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(56) Documents Cited
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EP 0638836 A1 WO97/06617 A1 WO97/06614 A1
WO96/09703 A1 US 5579143 A US 5467212 A

(58) Field of Search
UK CL (Edition P) **H4B BKX**
INT CL^6 **H04J 14/02**

(54) **An optical wavelength filter and a demultiplexer**

(57) An optical demultiplexer is constructed from a number of series connected optical wavelength filters, each of which comprises a first optical device (770) having first (771), second (772), and third (773) ports, for receiving an input optical signal having a plurality of wavelength components, directing the input optical signal to the second port (772), and directing an optical signal returning from the second port (772) to the third port (773), and a second optical device (870) having a fourth port (874) connected to the second port (772) of the first optical device (770) and a fifth port (875), for reflecting only an optical signal having a predetermined wavelength component in the optical signal received via the fourth port (874) and passing an optical signal having the other wavelength components. In a preferred embodiment, the second optical device (870) is a fiber Bragg grating reflection filter and the first optical device (770) is an optical circulator.

FIG. 8

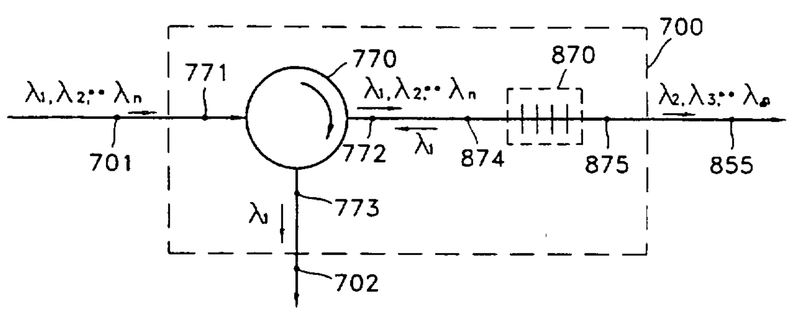

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FIG. 1

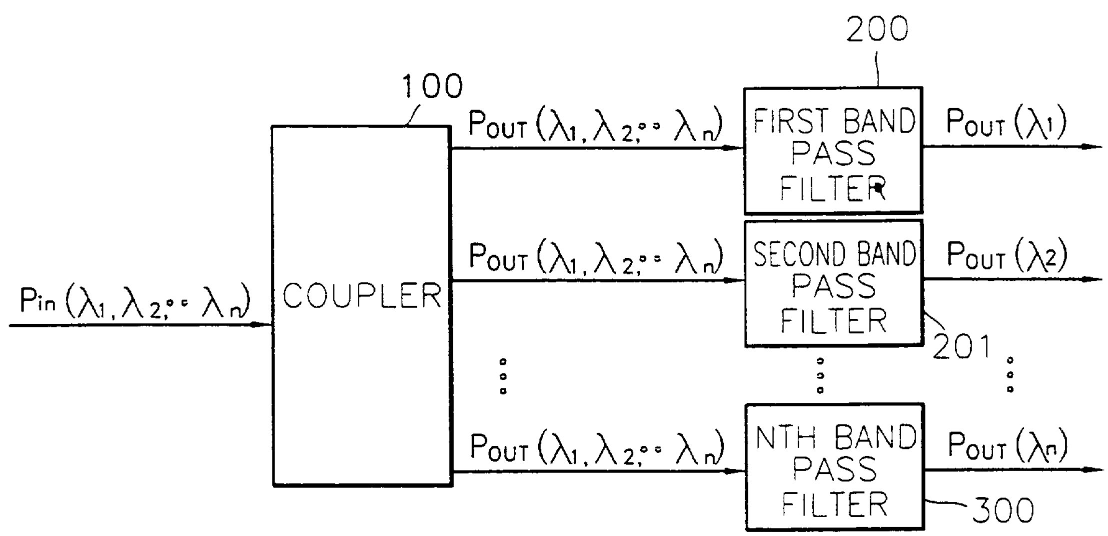

200
100
COUPLER
FIRST BAND PASS FILTER
SECOND BAND PASS FILTER
NTH BAND PASS FILTER
201
300
Pin (λ1, λ2, ·· λn)
Pout (λ1, λ2, ·· λn)
Pout (λ1)
Pout (λ2)
Pout (λn)

