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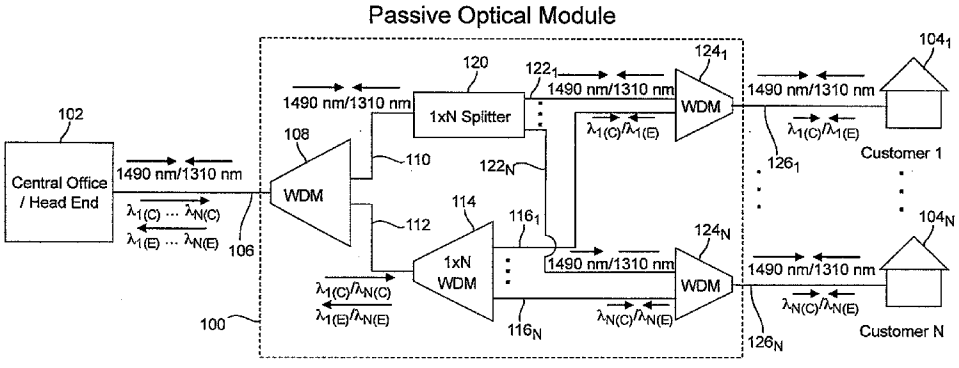


FIG. 2

(57) **Abstract:** A system for delivering multiple passive optical network services is disclosed. The system includes a first optical transmission service comprising a common wavelength pair routed from a source to each of a plurality of subscribers. The system further includes a second optical transmission service comprising a plurality of unique wavelength pairs, where each of the unique wavelength pairs is routed from the source to a subscriber among the plurality of subscribers. The system delivers the first optical transmission service and the second optical transmission service to the subscriber on a single optical fiber.

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METHODS AND SYSTEMS FOR DELIVERY OF MULTIPLE PASSIVE OPTICAL NETWORK SERVICES

Cross-Reference to Related Applications

This application is being filed on 24 October 2008, as a PCT International Patent application in the name of ADC Telecommunications, Inc., a U.S. national corporation, applicant for the designation of all countries except the U.S., and Steven C. Zimmel, a citizen of the U.S., Timothy G. Badar, a citizen of the U.S., and Trevor D. Smith, a citizen of the U.S., applicants for the designation of the U.S. only, and claims priority to U.S. Provisional Patent Application Serial No. 61/000,753 filed on 26 October 2007.

Technical Field

The present disclosure relates generally to delivery of passive optical network services, such as from an optical service provider to a home or business. More specifically, the present disclosure relates to methods and systems for delivery of multiple passive optical network services.

Background

Passive optical networks are becoming prevalent in part because service providers want to deliver high bandwidth communication capabilities to customers. Passive optical networks are a desirable choice for delivering high speed communication data because they may not employ active electronic devices, such as amplifiers and repeaters, between a central office and a subscriber termination. The absence of active electronic devices may decrease network complexity and cost and may increase network reliability.

Passive optical networks may take a signal from a single incoming fiber and make it available to a number of output fibers. For example, a distribution cable may include 24 optical fibers and may run from a central office to a distribution location, such as an equipment enclosure. At the equipment enclosure, each fiber in the distribution cable may be split into a number of outgoing fibers which are made available to subscribers. For example, passive optical networks may employ 1:2, 1:4, 1:8, 1:16 and 1:32 splitting ratios for each fiber, for making optical data available to subscriber locations.

In traditional gigabit passive optical network a single transmit wavelength and a single receive wavelength are used in each 1:32 split, requiring 32 subscribers to share bandwidth on a single fiber. However, in other systems, such as DWDM systems, dedicated wavelengths are used for each subscriber. Conversion between gigabit and DWDM systems requires substantial reconfiguration of the optical network to take advantage of the dedicated wavelength system. In certain instances, replacing wires leading to subscriber locations would be required. Such re-cabling is costly and time-consuming.

For these and other reasons, improvements are desirable.

