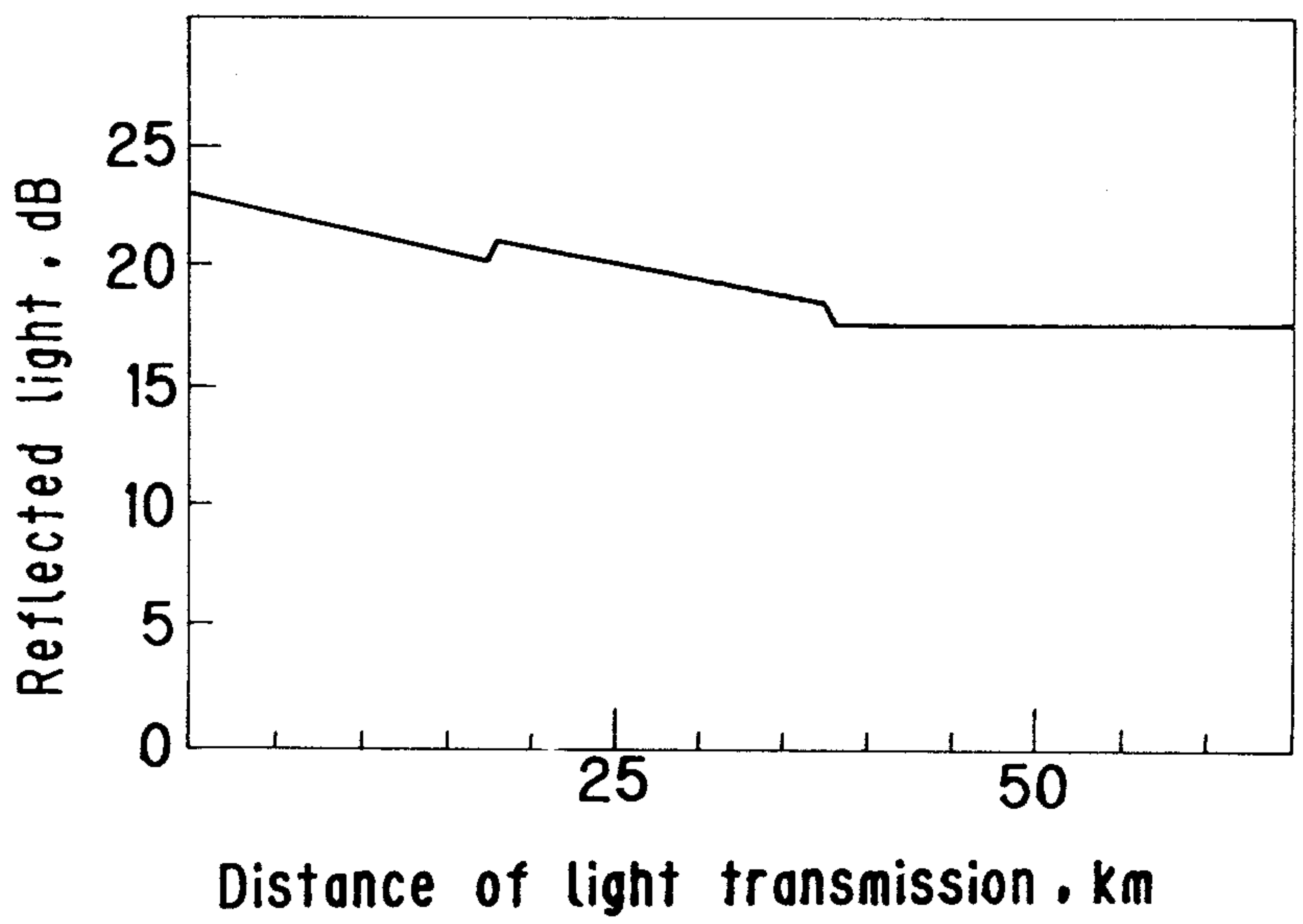
FIG.3

(a)



