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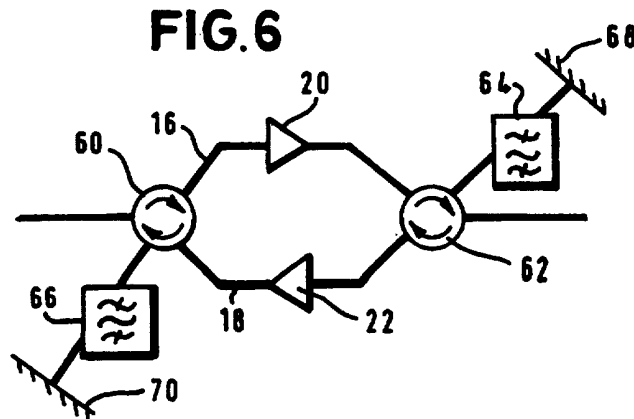
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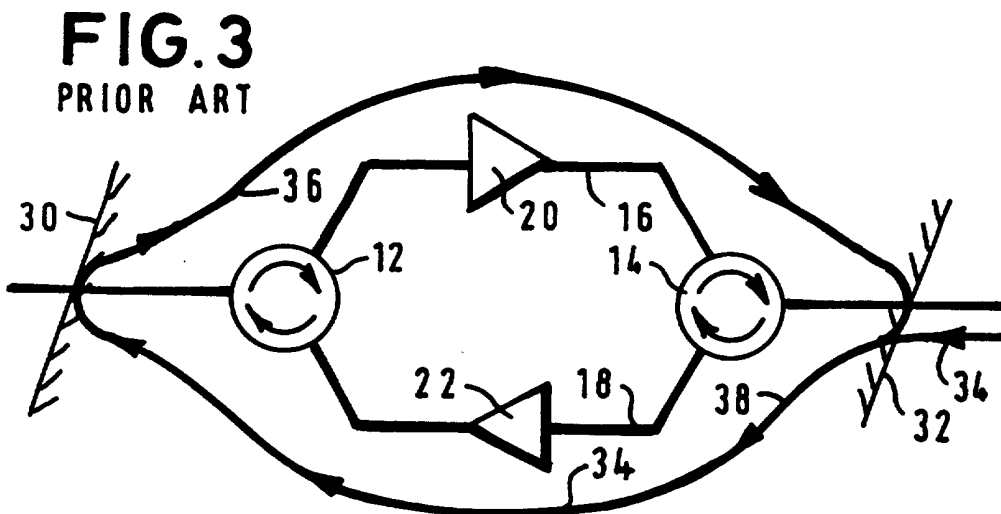
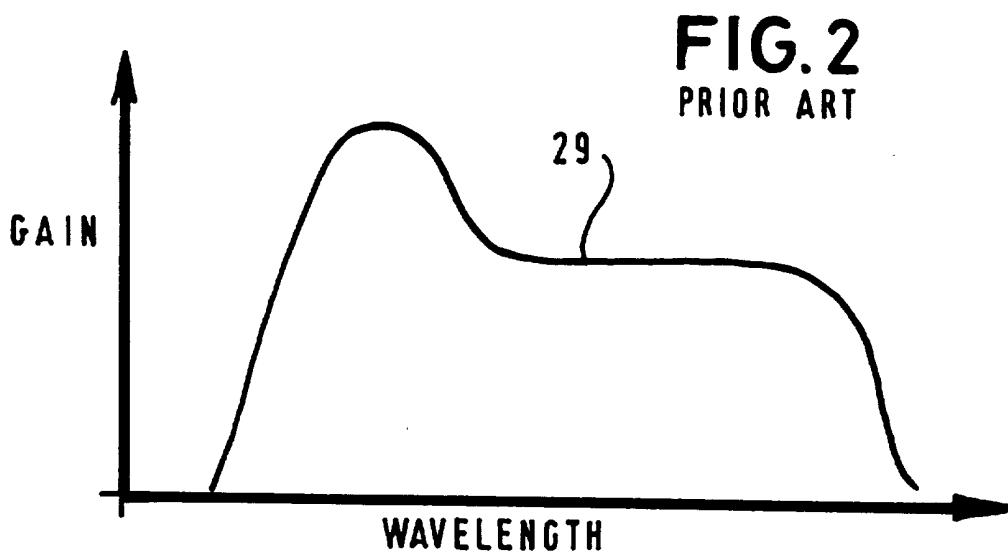
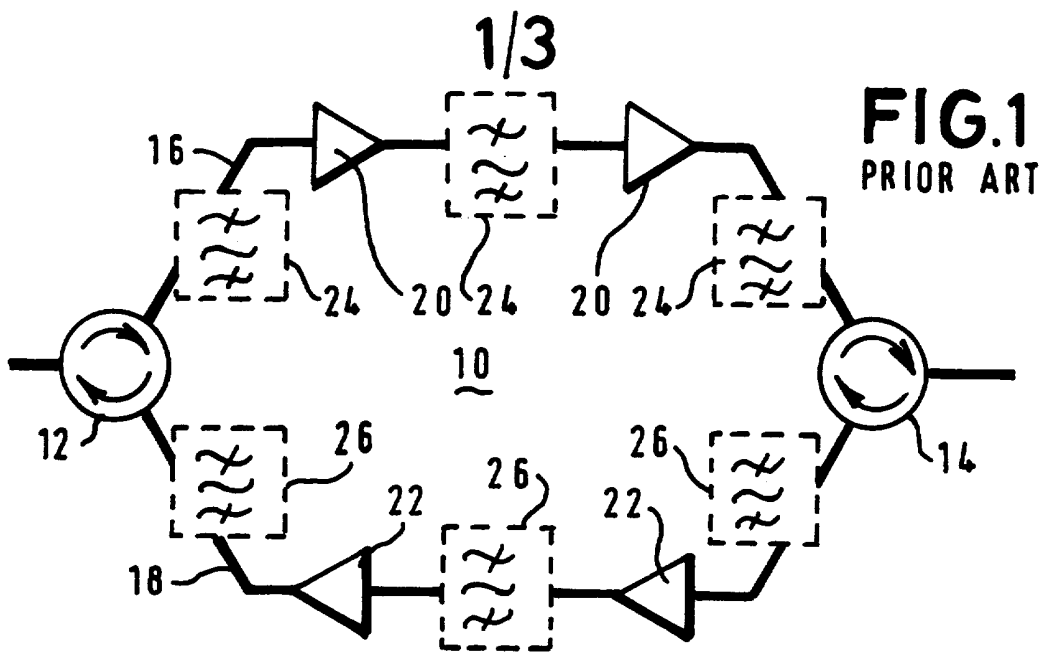
(54) Abstract Title  
**Optical frequency channel assignment plan and filtering technique to support it**

