

Description

The present invention relates to optical switching systems and in particular to wavelength division multiple access switching systems which use multiple wavelengths to route data from a multiplicity of input nodes to a multiplicity of outputs nodes. In this system the switching is achieved, in part, by means of wavelength assignment schemes and by passive multiplexing and demultiplexing devices in the switching network itself.

In recent years the rapid increase in transmission speed introduced by the use of optical fibers has emphasized the need for high speed optical switches (see [13]) and such products are (e.g., NEC NEOX32 photonic switching system), or will be made commercially available. Multiple optical switch structures have been investigated (see [14] or a brief review), and as these structures consist of Time Division, Space Division and Wavelength Division switches. Optical switches fall into two major categories: non-integrated and integrated switches.

Non-integrated switches are typically intended for applications which do not require high speed re-configuration. Such systems can be simple mechanical fiber switches [3, 16] or use piezo-electric or even holographic arrays [1, 7]. Most advanced optical switches are, however, integrated switches that rely on optical couplers, splitters (demultiplexors) and combiners (multiplexors). Early work on such integrated optical switches concentrated on space switches where electronically controlled crosspoints achieved connectivity between inputs and outputs [2, 4 - 6, 10, 12, 15, 19, 20]. However, as the number of wavelengths at which lasers and optical fibers could operate increased, wavelength based switches became feasible [8]. One major advantage presented by this latter class of switches is that control of the switch can now be distributed to the inputs or outputs rather than be centralized. This helps overcome the speed limitation of electronic controllers to take full advantage of the high speed available from optical technology.

Wavelength division based switching systems fall into two categories: active and passive switches. Active switches require that the inputs/outputs of the switch are capable of adjusting the wavelength at which they are transmitting/receiving. This requires active components such as tunable lasers/filters. Examples of such systems are given in U.S. Pat. No. 3,912,876 to J.J. Muller, issued Oct. 14, 1975; in U.S. Pat. No. 3,986,020 to H. W. Kogelnik, issued Oct. 12, 1976 and in U.K. Pat. No. GB 2,043,240 A to A.M. Hill, issued Oct. 1, 1980. The use of active devices not only limits the reconfiguration time of the switches, but also requires coordinated control between all input/output connections. For example, in a system where tunable lasers are used at the inputs, the case

where two inputs tune to the same wavelengths and contend for the same output must be avoided. Similar problems exist when tunable filters are used at the outputs.

Passive optical switches avoid active components by using fixed input to output wavelength assignments so that the switching function does not require any modification of either the switch fabric or the input and output adapters, and also avoids the need for control elements. Such a system has been described in Japanese Pat. No. JA 60-237793 to K. Nagashima, issued No. 1984. This patent uses a cyclic wavelength assignment scheme which allows simultaneous communications between all inputs and all outputs. An $N \times N$ switch requires a set of N distinct wavelengths $\{W_1, \dots, W_N\}$ and an input is assigned distinct wavelengths to transmit to each of the N outputs. The output wavelength assignment is cyclically shifted from input to input to ensure that no outputs receive the same wavelength from different inputs. The cyclic assignment scheme is, however, entirely independent of the type of multiplexors and demultiplexors used in the system, and does not attempt to make use of their structure and characteristics.

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It is, therefore, an object of this invention to provide a wavelength division-based switching system with fixed wavelength assignment schemes that take advantage of the characteristics of the multiplexors and demultiplexors. This results in a simple and compact structure for the switch fabric and allows for a high level of integration.

It is also an object of this invention to provide a passive integrated wavelength division optical switching system for a wavelength division switching network.

It is another object of this invention to use N distinct wavelengths to allow simultaneous and contention free transmission between all input and output ports of an $N \times N$ switching system. In the description of the preferred embodiment, it is assumed that $N = 2^n$ where n is an integer, but other values are feasible.

It is another object of this invention to provide a wavelength assignment scheme taking into account the structure and characteristics of the demultiplexors and multiplexors to eliminate line cross-connections in the switch fabric. This assignment is, in particular, detailed for demultiplexors and multiplexors made up of Mach-Zehnder filters of the interferometer type.

It is a further object of this invention to provide a method to arrange the demultiplexors and multiplexors used in the switch fabric to obtain an integrated and compact structure. This method is again detailed for demultiplexors and multiplexors made up of Mach-Zehnder filters of the interferometer type.

In this invention, a number of (N) of input nodes having a plurality of sources are connected, through a central switching fabric, to a number (N) of output nodes consisting of a plurality of destinations. Each input node has the capability to send data simultaneously to all output nodes and, conversely, each output node can receive data simultaneously from all input nodes. Each input node uses an input interface to the switch fabric. The interface modulates wavelengths with data according to their intended output node. Similarly, each output node uses an output interface which identifies data received at a particular wavelength as originating from a given input node.

In the input interface, data for each of the N output nodes are forwarded to optical transmitters (e.g., lasers) operating at different wavelengths. Each individual data stream is used to modulate its own transmitter, and the N resulting modulated wavelengths are then multiplexed and sent over a single fiber to the central switch fabric.