(b)

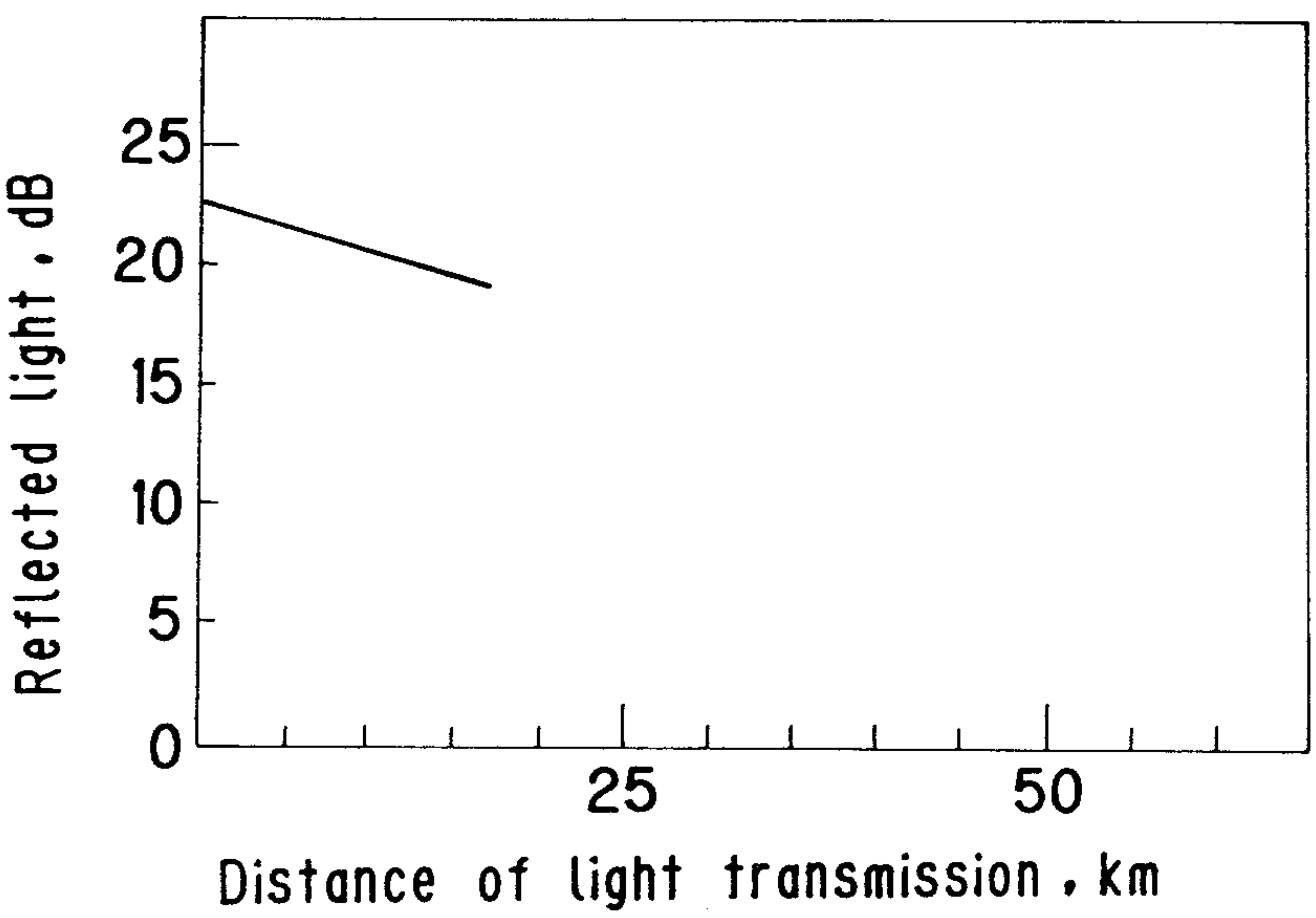


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FIG.4