FIG. 2

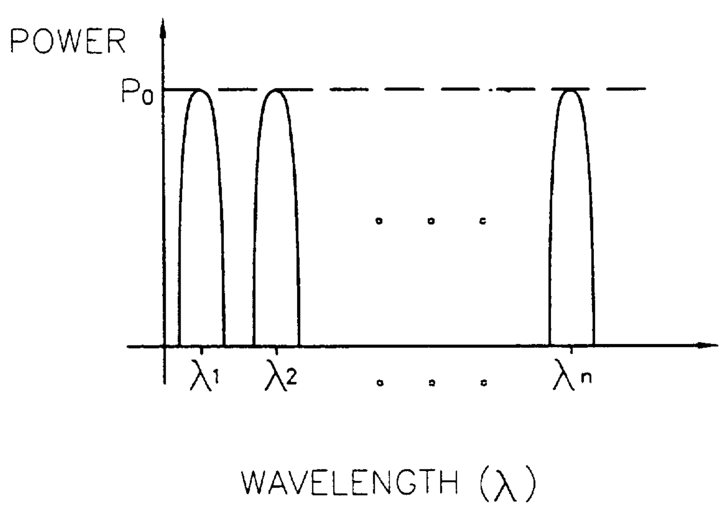

POWER
P0
λ1
λ2
λn
WAVELENGTH (λ)