In the central switch fabric the optical signals coming from each input interface are received at a switch input port, which is actually the input port of a demultiplexor of the fabric. The signals are then demultiplexed and recombined or multiplexed according

to their intended output node, before being forwarded to the corresponding switch output port, which is actually the output port of a multiplexor. The input node to output node wavelength assignment ensures that no two input nodes use the same wavelength to communicate with a given output node. In addition, the wavelength assignment is such that the demultiplexors and multiplexors used in the central switch fabric can be simply stacked and butted so as to achieve an integrated and compact structure. This aspect is detailed later in the description of the preferred embodiment.

The assignment scheme of this invention is particularly significant in that it allows for the compact structure of the switch fabric. This scheme is effected by the demultiplexors of the switching fabric. To describe the assignment scheme the method of demultiplexing $N = 2^n$ modulated wavelengths will be described for one of the demultiplexors of the switching fabric, and the assignment scheme for each other of the N demultiplexors can easily be derived from the assignment scheme for the one demultiplexor. First, N modulated wavelengths are demultiplexed by one of the demultiplexors by separating the N modulated wavelengths at a first branch point of the demultiplexor into two distinct first subgroups, each having $N/2$ modulated wavelengths. Each first subgroup is then assigned to one of a pair of first branches extending from the first branch point. Each first subgroup of $N/2$ modulated wavelengths is further separated at a corresponding second branch point on each one of the first branches into two distinct second subgroups of $N/4$ modulated wavelengths resulting in four distinct second subgroups. Each second subgroup is then assigned to one of a pair of second branches extending from a corresponding second branch point. This separation continues as above until each n -th subgroup has only one modulated wavelength therein. The n -th branches of the demultiplexor are the N outputs of the demultiplexor. Thus, for the one demultiplexor an assignment scheme of subgroups to branches is formed. N modulated wavelengths are demultiplexed in the same manner as described above for each other of the N multiplexors; however, the assignment scheme for the other demultiplexors is a permutation of the assignment scheme for the one demultiplexor with the assignment scheme of subgroups to branches being different for each of the N multiplexors. The assignment scheme does, however, have certain restrictions. First, no two outputs (n -th branches) in the same output position of any two demultiplexors have the same wavelength assigned thereto. Second, each subgroup for each assignment scheme still have the same wavelengths therein. Third, and finally, each pair of subgroups assigned to branches extending from a common branch point must always be assigned to branches extending from a common branch point in any assignment scheme. Using the above as-

signment scheme, along with its restrictions, if the modulated wavelength appearing on each output of each demultiplexor corresponds to a modulated wavelength assigned to each output (n -th branch), there will be N horizontal planes with N distinct modulated wavelengths appearing in each plane. In addition, for any given output position in the N horizontal planes, there will be N distinct modulated wavelengths. Since the same output position in N horizontal planes lies in a vertical plane, there will be N distinct modulated wavelengths in each of the N vertical planes. The N modulated wavelengths in each vertical plane are then multiplexed so that a signal having N modulated wavelengths appears at the output port of each multiplexor.

The optical signal coming out on the optical fiber at each output port of the switch fabric has N , one per input node, distinct modulated wavelengths. This signal is forwarded to a given output node where an output interface demultiplexes the N incoming modulated wavelengths and applies each of them to its own receiver. The original data coming from the N input nodes are then recovered and forwarded to their respective final destinations.

The different aspects and components of the invention are better understood with reference to the detailed drawings described below. For simplicity and clarity the number N of input and output nodes has been fixed to four (4) in all drawings. It should, however, be clear that this choice is for illustration purposes only and that the concepts can be extended to any value of N .

FIG. 1 is a block diagram of the embodiment of a switching system as described in the present invention. It consists of 4 input nodes, 4 input interfaces, a central switch fabric, 4 output interfaces and 4 output nodes. Each input interface is connected to the optical switch fabric by a dedicated optical fiber. Similarly, outgoing dedicated optical fibers connect the optical switch fabric to the 4 output interfaces which are, in turn, connected to their respective output node.

FIG. 2 is a block diagram of an input interface suitable for use in the Wavelength Division Switching Network system shown in FIG. 1.

FIG. 3 is a representation of a demultiplexor of the switch fabric used in this invention.

FIG. 4 is a table showing the corresponding between wavelengths, to be modulated and transmitted, and a given input port and selected output port.

FIG. 5 is a schematic illustration of a 4×4 central switching fabric with 4 demultiplexors each of whose outputs lie in a horizontal plane. Also shown are the inputs of two of the four multiplexors, each of whose inputs lie in a vertical plane.

FIG. 6 is a block diagram of an input interface suitable for use in the switching system shown in FIG. 1. The output interface assumes again that the central switching fabric has 4 inputs and 4 outputs.

The embodiment of the invention described below is in the context of a switching system for a digital network. An overview of the wavelength division switching network system is first provided with reference to FIG. 1 while a more detailed description is given with reference to FIGS. 2-6. For simplicity, the size of the system is taken to be $N = 4$, and this number is used in all figures.