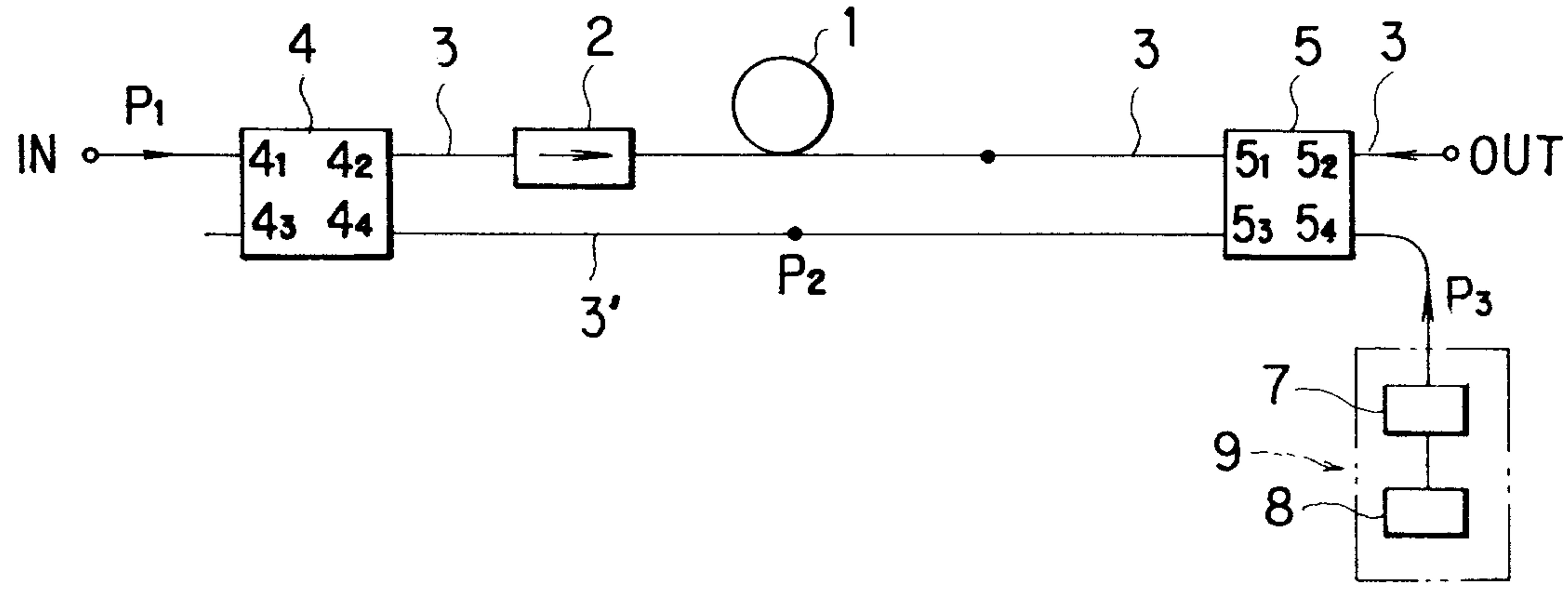

FIG.5

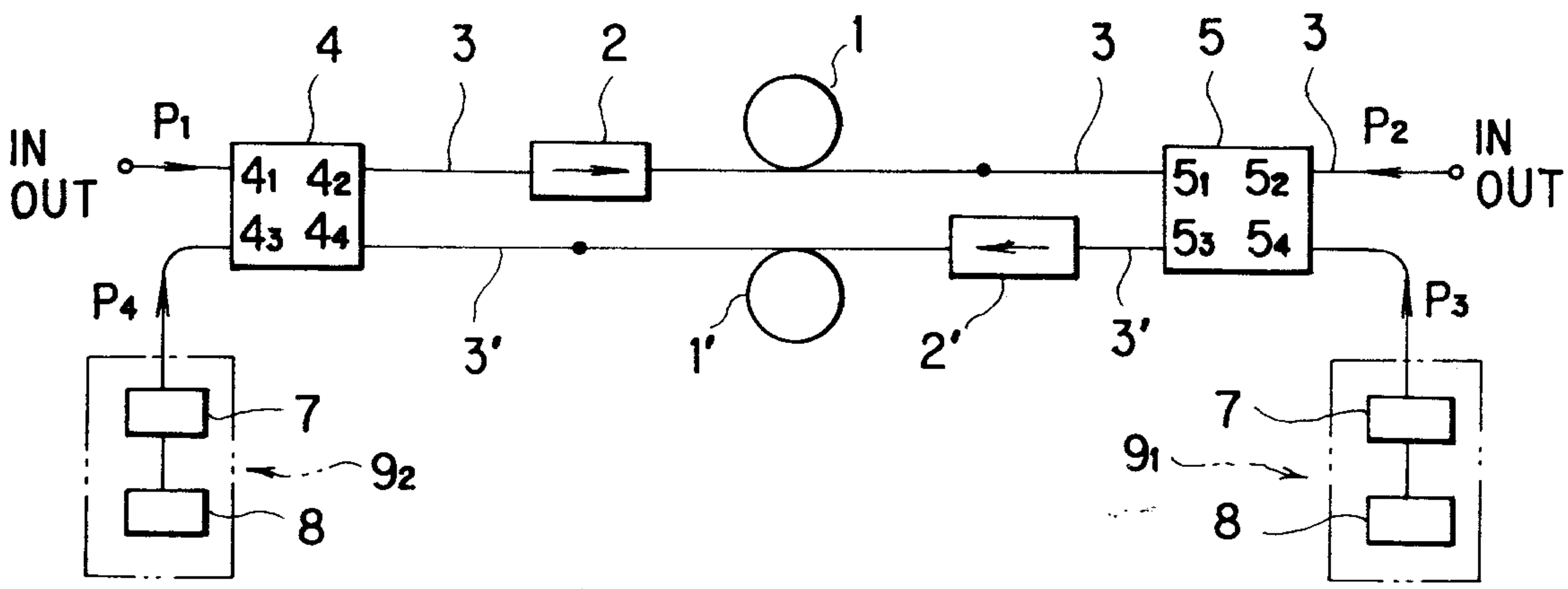

