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(54) **OPTICAL COMMUNICATION DEVICE,
OPTICAL COMMUNICATION SYSTEM, AND
OPTICAL COMMUNICATION METHOD**

(52) **U.S. Cl.**
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(2013.01); *H04B 10/0773* (2013.01)

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(57) **ABSTRACT**

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To provide an optical communication technology that brings flexibility to ROADM systems.

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An optical communication device according to the present invention drops and adds an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations, the device including: first means and second means capable of selecting an optical signal of a predetermined wavelength from inputted optical signals and of outputting the selected optical signal; third means for splitting optical signals inputted from a first terminal station on the main path into the first means and the second means; fourth means for splitting optical signals inputted from a branch path in the network into the first means and the second means; and fifth means capable of selectively outputting to a second terminal station on the main path either an optical signal outputted by the first means or an optical signal outputted by the second means.

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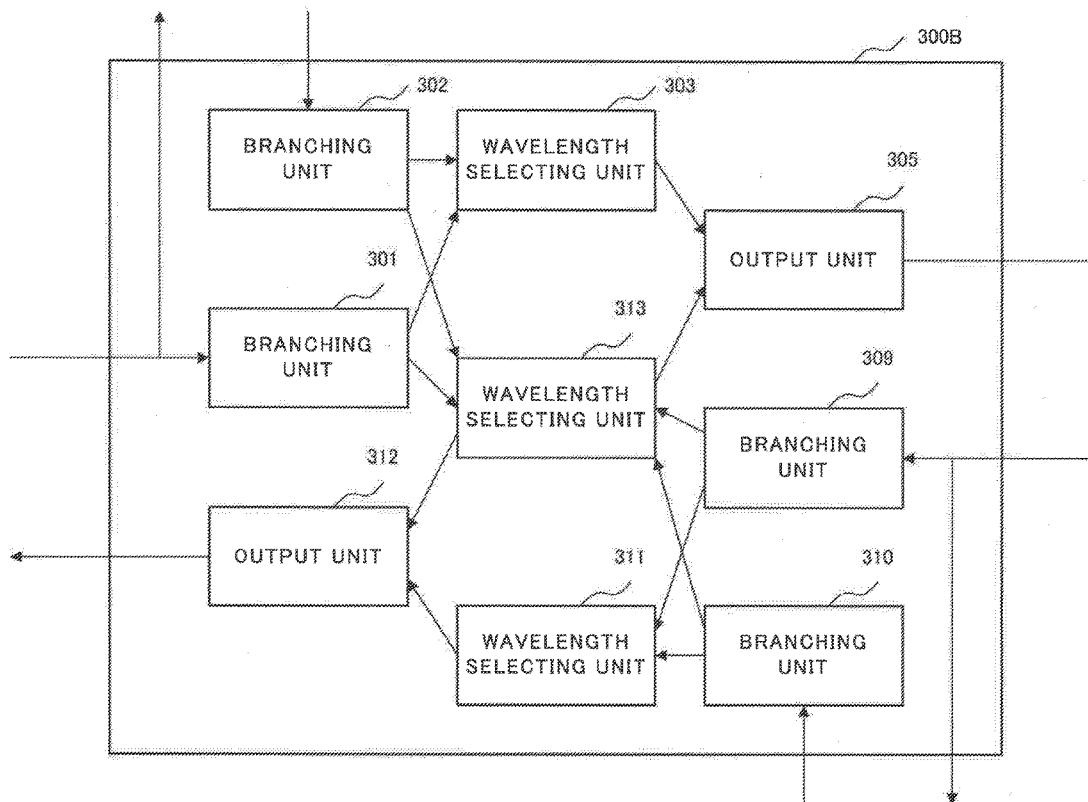
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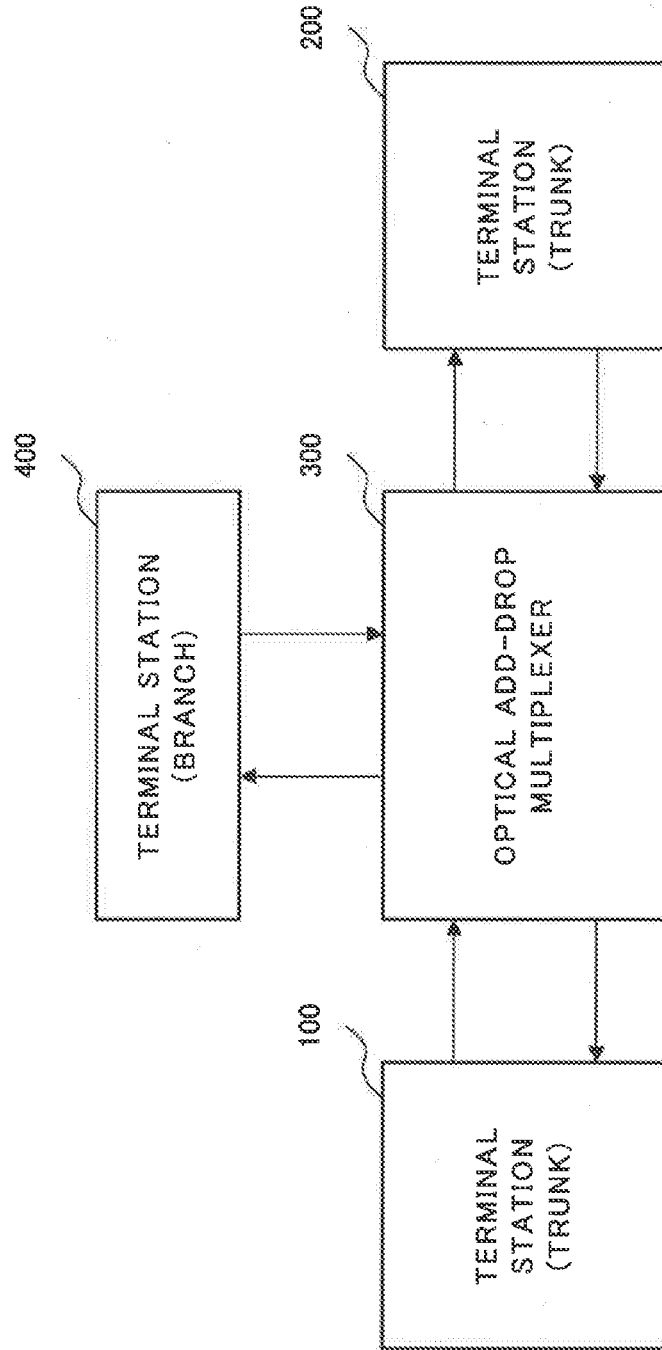