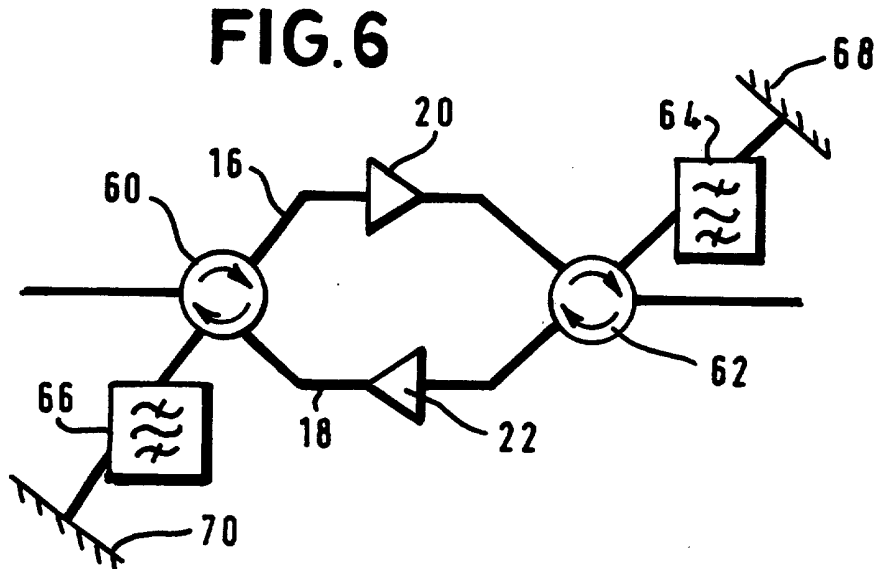
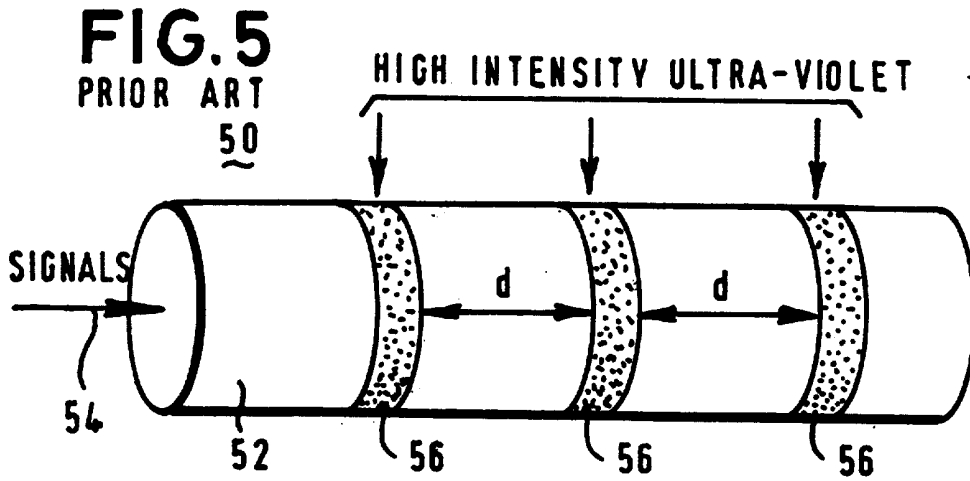
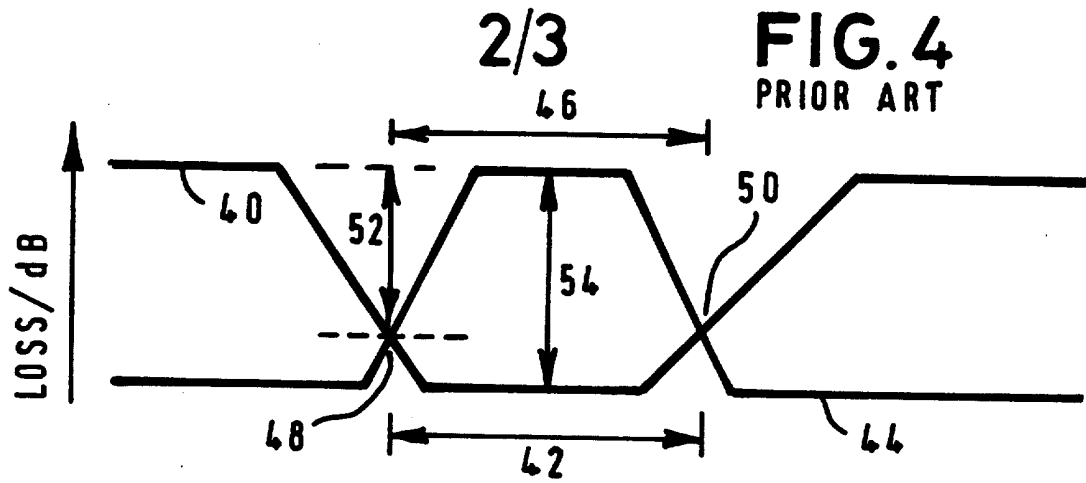
(57) In order to reduce four wave mixing between wavelength channels in a bidirectional optical fibre system the channels are assigned as follows: Each channel is mutually exclusive with respect to wavelength. At least one of the two communication directions has at least one pair of channels having adjacent wavelengths. Each direction also has at least one other channel which is not adjacent to this pair.