Summary

The above and other problems are solved in accordance with the present disclosure by the following:

In a first aspect, a system for delivering multiple passive optical network services is disclosed. The system includes a first optical transmission service comprising a common wavelength pair routed from a source to each of a plurality of subscribers. The system further includes a second optical transmission service comprising a plurality of unique wavelength pairs, where each of the unique wavelength pairs is routed from the source to a subscriber among the plurality of subscribers. The system delivers the first optical transmission service and the second optical transmission service to the subscriber on a single optical fiber.

In a second aspect, a method for delivering multiple passive optical network services is disclosed. The method includes splitting a first optical transmission service from source to a plurality of subscribers, the first optical transmission service including a common wavelength pair. The method further includes separating a second optical transmission service including a plurality of unique wavelength pairs onto a corresponding plurality of optical fibers, where each optical fiber receives a unique wavelength pair associated with a subscriber among the plurality of subscribers. The method also includes routing the first and second wavelengths of the first optical transmission service and the first and second wavelengths of the second optical transmission service to the subscriber on a single optical fiber.

Brief Description of the Drawings

Figure 1 illustrates a typical network in which aspects of the present disclosure can be implemented;

Figure 2 shows a schematic view of a system for delivery of multiple passive optical network services, according to one embodiment of the present disclosure;

Figure 3 shows a schematic view of a system for delivery of multiple passive optical network services, according to a second embodiment of the present disclosure; and

Figure 4 shows a schematic view of a system for delivery of multiple passive optical network services, according to a third embodiment of the present disclosure.

Detailed Description

Various embodiments of the present invention will be described in detail with reference to the drawings, wherein like reference numerals represent like parts and assemblies throughout the several views. Reference to various embodiments does not limit the scope of the invention, which is limited only by the scope of the claims attached hereto. Additionally, any examples set forth in this specification are not intended to be limiting and merely set forth some of the many possible embodiments for the claimed invention.

In general, the present disclosure relates to delivery of multiple passive optical network services to a single endpoint, such as a household, a business, or other entity requiring a telecommunications connection to a distribution hub. The present disclosure describes a variety of passive optical network configurations which allow for selective use of one or more of the passive optical network services, thereby allowing selective upgrading of endpoints based on customer desires or requirements. The methods and systems of the present disclosure allow use of the same optical fibers already deployed to customer homes.

The present disclosure is designed to enable providers of data/video/voice services who have currently deployed fiber-to-the-premise (FTTP) distribution networks for those services, be able to upgrade customers to higher data rate & bandwidth service(s) while maintaining the other services in their current

delivery format. For example, a service provider may upgrade its data service to deliver individual customers with a 1 Gbps data line via a DWDM passive optical network (DWDM PON) while continuing to deliver voice and video to that same customer on its traditional gigabit PON (GPON). However, both would be delivered to the customer premise on the same already installed fiber. In this example, the service provider would not have to upgrade all of its delivery equipment to work with the new DWDM PON system but can use the fiber network that is already deployed in the field to deliver all of these services.

In various examples of the present disclosure, delivery of gigabit passive optical networks and DWDM passive optical networks are considered; however, deployment of additional types of optical networks is possible as well using the systems and techniques disclosed herein. For example the present disclosure also relates to delivery of other types of systems with different wavelengths and parallelism, such as WDM-PON and CWDM-PON.

Referring now to Figure 1, a generalized network in which aspects of the methods and systems of the present disclosure may be implemented. The network 10 as shown is a passive optical network (PON) such as can contain various Fiber-to-the-premises (FTTP) systems. The network 10 connects a source 102, such as a central office of a telecommunications provider, to various subscribers 104, allowing the subscribers high speed data communications to other subscribers within the network and outside of the network (through other communication channels of the source). The network 10 includes a number of fiber optic components 103 that allow the network to route specific fiber optic signals to a subset of the entire subscriber base, thereby allowing the central office 102 to manage bandwidth concerns. The components can include, for example, splices, splitters, wavelength division multiplexers, repeaters, filters, and other optical components. These components may be modularly added or removed from the fiber optic system, such as by placing various combinations of such equipment in a fiber distribution hub or other modularly extensible system. The systems of the present disclosure breakout multifiber cable down to single fiber, limited wavelength spectra to allow a small number of users to share a particular available bandwidth. For example, in the case of gigabit PON, 32 subscribers 104 typically share a single wavelength for transmitting and receiving data with the source 102. In the case of DWDM PON,

each subscriber has a dedicated wavelength pair which it uses to communicate with the source 102, thereby effectively increasing the bandwidth to that subscriber as compared to gigabit PON by eliminating competing traffic using that subscriber's communication wavelength.