FIG. 3

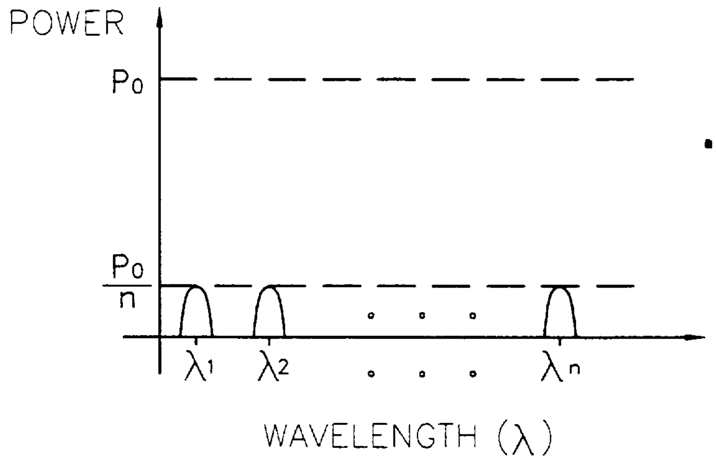


FIG. 4a

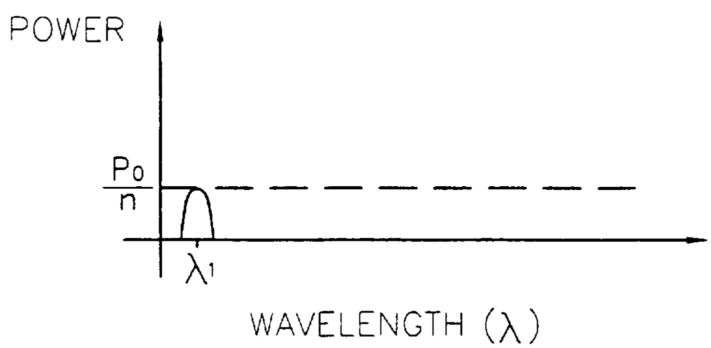


FIG. 4B

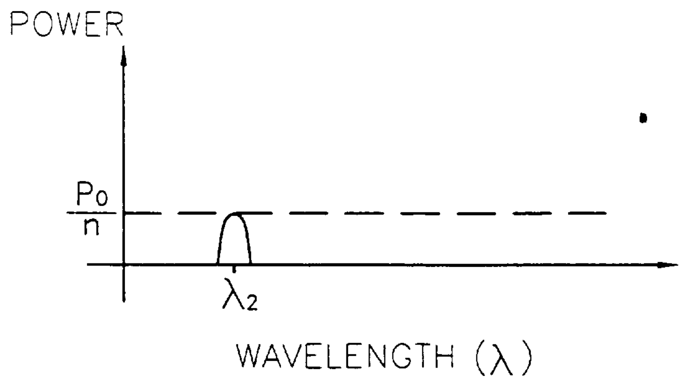


FIG. 4C

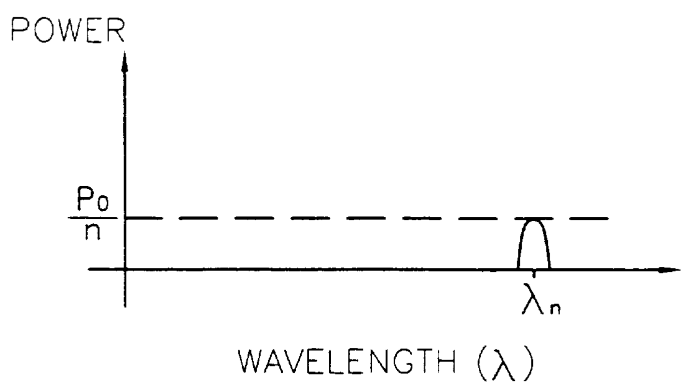


FIG. 5

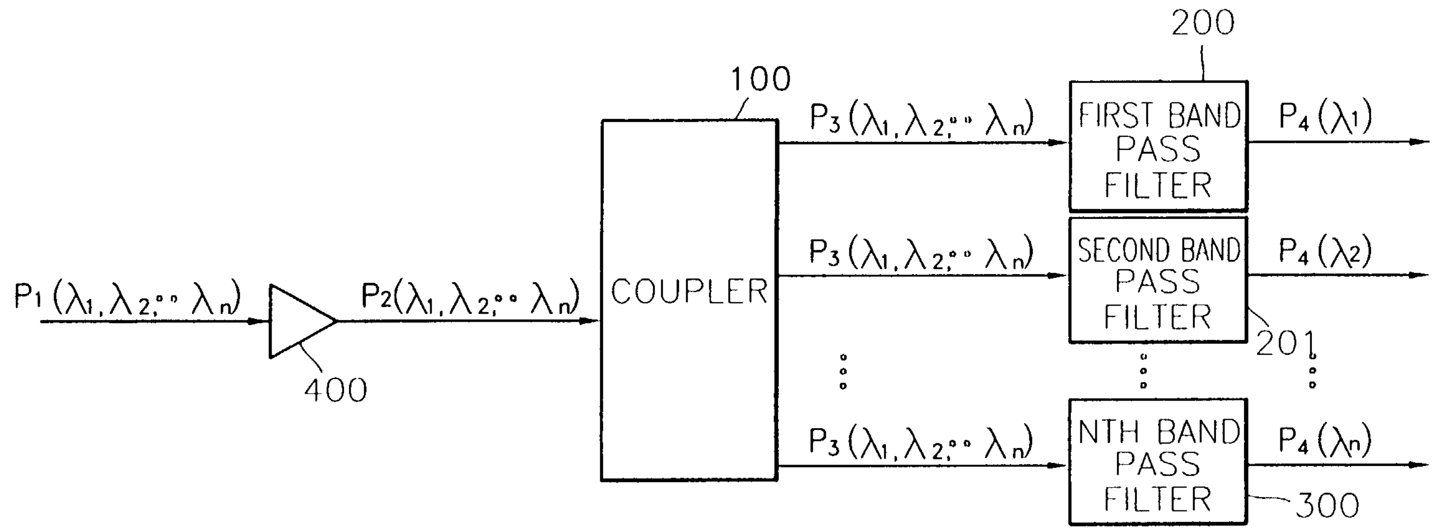

P1 (λ1, λ2,·· λn)
400
P2(λ1, λ2,·· λn)
100
COUPLER
P3 (λ1, λ2,·· λn)
P3 (λ1, λ2,·· λn)
P3 (λ1, λ2,·· λn)
200
FIRST BAND PASS FILTER
SECOND BAND PASS FILTER
201
NTH BAND PASS FILTER
300
P4 (λ1)
P4 (λ2)
P4 (λn)