In the system described in FIG. 1, four input/output nodes (111-114/131-134) labeled A through D, have ports coupled to the central switching fabric through input/output interfaces 115-118/135-138 so that any input node may communicate with any other output node. Also schematically illustrated in FIG. 1 are the input ports 151i-154i and output ports 161o-164o of the central switching fabric 150. Each of the input ports are actually input ports of demultiplexors of the switching fabric, while the output ports are actually output ports of the multiplexors of the switching fabric. Each input/output interface is, on one side, coupled to the corresponding input/output node while the other side is connected to the switch fabric 150 by means of an optical link. With reference to FIG. 1, optical links from input interfaces A through D are represented by the links 151-154 respectively. Similarly, the optical links from the central switching fabric to output interfaces A through D are represented by the links 161-164 respectively. In this embodiment of the switching system, the optical channels consist of single mode fibers. Other types of fibers could possibly be used.

Each input interface receives data from its input node destined to any of the N output nodes. Data destined to different output nodes are forwarded to optical transmitters operating at different wavelengths such that, for every input interface (or input port), each wavelength is uniquely associated to a given output interface (or output port), and no two input interfaces (or input ports) use the same wavelength to communicate with a given output. A particular wavelength assignment satisfying these requirements while taking into account the structure of the multiplexors and demultiplexors used is detailed below. Each input interface also receives a clock signal (e.g., MCKA for input interface 112) from its input node. This clock signal is used to generate the various clocks needed in each input interface. It should be noted that the clock signals provided by the different input nodes to the input interfaces need not be identical. In other words MCKA, MCKB, MCKC and MCKD can all be distinct. This allows the system to operate asynchronously.

In each input interface a multiplexor multiplexes the optical signals at different wavelengths destined to different output nodes. The output of each input interface (115-118) is coupled to one of the optical fiber links (151-154). Each outgoing optical link is connected to one of the input ports 151i-154i of the central

switching fabric 150. Within the central switching fabric 150, the optical signal, having N modulated wavelengths from each input port is first demultiplexed into its N distinct modulated wavelengths (one for each output node). A modulated wavelength is a wavelength that has been modulated by data to be transmitted. The N distinct modulated wavelengths from all N input ports and headed for the same output node are then re-multiplexed and forwarded to the corresponding central switching fabric output port, which is an output port of a corresponding multiplexor. Each central switching fabric output port corresponds to a given output node to which it is linked by means of an optical fiber link connected to the associated output interface (links 161-164 connected to output interfaces 135-138 respectively).

The optical signal carried by each optical link (161-164) coming from the central switching fabric 150 is received by the corresponding output interface (135-138 respectively). Each output interface demultiplexes the received optical signal into its N distinct modulated wavelengths. Each modulated wavelength carries data coming from a different input node. After the optical signals from different wavelengths have been demultiplexed and the information they carried received, data are made available to the output node which then forwards them to their final destination. Each output node provides a clock signal (RCKA, RCKB, RCKC and RCKD for output nodes 131-134 respectively) which is used to synchronize how data are read from the output interface. Note again that the clock signals from different output nodes need not be identical.

A more detailed description of the wavelength division switching system described above is now provided. The structure of an input interface is first detailed and possible implementations of the transmitters and the multiplexor are discussed. The structure of a central switching fabric based on using Mach-Zehnder filters is then briefly explained, and the wavelength assignment is presented and related to the switch fabric itself. Finally, the structure of the output interface is detailed. The descriptions are made with reference to FIG. 2 to FIG. 6 and $N = 4$ is assumed.

As shown in FIG. 2 an input interface receives simultaneously four data streams, one for each output node. It is assumed that the four signals are received byte-wise and are stored in separate buffers (220, 230, 240 and 250 for output nodes A, B, C and D respectively). The byte format of the received data is used for illustration purposes only and any other format could potentially be used. The write clock (WCK) for the buffers is provided by a clock generator 210 to each of the four buffers 220, 230, 240 and 250. The clock generator 210 also generates a read clock RCK, used to read data out of the buffers, and a bit clock BITCK eight times faster than RCK (assuming byte-wide buffers). Note that, for simplicity, one common

clock generator is used for the whole input interface. Different clock generators could, however, be used for data stream inputs destined to different output nodes as they need not be synchronized.

During each cycle of the RCK clock, data bytes are read from the buffers 220, 230, 240 and 250 and loaded into the parallel-in-serial-out shift registers 222, 232, 242 and 252. Within each cycle of RCK the 8 bits loaded into the shift registers are read out serially at BITCK and forwarded to the respective optical transmitters 224, 234, 244 and 254 each operating at a different wavelength. The output signals (modulated wavelengths of the transmitters 224, 234, 244 and 254 are then multiplexed through a multiplexor 260 and transmitted over the optical link 151.