Referring now to Figures 2-4, various systems for delivery of multiple passive optical network services are shown. These systems can be located within the network 10 of Figure 1, and provide at least a portion of the connecting optical components used to connect a source 102 to subscribers 104.

Referring now to Figure 2, a schematic view of a system 100 for delivery of multiple passive optical network services is shown, according to one embodiment of the present disclosure. The system 100 connects optical fibers from a source 102, shown as a central office or OLT, to one or more subscribers 104, shown as customers or ONT connections. The system receives an initial distribution fiber 106 leading from the source 102, on which all spectra of optical transmission coexist.

In the embodiment shown, the spectra of optical transmission include (1) a common wavelength pair and (2) a plurality of unique wavelength pairs. According to certain implementations the common wavelength pair is a 1310 nm wavelength and a 1490 nm wavelength used in gigabit passive optical network systems. In such systems, the 1490 nm wavelength is used to transmit data from the source 102 to all of the subscribers 104, while the 1310 nm wavelength is used by all of the subscribers to transmit data back to the source. Other common wavelengths may be used as well with different types of optical services.

The unique wavelength pairs include a predetermined number of wavelength pairs, each of which connects to a single subscriber. By dedicating a wavelength pair to each subscriber, that subscriber will not need to share the bandwidth available for that wavelength pair with other subscribers on a passive optical network, thereby allowing for higher data rates due to parallel transmission of the different unique wavelength pairs. Selection of the various unique wavelength pairs is largely a matter of design choice; however, in a possible embodiment, the wavelength pairs are the corresponding C-Band and E-Band frequencies used in DWDM data transmission.

A wavelength division multiplexer 108 is connected to the fiber 106, and separates the common wavelength signals from the unique wavelength signals. In the embodiment shown, the common wavelength gigabit PON signals (1310 and 1490 nm signals) are split to a fiber 110, while the DWDM PON signals are split to fiber 112.

The unique wavelength signals (e.g. DWDM PON signals) on fiber 112 are passed through a 1xN wavelength division multiplexer 114, which separates the signals onto N different fibers. In the embodiment shown, there are N different DWDM PON signals on fiber 112, and each of these signals is broken out onto a separate fiber $116_{1\text{-}N}$.

The gigabit PON signals on fiber 110 are passed to a splitter 120, which splits the signals into a corresponding number of optical fibers $122_{1\text{-}N}$, each carrying the common wavelength pair signals. In the embodiment shown, the splitter 120 is a 1xN splitter, corresponding to the 1xN wavelength division multiplexer 114.

Each of optical fibers $116_{1\text{-}N}$ and $122_{1\text{-}N}$ are passed into separate wavelength division multiplexers $124_{1\text{-}N}$, (of which only WDM 124_1 and 124_N are shown, for simplicity) which combine the common wavelength pair signals on the optical fibers $122_{1\text{-}N}$ with each individual (and now separated) unique wavelength pair signal on optical fibers $116_{1\text{-}N}$ to form subscriber lines $126_{1\text{-}N}$, which carry both the common wavelength pair signals and one of the sets of unique wavelength pair signals to a subscriber 104 (e.g. $104_1$and analogously to other subscribers $104_{2\text{-}N}$).

Through use of the system 100, a subscriber 104 therefore receives the common wavelength signals and one of the pairs of unique wavelength signals, allowing two different passive optical network services (e.g. gigabit PON and DWDM PON) to be delivered to the subscriber without requiring rewiring or additional wiring to the subscriber's premises.