FIG. 6

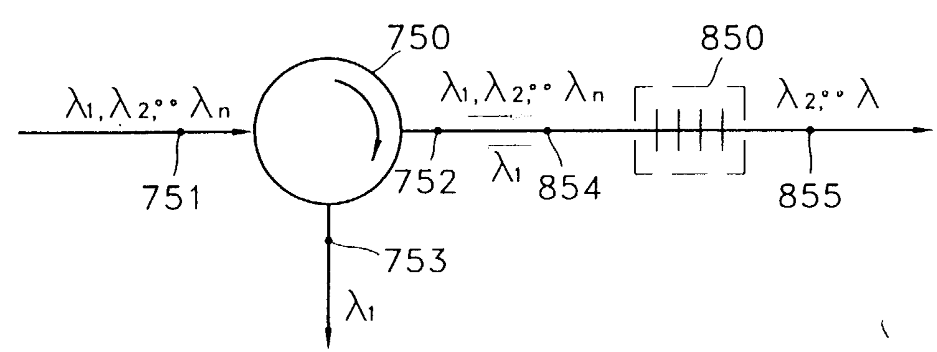

λ1, λ2,·· λn
751
750
752
λ1, λ2,·· λn
λ1
854
850
λ2,·· λ
855
753
λ1

FIG. 7

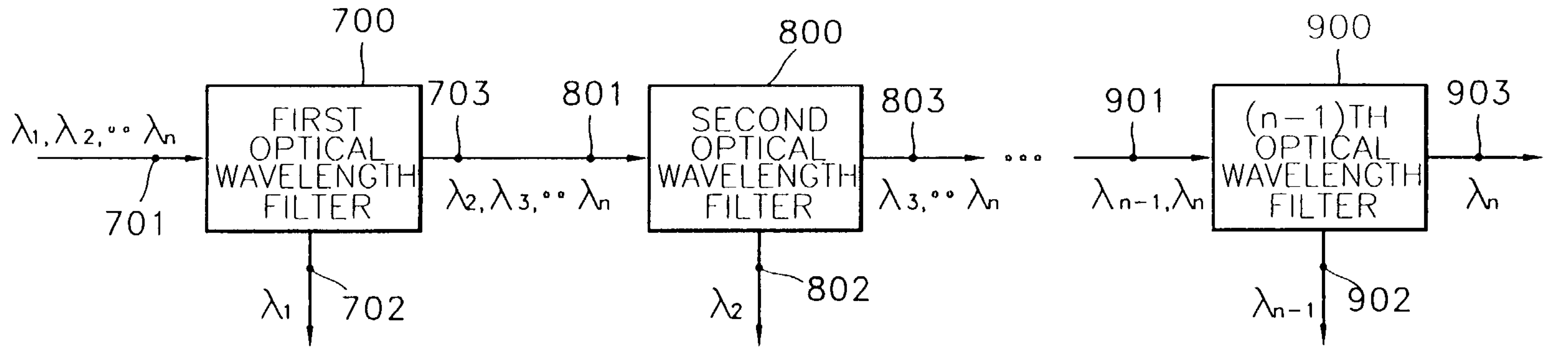
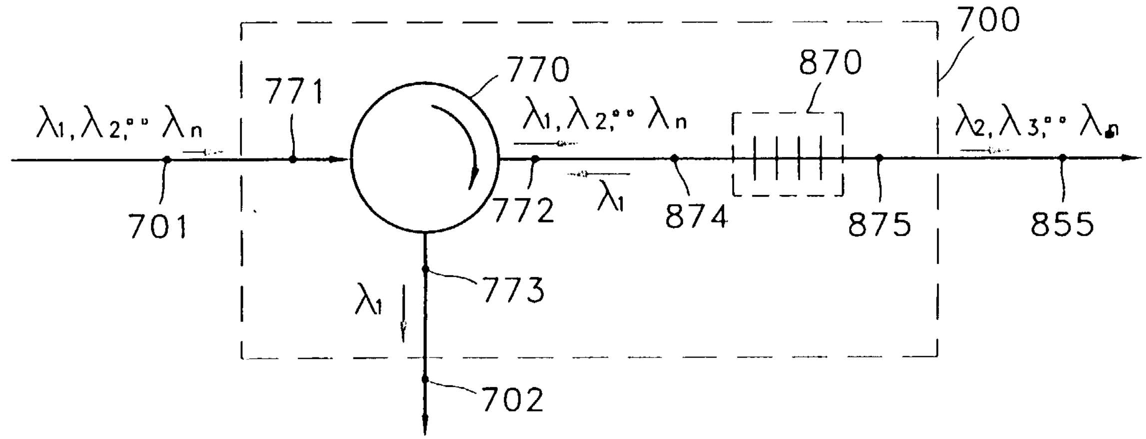

FIRST OPTICAL WAVELENGTH FILTER
SECOND OPTICAL WAVELENGTH FILTER
(n−1)TH OPTICAL WAVELENGTH FILTER
700
701
702
703
800
801
802
803
900
901
902
903
λ1, λ2, ··· λn
λ1
λ2, λ3, ··· λn
λ2
λ3, ··· λn
λn−1, λn
λn−1
λn

FIG. 8


700
701
702
770
771
772
773
870
874
875
855
λ1, λ2, ··· λn
λ1
λ2, λ3, ··· λn

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AN OPTICAL WAVELENGTH FILTER AND A DEMULTIPLEXER

A WDM transmission system multiplexes the wavelength area of an optical fiber into several channels by simultaneously transmitting signals of several wavelength bands, relying on wavelength characteristics of an optical signal. In the WDM transmission system, an input optical signal, having been multiplexed to have several wavelength components, is demultiplexed at the receiver and recognized in the respective channels.