Several solutions can be used to implement the transmitters and the associated multiplexor in the input interface. One solution integrates both the transmitter and the multiplexor on the same device. Such an approach is described in U.S. Pat. No. 3,908,121 to L.A. Riseberg et al., issued Sept. 23, 1975. Another possibility is to have separate sources and a multiplexor. In other words, the transmitters are, for example, individual lasers operating at different wavelengths and the multiplexor is a separate device such as the one described in U.S. Pat. No. 4,483,582 to S.K. Sheem, issued Nov. 20, 1984 or a Mach-Zehnder filter similar to those used in the switch fabric. As we shall see, this solution is potentially preferable as it reduces the number of distinct parts used in the system.

The wavelengths assigned to the different transmitters depend on both the output node to which the transmitters send data and the input interface where they are located. In other words, a transmitter sending data to, for example, output node A is assigned a different wavelength in each input interface. This is required so that output nodes can receive data simultaneously from all input nodes. In addition to satisfying the above requirement, the assignment schemes described in this invention takes into account the structure of the central switching fabric its purpose is best understood after describing the central switching fabric which first requires a brief explanation of the structure of the fabric.

We assume that $N = 2^n$ and that the N distinct wavelengths used are equispaced by frequency f . The structure of the fabric based on using Mach-Zehnder filters is now described. Such fabric has a tree structure where the multiplexing/demultiplexing function is gradually performed at the branch points of the tree, where a branch point has two branches extending therefrom.

With each demultiplexor of the central switching fabric, the first branch point receives modulated wavelengths $W_1, W_2, \dots, W_{2^n}$, and separates them into two equal first subgroups. One first subgroup contains all odd numbered modulated wavelengths $W_1, W_3, \dots, W_{(2^n - 1)}$, while the other first subgroup con-

tains even numbered modulated wavelengths $W_2, W_4, \dots, W_{2^n}$. Each first subgroup is then assigned to one of the pair of first branches extending from a first branch point. The partition is achieved by properly adjusting the length difference Δl_1 of the two arms of the

first branch point (Mach-Zehnder filter ($\Delta l_1 = \frac{c}{2rf}$ where c is the velocity of light in a vacuum, r is the refractive index of the waveguide, and f is the frequency spacing between wavelengths). For a more detailed explanation see reference 17. Each of the second branch points of the demultiplexor acts in a similar manner, by separating again incoming wavelengths into two second subgroups of equispaced modulated wavelengths (each second branch point uses $\Delta l_2 = \Delta l_1 / 2$). For example, the first subgroup containing modulated wavelengths $W_1, W_3, \dots, W_{(2^n - 1)}$ are partitioned into one second subgroup containing modulated wavelengths $W_1, W_5, \dots, W_{(2^n - 3)}$ and another second subgroup containing modulated wavelengths $W_3, W_7, \dots, W_{(2^n - 1)}$. Each second subgroup is then assigned to one of a pair of second branches extending from a corresponding second branch point. A similar partition is performed with even numbered modulated wavelengths. These successive partitions into smaller and smaller subgroups with alternate modulated wavelengths continue until each of the n -th subgroups consists of a single modulated wavelength, at which point the demultiplexing is completed. The frequency separation S_x between wavelengths in any x -th subgroup can be obtained by the formulas $S_x = 2^x(f)$ where f is the frequency separation in the original group of wavelengths $W_1, W_2, \dots, W_N$. Then, each n -th subgroup which consists of only one modulated wavelength is assigned to a corresponding n -th branch which is actually an output of the demultiplexor of the central switching fabric. The above assignment of first, second, ... and n -th subgroups to branches shall be referred to as an assignment scheme for a demultiplexor.

Shown in FIG. 3.1 is a schematic illustration of a demultiplexor of the switching fabric, and the associated assignment scheme for that demultiplexor. The multiplexor in this example has an input port 151, one first branch point 30, two first branches 32 and 34, two second branch points 36, 38, and four second branches or outputs 41-44. Shown are $N = 4$ modulated wavelength $W_1, \dots, W_4$ being demultiplexed into N distinct modulated wavelengths. The four distinct modulated wavelengths are separated at first branch point 30 into two distinct first subgroups with each first subgroup having $N/2 = 2$ modulated wavelengths. One first subgroup has modulated wavelengths W_1 and W_3 , while the other first subgroup has modulated wavelengths W_2 and W_4 . The one first subgroup is assigned to a first branch 32 extending from first branch point 30, while the other first subgroup is assigned to first branch 34. The first sub-