Referring now to Figure 3, a schematic view of a system 200 for delivery of multiple passive optical network services is shown, according to a second embodiment of the present disclosure. The system 200 generally corresponds to system 100 of Figure 2 in effect, but separates and recombines the common wavelength pair and unique wavelength pairs in a slightly different manner. Specifically, the optical fiber 106 leading from the source 102 connects to

a 1x2 splitter 208, which splits, but does not filter, the common wavelength pairs and the unique wavelength pairs onto optical fibers 110 and 112. One path connects to a 1xN DWDM 214, which filters out the common wavelength signal and also splits the unique wavelength signals onto N corresponding fibers $116_{1\text{-}N}$, as previously described. The second path includes a filter 209 connected to the fiber 110, which filters out the unique wavelength pairs, leaving only the common wavelength signal on a fiber 211 leading from the filter. The fiber 211 leads to a 1xN splitter 120 as previously described, which outputs the common wavelength signals onto fibers $122_{1\text{-}N}$. The common wavelength signal, carried on each of fibers $122_{1\text{-}N}$, is combined with each individual unique wavelength signal on the fibers $116_{1\text{-}N}$ via 1x2 splitters $224_{1\text{-}N}$. The splitters $224_{1\text{-}N}$ are connected to output cables $126_{1\text{-}N}$, which connect to subscribers $104_{1\text{-}N}$.

Referring now to Figure 4, a schematic view of a system 300 for delivery of multiple passive optical network services is shown, according to a third embodiment of the present disclosure. In this embodiment, the system 300 includes an AWG DWDM 350 connecting optical fiber 106 from the source 102 to the various subscribers $104_{1\text{-}N}$. The AWG DWDM separates the unique wavelength signals, while allowing the common wavelength signals to pass to all of the output fibers $126_{1\text{-}N}$ that lead to various customers $104_{1\text{-}N}$.

Alternative designs exist in which multiple fibers are used leading from the source 104. For example, in the systems of Figures 2 and 3, above, separate fibers could be used leading from the source 104 carrying the unique wavelength pairs to the wavelength division multiplexer 114, 214 and the common wavelength pairs to the splitter 120 of Figures 2 and 3, respectively. This would eliminate the need for the wavelength division multiplexer 108 of Figure 2 or the splitter 208 and filter 209 of Figure 3. Other embodiments are possible as well which include different levels and combinations of splitters, filters, and wavelength division multiplexers.

In the embodiments shown in Figures 2-4, the systems for delivery of multiple passive optical network services are illustrated as passive optical modules. However, it is understood that the system can be configured from a number of separate components, and could include additional passive or active optical

components. Furthermore, additional optical networking components can be incorporated into networks having the systems described herein.

Through use of the systems disclosed herein, a provider of passive optical network services can connect multiple services to a single subscriber location while avoiding the need to lay additional fibers to those locations. A provider or maintainer of an optical network such as are disclosed herein can install the splitters, filters, and wavelength division multiplexers as described herein to split a common wavelength pair into a number of fibers, and to separate unique wavelength pairs onto a corresponding number of fibers. The fibers carrying the common wavelength pair can be joined to each one of the fibers carrying different unique wavelength pairs to allow connection of a subscriber to either one or both services by using a single preexisting optical fiber connected to the subscriber.

The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

Claims:

1. A system for delivering multiple passive optical network services comprising:

a first optical transmission service comprising a common wavelength pair routed from a source to each of a plurality of subscribers; and

a second optical transmission service comprising a plurality of unique wavelength pairs, each of the unique wavelength pairs routed from the source to a subscriber among the plurality of subscribers;

wherein the first optical transmission service and the second optical transmission service are delivered to the subscriber on a single optical fiber.

2. The system of claim 1, further comprising a wavelength division multiplexer configured to separate each of the unique wavelength pairs of the second optical transmission service onto separate optical fibers.