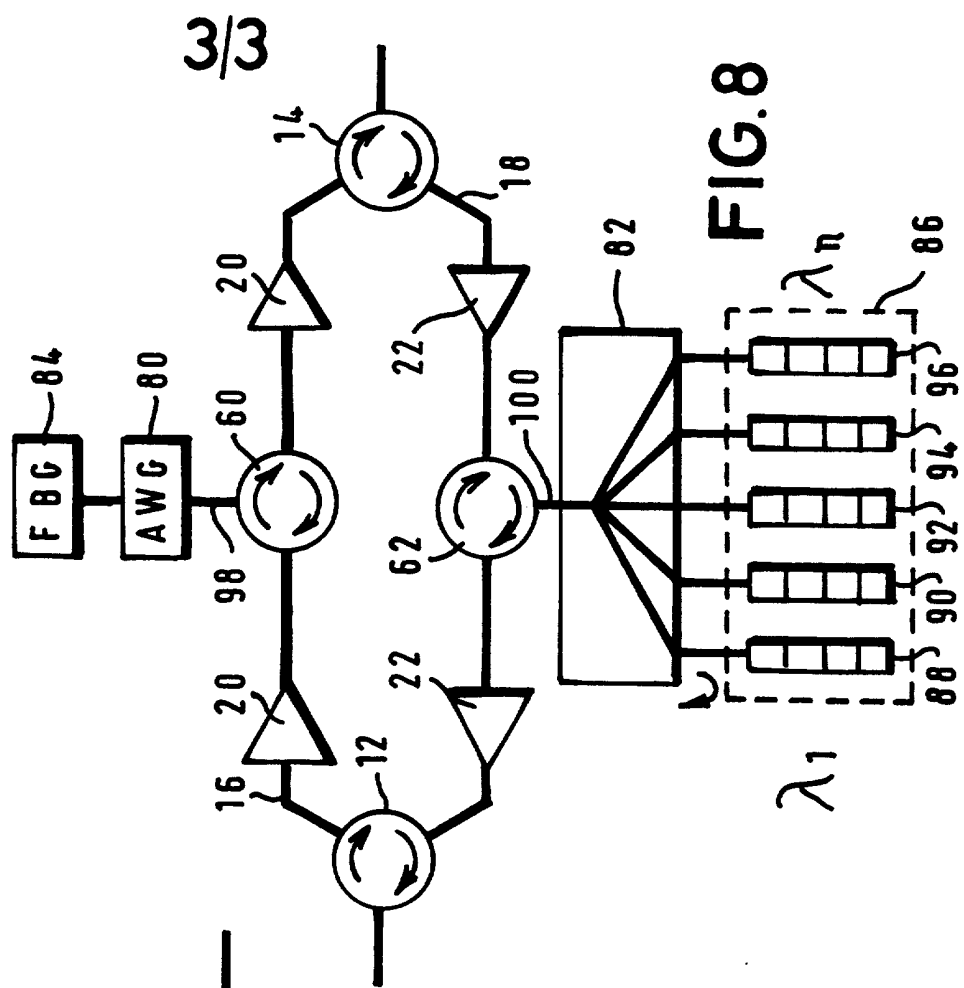
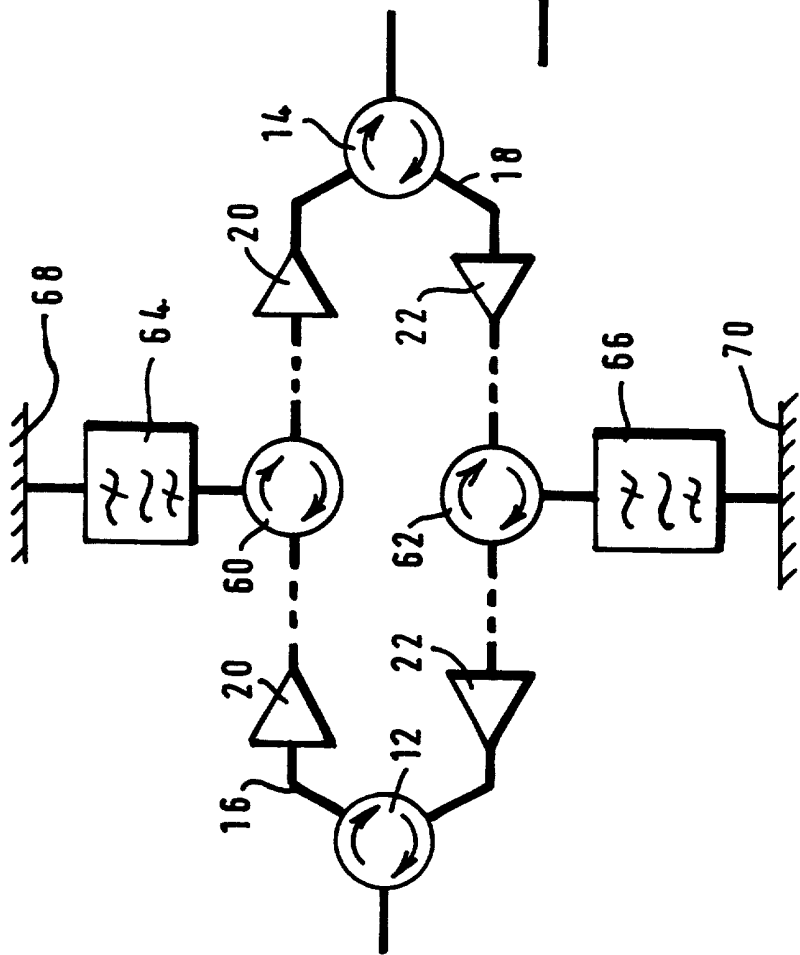
To support this interleaving of optical channels and to provide sufficient isolation between them an optical filtering circuit is used. This circuit comprises two circulators 60 and 62, optical fibres 16 and 18, amplifiers 20 and 22, transmission filters 64 and 66 and mirrors 68 and 70. Broadband signals, containing a plurality of adjacent channels, entering this circuit are routed via one circulator, 60 or 62, through one of the filters, 64 or 66, to isolate, on an individual basis, at least one desired channel. This filtered signal, is then reflected back into the filter 64 or 66, by the mirror 68 or 70, such that the at least one desired channel is subjected to a second filtering process that further improves its isolation. Following this second filtering process the at least one desired channel exits the circuit via the other circulator 62 or 60. Other optical circuits, utilising four circulators are also disclosed.