Fig. 1

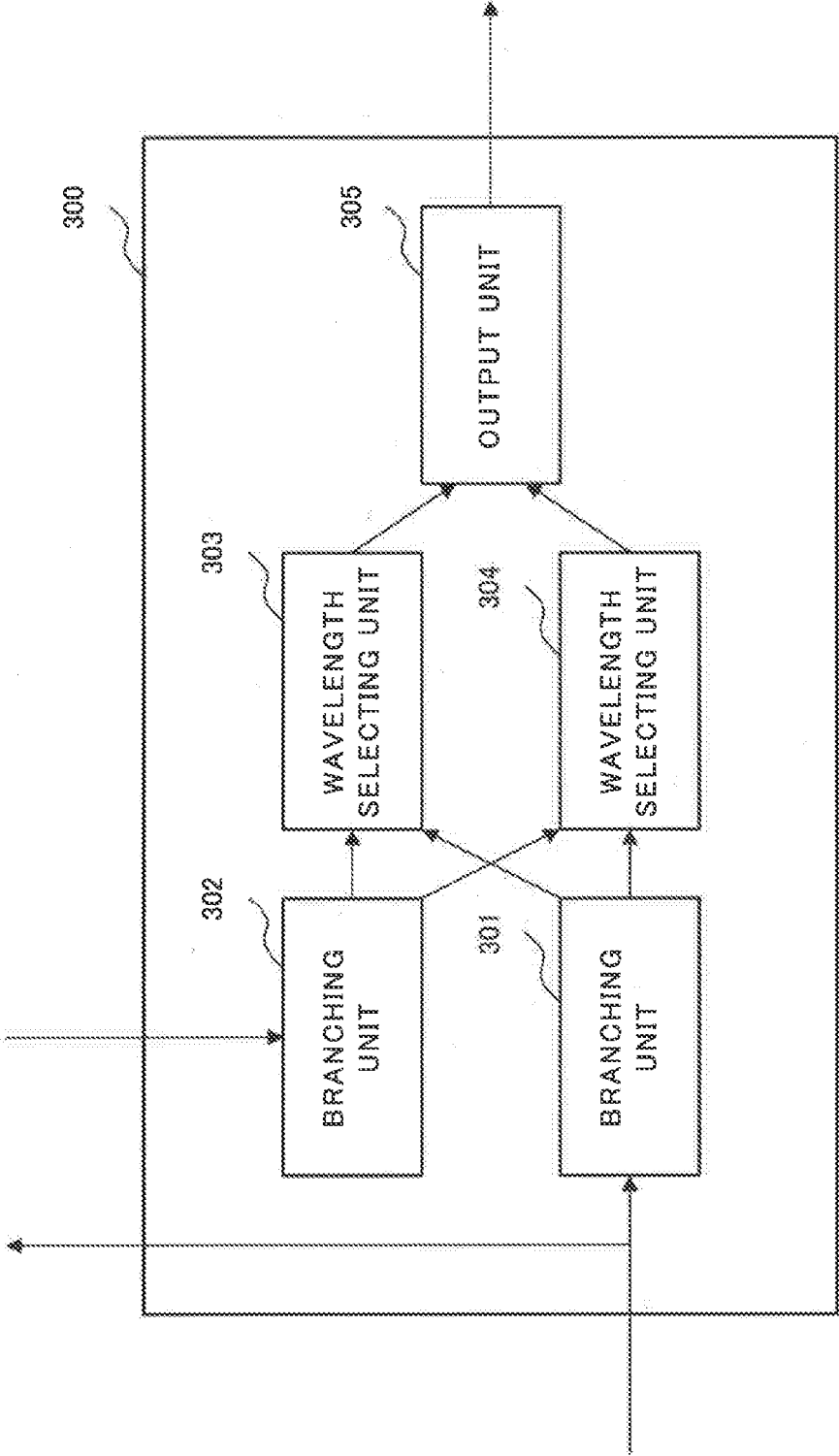
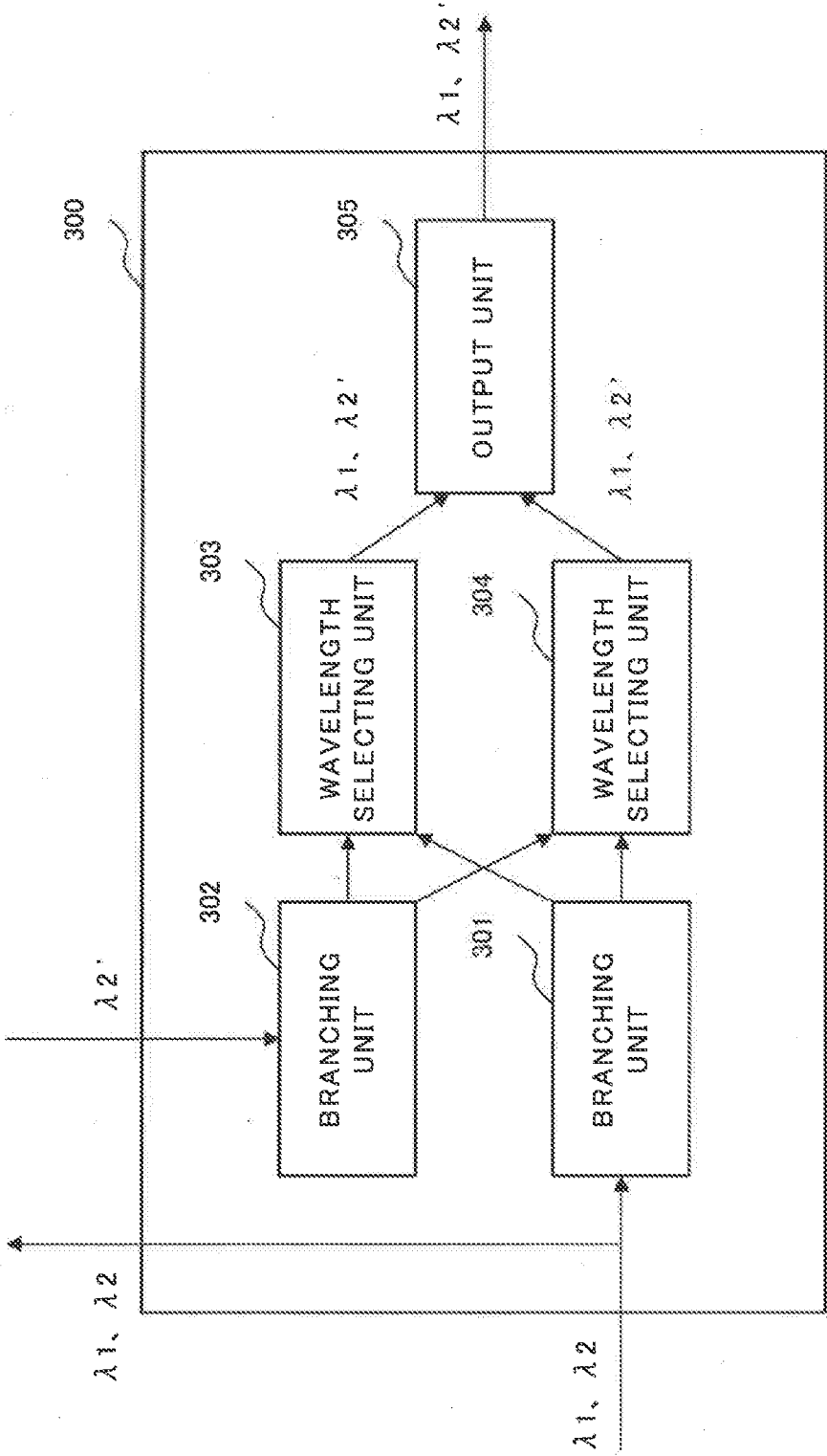


Fig. 2

Fig. 3



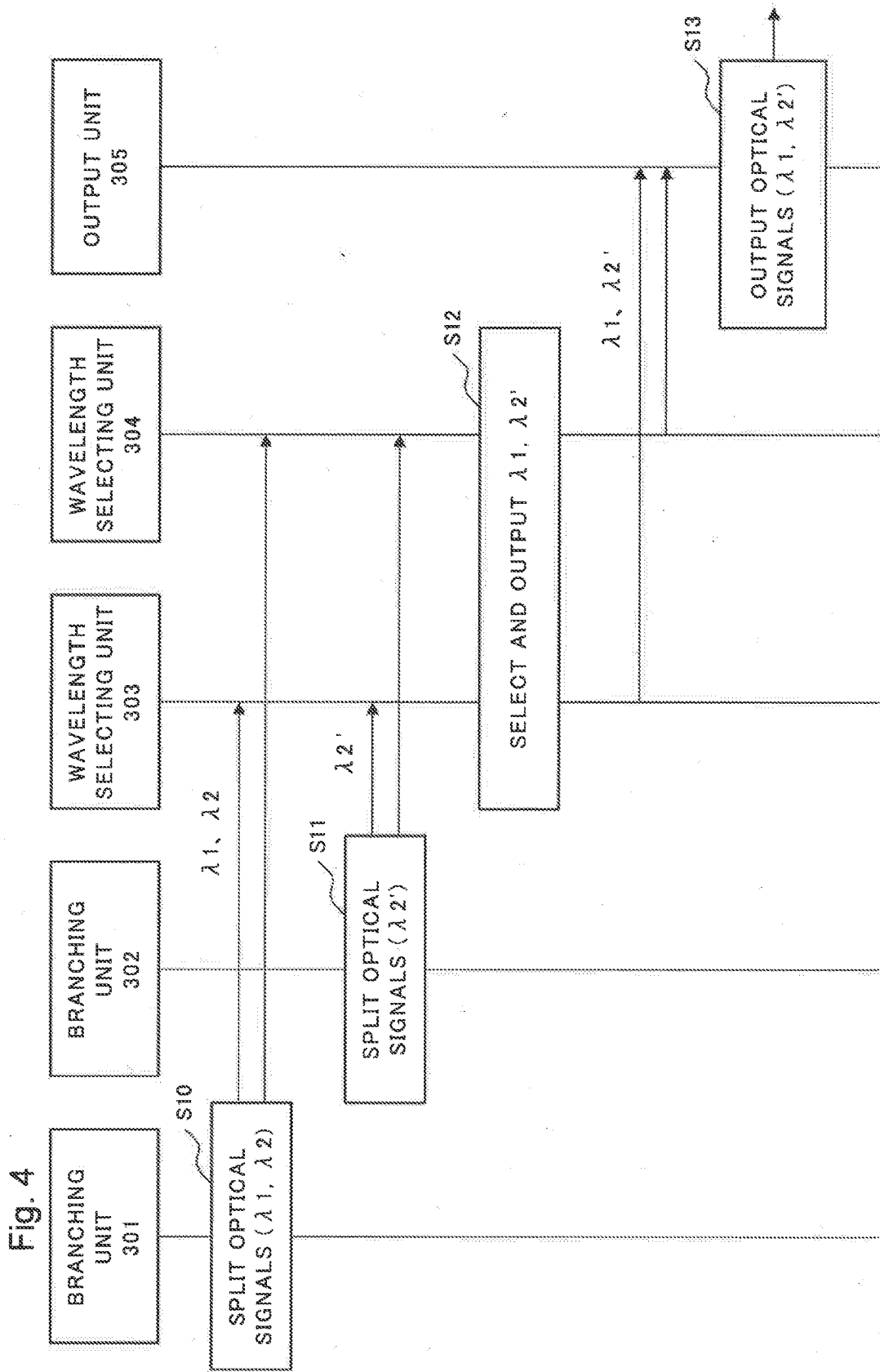
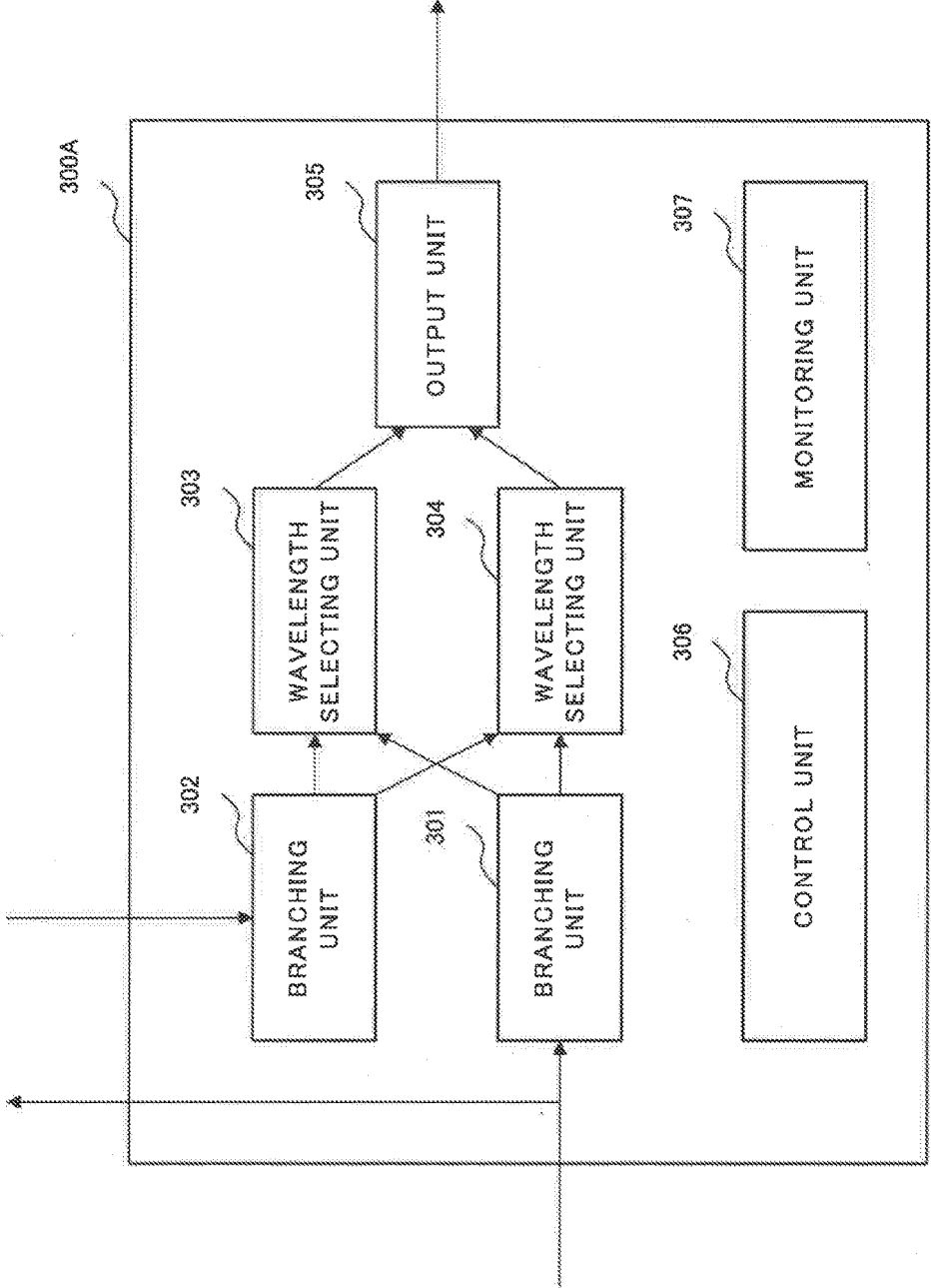