In FIG. 1, the optical demultiplexer for the receiver of a conventional WDM transmission system includes a $1 \times n$ coupler 100 and first through nth band pass filters 200-300. Here, n represents the number of channels of a transmitted optical signal.

A coupler is a passive device for branching or coupling optical signals, that is, for branching an input channel into several output channels or coupling several input channels into an output channel. The $1 \times n$ coupler 100 branches an input optical signal, produced by multiplexing optical signals having many wavelength components, for example, λ_1, $\lambda_2, \ldots, \lambda_n$, into n branch optical signals $P_{out}(\lambda_1, \lambda_2, \ldots, \lambda_n)$, and outputs them via n respective ports. Here, the power of each branch optical signal $P_{out}(\lambda_1, \lambda_2, \ldots, \lambda_n)$ is (1/n)th that of the input optical signal of the $1 \times n$ coupler 100. The first through nth band pass filters 200-300 receive the branch optical signals $P_{out}(\lambda_1, \lambda_2, \ldots, \lambda_n)$ from the n ports, pass only their corresponding wavelength components, and output optical signals $P_{out}(\lambda_1)$, $P_{out}(\lambda_2)$, ..., $P_{out}(\lambda_n)$ of n channels having wavelength components λ_1-λ_n, respectively. Hence, the power of each of the n optical signals $P_{out}(\lambda_1)$, $P_{out}(\lambda_2), \ldots$, $P_{out}(\lambda_n)$ is (1/n)th that of the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$.

FIG. 2 is a waveform diagram illustrating the power of the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$ of the $1\times n$ coupler shown in FIG. 1. Here, λ_1-λ_n and P_0 represent the wavelength components and the power value of the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$, respectively.

FIG. 3 is a waveform diagram illustrating the power of the branch optical signal $P_{out}(\lambda_1, \lambda_2, \ldots, \lambda_n)$ output from the $1\times n$ coupler shown in FIG. 1 to each band pass filter. In FIG. 3, the branch optical signal $P_{out}(\lambda_1, \lambda_2, \ldots, \lambda_n)$ has (1/n)th the power of the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$, while keeping the wavelength components of the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$.

FIGs. 4A-4C are waveform diagrams illustrating the powers of optical signals $P_{out}(\lambda_1)$, $P_{out}(\lambda_2)$, and $P_{out}(\lambda_n)$ output from the first, second, and nth band pass filters shown in FIG. 1. Here, the vertical axis on the graphs indicates the powers P of the optical signals, and the horizontal axis indicates the wavelengths λ of the optical signals. P_0 denotes the power value of the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$, and λ_1-λ_n denote the wavelength components multiplexed in the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$. As shown in FIG. 3, the power of the branch optical signal $P_{out}(\lambda_1, \lambda_2, \ldots, \lambda_n)$ output from the $1\times n$ coupler is (1/n)th that of the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$, that is, P_0/n. Thus, each of the optical signals $P_{out}(\lambda_1)$, $P_{out}(\lambda_2), \ldots$, $P_{out}(\lambda_n)$ having their respective wavelength components, which are output from the first through nth band pass filters 200-300, also have (1/n)th the power of the input optical signal $P_{in}(\lambda_1, \lambda_2, \ldots, \lambda_n)$, that is, P_0/n.

In a conventional WDM transmission system, use of the $1\times n$ coupler for demultiplexing a multiplexed optical signal at a receiver offers only (1/n)th the power of an input optical signal of the $1 \times n$ coupler.

In order to make up for the power loss caused by this $1 \times n$ coupler, the optical demultiplexer for the receiver in the conventional WDM transmission system further includes an optical amplifier for amplifying an optical signal to increase the power by n times before it is input to the $1 \times n$ coupler.

Referring to FIG. 5, the optical demultiplexer has an optical amplifier 400, a $1 \times n$ coupler 100, and first through nth band pass filters 200-300. Here, n denotes the number of channels of a transmitted optical signal.