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**CIRCUIT AND CHANNEL ASSIGNMENT PLAN  
FOR OPTICAL TRANSMISSIONS**

Background to the invention

5 This invention relates, in general, to an optical transmission plan and optical amplifier circuit therefor, and is particularly, but not exclusively, applicable to a bi-directional wave division multiplexed (WDM) amplifier circuit and a channel assignment plan for optical transmissions therein.

10 Summary of the Prior Art

One method of increasing the transmission capacity of an optical fibre is to use wavelength division multiplexed (WDM) channels. Indeed, in this respect, optical amplifier designs have been optimised for WDM operation. For example, in uni-directional systems, all the WDM channels will be transmitted through the transmission fibre in the same direction, while an alternative, bi-directional transmission configuration has some channels within the fibre travelling in one direction and other channels travelling in an opposite direction. This latter system configuration offers a number of advantages, especially in relation to the number of redundant transmission terminals required for reliability. As such, optical amplified designs are currently being optimised for bi-directional transmission.

One particular mechanism by which bi-directional transmission are optimised is provided by splitting the available channels into distinct operating bands, one for each direction. These bands are sometimes referred to as the 'blue' and 'red' bands, and can contain varying numbers of channels. For example, the blue band may have channels based within a wavelength range of 1527 to 1540 nanometres (nm), while the red band may have channels based within a wavelength range of 1545nm to 1560nm. Each channel supports information

transfer through the modulation of data onto a carrier frequency (generated by a laser). In an optical system, typical modulation techniques include amplitude and phase modulation, and frequency shift keying (FSK).

- 5 As will be understood, WDM channel allocation is typically based on the International Telecommunications Union (ITU) standardised wavelength grid, and is therefore subject to specified minimum channel spacing. Specifically, the present ITU standard requires a channel spacing of 100 GigaHertz (GHz), with possible channel combinations using multiples of this 100 GHz channel spacing. In practice (and bearing in mind the constraints imposed by laser light resolution), each band can support sixteen channels having a 100 GHz spacing regime, i.e. thirty-two channels in total.

15 Unfortunately, as channel spacing decreases, each channel suffers from higher levels of performance degradation due to multi-channel operation. Specifically, the superposition of harmonics results in significant detrimental effects on data integrity within a specific channel. More particularly, in an optical transmission system, densely packed channels exhibit an intermodulation product, known as "four-wave mixing". Basically, the degradation from the intermodulation product

20 arises from sidebands being superpositioned on or about adjacent optical channels, with each sideband generated as a consequence of the spacing between adjacent channels. Increasing the channel separation therefore improves transmitted signal integrity, but this improved performance only results from sacrificing overall transmission capacity.

25

One way to maintain the same total number of channels in a bi-directional amplifier, whilst reducing the channel degradation arising from an intermodulation product is to adopt an interleaved channel plan in which adjacent channels propagate in opposite directions. In practice, this means that

30 the channel spacing between adjacent channels in one direction has been

doubled, with the effects on adjacent co-propagating channels accordingly reduced. An additional advantage of this scheme arises from the distribution of the "dead band" in which channels cannot be used. Specifically, in relation to a dual band system in which distinct bands are allocated for up-link and down-link transmissions, it is imperative that the bands be separated, (isolated) to prevent corruption of data. Unfortunately, in any attenuated system (as implemented within a filter, for example) isolation is dependent on operating parameters of the actual attenuation devices. In the specific case of filters in an optical system, the filters have a response curve that gradually rises and gradually tails off. Consequently, a minimum extinction zone must exist between the separate channel bands, with the width of the extinction zone necessarily excluding any overlap potentially arising from the lead-in or tail-off profiles of the filter response characteristics. In other words, the rate of increase of attenuation against wavelength (termed "roll-off") that is achievable between the channel bands through filtering produces a portion of the bandwidth that cannot be used for communication information; this is the overlapping region of the "dead band". In an interleaved case, the channel spacing in one direction is doubled and so the filter edges are steep enough not to lose a channel slot due to dead bands. Indeed, in practice, the dead band is distributed across the whole of the operating bandwidth, and so the optical system is able to increase the total number of available channels.

Although it will now be understood that interleaving in an optical transmission system is desirable, the problems associated with the provision of a suitable optical amplifier discourage the implementation of such interleaved schemes. Specifically, the design of a suitable optical amplifier is presently both complex and expensive. Consequently, with the development of a new and improved architecture for an optical amplifier, interleaved optical transmission systems could and would be implemented more frequently, which systems would therefore provide an improvement in the standard, quality and rate of

information transfer, as will be appreciated.

### Summary of the Invention

5 According to a first aspect of the present invention there is provided a method of assigning a band of optical channels to an optical fibre arranged to support bi-directional communication in an up-link and a down-link, the band of optical channels having adjacent wavelengths, the method arranged to reduce intermodulation in each of the up-link and down-link by assigning to at least one of the up-link and the down-link at least one pair of channels having adjacent  
10 wavelengths in the band of optical channels, wherein assignment of channels to the up-link and down-link are mutually exclusive and each of the up-link and the down-link comprises at least one other optical channel having a wavelength not adjacent to said at least one pair of channels.