Fig. 5



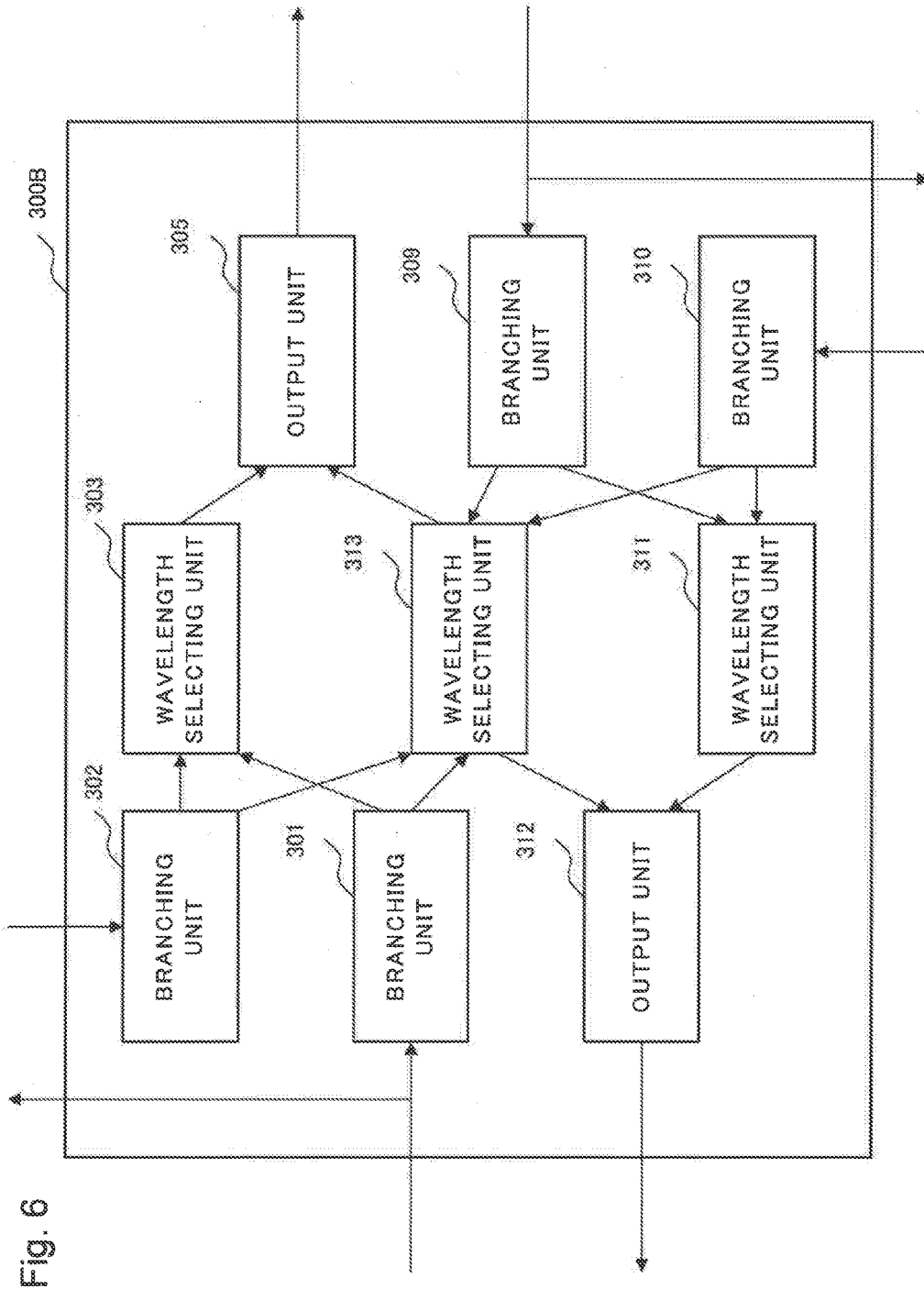


Fig. 6

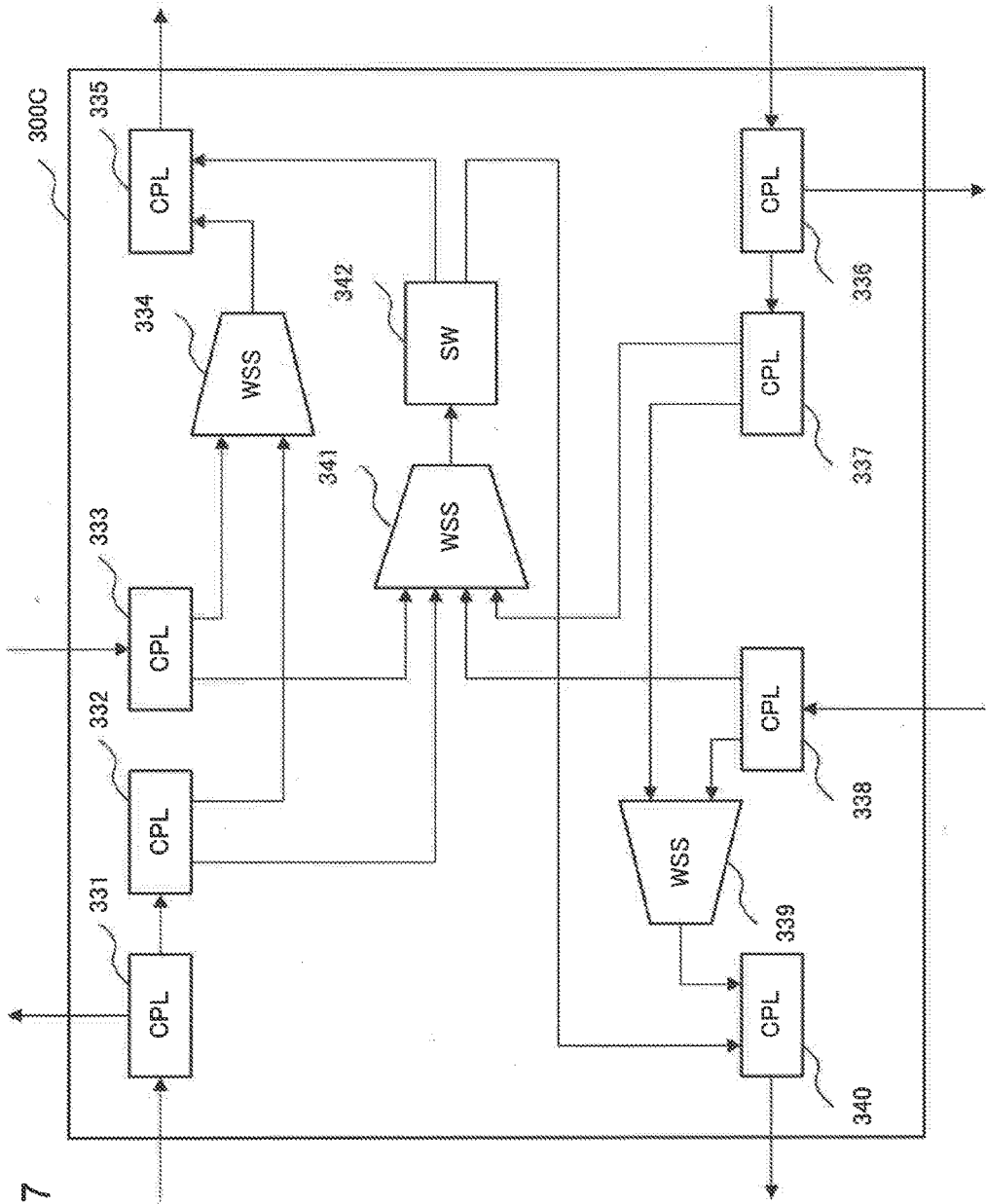
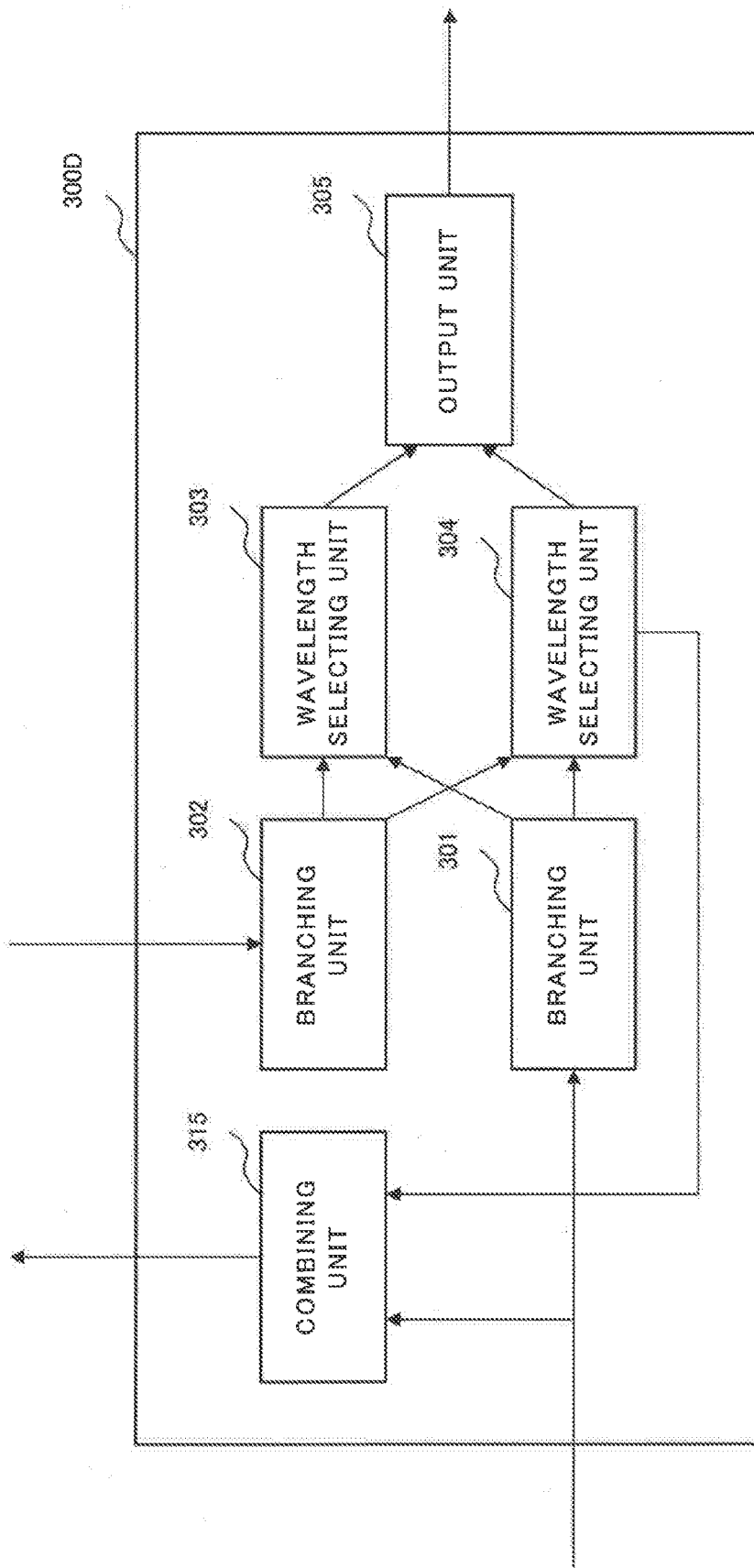