groups are then further separated at second branch points 36 and 38 to form four distinct second subgroups. Since the second subgroups have only one modulated wavelength in each second subgroup, no further separation is required. The second subgroups are assigned to corresponding second branches 41-44. This assignment of subgroups to branches is referred to as an assignment scheme for a demultiplexor of the switching fabric. The second branches in this case ($n = 2$) are actually the outputs of the demultiplexor, and these outputs will all appear in one of the N horizontal planes. The position of these outputs relative to one another is referred to as the output position in the horizontal planes. For example, W1 could be said to be in the first output position while W3, W2 and W4 could be said to be in the second, third and fourth output positions respectively. As discussed in the next paragraph, other demultiplexors of the switching fabric will also have assignment schemes similar to the above assignment schemes. Further, there will be four output positions for each of the demultiplexors, and the same output position in the four horizontal planes will appear in one of the $N = 4$ vertical planes. Once one assignment scheme for a demultiplexor is obtained, the other assignment schemes for the demultiplexors is merely a permutation of the first assignment scheme obtained. An assignment scheme, however, is not just any permutation of the original assignment scheme obtained. There are certain restrictions. First, no two outputs (n -th branches) in the same output position of any two demultiplexors have the same wavelength assigned thereto. Second, each subgroup for each assignment scheme will have the same wavelengths therein. Third, and finally, each pair of subgroups assigned to branches extending from a common branch point must always be assigned to branches extending from the common branch point in any assignment scheme. Using the above assignment schemes, along with the restrictions, if the modulated wavelength appearing on each output of each demultiplexor corresponds to modulated wavelength assigned to each output (n -th branch), there will be N horizontal planes with N distinct modulated wavelengths appearing in each plane. It should be noted that there are as many assignment schemes as demultiplexors in the switching fabric. In addition, for any given output position in the N horizontal planes, there will be N distinct modulated wavelengths. Moreover, since the same output position in N horizontal planes lies in a vertical plane, there will be N distinct modulated wavelengths in each of the N vertical planes. The N modulated wavelengths in each vertical plane are then multiplexed so that a signal having N modulated wavelengths appears at each output port of each multiplexor. Shown in FIG. 3.2 is a schematic illustration of one (550) of the four multiplexors of the central switching fabric. Note that the inputs 45-48 all lie in a

vertical plane 505. Note also that the modulated wavelengths appearing at these inputs correspond to modulated wavelengths appearing at the first output position of the four demultiplexors. See FIG. 5.

Referring to FIG. 2, there is shown a schematic illustration of the input interface (115) node A (111). The other input interfaces are similar in structure.

With reference to FIG. 2, the transmitters 224, 234, 244 and 254 are used for transmission to output nodes A, B, C and D using wavelengths W1, W2, W3 and W4 respectively. The table given in FIG. 4 gives the complete wavelength correspondence, where 'In' indicates the input interface where the transmitters are located and 'Out' gives the destination output node.

The above correspondence satisfies the requirement that each input uses different wavelengths for each output and that for a given output the wavelengths used by each input are different. The main feature of correspondence is, however, its impact on the structure of the central switching fabric as illustrated in FIG. 5 when used with the assignment scheme for each of the demultiplexors of the switching fabric.

Referring to FIG. 5, the central switching fabric 150 receives the optical signals coming from the four input interfaces A, B, C and D (115-118 of FIG. 1, respectively) on four incoming optical links 151-154 respectively. Similarly, the switch fabric forwards optical signals to the four output interfaces A, B, C and D (135-138 of FIG. 1 respectively) on four outgoing optical links 161-164). For clarity, only two (161 and 162) of the four outgoing optical links are represented in the figure.

The incoming optical links 151-154 are connected to the demultiplexors at input ports 151i-154i, respectively. These demultiplexors use Mach-Zehnder interferometer type filters and are obtained by simple modification (permutation) of the assignment scheme shown in FIG. 3.1. Such demultiplexors, as described in [18] can be implemented using an integrated wave-guide structure on a silicon substrate (other types of implementations are possible, see for example [11]). This allows for small compact devices. The different assignment schemes for the various multiplexors (510, 520, 530, 540) of the switching fabric can be obtained by simple permutation of subgroups between branches extending from the same branch point. The four assignment schemes, one for each of the four demultiplexors, are also shown in FIG. 5. Notice that the assignment scheme for demultiplexor 510 is the same as the assignment scheme shown in FIG. 3.1. Also, observe that the array of outputs of the four multiplexors and the modulated wavelengths assigned thereto corresponds to the array of wavelengths shown in FIG. 4. These permutations are chosen such that the ordering of the demultiplexed wavelengths present at the n -th branches

(outputs of the demultiplexors or "leaves") of the tree-structured demultiplexors 510, 520, 530 and 540 corresponds to the ordering specified in rows A, B, C and D respectively of the wavelength correspondence table shown in FIG. 4. Other variations of table 4 would also be permissible, such as permuting the rows or columns of table 4.

Referring again to FIG. 5, in the switch fabric the demultiplexors 510, 520, 530 and 540 are stacked on top of each other so that their output (leaves) are vertically aligned. Notice, that the outputs of each demultiplexor lie in a corresponding horizontal plane while the inputs of each multiplexor lie in a corresponding vertical plane. Shown in FIG. 5 are four such horizontal planes (501-504) and two (505-506) of four such vertical planes, although the planes could be merely two sets of planes with planes in each set being parallel or non-intersecting within the fabric. A set of the latter planes will be referred to as non-intersecting planes. However, all of the planes in the first set must intersect all of the planes in the second set. Because the wavelength assignment schemes take into account the tree-structure of the demultiplexors, the outputs of the demultiplexors which are aligned along a vertical axis carry distinct wavelengths and are destined to the same output node. This means that wavelengths destined to the same output now always lie on the same vertical axis (or in the same output position in N horizontal planes) and can therefore easily be recombined while avoiding any line crossing.