15 In particular embodiments, the optical channels in the up-link and down-link are separated by no more than two contiguous optical channels. Alternatively or additionally, at least one of the up-link and the down-link comprises at least two pairs of adjacent optical channels, the at least two pairs being separated by no more than two adjacent channels.

20

In a second aspect of the present invention there is provided a circuit responsive to a broadband optical signal supporting a plurality of channels, the circuit comprising: a directional coupler arranged to receive the broadband optical signals and configured to provide an output signal; a filter, responsive to  
25 the output signal, having a characteristic arranged to isolate from the output signal at least one desired channel on at least one filtered output; and a reflector coupled to the at least one filtered output and arranged to reflect the at least one filtered output back into the filter such that the at least one filtered output is subjected to a second filtering process that improves isolation of the at  
30 least one desired channel.



In another aspect of the present invention there is provided a method of isolating at least one desired optical channel from a broadband optical signal applied to a filter, the broadband optical channel supporting a plurality of channels and the filter having a characteristic arranged to isolate the at least one desired channel, the method comprising the steps of: filtering the  
5 broadband optical signal to produce a filtered output signal containing the at least one desired channel; and re-filtering the filtered output signal in the filter to isolate further the at least one desired channel.

10

#### Description of the Drawings

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

- FIG. 1 illustrates a block diagram of a prior art optical amplifier;  
15 FIG. 2 illustrates a typical profile for an Erbium window;  
Fig. 3 illustrates the oscillation and multi-path interference routes in the optical amplifier circuit of FIG. 1;  
FIG. 4 illustrates a filter characteristic that satisfies the operational requirements of a bi-directional WDM amplifier arrangement of a preferred  
20 embodiment of the present invention;  
FIG. 5 illustrates a prior art fibre-based Bragg grating;  
FIG. 6 shows a block diagram of a preferred embodiment of the present invention in which a double pass of an optical filtering element is achieved;  
FIG. 7 shows a block diagram of an alternative embodiment of the present  
25 invention in which a double pass of an optical filtering element is achieved;  
and  
FIG. 8 shows a block diagram of yet another alternative embodiment of the present invention in which a double pass of an optical filtering element is achieved.

Detailed Description of a Preferred Embodiment

For a bi-directional optical transmission, an aspect of the present invention has identified several channel allocation schemes that generally reduce interference from that associated with a conventional single interleaved structure in which alternate (rather than adjacent) carrier frequencies are assigned to the up-link or down-link communication paths. The conventional interleaved structure is identified as scheme A in Table 1 below. As a key to understanding the channel allocation scheme presented in the table, channel numbers that are shown in *italic underlining* are all uni-directional channels and, as such, are each assigned (on a mutually exclusive basis) to either the up-link or down-link. For example, in scheme A, channel numbers 1+2n (where n is zero or a positive integer) are all assigned to the down-link, while channel numbers 2+2n (where n is zero or a positive integer) are all assigned to the up-link. Clearly, it is an arbitrary decision whether these channel allocation are reversed for the up-link and down-link.

Table 1

#	Channel Number															
A	1	<u>2</u>	3	<u>4</u>	5	<u>6</u>	7	<u>8</u>	9	<u>10</u>	11	<u>12</u>	13	<u>14</u>	15	<u>16</u>
B	1	2	<u>3</u>	<u>4</u>	5	6	<u>7</u>	<u>8</u>	9	10	<u>11</u>	<u>12</u>	13	14	<u>15</u>	<u>16</u>
C	1	<u>2</u>	<u>3</u>	4	5	<u>6</u>	<u>7</u>	8	9	<u>10</u>	<u>11</u>	12	13	<u>14</u>	<u>15</u>	16
D	1	2	<u>3</u>	4	<u>5</u>	<u>6</u>	7	8	<u>9</u>	<u>10</u>	11	<u>12</u>	13	14	<u>15</u>	<u>16</u>
E	1	<u>2</u>	3	<u>4</u>	5	<u>6</u>	<u>7</u>	8	9	<u>10</u>	11	<u>12</u>	13	<u>14</u>	<u>15</u>	16

→ λ<sub>0</sub>

Although Table 1 is indicative of a sixteen channel system, the patterns provided in relation to the channel allocation mechanisms of scheme B though scheme E can be extended or truncated to systems containing, respectively, more or fewer channels, as will be understood. The channels may

be evenly spaced, but in all cases an increasing channel number is indicative of an increased wavelength of a channel carrier. Additionally, although the up-link and down-link are considered to contain the same numbers of channels, this need not be the case. Furthermore, it is assumed that the fibre design parameter lambda zero ( $\lambda_0$ ) is located beyond, i.e. at a longer wavelength, the largest channel number. As will be understood, the efficiency or effectiveness of four-wave mixing also depends upon a relative positioning of each channel in relation to  $\lambda_0$ , with reduced intermodulation products (from non-coherent combinations) occurring with a lengthening in distance away from  $\lambda_0$ ,

10

In the specific instances of schemes B, C, D and E of Table 1, it can be seen that their individual channel allocation schemes are arranged to produce a reduced four-wave mixing through the provision, in each of the up-link and down-link, of at least one pair of contiguous channels (from an available operating spectrum), with the channels in the up-link and down-link being mutually exclusive. Furthermore, in terms of the channel spacing, there is no more than a separation of two contiguous channels from a respective sequence of channels for either the up-link or down-link. Thirdly, there is a separation of at least two adjacent channels between adjacent contiguous pairs of directionally similar channels, perhaps best demonstrated in relation to schemes B and C of Table 1.

20

Generally, in relation to the channel allocation schemes of Table 1, sidebands of an intermodulation product are not successively superimposed on the evenly spaced channels because the variations in channel separation reduce the four-wave mixing phenomena.