An optical signal $P_1(\lambda_1, \lambda_2, \ldots, \lambda_n)$ received in the optical amplifier 400 is produced by multiplexing optical signals of many wavelength components, for example, $\lambda_1, \lambda_2, \ldots, \lambda_n$. The optical amplifier 400 amplifies the input optical signal $P_1(\lambda_1, \lambda_2, \ldots, \lambda_n)$ by two or more times the number of wavelength components included in the input optical signal $P_1(\lambda_1, \lambda_2, \ldots, \lambda_n)$, and outputs an amplified input optical signal $P_2(\lambda_1, \lambda_2, \ldots, \lambda_n)$. The $1 \times n$ coupler 100 receives the amplified input optical signal $P_2(\lambda_1, \lambda_2, \ldots, \lambda_n)$, branches the amplified signal, and outputs n branch input optical signals $P_3(\lambda_1, \lambda_2, \ldots, \lambda_n)$. Here, the n branch input optical signals each have (1/n)th the power of the amplified input optical signal $P_2(\lambda_1, \lambda_2, \ldots, \lambda_n)$, that is, a power value as great as or greater than the output of the input optical signal $P_1(\lambda_1, \lambda_2, \ldots, \lambda_n)$, while keeping the wavelength components included in the input optical signal $P_1(\lambda_1, \lambda_2, \ldots, \lambda_n)$. The first through nth band pass filters 200-300 separate optical signals $P_4(\lambda_1)$, $P_4(\lambda_2), \ldots, P_4(\lambda_n)$ of their corresponding wavelength components from the branch input optical signals $P_3(\lambda_1, \lambda_2,\ldots, \lambda_n)$. Here, the powers of the optical signals $P_4(\lambda_1)$, $P_4(\lambda_2),\ldots$, $P_4(\lambda_n)$ each are larger than that of the input optical signal $P_1(\lambda_1, \lambda_2,\ldots, \lambda_n)$.

According to a first aspect of the present invention, an optical wavelength filter comprises a first optical device and a second optical device. The first optical device includes first, second, and third ports, receives an input optical signal having a plurality of wavelength components, directs the input optical signal to the second port, and directs an optical signal returning from the second port only to the third port. The second optical device includes fourth and fifth ports. The fourth port is connected to the second port of the first optical device. The second optical device reflects only an optical signal having a predetermined wavelength component in the optical signal received via the fourth port and passes an optical signal having the other wavelength components to the fifth port.

According to a second aspect of the present invention, an optical demultiplexer comprises a plurality of optical wavelength filters in accordance with the first aspect of the present invention connected in series.

Examples of the present invention will now be described in detail with reference to the accompanying drawings, in which:

FIG. 1 is a block diagram of an optical demultiplexer for a receiver of a conventional wavelength division multiplexing (WDM) transmission system;

FIG. 2 is a waveform diagram illustrating the power of an optical signal received in the 1×n coupler shown in FIG. 1;

FIG. 3 is a waveform diagram illustrating the power of an optical signal received in each of the first through nth band pass filters from the 1×n coupler shown in FIG. 1;

FIG. 4A is a waveform diagram illustrating the power of an optical signal output from the first band pass filter shown in FIG. 1;

FIG. 4B is a waveform diagram illustrating the power of an optical signal output from the second band pass filter shown in FIG. 1;

FIG. 4C is a waveform diagram illustrating the power of an optical signal output from the nth band pass filter shown in FIG. 1;

FIG. 5 is a block diagram of an optical demultiplexer for compensating for power loss caused by a 1×n coupler in a receiver of the conventional WDM transmission system;

FIG. 6 is a block diagram of an optical wavelength filter according to one embodiment of the present invention;

FIG. 7 is a block diagram of an optical demultiplexer according to another embodiment of the present invention; and,

FIG. 8 is a block diagram of a first optical wavelength filter shown in FIG. 7.

Referring to FIG. 6, an optical wavelength filter according to one embodiment of the present invention has a circulator 750 and a fiber grating reflection filter 850.

The circulator 750 has first through third ports 751-753. The first port 751 receives an optical signal having a plurality of wavelength components, for example, (λ_1, λ_2,..., λ_n) and directs the received optical signal to the second port 752. The circulator 750 directs an optical signal having only a wavelength component, for example, λ_1, which is reflected back from the fiber grating reflection filter 850 to the second port 752, only to the third port 753.