Referring to FIG. 4, the input to output wavelength correspondence is determined by the assignment scheme used to construct each demultiplexor of the switch fabric. Once the assignment of n-th subgroups to n-th branches is complete, the wavelength correspondence is set. The requirement is that for any output position of the demultiplexors used in the switch fabric all the associated wavelengths must be from distinct wavelengths. As there are $2^{\log N} = N$ permutations of the tree structure such that, for any output position of the demultiplexors, the wavelengths are distinct, it is possible to obtain the complete wavelength correspondence by systematically constructing all the above assignment schemes of the tree structure. The table of FIG. 4 illustrates this construction in the case $N = 4$. If one wishes to transmit data from input port B (152i) to output port D (164o), one could see from table 4, that one must modulate wavelength W2 with the data.

Multiplexing the wavelengths heading for a given output port simply requires that a multiplexor or coupler be vertically butted to the same output position of the horizontally stacked demultiplexors which position lies along the appropriate vertical axis, and in the N horizontal planes. Multiplexing can be achieved using either standard couplers or multiplexors symmetrical in structure to the switch demultiplexors 510, 520, 530 and 540. This approach is assumed in FIG.

5 where multiplexor 550 is symmetrical to demultiplexor 510 and, similarly, multiplexor 560 is symmetrical to demultiplexor 520. In general, it can be seen that the multiplexor for output node k is identical to the demultiplexor for input node k, where $k = A, B, C$, or D. Such a solution presents the additional advantage of decreasing the number of parts needed in the system.

The optical signals from different wavelengths and headed for the same output are recombined in the multiplexors, and then they are transmitted over optical fiber links (for example, over link 161 from multiplexor 550) which are connected to a corresponding output interface. It should be noted that the switch fabric is entirely passive and simply routes incoming optical signal to an appropriate output port.

After being sent over an optical fiber link leaving the switch fabric 150, the optical signal carrying information from all input nodes and destined to a given output node is received by the corresponding output interface. The structure of such an output interface, for example output interface 135, is described in FIG. 6. The optical signals consisting of four modulated wavelengths from wavelengths W1, W2, W3 and W4 arrive over the optical fiber link 161, for example. As mentioned earlier, the correspondence of wavelengths W1, W2, W3 and W4 to input and output ports depends on which output port they are destined for and from which input port they came. These wavelengths can be deduced by reference to the table of FIG. 4. For example, wavelength W3 from input port A (151i) corresponds to output port B (162o), and wavelength W3, from input port B (152i) corresponds to output port A. Thus, if one wished to transmit data from input port A to output port B, one would transmit the modulated wavelength W3 (modulated by the last mentioned data) through the switching fabric 150.

Referring to the output interface shown in FIG. 6, an incoming optical signal is first demultiplexed into its individual wavelength components (or into N distinct modulated wavelengths) in a demultiplexor 620, for example. The demultiplexor used can be of any type available but, as mentioned earlier, is likely to be identical to the demultiplexors used in the switch fabric so as to minimize the number of parts used in the system. Once the optical signal has been demultiplexed, each wavelength component is forwarded to its own receiver (630, 640, 650 and 660 for W1, W3, W2 and W4 respectively). Receivers 630, 640, 650 and 660 convert the optical signal into an electronic signal and provide an input to the associated clock generators 632, 642, 652 and 662. The clock generators provide two clock signals. The first one, BITCK, gives the bit clock for the received signal and is used to load bits into the serial-in-parallel-out shift registers 634, 644, 654 and 664. The second signal, WCK, is synchronized to BITCK but eight times slower. It is used to write, every cycle, the byte contained in the

shift registers 634, 644, 654 and 664 into the corresponding buffers 636, 646, 656 and 666. Note that the clock signals, WCK and BITCK, provided by the different clock generators need not be in phase or even identical.

Once the data bytes have been written into the buffers 636, 646, 656 or 666, each associated to information originating from a given input node, they are available to the output node. The output node uses the clock RCK to read data bytes out of buffers 636, 646, 656 and 666 and forwards them to their final destination.

Claims

1. Adapted to be used in a wavelength division switching network having a central switching fabric (150) which has N demultiplexors (620) with each demultiplexor having one input port (161) and N output ($W_1 - W_n$), said N outputs for each said demultiplexor lying in a single plane of a first set of N nonintersecting planes (501 - 504) of said switching fabric, said fabric also having N multiplexors (260) with each of said multiplexors having N inputs ($W_1 - W_n$) and one output port (151), said N inputs of each of said multiplexors lying in a single plane of a second set of N nonintersecting planes (505, 506) of said switching fabric, each input in each plane of said second set of planes in optical contact with only one output in only one of said first set of planes with no two inputs of said each plane of said second set of planes in optical contact with outputs on the same plane of said first set of planes, a method of transmitting from any one of said input ports of demultiplexors to any one of said output ports of said multiplexors characterized by performing the steps of:

a) for each data stream (A - D) to be transmitted to one of said output ports of said N multiplexors, modulating a particular wavelength of N wavelengths with said each data stream to be transmitted from an input port (161) on one of said N demultiplexors to an output port ($W_1 - W_4$) of a selected one of said N multiplexors, said particular wavelength corresponding to said input port and said selected output port;

b) multiplexing, for each said input port of said demultiplexors, said N wavelengths, modulated as in step (a), said N wavelengths to be transmitted to N different said output ports of said N multiplexors;

c) demultiplexing N modulated wavelengths, multiplexed in step (b), with one of said demultiplexors into distinct modulated wavelengths by separating said N modulated wavelengths

at a first branch point (30) of said one demultiplexor into two distinct first subgroups of N/2 modulated wavelengths with each first subgroup being assigned to one of two first branches extending from said first branch point, said each first subgroup of N/2 modulated wavelengths being further separated at a corresponding second branch point (36, 38) on each one of said first branches into two distinct second subgroups of N/4 modulated wavelengths resulting in four distinct second subgroups with each second subgroup being assigned to one of a pair of second branches extending from a corresponding second branch point, further separating, if necessary, said second subgroups as above until each n-th subgroup has only one modulated wavelength, with the n-th branches of said one demultiplexor being said N outputs of said one demultiplexor, thereby forming for one said demultiplexor an assignment scheme of subgroups to branches with a respective assignment scheme for each other of said demultiplexors being a permutation of said assignment scheme for said one demultiplexor when N modulated wavelengths are demultiplexed as above by each other of said N demultiplexors, the assignment scheme of subgroups to said n-th branches being different for said each of said demultiplexors, with no two outputs in the same output position of any two of said demultiplexors having the same wavelength assigned thereto, with each subgroup for each assignment scheme still having the same wavelengths therein and with each pair of subgroups assigned to branches extending from a common branch point still being assigned to branches extending from a common branch point, thereby having N distinct modulated wavelengths from said N distinct wavelengths assigned to said N outputs of said each demultiplexor, the modulated wavelength appearing on said each output of said each demultiplexor corresponding to modulated wavelengths assigned thereto, with no two modulated wavelengths from the same wavelength appearing in the same output position of two planes of said first set of N planes, thereby having N distinct modulated wavelengths from said N distinct wavelengths in the same output position in said first set of N planes, which said same output position in said first set of N planes lies in one plane of said second set on N planes, thereby having N distinct modulated wavelengths from said N distinct wavelengths appearing on said N inputs of said each multiplexor, said N inputs of said each multiplexor being in one plane of



shift registers 634, 644, 654 and 664 into the corresponding buffers 636, 646, 656 and 666. Note that the clock signals, WCK and BITCK, provided by the different clock generators need not be in phase or even identical.

Once the data bytes have been written into the buffers 636, 646, 656 or 666, each associated to information originating from a given input node, they are available to the output node. The output node uses the clock RCK to read data bytes out of buffers 636, 646, 656 and 666 and forwards them to their final destination.

Claims

1. Adapted to be used in a wavelength division switching network having a central switching fabric (150) which has N demultiplexors (620) with each demultiplexor having one input port (161) and N output ($W_1 - W_n$), said N outputs for each said demultiplexor lying in a single plane of a first set of N nonintersecting planes (501 - 504) of said switching fabric, said fabric also having N multiplexors (260) with each of said multiplexors having N inputs ($W_1 - W_n$) and one output port (151), said N inputs of each of said multiplexors lying in a single plane of a second set of N nonintersecting planes (505, 506) of said switching fabric, each input in each plane of said second set of planes in optical contact with only one output in only one of said first set of planes with no two inputs of said each plane of said second set of planes in optical contact with outputs on the same plane of said first set of planes, a method of transmitting from any one of said input ports of demultiplexors to any one of said output ports of said multiplexors characterized by performing the steps of:

a) for each data stream (A - D) to be transmitted to one of said output ports of said N multiplexors, modulating a particular wavelength of N wavelengths with said each data stream to be transmitted from an input port (161) on one of said N demultiplexors to an output port ($W_1 - W_4$) of a selected one of said N multiplexors, said particular wavelength corresponding to said input port and said selected output port;

b) multiplexing, for each said input port of said demultiplexors, said N wavelengths, modulated as in step (a), said N wavelengths to be transmitted to N different said output ports of said N multiplexors;

c) demultiplexing N modulated wavelengths, multiplexed in step (b), with one of said demultiplexors into distinct modulated wavelengths by separating said N modulated wavelengths