25

Referring now to Fig. 1, a block diagram of a prior art optical amplifier circuit 10 is illustrated. Specifically, the optical amplifier circuit 10 contains a circulator 12-14, a WDM splitter or another equivalent component that isolates and then

30

routes incident signals in an identified directions only (hereinafter generically termed "directional couplers") at the respective inputs to the alternate transmission paths 16-18.

- 5 As will be understood, the circulators 12-14 operate on a directional basis and provide separation of bi-directional signals whilst maintaining isolation between the bi-directional components of the incident data transmissions. In other words, the circulators 12-14 operate to direct communication traffic (supported on the optical channels) along a predefined path and therefore to prevent a first path  
10 16, e.g. an up-link, from merging and interfering with a second path 18, e.g. a down-link, at a circuit juncture.

The optical amplifier circuit 10 further includes a separate amplification module 20-22, typically having two amplification stages, for each direction 16-18.  
15 Furthermore, in order to isolate and correctly amplify the separate directional band, filters 24-26 must be included to attenuate unwanted optical channels associated with the directionally opposing transmission path. These filters 24-26 therefore necessarily operate in a selective bandpass mode, and typically take the form of a comb filter, or the like, that is arranged to eliminate undesired  
20 wavelengths (i.e. channels). For example, in the case of the regular interleaved channel allocation scheme A (of Table 1), the comb filter is arranged to screen out the carrier frequencies associated with every other channel. Clearly, when considering both transmission paths 16-18, the combs on each filter 24-26 would have an inverse but complementary relation.

25 Typically, the amplification functions are provided by broadband gain (amplification) blocks having Erbium window profiles, while the filters are constructed from components that allow light to propagate in a single direction, as will be readily appreciated. For example, the filters are more typically  
30 realised by a multi-layer optical dielectric filter that exhibits local

transmission/reflection properties, or waveguide devices or transmissive Bragg gratings.

The filters 24-26 of FIG. 1 can, however, be located at a number of alternative  
5 positions in each transmission path 16-18 of the optical amplifier circuit 10. This  
is indicated in the diagram by the fact that the filters 24-26 are shown in dotted  
outline. Specifically, a filter can be positioned before the amplification module,  
between the amplification stages (perhaps at an intersection position), or after a  
second one of a pair of serially coupled amplification stages. Each different  
10 position does, however, effect the performance of the optical amplifier circuit in  
a different way. Specifically, if amplification occurs before the first amplification  
module, there is a direct impact on amplifier noise performance that arises from  
noise being amplified; this is clearly undesirable. Placing a filter 24-26 between  
the amplification stages provides an optimum performance solution, while  
15 placing a filter 24-26 after the second serially coupled amplification stage  
impacts the obtainable maximum output power from the optical amplifier circuit  
10. The latter case is particularly attractive when considering a modular  
approach to circuit design in which two uni-directional amplifiers are combined  
using an add-on circulator/filter arrangement to produce the bi-directional  
20 optical amplifier circuit of FIG. 1.

Providing an appropriate and requisite amount of filtering for the optical  
amplifier circuit of FIG. 1 is a key design issue. In this respect, the specification  
for the comb filter must take into account two limitations, namely the need to  
25 prevent oscillation in the region of overlap between the two combs and the  
extinction (isolation) required in the rejected channels to limit sufficiently the  
adverse effects of multi-path interference (usually considered to be  
~50 decibels (dB) net round trip loss).

30 FIG. 2 illustrates a typical profile 29 for an Erbium window that demonstrates

how amplification (gain) varies with wavelength,  $\lambda$ . Specifically, after a fairly rapid parabolic rise to a maximum gain at about 15% of the window, there is a parabolic drop off in gain until, at about 30%, a substantially uniform gain is achieved for a significant portion of the remaining Erbium window. Gain then  
5 tails off rapidly.

FIG. 3 illustrates the oscillation and multi-path interference routes in the optical amplifier circuit of FIG. 1. As can be seen, FIG. 3 ostensibly corresponds to the structure previously described in relation to FIG. 1, although a pair of optical  
10 connectors 30-32 are coupled to circulators 12-14 and define an edge for the optical amplifier circuit 10. The pair of optical connectors 30-32 each typically exhibits a maximum reflection level between a transmission fibre and the optical amplifier circuit defined by the Bellcore standard, i.e. a level of  $-24\text{dB}$ . Consequently, assuming that an optical channel 34 is incident on a first one of  
15 the pair of optical connectors, e.g. reference numeral 30, then the optical channel passes 34 through circulator 14, along transmission path 18, through a series combination of amplification module 22 and circulator 12 before being reflected by a second one of the pair 30 and back along transmission path 16. Similarly, a reflected signal 36 originating from the optical channel 34 passes  
20 through circulator 12, a series combination of amplification module 20 and circulator 14 before undergoing a second reflection 38 (back along transmission path 16) at the first one of the pair of optical connectors 30.

Fig. 4 illustrates a filter characteristic that satisfies the operational requirements  
25 of a bi-directional WDM amplifier arrangement of a preferred embodiment of the present invention. The filter characteristic (a plot of loss against wavelength) is, however, illustrated in an exaggerated format. More particularly, two filter characteristics are actually shown and with their respective pass bands superimposed (one on the other) to illustrate the combined properties of the  
30 filter. In other words, a filter characteristic 40 for an up-link has a passband 42

corresponding to a stop-band for a second filter characteristic 44 for a downlink. First and second points of intersection 48-50 between the first filter characteristics 40 and the second filter characteristic 44 represent a most favourable position for oscillation (i.e. a position where the entire circuit offers

5 sufficient gain in a round-trip path), with these points of intersection provided at a first level 52 corresponding to a difference in loss between the stop-band 46 of the second filter characteristic 44 and the point of intersection of the respective first and second filter characteristics. For the sake of the preferred embodiment, the first level 52 has a considered to have a level of  $-5\text{dB}$  for

10 stable operation. A second level 54 corresponding to the difference in loss between the stop-band 46 of the second filter and the passband of the first filter characteristic is associated with an isolation level required to address the effects of multi-path within the optical amplifier circuit.