3. The system of claim 2, further comprising a splitter joining a fiber carrying the common wavelength pair with one of the fibers leading from the wavelength division multiplexer carrying one of the unique wavelength pairs to transmit the common wavelength pair and the unique wavelength pair to the subscriber on the single optical fiber.

4. The system of claim 2, further comprising a second wavelength division multiplexer joining a fiber carrying the common wavelength pair with one of the fibers leading from the wavelength division multiplexer carrying one of the unique wavelength pairs to transmit the common wavelength pair and the unique wavelength pair to the subscriber on the single optical fiber.

5. The system of claim 1, further comprising an arrayed-waveguide grating wavelength division multiplexer connecting the source to the plurality of subscribers, the arrayed-waveguide grating wavelength division multiplexer arranged to separate the unique wavelength pairs onto unique optical fibers and also transmit the common wavelength pair on each of the unique optical fibers.

6. The system of claim 1, wherein the first and second optical transmission services connect to the source on a single optical fiber.

7. The system of claim 1, wherein the source is a central office of a fiber optic communications service provider.

8. A method of delivering multiple passive optical network services, the method comprising:

splitting a first optical transmission service from source to a plurality of subscribers, the first optical transmission service including a common wavelength pair;

separating a second optical transmission service including a plurality of unique wavelength pairs onto a corresponding plurality of optical fibers, each optical fiber receiving a unique wavelength pair associated with a subscriber among the plurality of subscribers; and

routing the first and second wavelengths of the first optical transmission service and the first and second wavelengths of the second optical transmission service to the subscriber on a single optical fiber.

9. The method of claim 8, wherein, in the first optical transmission service, the first wavelength is 1490 nm and the second wavelength is 1310 nm.

10. The method of claim 8, wherein separating the second optical transmission service involves employing a wavelength division multiplexer on an optical cable carrying the plurality of wavelength pairs.

11. The method of claim 10, wherein the optical cable carrying the plurality of wavelength pairs also carries the first and second wavelengths of the first optical transmission service.

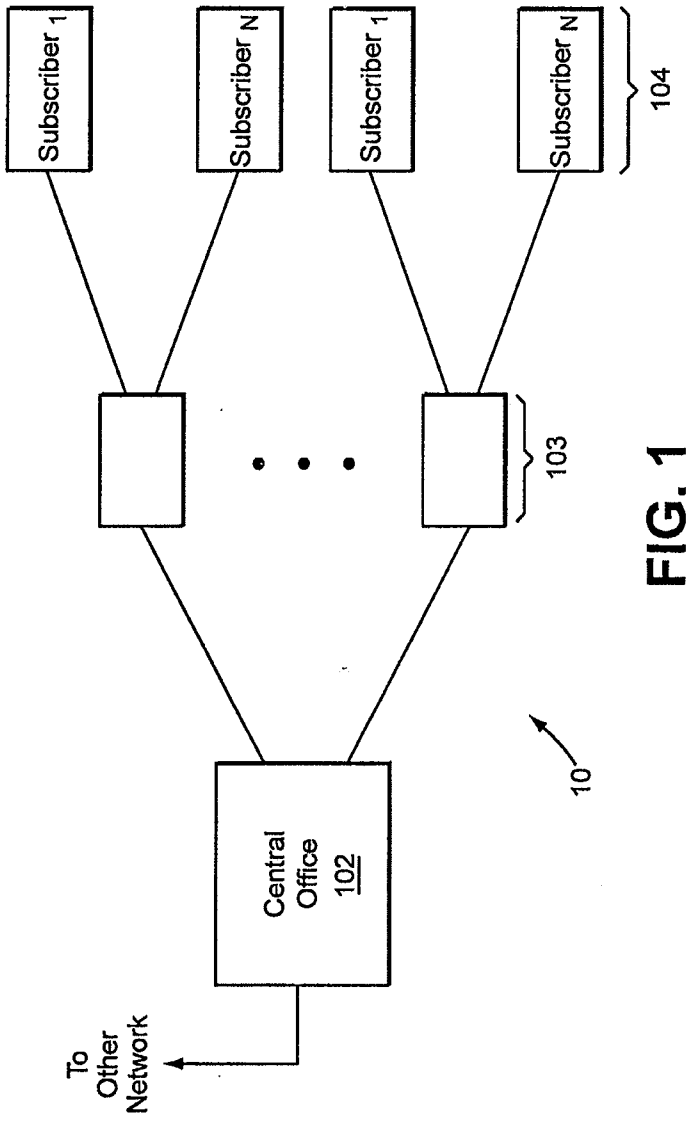

Subscriber 1
Subscriber N
Subscriber 1
Subscriber N
104
103
10
Central Office 102
To Other Network