Fig. 7

Fig. 8



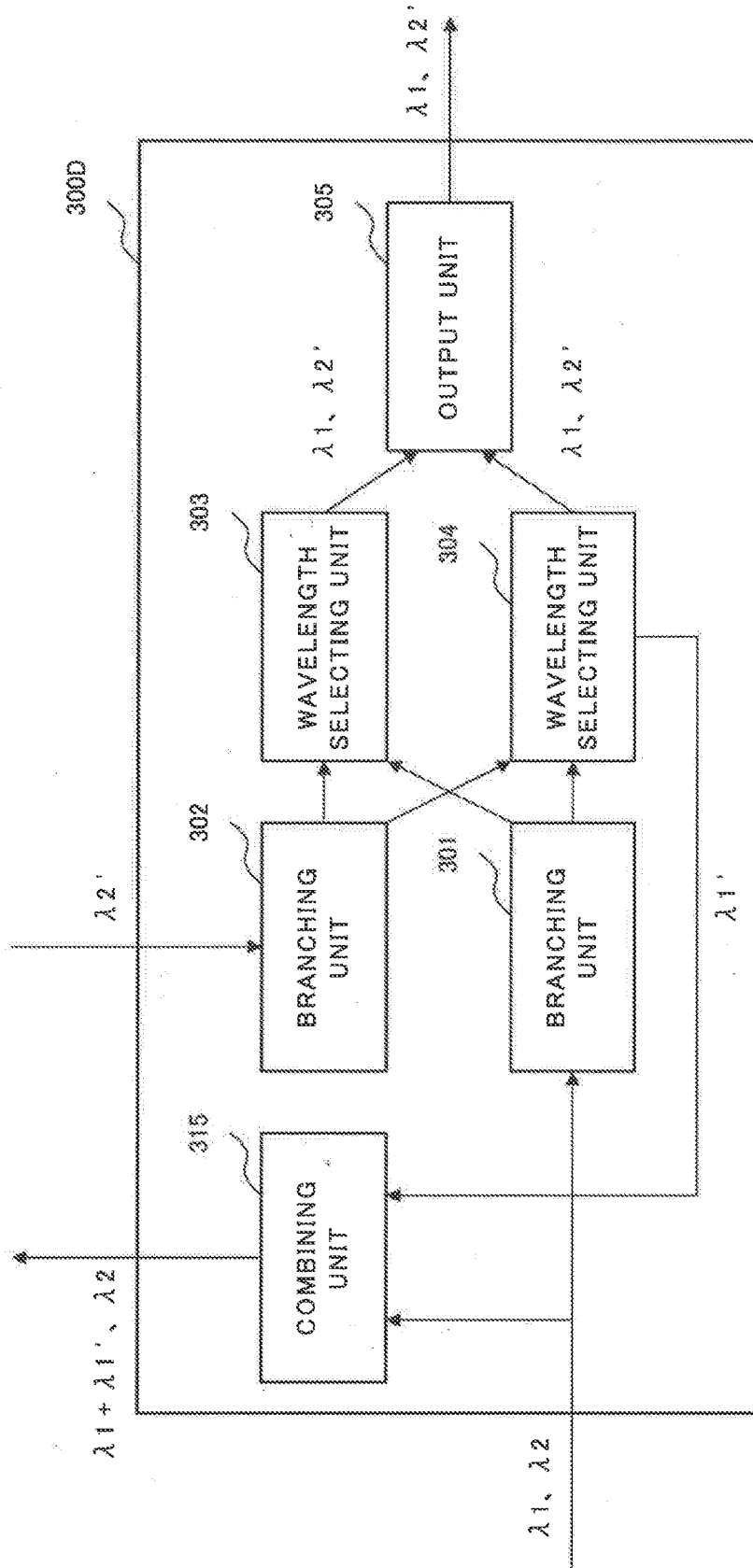


Fig. 9

Fig. 10

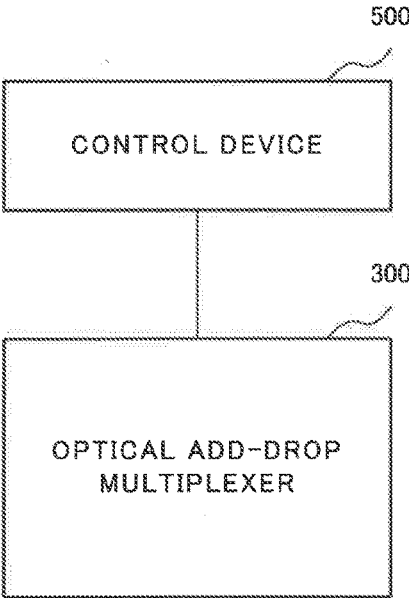
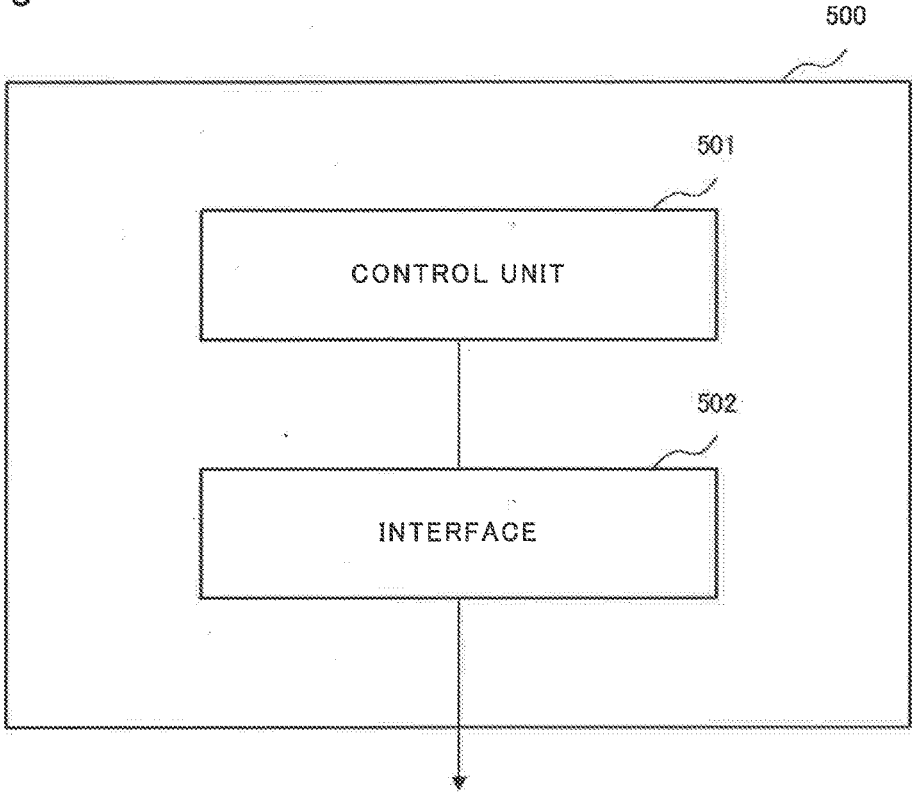


Fig. 11



**OPTICAL COMMUNICATION DEVICE,
OPTICAL COMMUNICATION SYSTEM, AND
OPTICAL COMMUNICATION METHOD**

CROSS-REFERENCE TO RELATED PATENT
APPLICATIONS

[0001] This application is a National Stage Entry of International Application No. PCT/JP2015/003856, filed Jul. 30, 2015, which claims priority from Japanese Patent Application No. 2014-157718, filed Aug. 1, 2014. The entire contents of the above-referenced applications are expressly incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to an optical communication technology, and more particularly, to a reconfigurable optical add-drop multiplexer (ROADM) technology in a wavelength-division multiplex (WDM) optical communication system.