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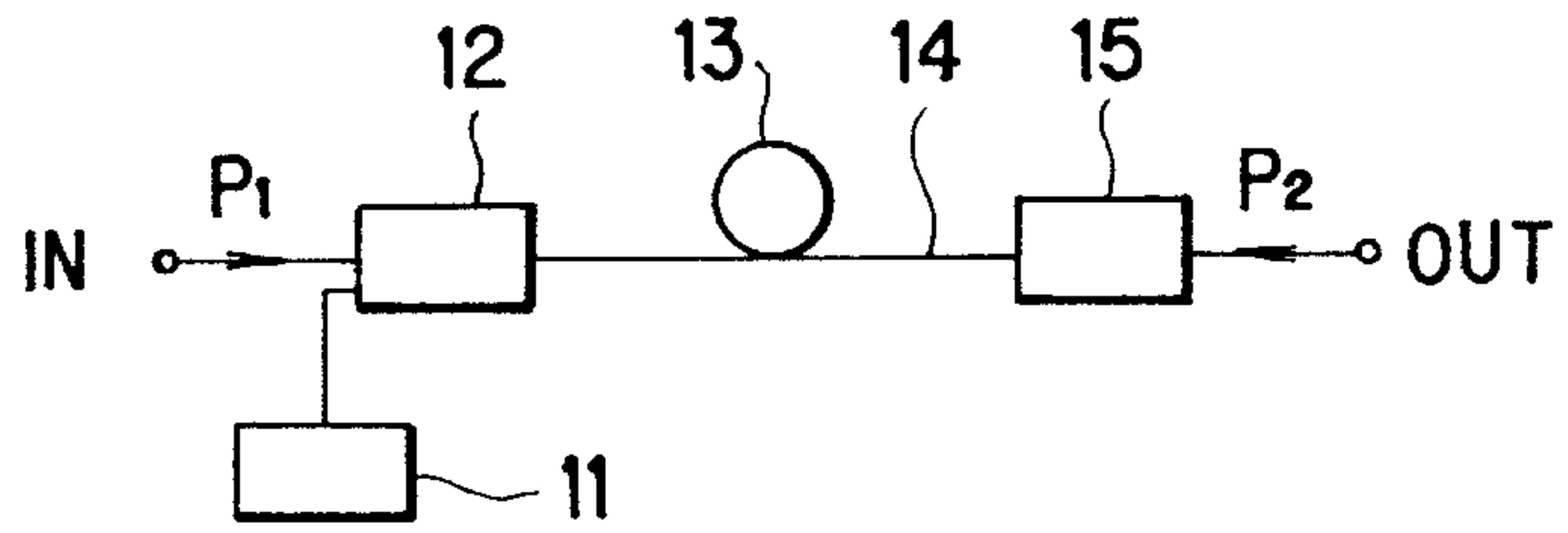