FIG. 1

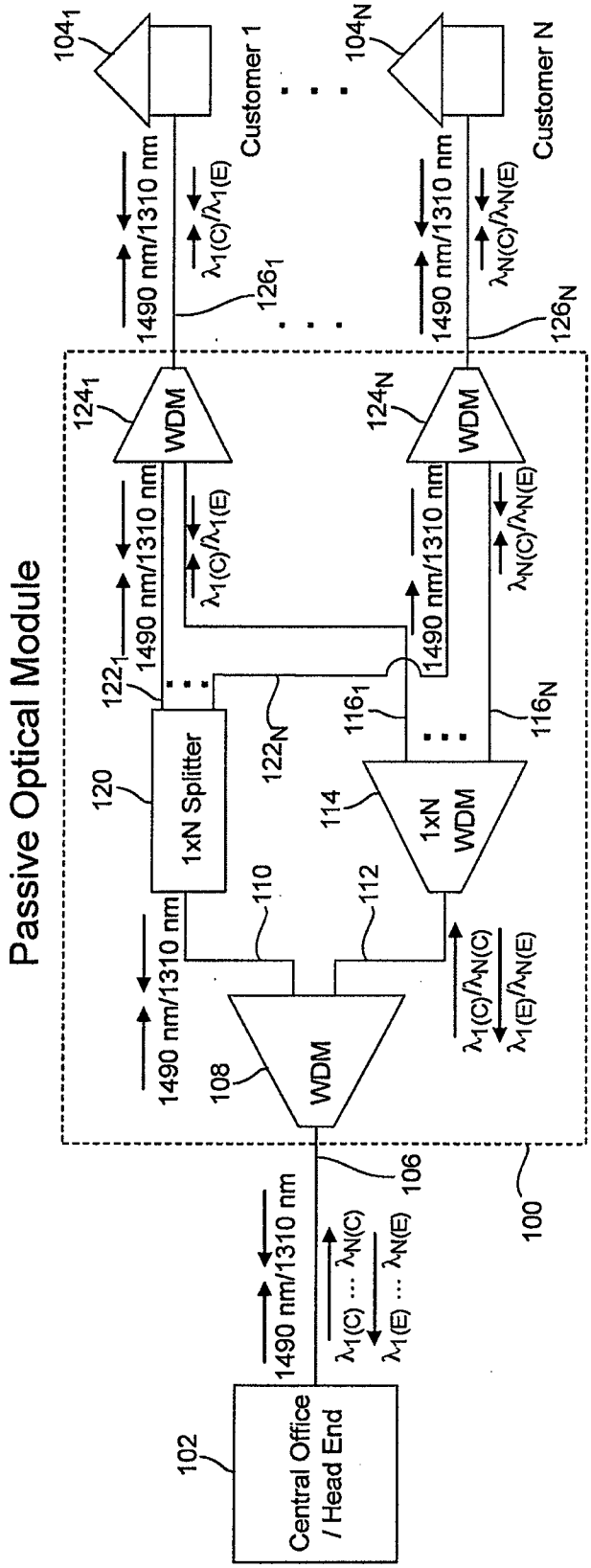

Passive Optical Module
Customer 1
Customer N
1490 nm/1310 nm
WDM
1xN Splitter
1xN WDM
Central Office / Head End
100
102
106
108
110
112
114
116
120
122
124
126