The fiber grating reflection filter 850 can reflect only an optical signal having a predetermined wavelength component backward from a signal traveling direction by periodically varying the refractive index of a fiber sensitive to ultraviolet rays, that is, relying on Bragg conditions by varying the refractive index of the fiber through irradiation of ultraviolet rays onto the fiber sensitive to the ultraviolet rays.

The fiber grating reflection filter 850 includes fourth and fifth ports 854 and 855. The fourth port 854 is connected to the second port 752. The fiber grating reflection filter 850 reflects only the optical signal having the predetermined wavelength component λ_1 among the wavelength components, for example, λ_1, λ_2, ..., λ_n, of the optical signal received from the fourth port 854 backward from the light traveling direction to the second port 752 of the circulator 750, and outputs an optical signal having the other wavelength components λ_2, ..., λ_n to the fifth port 855.

In the present invention, an optical wavelength filter comprises the circulator 750 and the fiber grating reflection filter 850 arrangement, thus separating only an optical signal having a predetermined wavelength component from an optical signal having a plurality of multiplexed wavelength components. Therefore, application of the optical wavelength filter to a WDM transmission system obviates the need for an optical amplifier used to compensate for division-incurring power loss of an optical signal in a receiver.

Referring to FIG. 7, the optical multiplexer has first through nth optical wavelength filters 700-900 which are connected in series.

The first through nth optical wavelength filters 700, 800 and 900 have input ports 701, 801 and 901, first output ports 702, 802 and 902, and second output ports 703, 803 and 903.

The first optical wavelength filter 700 receives an input optical signal having a plurality of wavelength components, for example, λ_1, λ_2,..., λ_n via the input port 701, and outputs only an optical signal having a wavelength component, for example, λ_1, among the wavelength components, for example, λ_1, λ_2,..., λ_n of the input optical signal, via the first output port 702. The first optical wavelength filter 700 outputs an optical signal having the other non-λ_1 wavelength components, that is, λ_2,..., λ_n received from the first output port 702, via the second port 703. The second optical wavelength filter 800 receives the optical signal having the other non-λ_1 wavelength components λ_2,..., λ_n via the input port 801 from the second output port 703. Similarly, the second optical wavelength filter 800 outputs an optical signal having a wavelength component, for example, λ_2 among the wavelength components $\lambda_2, \ldots, \lambda_n$ via the first output port 802, and an optical signal having the other wavelength components $\lambda_3, \ldots, \lambda_n$ via the second output port 803. Through this procedure, the (n-1)th optical wavelength filter 900 receives an optical signal having wavelength components λ_{n-1} and λ_n via the input port 901, and outputs an optical signal having a wavelength component, for example, λ_{n-1} via the first output port 902 and an optical signal having the other wavelength component λ_n via the second output port 903.

FIG. 8 is a block diagram of the first optical wavelength filter 700 shown in FIG. 7.

The optical wavelength filter 700 includes a circulator 770 and a fiber grating reflection filter 870.

The circulator 770 has first, second, and third ports 771, 772, and 773. The first port 771 is connected to the input port 701 of the optical wavelength filter 700. The circulator 770 receives an optical signal having a plurality of wavelength components, for example, $\lambda_1, \lambda_2, \ldots, \lambda_n$ via the first port 771 and outputs the optical signal to the fiber grating reflection filter 870 via the second port 772. The circulator 770 directs an optical signal having only one wavelength component, for example, λ_1, reflected back from the fiber grating reflection filter 870 via the second port 772, only to the third port 773.

The fiber grating reflection filter 870 can reflect only an optical signal having a predetermined wavelength component backward from a signal traveling direction by periodically varying the refractive index of a fiber sensitive to ultraviolet rays, that is, relying on Bragg conditions by varying the refractive index of the fiber through irradiation of ultraviolet rays onto the fiber sensitive to the ultraviolet rays.

The fiber grating reflection filter 870 has fourth and fifth ports 874 and 875, and the second port 772 of the circulator 770 is connected to the fourth port 874. The fiber grating reflection filter 870 receives the optical signal having the wavelength components $\lambda_1, \lambda_2, \ldots, \lambda_n$ via the fourth port 874, reflects only the optical signal having the wavelength component λ_1 backward from a light traveling direction to the circulator 770 via the second input port 772, and outputs the optical signal having the other wavelength components $\lambda_2, \ldots, \lambda_n$ via the fifth port 875. The optical signal having the other wavelength components is output from the fifth port 875 to the first optical wavelength filter 700 via the second output port 703.