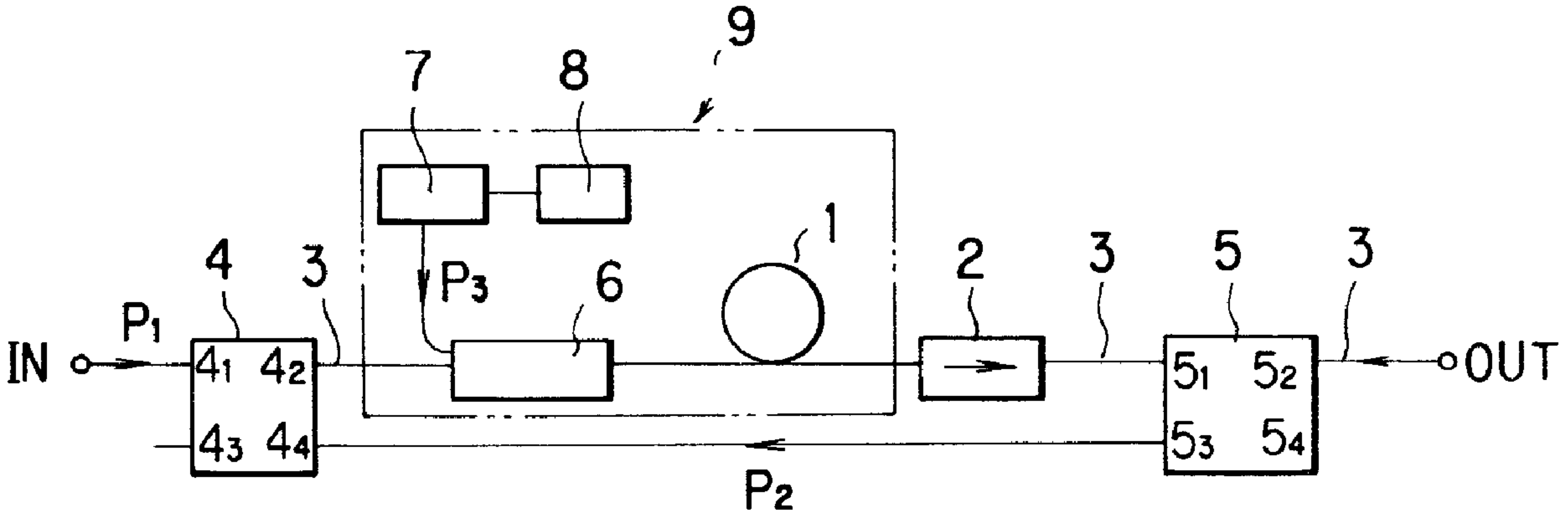
FIG.6





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P2