FIG. 2

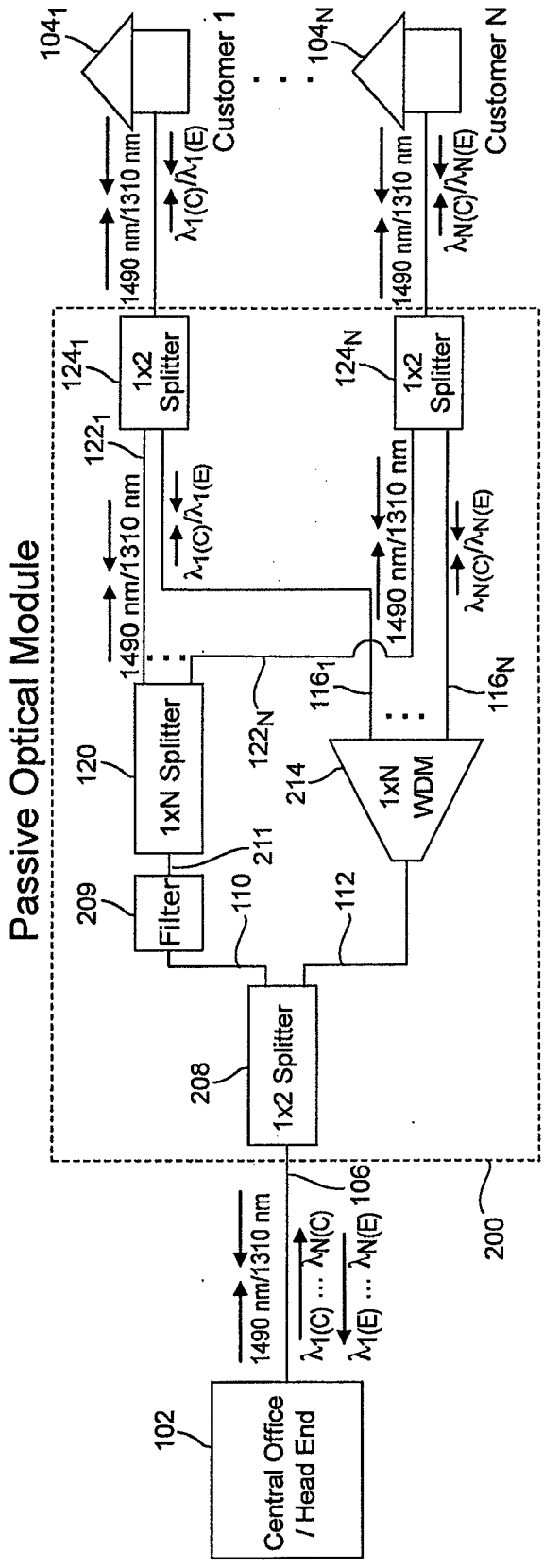

Passive Optical Module
Central Office / Head End
102
1490 nm/1310 nm
λ1(C) ... λN(C)
λ1(E) ... λN(E)
106
200
1x2 Splitter
208
Filter
209
110
112
1xN Splitter
120
211
1xN WDM
214
122N
1161
116N
1221
1241
124N
1041
1042
Customer 1
Customer N
λ1(C)/λ1(E)
λN(C)/λN(E)