BACKGROUND ART

[0003] In general, a branching device with the optical add-drop multiplexer (OADM) function is introduced into a WDM optical communication system. Conventionally, in order to change a network configuration in such optical communication system, paths and wavelengths in the branching device with the OADM function have to be reconfigured by replacing components such as optical filters.

[0004] In view of such circumstances, there has recently been an increasing demand for a branching device with the ROADM function, which allows for flexible reconfiguration of a network being already in operation. The ROADM function can be fulfilled by using a wavelength selective switch (WSS) that has splitting, switching, and combining functions. Devices provided with the ROADM function are disclosed in, for example, PTL 1 to PTL 4.

[0005] PTL 1 discloses an ROADM branching device based on a WSS. According to PTL 1, wavelength-division multiplexed signals inputted to the branching device are combined and subjected to wavelength selection in a WSS and then outputted.

CITATION LIST

Patent Literature

[0006] [PTL 1] Japanese Unexamined Patent Application Publication No. 2012-15726

[0007] [PTL 2] Japanese Unexamined Patent Application Publication No. 2010-130575

[0008] [PTL 3] Japanese Unexamined Patent Application Publication No. 2010-283446

[0009] [PTL 4] Japanese Unexamined Patent Application Publication No. 2011-109173

SUMMARY OF INVENTION

Technical Problem

[0010] According to PTL 1, functions to select wavelengths to be outputted are centered on a WSS located on the output-side of the branching device. Thus, the technique described in PTL 1 makes it difficult to flexibly deal with

changes in the state of the device or network to, for example, continue providing communication services in case of a failure in any WSS.

[0011] The present invention has been created in view of the problems described above, and an object of the invention is to provide an optical communication technology that brings flexibility to an ROADM system.

Solution to Problem

[0012] To achieve the aforementioned object, an optical communication device according to the present invention drops and adds an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations, the device including: first means and second means capable of selecting an optical signal of a predetermined wavelength from inputted optical signals and of outputting the selected optical signal; third means for splitting optical signals inputted from a first terminal station on the main path into the first means and the second means; fourth means for splitting optical signals inputted from a branch path in the network into the first means and the second means; and fifth means capable of selectively outputting to a second terminal station on the main path either an optical signal outputted by the first means or an optical signal outputted by the second means.

[0013] To achieve the aforementioned object, an optical communication method according to the present invention is a method for dropping and adding an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations, the method including: splitting optical signals inputted from a first terminal station on the main path into first and second wavelength selecting units that are capable of selectively outputting a predetermined wavelength; splitting optical signals inputted from a branch path in the network into the first and second wavelength selecting units; and selectively outputting to a second terminal station on the main path either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit.

[0014] To achieve the aforementioned object, an optical communication system according to the present invention includes: an optical communication device dropping and adding an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations; and a control device controlling the optical communication device, wherein the optical communication device includes: first means and second means capable of selecting an optical signal of a predetermined wavelength from inputted optical signals and of outputting the selected optical signal; third means for splitting optical signals inputted from a first terminal station on the main path to the optical communication device into the first means and the second means; fourth means for splitting optical signals inputted from a branch path in the network to the optical communication device into the first means and the second means; and fifth means capable of outputting an optical signal to a second terminal station on the main path, and wherein the control device instructs the optical communication device to cause the fifth means to selectively output either an optical signal outputted by the first means or an optical signal outputted by the second means.

Advantageous Effects of Invention

[0015] The above-described aspects of the present invention can provide an optical communication technology that brings flexibility to ROADM systems.

BRIEF DESCRIPTION OF DRAWINGS

[0016] FIG. 1 is a system configuration diagram illustrating an optical communication system according to a first example embodiment.

[0017] FIG. 2 is a block configuration diagram illustrating an optical add-drop multiplexer 300 according to the first example embodiment.

[0018] FIG. 3 illustrates example flows of optical signals having their respective wavelengths in the optical add-drop multiplexer 300 according to the first example embodiment.

[0019] FIG. 4 illustrates example operations according to the first example embodiment.

[0020] FIG. 5 is a block configuration diagram illustrating an optical add-drop multiplexer 300A according to a second example embodiment.

[0021] FIG. 6 is a block configuration diagram illustrating an optical add-drop multiplexer 300B according to a third example embodiment.

[0022] FIG. 7 is a block configuration diagram illustrating an optical add-drop multiplexer 300C according to a variation of the third example embodiment.

[0023] FIG. 8 is a block configuration diagram illustrating an optical add-drop multiplexer 300D according to a fourth example embodiment.

[0024] FIG. 9 illustrates example flows of optical signals having their respective wavelengths in the optical add-drop multiplexer 300D according to the fourth example embodiment.

[0025] FIG. 10 is a system configuration diagram illustrating an optical communication system according to a fifth example embodiment.

[0026] FIG. 11 is a block configuration diagram illustrating a control device 500 according to the fifth example embodiment.

DESCRIPTION OF EMBODIMENTS

First Example Embodiment

[0027] An optical add-drop multiplexer 300 according to a first example embodiment of the present invention has a function to split wavelength-division multiplexed optical signals being transmitted in an optical communication network. According to the present example embodiment, the optical add-drop multiplexer 300, which includes a plurality of wavelength selecting units that selectively output optical signals of predetermined wavelengths from among inputted wavelength-division multiplexed optical signals, outputs an optical signal of a desired wavelength by selecting one of the wavelength selecting units. The optical add-drop multiplexer 300 outputs an optical signal coming from an appropriate wavelength selecting unit, thereby ensuring flexibility of an ROADM device.

[0028] FIG. 1 is a system configuration diagram illustrating an optical communication system according to the present example embodiment. With reference to FIG. 1, the optical communication system includes two terminal stations (trunk stations) 100 and 200, an optical add-drop multiplexer 300, and a terminal station (branch station) 400.

[0029] The terminal stations (trunk stations) 100 and 200 perform WDM optical communications with each other via optical transmission lines. Each of the terminal stations 100 and 200 has a function to transmit, and a function to receive, wavelength-division multiplexed optical signals.

[0030] The optical add-drop multiplexer 300 branches the optical transmission line between the terminal stations 100 and 200, the line constituting the main path in the optical communication network, to the terminal station (branch station) 400 on a branch path in the optical communication network. Specifically, the optical add-drop multiplexer 300 drops an optical signal of a predetermined wavelength from wavelength-division multiplexed optical signals transmitted between the terminal stations 100 and 200, and sends the signal to the terminal station 400 on the branch path (the Drop function). In addition, the optical add-drop multiplexer 300 adds an optical signal of a predetermined wavelength sent from the terminal station 400 to the optical signals transmitted between the terminal stations 100 and 200 (the Add function).

[0031] The following description assumes that, by way of example, the terminal station 100 is a station transmitting optical signals while the terminal station 200 is a station receiving optical signals. Likewise, by way of example, it can be assumed that the terminal station 200 is a transmitting station and the terminal station 100 is a receiving station.

[0032] FIG. 2 is a block configuration diagram illustrating the optical add-drop multiplexer 300. The optical add-drop multiplexer 300 in FIG. 2 includes a branching unit 301, a wavelength selecting unit 302, a wavelength selecting unit 303, a wavelength selecting unit 304, and an output unit 305.

[0033] The branching unit 301 splits wavelength-division multiplexed optical signals that are inputted from the terminal station 100 to the optical add-drop multiplexer 300 into the wavelength selecting units 303 and 304. The branching unit 302 splits optical signals that are inputted from the terminal station 400 to the optical add-drop multiplexer 300 into the wavelength selecting units 303 and 304. The optical signals inputted from the terminal station 400 to the optical add-drop multiplexer 300 may be optical signals of a single wavelength or may be wavelength-division multiplexed optical signals.

[0034] Each of the wavelength selecting units 303 and 304 extracts an optical signal of a predetermined wavelength from the wavelength-division multiplexed optical signals inputted from the branching units 301 and 302, and outputs the extracted signal to the output unit 305. The output unit 305 outputs either the optical signal inputted from the wavelength selecting unit 303 or the optical signal inputted from the wavelength selecting unit 304 to the terminal station 200.

[0035] To implement the Drop function, the optical add-drop multiplexer 300 uses an optical coupler or the like to split, before the branching unit 301, the wavelength-division multiplexed optical signals inputted from the terminal station 100, and outputs branched signals to the terminal station 400.

[0036] The branching units 301 and 302 each include an optical component having an optical splitting function, such as an optical coupler. The wavelength selecting units 303 and 304 each include, for example, a WSS. If the wavelength selecting units 303 and 304 each include a WSS, the units 303 and 304 may, for example, distribute the inputted wavelength-division multiplexed optical signals into a plu-

ality of output ports according to their wavelengths or adjust optical power levels by attenuating the power levels according to the wavelengths. The output unit 305 includes an optical component having a function to switch optical paths, such as an optical switch.

[0037] FIG. 3 illustrates flows of optical signals transmitted in the optical add-drop multiplexer 300, where wavelength-division multiplexed optical signals including optical signals of wavelengths λ_1 and λ_2 are sent from the terminal station 100 to the terminal station 200. The optical add-drop multiplexer 300 adds/drops optical signals of wavelengths λ_2 and λ_2' . Wavelengths λ_2' and λ_2 are of the same wavelength, but with different information content since their optical signals are outputted from the terminal station 100 and the terminal station 400, respectively.