15 As will be understood, oscillation in an optical circuit comprised from reflectors and amplifiers is most likely to occur at a point of highest gain, i.e. corresponding to the points of intersection 48-50 of FIG. 4. Specifically, in the event that oscillation occurs, the circular path (illustrated in FIG. 3) between reflectors acts as a cavity, whereby the circuit acts as a laser. Consequently,

20 spurious power is distributed across the frequency spectrum causing disruption of data integrity. Multi-path interference arises from the destructive combination of identical signals that have travelled different paths through the optical circuit.

It has been identified that the characteristics for operation of the optical amplifier circuit of the present invention must satisfy a requirement of 35dB gain per direction and -24dB reflectivity at the input and output stages to the amplification module. Consequently, to avoid oscillation, the points of intersection 48-50 of the filter characteristics of FIG. 4 must satisfy the following calculation:

$$35\text{dB}+35\text{dB}+(-24\text{dB})+(-24\text{dB})-(\text{first level, } 52)<-5\text{dB}$$

$$\Rightarrow \text{first level } 52 \text{ of filter characteristic} > 27\text{dB}$$

To achieve an acceptable level of multi-path interference, i.e. 1%, the following calculation must be satisfied:

$$35\text{dB}+35\text{dB}+(-24\text{dB})+(-24\text{dB})-(\text{second level, } 54)<50\text{dB}$$

$$\Rightarrow \text{second level } 54 \text{ of filter characteristic} > 72\text{dB}$$

To date, present techniques have been unable to satisfy this isolation performance, but the present invention has identified a mechanism by which a loss specification for a fibre-based Bragg grating device can be improved sufficiently through either the cascading of such gratings or through the realisation of a double pass through a filter.

A fibre-based Bragg grating 50 is illustrated in FIG. 5. The Bragg grating comprises a photosensitive optical fibre 52 that is arranged to receive incident optical signals 54. To produce the Bragg grating 50, a series of high refractive index steps 56 (relatively high with respect to a refractive index of the fibre 52) may be equidistantly spaced (at a distance  $d$ ) through the photosensitive optical fibre 52, although the Bragg grating may be chirped. These high index steps 56 are illuminated by a high intensity light beams, typically of an ultra-violet wavelength (e.g. ~200nm). The spacing between the index steps determines the reflective or transmissive properties of the grating, as will be understood. The multitude of index steps in the Bragg diffraction grating could be of the same width.



According to the present invention, a double pass of the filtering elements can be achieved by the circuit designs shown in FIG. 6 and FIG. 7.

Referring to FIG. 6, an optical amplifier circuit is shown, which circuit is  
5 substantially similar to that previously described in relation to FIG. 1. In this respect, therefore, elements in FIG. 6 that are common with FIG. 1 share common reference numerals. However, in relation to the location of the filters 24-26, these filter are not now in series with the amplification modules 20-22, but instead are positioned relative to four-port circulators 60-62. More  
10 specifically, in each of the respective transmission paths 16 and 18, a serially coupled combination of a comb transmission filter 64-66 and a broadband mirror 68-70 tap the respective four-port circulators 60-62 and give a double pass through the filter. Therefore, a signal (or channel) that is applied to an input of the four-port circulator from a particular transmission path is filtered through an  
15 appropriate comb transmission filter, reflected from the associated broadband mirror, filtered for a second time in the comb transmission filter to improve isolation, and then re-inserted into the transmission path by the four-port circulator.

20 If a modular system is desired, then the preferred embodiment of FIG. 6 can be modified to take on the appearance of FIG. 7. In this case, the four-port circulator serves as an extra circulator to the basic design of FIG. 1, which extra four-port circulator is inserted between distinct amplification stages of the respective up-link and down-link transmission paths. In this case, the  
25 amplification stages may be recognised by discrete circuit elements, which amplification stages may be separated by a considerable distance and, perhaps, be supported on different fibres. Routing of the signal through the four-port circulator is identical to the mechanism described in relation to FIG. 6.

30 In yet another embodiment of the present invention, a WDM demultiplexer can

be combined with a wavelength selective reflector to replace the comb transmission filters; this is shown in FIG. 8. Specifically, but based on the general structures of Fig. 1 and FIG. 7, each comb transmission filters 64-66 of FIG. 7 is replaced by a series combination of an array waveguide (AWG) WDM demodulator/modulator 80-82 and a reflector 84-86, such as implemented as a plurality of parallel fibre Bragg gratings 88-96. Therefore, a broadband input 98-100 (provided by an appropriate circulator 60-62 and containing adjacent channels  $\lambda_1$  to  $\lambda_n$ ) to the WDM demodulator/modulator 80-82) is split into selected individual channels (based on wavelength), which individual channels are then applied to corresponding, wavelength dependent fibre Bragg gratings (or an equivalent form of reflector) for reflection back through the WDM demodulator/modulator 80-82. As such, the selection of the individual channels in the corresponding AWG WDM 80-82 and their passages through the AWG WDM 80-82 provide the necessary levels of isolation. The multiplexer of the AWG WDM then acts to recombine the selected channels into a broadband signal that can be applied to a single fibre.

As will be appreciated, alternative technologies could be used for the comb transmission filters, WDM multiplexers and the wavelength selective reflectors. Again, in relation to the specific embodiments described in FIGs. 6 to 8 and for the sake of brevity, filtering components have been shown to be in positions relative to the amplifier (for the purposes of explanation and illustration only). In each case, the filtering components could be before, half-way along or after each amplification module, as expressly detailed and shown in relation to FIG. 1.