FIG. 3

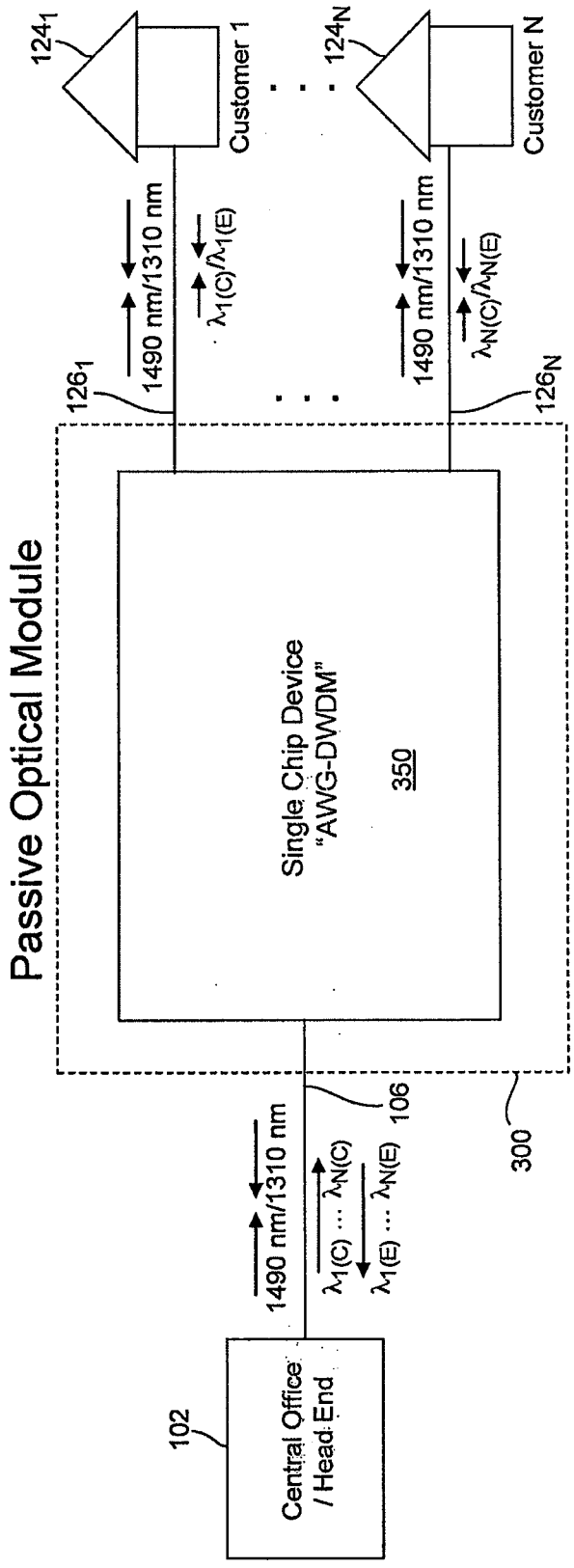

Passive Optical Module
Single Chip Device
"AWG-DWDM"
350
Customer 1
Customer N
1490 nm/1310 nm
1490 nm/1310 nm
Central Office
/ Head End
102
106
300

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/081118

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04J14/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04J H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/092361 A (AT & T CORP [US]) 16 August 2007 (2007-08-16) paragraph [0001] paragraph [0022] - paragraph [0025]; figures 3,4a,4b,5,6	1-11
X	KI-MAN CHOI ET AL: "An Efficient Evolution Method From TDM-PON to Next-Generation PON" IEEE PHOTONICS TECHNOLOGY LETTERS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 19, no. 9, 1 May 2007 (2007-05-01), pages 647-649, XP011184438 ISSN: 1041-1135 page 647, right-hand column, paragraph 1 - page 648, left-hand column, paragraph 4; figures 1,2	1-11

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
2 February 2009	16/02/2009

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/081118

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/092346 A (FUJITSU LTD [JP]; BOUDA MARTIN [US]; SMITH STEPHEN A [US]) 16 August 2007 (2007-08-16) page 9, line 3 - page 10, line 13; figure 2 page 10, line 21 - page 13, line 9 page 16, line 11 - page 17, line 3; figure 3 page 22, line 23 - page 31, line 11; figure 4	1-11
X	HILBK U ET AL: "HIGH CAPACITY WDM OVERLAY ON A PASSIVE OPTICAL NETWORK" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 32, no. 23, 7 November 1996 (1996-11-07), pages 2162-2163, XP000643881 ISSN: 0013-5194	1-8,10, 11
A	page 2162, right-hand column, paragraph 1 - page 2163, left-hand column, paragraph 3; figure 1	9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2008/081118

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2007092361 A	16-08-2007	US 2007212072 A1	13-09-2007
WO 2007092346 A	16-08-2007	NONE	