[0038] The branching unit 301 branches and outputs the wavelength-division multiplexed optical signals, which are inputted from the terminal station 100 and include optical signals of wavelengths λ_1 and λ_2 , into the wavelength selecting units 303 and 304. On the other hand, the branching unit 302 branches and outputs the optical signals of wavelength λ_2' , which are inputted from the terminal station 400, into the wavelength selecting units 303 and 304.

[0039] The wavelength selecting units 303 and 304 each select optical signals of wavelengths λ_1 and λ_2 from among the inputted optical signals of wavelengths λ_1 , λ_2 , and λ_2' , and output the selected optical signals to the output unit 305. Since wavelengths λ_2 and λ_2' are of the same wavelength, the wavelength selecting units 303 and 304 each preferably have a plurality of input ports to accept the wavelength λ_2 and the wavelength λ_2' on different ports so as to prevent the wavelengths λ_2 and λ_2' from interfering with each other.

[0040] For example, if the wavelength selecting units 303 and 304 are WSSs, an output port to which optical signals of wavelengths λ_1 and λ_2' are outputted is connected to the output unit 305, while another output port to which optical signals of wavelength λ_2 are outputted is connected to anything other than the output unit 305. Alternatively, the wavelength selecting units 303 and 304 may attenuate the level of optical signals of wavelength λ_2 .

[0041] The output unit 305 selects either the wavelength selecting unit 303 or the wavelength selecting unit 304, and outputs the optical signals of wavelengths λ_1 and λ_2' , as inputted from the selected wavelength selecting unit, to the terminal station 200.

[0042] FIG. 4 illustrates operations of the individual components in the optical add-drop multiplexer 300 in time series. The branching unit 301 splits the wavelength-division multiplexed optical signals, which are inputted from the terminal station 100 and include optical signals of wavelengths λ_1 and λ_2 , into the wavelength selecting units 303 and 304 (S10).

[0043] The branching unit 302 splits the optical signals of wavelength λ_2' inputted from the terminal station 400 into the wavelength selecting units 303 and 304 (S11).

[0044] Each of the wavelength selecting units 303 and 304 selects optical signals of wavelengths λ_1 and λ_2' from the wavelength-division multiplexed optical signals including optical signals of wavelengths λ_1 and λ_2 and from the optical signals of wavelength λ_2' , as inputted from the branching units 301 and 302, and outputs the selected optical signals to the output unit 305 (S12).

[0045] The output unit 305 selects either the wavelength selecting unit 303 or the wavelength selecting unit 304, and

outputs the optical signals of wavelengths λ_1 and λ_2' , as inputted from the selected selecting unit, to the terminal station 200 (S13).

[0046] The output unit 305 may include an optical coupler or the like for combining optical signals inputted from the wavelength selecting unit 303 with optical signals inputted from the wavelength selecting unit 304. In this case, the optical signal to be outputted from the output unit 305 is selected in advance by the branching units 301 and 302 or by the wavelength selecting units 303 and 304.

[0047] If the optical signal to be outputted from the output unit 305 is selected by the branching units 301 and 302, the branching units 301 and 302 each include an optical switch. The branching units 301 and 302 then output optical signals to either the wavelength selecting unit 303 or the wavelength selecting unit 304.

[0048] If the optical signal to be outputted from the output unit 305 is selected by the wavelength selecting units 303 and 304, the wavelength selecting unit 303 and 304 each include, for example, a WSS. In this case, a setting is made so as to prevent one of the WSSs from outputting optical signals of wavelengths λ_1 and λ_2' to the output unit 305.

Second Example Embodiment

[0049] An optical add-drop multiplexer 300A according to a second example embodiment includes a monitoring unit for monitoring the state of the network and the local multiplexer itself and a control unit for switching optical signals to be outputted depending on the monitoring result. FIG. 5 illustrates an example configuration of the optical add-drop multiplexer 300A according to the present example embodiment.

[0050] The monitoring unit 307 monitors the state of the network to which the optical add-drop multiplexer 300A belongs and of the local multiplexer itself, and outputs the result of monitoring. The state of the network monitored by the monitoring unit 307 may be, for example, the state of the network configuration such as topology, the state of traffic, or the state of loads imposed on devices included in the network. Additionally, the monitoring unit 307 may monitor any occurrence of a failure and the state of communication in the individual components of the optical add-drop multiplexer 300A. The monitoring unit 307 may also receive information about the state of the network from an external monitoring device.

[0051] The control unit 306 switches optical signals to be outputted from the output unit 305 depending on the outputted result of monitoring. For example, when the monitoring unit 307 detects a failure in the wavelength selecting unit 304, the control unit 306 controls the output unit 305 so that optical signals coming from the wavelength selecting unit 303 are outputted from the output unit 305. If, for example, the output unit 305 is a component capable of switching paths, such as an optical switch, the control unit 306 causes the output unit 305 to switch paths between input and output ports in the output unit 305. In another example, if each of the wavelength selecting units 303 and 304 is a WSS, the control unit 306 controls a combination of an input port with an output port for a wavelength or controls the amount of optical power attenuation for each wavelength. If, for example, each of the branching units 301 and 302 is a component having a switching function such as an optical switch, the control unit 306 controls output paths for the branching units 301 and 302.

[0052] As described above, the optical add-drop multiplexer 300A according to the present example embodiment includes the monitoring unit 307, which monitors the state of the network to which the optical add-drop multiplexer 300A belongs and of the local multiplexer itself. As a result, in case of a failure, the control unit 306 can immediately and precisely switch optical signal paths on the basis of the monitoring result outputted from the monitoring unit 307.

Third Example Embodiment

[0053] FIG. 6 is a block configuration diagram illustrating an optical add-drop multiplexer 300B according to a third example embodiment. The optical add-drop multiplexer 300B has a two-way communication configuration that deals with both the optical transmission from the terminal station 100 to the terminal station 200 and the optical transmission from the terminal station 200 to the terminal station 100. The optical add-drop multiplexer 300B uses an optical coupler or the like to split, before the branching unit 309, the wavelength-division multiplexed optical signals inputted from the terminal station 200, and outputs branched signals to the terminal station 400. In addition, optical signals from the terminal station 400 are inputted to the branching unit 310.

[0054] The branching unit 309, the branching unit 310, the wavelength selecting unit 311, and the output unit 312 respectively correspond to the branching unit 301, the branching unit 302, the wavelength selecting unit 303, and the output unit 305. The branching unit 301 receives wavelength-division multiplexed optical signals from the terminal station 100, while the branching unit 309 receives wavelength-division multiplexed optical signals from the terminal station 200. Likewise, the output unit 305 outputs wavelength-division multiplexed optical signals to the terminal station 200, while the output unit 312 outputs wavelength-division multiplexed optical signals to the terminal station 100.

[0055] The wavelength selecting unit 313 extracts an optical signal of a predetermined wavelength from the wavelength-division multiplexed optical signals inputted from the branching units 301 and 302, and outputs the extracted signal to the output unit 305. In addition, the wavelength selecting unit 313 extracts an optical signal of a predetermined wavelength from the wavelength-division multiplexed optical signals inputted from the branching units 309 and 310, and outputs the extracted signal to the output unit 312. The wavelength selecting unit 313 may implement the selection of an input source and an output destination by, for example, switching paths like an optical switch or using any of a plurality of input ports and output ports.

Variation of Third Example Embodiment

[0056] FIG. 7 is a block configuration diagram illustrating an optical add-drop multiplexer 300C according to a variation of the third example embodiment. The optical add-drop multiplexer 300C in FIG. 7 includes eight optical couplers (CPLs) 331, 332, 333, 335, 336, 337, 338, and 340, three wavelength selective switches (WSSs) 334, 339, and 341, and one optical switch (SW) 342.

[0057] The CPL 331 bifurcates wavelength-division multiplexed optical signals including optical signals of wavelengths λ_1 and λ_2 , as inputted from the terminal station 100, to output them to the terminal station 400 and the CPL 332.

The CPL 332 bifurcates the inputted wavelength-division multiplexed optical signals including optical signals of wavelengths λ_1 and λ_2 to output them to the WSSs 334 and 341.

[0058] The CPL 333 bifurcates optical signals of wavelength λ_2' , as inputted from the terminal station 400, to output them to the WSSs 334 and 341. Wavelengths λ_2 and λ_2' are of the same wavelength, but with different information content since their optical signals are outputted from the terminal station 100 and the terminal station 400, respectively.

[0059] The WSS 334 extracts optical signals of wavelengths λ_1 and λ_2' from wavelength-division multiplexed optical signals including optical signals of wavelengths λ_1 and λ_2 as well as from optical signals of wavelength λ_2' , as inputted from the CPLs 332 and 333, and outputs the extracted optical signals of wavelengths λ_1 and λ_2' to the CPL 335. The CPL 335 combines the optical signals of wavelengths λ_1 and λ_2' , as inputted from the WSS 334, with the optical signals of wavelengths λ_1 and λ_2' , as inputted from the SW 342, which will be described later, and outputs a resultant signal to the terminal station 200.

[0060] The CPL 336 bifurcates wavelength-division multiplexed optical signals including optical signals of wavelengths λ_3 and λ_4 to output them to the terminal station 400 and the CPL 337. The CPL 337 bifurcates the inputted wavelength-division multiplexed optical signals including optical signals of wavelengths λ_3 and λ_4 to output them to the WSSs 339 and 341.

[0061] The CPL 338 bifurcates optical signals of wavelength λ_4' , as inputted from the terminal station 400, to output them to the WSSs 339 and 341. Wavelengths λ_4 and λ_4' are of the same wavelength, but with different information content since their optical signals are outputted from the terminal station 200 and the terminal station 400, respectively.

[0062] The WSS 339 extracts optical signals of wavelengths λ_3 and λ_4' from wavelength-division multiplexed optical signals including optical signals of wavelengths λ_3 and λ_4 as well as from optical signals of wavelength λ_4' , as inputted from the CPLs 337 and 338, and outputs the extracted optical signals of wavelengths λ_3 and λ_4' to the CPL 340. The CPL 340 combines the optical signals of wavelengths λ_3 and λ_4' , as inputted from the WSS 339, with the optical signals of wavelengths λ_3 and λ_4' , as inputted from the SW 342, which will be described later, and outputs a resultant signal to the terminal station 100.