The present invention there advantageously provides a mechanism of assigning optical channels to reduce the effects of four-wave mixing, and realises an optical amplifier circuit that can isolate interleaved optical channels to an extent whereby a practical, bi-directional WDM amplifier can be manufactured at

relatively low cost.

It will, of course, be understood that the above description has been given by way of example only and that modifications in detail may be made within the scope of the present invention. For example, the filters of FIG. 6 and FIG. 7  
5 could be implemented from waveguide devices, dielectric filters or transmissive Bragg gratings, but all of these are unable to meet the extinction specification in a single pass design and so a double pass of a comb shaped filter would be required, as described above. An alternative structure to the solitary  
10 transmissive Bragg grating or dielectric filter, would also be realised by a combination of a serial comb filter and a notch filter. Such a combination would increase the rejection of unwanted signals to a level sufficiently high or realise a bi-directional WDM amplifier.

Claims

1. A method of assigning a band of optical channels to an optical fibre arranged to support bi-directional communication in an up-link and a down-link, the band of optical channels having adjacent wavelengths, the method arranged  
5 to reduce four-wave mixing in each of the up-link and down-link by assigning to at least one of the up-link and the down-link at least one pair of channels having adjacent wavelengths in the band of optical channels, wherein assignment of channels to the up-link and down-link are mutually exclusive and each of the up-link and the down-link comprises at least one other optical channel having a  
10 wavelength not adjacent to said at least one pair of channels.
2. The method of claim 1, wherein the optical channels in the up-link and down-link are separated by no more than two contiguous optical channels.
- 15 3. The method of claim 1 or 2, wherein at least one of the up-link and the down-link comprises at least two pairs of adjacent optical channels, the at least two pairs being separated by no more than two adjacent channels.
4. The method of claim 1, 2 or 3, wherein the optical channels each have a  
20 common bandwidth.
5. The method of any preceding claim, wherein the intermodulation is four-wave mixing.

6. A circuit responsive to a broadband optical signal supporting a plurality of channels, the circuit comprising:

a directional coupler arranged to receive the broadband optical signals and configured to provide an output signal;

5 a filter, responsive to the output signal, having a characteristic arranged to isolate from the output signal at least one desired channel on at least one filtered output; and

a reflector coupled to the at least one filtered output and arranged to reflect the at least one filtered output back into the filter such that the at least  
10 one filtered output is subjected to a second filtering process that improves isolation of the at least one desired channel.

7. The circuit of claim 6, wherein the circuit supports a bi-directional transfer of information on an up-link having a first subset of channels from the plurality of  
15 channels and a down-link comprising a second subset of channels from the plurality of channels, the first subset and the second subset having mutually exclusive channels.

8. The circuit of claim 7, wherein the circuit comprises two directional  
20 couplers interconnected by two optical fibres, a first optical fibre arranged to support the up-link and a second optical fibre arranged to support the down-link, and wherein each directional coupler has a filter and reflector associated therewith.

25 9. The circuit of claim 8, further comprising:

a first amplification module coupled within the up-link and between the two directional couplers; and

a second amplification module coupled within the down-link and between  
the two directional couplers.

10. The circuit of claim 9, further comprising third and fourth directional couplers coupled respectively within the up-link and the down-link, the third directional coupler connected within the first amplification module and the fourth directional coupler connected within the second amplification module, and  
5 wherein the filter in the up-link is coupled to the third directional coupler and the filter in the down-link is coupled to the fourth directional coupler.

11. The circuit of any one of claims 6 or 10, wherein the first subset and second subset have channels allocated thereto based on the method of any one  
10 of claims 1 to 4.

12. The circuit of any one of claims 6 to 11, wherein the filter is one of a waveguide device, a dielectric filter and transmissive Bragg grating.

13. The circuit of claim 9, wherein the filter in the up-link is coupled into the circuit after the first amplification module and the filter in the down-link is  
15 coupled into the second amplification module.

14. A method of isolating at least one desired optical channel from a  
20 broadband optical signal applied to a filter, the broadband optical channel supporting a plurality of channels and the filter having a characteristic arranged to isolate the at least one desired channel, the method comprising the steps of:

filtering the broadband optical signal to produce a filtered output signal containing the at least one desired channel; and

25 re-filtering the filtered output signal in the filter to isolate further the at least one desired channel.

15. The method of claim 14, further comprising the step of:  
reflecting the filtered output signal back into the filter prior to the step of  
30 re-filtering.

16. The method of claim 14 or 15, wherein at least one desired channel supports data transmission in an optical fibre arranged to provide bi-directional communication in an up-link and a down-link, and wherein the at least one desired channel is associated with only one of the up-link and the down-link.

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17. An allocation scheme for assigning a band of optical channels to an optical fibre arranged to support bi-directional communication in an up-link and a down-link substantially as hereinbefore described.

10 18. A circuit responsive to a broadband optical signal supporting a plurality of channels, substantially as hereinbefore described with reference to FIGs. 6 to 8 of the accompanying drawings.



Application No: GB 9715268.0  
Claims searched: 6-16 & 18

Examiner: Stephen Brown  
Date of search: 31 October 1997

**Patents Act 1977  
Further Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK Cl (Ed.O): H4B (BK12C, BKX)  
Int Cl (Ed.6): H04B: 10/12, H04J: 14/02, 14/06.  
Other: Online: WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2 281 670 A (Northern Telecom) See whole document	6 & 14 at least
X	JAPIO Abstract Accession No.: 05154987 & JP 08 110487 A (Koshin Kogaku) 30/4/96 - see abstract.	6 & 14 at least

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.





Application No: GB 9715268.0  
Claims searched: 1-5 & 17

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**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK Cl (Ed.O): H4B (BKX, BK24)  
Int Cl (Ed.6): H04B: 10/24, H04J: 14/02  
Other: Online: WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0 680 168 A2 (AT&T)	-
A	EP 0 668 675 A2 (AT&T)	-
A	US 5 390 043 (GTE)	-

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.