As described above, by constructing an optical demultiplexer using serially connected optical wavelength filters each including a circulator and a fiber grating reflection filter, power loss of an optical demultiplexer, which is caused by an $1 \times n$ coupler of an optical demultiplexer in a receiver of the conventional WDM transmission system, can almost be eliminated.

Power loss generated when an optical signal of a plurality of wavelength components is divided into optical signals each having a wavelength component in the conventional optical demultiplexer and the optical demultiplexer in the present invention will now be described.

For example, it is assumed that the number of channels to be transmitted is 10 and the input power of each channel is 10mW. In the conventional optical demultiplexer, 10 optical signals, branched from an $1 \times n$ coupler and having their corresponding respective wavelength components by band pass filters, each have 1mW, that is, a 1/10th of 10mW. However, in the optical demultiplexer, a total loss of 2dB is produced due to insertion loss of the circulator itself while an input 10mW optical signal is received in the circulator, reflected by a fiber grating reflection filter to be an optical signal having a predetermined wavelength component, and output from the circulator. That is, the output power of the optical signal having the predetermined wavelength component divided from the 10mW input optical signal is 6.3mW. Therefore, there is no need for an optical amplifier for compensating for power loss of an optical signal caused by $1 \times n$ coupling in an optical demultiplexer of the conventional WDM transmission system.

The optical demultiplexer of the present invention is useful in a high-density WDM transmission system for increasing transmission capacity since there is no limit to the number of divided wavelengths.

CLAIMS

1. An optical wavelength filter comprising:

a first optical device having first, second, and third ports, for receiving an input optical signal having a plurality of wavelength components, directing the input optical signal to the second port, and directing an optical signal returning from the second port to the third port; and,

a second optical device having a fourth port connected to the second port of the first optical device and a fifth port, for reflecting only an optical signal having a predetermined wavelength component in the optical signal received via the fourth port and passing an optical signal having the other wavelength components.

2. An optical wavelength filter according to claim 1, in which the second optical device is a fiber Bragg grating reflection filter for making a refractive index difference with a grating period having regular intervals using light interference, and reflecting only a predetermined wavelength backward from a light traveling direction.

3. An optical wavelength filter according to claim 2, in which the predetermined wavelength can be set according to user demands by controlling the grating period according to Bragg conditions for an intended wavelength.

4. An optical wavelength filter according to any preceding claim, in which the first optical device comprises a circulator having an input port, a first output port and a second output port, for directing an input optical signal from the input port to the first output

port, and directing an optical signal received via the first output port only to the second output port.

5. An optical demultiplexer comprising a plurality of optical wavelength filters according to any preceding claim connected in series.

6. An optical demultiplexer according to claim 5, in which the plurality of second optical devices have different grating periods, reflect only optical signals having different wavelength components, and pass optical signals having the other wavelength components, so that an optical signal having a corresponding wavelength component is separated whenever an optical signal having a plurality of wavelength components pass through the plurality of second optical devices.

7. An optical wavelength filter substantially as shown in and/or described with reference to any of Figures 6 to 8 of the accompanying drawings.

8. An optical wavelength demultiplexer substantially as shown in and/or described with reference to any of Figures 6 to 8 of the accompanying drawings.

The Patent Office

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Application No: GB 9724821.5
Claims searched: 1-8

Examiner: Stephen Brown
Date of search: 6 March 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4B (BKX)

Int Cl (Ed.6): H04J: 14/02

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2 315 380 A	(Fujitsu) See especially figures 6 & 11 and the abstract.	1-5 & 7
X	GB 2 303 010 A	(France Telecom) See especially the abstract, figure 3, & page 7, lines 5-27.	1-4 & 7
X	EP 0 794 629 A2	(Denwa) See especially figure 3.	1-7
X	EP 0 638 836 A1	(CSELT) See especially figure 1 & the abstract.	1-5 & 7
X	WO 97/06617 A1	(STC) See especially figures 12-14.	1-5 & 7
X	WO 97/06614 A1	(STC) See especially figures 3 & 9.	1-7
X	WO 96/09703 A1	(United Technologies) See especially figure 6.	1-3, 5, 6
X	US 5 579 143	(Ciena) See especially figure 10.	1-4 & 7
X	US 5 467 212	(Huber) See especially figure 10.	1-4 & 7

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.