[0063] In accordance with an instruction given by a control unit (not illustrated), the WSS 341 extracts an optical signal of a predetermined wavelength from the wavelength-division multiplexed optical signals and the optical signals, as inputted from the CPLs 332, 333, 337, and 338, and outputs the extracted optical signal to the SW 342. Optical signals inputted to the WSS 341 according to the present example embodiment are: wavelength-division multiplexed optical signals including optical signals of wavelengths λ_1 and λ_2 , optical signals of wavelength λ_2' , wavelength-division multiplexed optical signals including optical signals of wavelengths λ_3 and λ_4 , and optical signals of wavelength λ_4' .

[0064] In accordance with an instruction given by the control unit (not illustrated), the SW 342 selects either the CPL 335 or the CPL 340, and outputs optical signals

inputted from the WSS 341 to the selected CPL. The SW 342 may be configured to additionally select the ground.

[0065] The control unit (not illustrated) operates as described below. When the WSSs 334 and 339 are normally operating, the control unit controls the WSS 341 so that a maximum attenuation level is set to the WSS 341 to prevent the WSS 341 from outputting optical signals. If the SW 342 can select the ground, the control unit causes the SW 342 to select the ground.

[0066] On the other hand, when the control unit determines that the WSS 334 has a failure, the control unit causes the WSS 341 to extract optical signals of wavelengths λ_1 and λ_2' and output the extracted signals to the SW 342. In addition, the control unit causes the SW 342 to select the CPL 335 and output optical signals of wavelengths λ_1 and λ_2' , as inputted from the WSS 341, to the selected CPL 335. Thus, in case the WSS 334 has a failure, optical signals of wavelengths λ_1 and λ_2' are still outputted to the terminal station 200 through the WSS 341, the SW 342, and the CPL 335.

[0067] On the other hand, when the control unit determines that the WSS 339 has a failure, the control unit causes the WSS 341 to extract optical signals of wavelengths λ_3 and λ_4' and output the extracted signals to the SW 342. In addition, the control unit causes the SW 342 to select the CPL 340 and output optical signals of wavelengths λ_3 and λ_4' , as inputted from the WSS 341, to the selected CPL 340. Thus, in case the WSS 339 has a failure, optical signals of wavelengths λ_3 and λ_4' are still outputted to the terminal station 100 through the WSS 341, the SW 342, and the CPL 340.

[0068] In general, a wavelength selective device, e.g., a WSS, includes optical elements such as micro-electro-mechanical systems (MEMS) and liquid crystal on silicon (LCOS), optical components such as lenses, and electronic circuits. Accordingly, a WSS tends to be expensive and carries a higher risk of failure than general optical devices.

[0069] On the other hand, the optical add-drop multiplexer 300C according to the present example embodiment uses the WSS 341 in common, as a backup WSS to be used when a failure or the like occurs in the WSS 334 or WSS 339. Using the WSS 341 in case of a failure or the like in the WSS 334 or WSS 339 can reduce line disconnects between trunk and branch stations and signal deteriorations. Thus, for a submarine optical cable system and other systems on which requirements for reliable, long-lasting stable operations are imposed, the present example embodiment can ensure the reliability at lower cost.

[0070] Each of the CPLs 335 and 340, which are included in the optical add-drop multiplexer 300C illustrated in FIG. 7 and are used for outputting optical signals to the terminal station 100 or 200, may be replaced by an optical switch. In this case, for example, if a breakdown occurs in such a way that the WSS 339 allows optical signals including abnormal signals to flow into the optical switch that replaces the CPL 340, the optical switch can switch the input from the WSS 339 to the WSS 341, thereby preventing abnormal signals coming from the WSS 339 from merging with optical signals of wavelengths λ_3 and λ_4' to be outputted to the terminal station 200.

Fourth Example Embodiment

[0071] In a fourth example embodiment, an optical signal dropped in an optical add-drop multiplexer is combined with

an optical signal outputted from a wavelength selecting unit. This makes it impossible to restore information in an optical signal of unwanted wavelength, as included in a dropped optical signal. In addition, one wavelength selecting unit can be used for filtering optical signals to be outputted to the terminal station 200, while the other wavelength selecting unit can be used for combining dropped optical signals with desired optical signals. Accordingly, the present example embodiment can enhance security by reducing transmission of unwanted information, while achieving efficient use of resources.

[0072] FIG. 8 is a block configuration diagram illustrating an optical add-drop multiplexer 300D according to the present example embodiment. The optical add-drop multiplexer 300D in FIG. 8 adds a combining unit 315 to the configuration of the optical add-drop multiplexer 300 according to the first example embodiment as illustrated in FIG. 2.

[0073] The wavelength selecting unit 304 extracts a plurality of optical signals of predetermined wavelengths from the wavelength-division multiplexed optical signals inputted from the branching units 301 and 302, and outputs the extracted optical signals to the combining unit 315 and to the output unit 305. The combining unit 315 combines the branched wavelength-division multiplexed optical signals, as inputted from the terminal station 100, with the optical signals coming from the wavelength selecting unit 304, and outputs a resultant signal to the terminal station 400.

[0074] FIG. 9 illustrates flows of optical signals transmitted in the optical add-drop multiplexer 300D, where wavelength-division multiplexed optical signals including optical signals of wavelengths λ_1 and λ_2 are sent from the terminal station 100 to the terminal station 200. The branching unit 301 branches and outputs the wavelength-division multiplexed optical signals, which are inputted from the terminal station 100 and include optical signals of wavelengths λ_1 and λ_2 , into the wavelength selecting units 303 and 304. On the other hand, the branching unit 302 branches and outputs the optical signals of wavelength λ_2' , which are inputted from the terminal station 400, into the wavelength selecting units 303 and 304.

[0075] The wavelength selecting unit 304 selects an optical signal of wavelength λ_1' from the inputted optical signals of wavelengths λ_1 , λ_2 , and λ_2' , and outputs the selected optical signal to the combining unit 315. The combining unit 315 combines the branched optical signals of wavelengths λ_1 and λ_2 , as inputted from the terminal station 100, with the optical signal of wavelength λ_1' inputted from the wavelength selecting unit 304, and outputs a resultant signal to the terminal station 400. Since wavelengths λ_1 and λ_1' are of the same wavelength, optical signals of wavelengths λ_1 and λ_1' will interfere with each other at the combining unit 315. The interference with each other causes the modulation pattern included in the optical signal of wavelength λ_1 to be mixed with the modulation pattern included in the optical signal of wavelength λ_1' , which makes it impossible to restore the optical signal of wavelength λ_1 from optical signals inputted from the combining unit 315 to the terminal station 400.

[0076] In normal times (no failure occurring), the optical add-drop multiplexer 300D as configured above allows the wavelength selecting unit 303 to output optical signals of wavelengths λ_1 and λ_2' to the output unit 305, while allowing the wavelength selecting unit 304 to output optical

signals of wavelength λ_1' to the combining unit 315. On the other hand, in case a failure occurs in the wavelength selecting unit 303, the optical add-drop multiplexer 300D switches operations so that the wavelength selecting unit 304 outputs optical signals of wavelengths λ_1 and λ_2' to the output unit 305.

Fifth Example Embodiment

[0077] FIG. 10 is a system configuration diagram illustrating an optical communication system according to a fifth example embodiment. Any of the optical add-drop multiplexers 300A to 300D described in the respective example embodiments may be applied to the optical add-drop multiplexer 300. A control device 500 gives an instruction regarding communications to the optical add-drop multiplexer 300 by sending control information thereto.

[0078] FIG. 11 is a block configuration diagram illustrating the control device 500. The control device 500 includes a control unit 501 and an interface 502. The control unit 501 communicates with the optical add-drop multiplexer 300 via the interface 502.

[0079] The control unit 501 causes the optical add-drop multiplexer 300 to select either the wavelength selecting unit 303 or the wavelength selecting unit 304 and to output optical signals coming from the selected wavelength selecting unit through the output unit 305.

[0080] The optical add-drop multiplexer 300 switches internal optical signal paths, in accordance with an instruction given by the control unit 501. The control unit 501 causes the optical add-drop multiplexer 300 to select the wavelength selecting unit 303 in normal times, while causing the multiplexer 300 to select the wavelength selecting unit 304 in case of a failure.

[0081] The control unit 501 may give an instruction so that the output unit 305 selects either the wavelength selecting unit 303 or the wavelength selecting unit 304 and outputs optical signals therefrom. The control unit 501 may also give an instruction so that input/output ports and output wavelengths for the wavelength selecting units 303 and 304 are configured. The control unit 501 may also give an instruction so that the branching units 301 and 302 output optical signals to either the wavelength selecting unit 303 or the wavelength selecting unit 304.

[0082] The control unit 501 may obtain status information about the optical communication network and optical add-drop multiplexer 300 from the multiplexer 300 itself or from another device included in the network, and control the optical add-drop multiplexer 300 on the basis of the status information. The control unit 501 may obtain a result of monitoring from, for example, the monitoring unit 307 illustrated in FIG. 5.

Other Example Embodiments

[0083] The whole or part of the above example embodiments can be described as, but is not limited to, the following supplementary notes.

(Supplementary Note 1)

[0084] An optical communication device dropping and adding an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations, the device including:

[0085] first means and second means capable of selecting an optical signal of a predetermined wavelength from inputted optical signals and of outputting the selected optical signal;

[0086] third means for splitting optical signals inputted from a first terminal station on the main path into the first means and the second means;

[0087] fourth means for splitting optical signals inputted from a branch path in the network into the first means and the second means; and

[0088] fifth means capable of selectively outputting to a second terminal station on the main path either an optical signal outputted by the first means or an optical signal outputted by the second means.

(Supplementary Note 2)

[0089] The optical communication device according to Supplementary Note 1, further including:

[0090] sixth means capable of performing control so that an optical signal outputted by the fifth means is switched between an optical signal outputted by the first means and an optical signal outputted by the second means.

(Supplementary Note 3)

[0091] The optical communication device according to Supplementary Note 2, further including:

[0092] seventh means capable of monitoring a state of the communication device,

[0093] wherein the sixth means performs control so that an optical signal outputted by the fifth means is switched between an optical signal outputted by the first means and an optical signal outputted by the second means, depending on a result of monitoring by the seventh means.

(Supplementary Note 4)

[0094] The optical communication device according to any one of Supplementary notes 1 to 3, further including:

[0095] eighth means capable of outputting an optical signal to the first terminal station,

[0096] wherein the second means is capable of selecting an optical signal of a predetermined wavelength from optical signals inputted from the second terminal station and from the branch path, and of outputting the selected optical signal to the eighth means.

(Supplementary Note 5)

[0097] The optical communication device according to any one of Supplementary Notes 1 to 4, further including:

[0098] ninth means for combining an optical signal inputted from the first terminal station with an optical signal outputted by the second means, and for outputting a resultant signal to the branch path,

[0099] wherein the second means is capable of outputting to the ninth means optical signals including at least one of wavelengths included in optical signals inputted from the first terminal station.

(Supplementary Note 6)

[0100] The optical communication device according to any one of Supplementary Notes 1 to 5,

[0101] wherein the first means and the second means each include a wavelength selective switch.

(Supplementary Note 7)

[0102] An optical communication method for dropping and adding an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations, the method including:

[0103] splitting optical signals inputted from a first terminal station on the main path into first and second wavelength selecting units that are capable of selectively outputting a predetermined wavelength;

[0104] splitting optical signals inputted from a branch path in the network into the first and second wavelength selecting units; and

[0105] selectively outputting to a second terminal station on the main path either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit.

(Supplementary Note 8)

[0106] The optical communication method according to Supplementary

[0107] Note 7, including:

[0108] outputting either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit by switching from each other.

(Supplementary Note 9)

[0109] The optical communication method according to Supplementary Note 7 or 8, including:

[0110] monitoring a state of an optical communication device that includes the first and second wavelength selecting units; and

[0111] outputting either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit by switching from each other, depending on a result of the monitoring.

(Supplementary Note 10)

[0112] The optical communication method according to any one of Supplementary Notes 7 to 9, including:

[0113] combining an optical signal that is inputted from the first terminal station with an optical signal that is outputted by the second wavelength selecting unit and includes at least one of wavelengths included in optical signals inputted from the first terminal station, and outputting a resultant signal to the branch path.

(Supplementary Note 11)

[0114] An optical communication system including:

[0115] an optical communication device dropping and adding an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations; and

[0116] a control device controlling the optical communication device,

[0117] wherein the optical communication device includes:

[0118] first means and second means capable of selecting an optical signal of a predetermined wavelength from inputted optical signals and outputting the selected optical signal;

[0119] third means for splitting optical signals that are inputted from a first terminal station on the main path to the optical communication device into the first means and the second means;

[0120] fourth means for splitting optical signals that are inputted from a branch path in the network to the optical communication device into the first means and the second means; and

[0121] fifth means capable of outputting an optical signal to a second terminal station on the main path,

[0122] and wherein the control device

[0123] instructs the optical communication device to cause the fifth means to selectively output either an optical signal outputted by the first means or an optical signal outputted by the second means.

(Supplementary Note 12)

[0124] A program used for an optical communication device dropping and adding an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations, the program being executed to:

[0125] split optical signals inputted from a first terminal station on the main path into first and second wavelength selecting units that are capable of selectively outputting a predetermined wavelength;

[0126] split optical signals inputted from a branch path in the network into the first and second wavelength selecting units; and

[0127] selectively output to a second terminal station on the main path either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit.

[0128] The present invention is not limited to the above example embodiments and includes design changes and the like that do not depart from the spirit and scope of the present invention.

INDUSTRIAL APPLICABILITY

[0129] The present invention may be widely applied to optical communication systems having a function to add/drop an optical signal of a predetermined wavelength.

[0130] The present application claims priority based on Japanese Patent Application No. 2014-157718 filed on Aug. 1, 2014, the entire disclosure of which is incorporated herein.

REFERENCE SIGNS LIST

[0131] 100, 200, 400 Terminal station
[0132] 300, 300A to 300D Optical add-drop multiplexer
[0133] 301, 302 Branching unit
[0134] 303, 304 Wavelength selecting unit
[0135] 305 Output unit
[0136] 306 Control unit
[0137] 307 Monitoring unit
[0138] 309, 310 Branching unit
[0139] 311, 313 Wavelength selecting unit
[0140] 312 Output unit
[0141] 331, 332, 333, 335 Optical coupler
[0142] 336, 337, 338, 340 Optical coupler
[0143] 334, 339, 341 WSS
[0144] 342 Optical switch
[0145] 315 Combining unit

[0146] 500 Control device

[0147] 501 Control unit

[0148] 502 Interface

1. An optical communication device dropping and adding an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations, the device comprising:

first unit and second unit that selects an optical signal of a predetermined wavelength from inputted optical signals and outputs the selected optical signal;

third unit that splits optical signals inputted from a first terminal station on the main path into the first unit and the second unit;

fourth unit that splits optical signals inputted from a branch path in the network into the first unit and the second unit; and

fifth unit capable of selectively outputting to a second terminal station on the main path either an optical signal outputted by the first unit or an optical signal outputted by the second unit.

2. The optical communication device according to claim 1, further comprising:

sixth unit capable of performing control so that an optical signal outputted by the fifth unit is switched between an optical signal outputted by the first unit and an optical signal outputted by the second unit.

3. The optical communication device according to claim 2, further comprising:

seventh unit capable of monitoring a state of the communication device,

wherein the sixth unit performs control so that an optical signal outputted by the fifth unit is switched between an optical signal outputted by the first unit and an optical signal outputted by the second unit, depending on a result of monitoring by the seventh unit.

4. The optical communication device according to claim 1, further comprising:

eighth unit capable of outputting an optical signal to the first terminal station,

wherein the second unit is capable of selecting an optical signal of a predetermined wavelength from optical signals inputted from the second terminal station and from the branch path, and of outputting the selected optical signal to the eighth unit.

5. The optical communication device according to claim 1, further comprising:

ninth unit that combines an optical signal inputted from the first terminal station with an optical signal outputted by the second unit, and outputs a resultant signal to the branch path,

wherein the second unit is capable of outputting to the ninth unit optical signals including at least one of wavelengths included in optical signals inputted from the first terminal station.

6. The optical communication device according to claim 1,

wherein the first unit and the second unit each include a wavelength selective switch.

7. An optical communication method that drops and adds an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations, the method comprising:

splitting optical signals inputted from a first terminal station on the main path into first and second wave-

length selecting units that are capable of selectively outputting a predetermined wavelength;

splitting optical signals inputted from a branch path in the network into the first and second wavelength selecting units; and

selectively outputting to a second terminal station on the main path either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit.

8. The optical communication method according to claim 7, comprising:

outputting either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit by switching from each other.

9. The optical communication method according to claim 7, comprising:

monitoring a state of an optical communication device that includes the first and second wavelength selecting units; and

outputting either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit by switching from each other, depending on a result of the monitoring.

10. An optical communication system comprising:

an optical communication device that drops and adds an optical signal from and to wavelength-division multiplexed optical signals that are transmitted on a main path between network terminal stations; and

a control device that controls the optical communication device,

wherein the optical communication device includes:

first unit and second unit capable of selecting an optical signal of a predetermined wavelength from inputted optical signals and of outputting the selected optical signal;

third unit for splitting optical signals that are inputted from a first terminal station on the main path to the optical communication device into the first unit and the second unit;

fourth unit for splitting optical signals that are inputted from a branch path in the network to the optical communication device into the first unit and the second unit; and

fifth unit capable of outputting an optical signal to a second terminal station on the main path,

and wherein the control device

instructs the optical communication device to cause the fifth unit to selectively output either an optical signal outputted by the first unit or an optical signal outputted by the second unit.

11. The optical communication device according to claim 2, further comprising:

eighth unit capable of outputting an optical signal to the first terminal station,

wherein the second unit is capable of selecting an optical signal of a predetermined wavelength from optical signals inputted from the second terminal station and from the branch path, and of outputting the selected optical signal to the eighth unit.

12. The optical communication device according to claim 3, further comprising:

eighth unit capable of outputting an optical signal to the first terminal station,
 wherein the second unit is capable of selecting an optical signal of a predetermined wavelength from optical signals inputted from the second terminal station and from the branch path, and of outputting the selected optical signal to the eighth unit.
13. The optical communication device according to claim **2**, further comprising:
 ninth unit that combines an optical signal inputted from the first terminal station with an optical signal outputted by the second unit, and outputs a resultant signal to the branch path,
 wherein the second unit is capable of outputting to the ninth unit optical signals including at least one of wavelengths included in optical signals inputted from the first terminal station.
14. The optical communication device according to claim **3**, further comprising:
 ninth unit that combines an optical signal inputted from the first terminal station with an optical signal outputted by the second unit, and outputs a resultant signal to the branch path,
 wherein the second unit is capable of outputting to the ninth unit optical signals including at least one of wavelengths included in optical signals inputted from the first terminal station.
15. The optical communication device according to claim **4**, further comprising:
 ninth unit that combines an optical signal inputted from the first terminal station with an optical signal outputted by the second unit, and outputs a resultant signal to the branch path,

wherein the second unit is capable of outputting to the ninth unit optical signals including at least one of wavelengths included in optical signals inputted from the first terminal station.
16. The optical communication device according to claim **2**, wherein the first unit and the second unit each include a wavelength selective switch.
17. The optical communication device according to claim **3**, wherein the first unit and the second unit each include a wavelength selective switch.
18. The optical communication device according to claim **4**, wherein the first unit and the second unit each include a wavelength selective switch.
19. The optical communication method according to claim **8**, comprising:
 monitoring a state of an optical communication device that includes the first and second wavelength selecting units; and
 outputting either an optical signal outputted by the first wavelength selecting unit or an optical signal outputted by the second wavelength selecting unit by switching from each other, depending on a result of the monitoring.
20. The optical communication system according to claim **10**, wherein the optical communication device further comprising:
 sixth unit capable of performing control so that an optical signal outputted by the fifth unit is switched between an optical signal outputted by the first unit and an optical signal outputted by the second unit.

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