at a first branch point (30) of said one demultiplexor into two distinct first subgroups of N/2 modulated wavelengths with each first subgroup being assigned to one of two first branches extending from said first branch point, said each first subgroup of N/2 modulated wavelengths being further separated at a corresponding second branch point (36, 38) on each one of said first branches into two distinct second subgroups of N/4 modulated wavelengths resulting in four distinct second subgroups with each second subgroup being assigned to one of a pair of second branches extending from a corresponding second branch point, further separating, if necessary, said second subgroups as above until each n-th subgroup has only one modulated wavelength, with the n-th branches of said one demultiplexor being said N outputs of said one demultiplexor, thereby forming for one said demultiplexor an assignment scheme of subgroups to branches with a respective assignment scheme for each other of said demultiplexors being a permutation of said assignment scheme for said one demultiplexor when N modulated wavelengths are demultiplexed as above by each other of said N demultiplexors, the assignment scheme of subgroups to said n-th branches being different for said each of said demultiplexors, with no two outputs in the same output position of any two of said demultiplexors having the same wavelength assigned thereto, with each subgroup for each assignment scheme still having the same wavelengths therein and with each pair of subgroups assigned to branches extending from a common branch point still being assigned to branches extending from a common branch point, thereby having N distinct modulated wavelengths from said N distinct wavelengths assigned to said N outputs of said each demultiplexor, the modulated wavelength appearing on said each output of said each demultiplexor corresponding to modulated wavelengths assigned thereto, with no two modulated wavelengths from the same wavelength appearing in the same output position of two planes of said first set of N planes, thereby having N distinct modulated wavelengths from said N distinct wavelengths in the same output position in said first set of N planes, which said same output position in said first set of N planes lies in one plane of said second set on N planes, thereby having N distinct modulated wavelengths from said N distinct wavelengths appearing on said N inputs of said each multiplexor, said N inputs of said each multiplexor being in one plane of



said second set of N planes;

and

d) multiplexing N modulated wavelengths at N inputs of each of said N multiplexors, thereby having N modulated wavelengths from said N distinct wavelengths at each single output port of said each multiplexor with each of said N modulated wavelengths at each output port being transmitted from a different input port of said N demultiplexors.

2. A method as recited in claim 1, wherein said first set of planes (501 - 504) has N parallel planes and said second set of planes (505, 506) has N parallel planes.

3. A method as recited in claim 1, wherein said first set of planes (501 - 504) has N horizontal planes and said second set of planes (505, 506) has N vertical planes.

4. Adapted to be used in a wavelength division switching network having a central switching fabric (150) which has N demultiplexors (620) with each demultiplexor having one input port (161) and N outputs (W1 - W4), said N outputs for each said demultiplexor lying in a single horizontal plane, said switching fabric thus having N parallel horizontal planes (501 - 504) with N outputs in each of said horizontal planes, said fabric also having N multiplexors (260) with each of said multiplexors having N inputs and one output port, said N inputs lying in a single vertical plane (505, 506), said switching fabric thus having N parallel vertical planes with N inputs in each of said vertical planes, each input in each vertical plane in optical contact with only one output in only one of said horizontal planes with no two inputs of said each vertical plane in optical contact with outputs on the same horizontal plane of said N horizontal planes, a method of transmitting from any one of said input ports of demultiplexors to any one of said output ports of said multiplexors characterized by performing the steps of:

a) for each data stream (A - D) to be transmitted to one of said output ports of said N multiplexors, modulating a particular wavelength of N wavelengths with said each data stream to be transmitted from an input port (161) of one of said N demultiplexors to an output port (W1 - W4) of a selected one of said N multiplexors, said particular wavelength corresponding to said input port and said selected output port;

b) multiplexing, for each said input port of said demultiplexors, said N wavelengths, modulated as in step (a), said N wavelengths to be transmitted to N different said output ports of

said N multiplexors;

c) demultiplexing N modulated wavelengths, multiplexed in step (b), with one of said demultiplexors into distinct modulated wavelengths by separating said N modulated wavelengths at first branch point (30) of said one demultiplexor into two distinct first subgroups of N/2 modulated wavelengths with each first subgroup being assigned to one of two first branches extending from said first branch point, said each first subgroup of N/2 modulated wavelengths being further separated at a corresponding second branch point (36, 38) on each one of said first branches into two distinct second subgroups of N/4 modulated wavelengths resulting in four distinct second subgroups with each second subgroup being assigned to one of a pair of second branches extending from a corresponding second branch point, further separating, if necessary, said second subgroups as above until each n-th subgroup has only one modulated wavelength, with the n-th branches of said one demultiplexor being said N outputs of said one demultiplexor, thereby forming for one said demultiplexor an assignment scheme of subgroups to branches with a respective assignment scheme for each other of said demultiplexors being a permutation of said assignment scheme for said one demultiplexor when N modulated wavelengths are demultiplexed as above by each other of said N demultiplexors, the assignment scheme of subgroups to said n-th branches being different for said each of said demultiplexors, with no two outputs in the same output position of any two of said demultiplexors having the same wavelength assigned thereto, with each subgroup for each assignment scheme still having the same wavelengths therein and with each pair of subgroups assigned to branches extending from a common branch point still being assigned to branches extending from a common branch point, thereby having N distinct modulated wavelengths from said N distinct wavelengths assigned to said N outputs of said each demultiplexor, the modulated wavelength appearing on said each output of said each demultiplexor corresponding to modulated wavelengths assigned thereto, with no two modulated wavelengths from the same wavelength appearing in the same output position of two horizontal planes, thereby having N distinct modulated wavelengths from said N distinct wavelengths in the same output position in said N horizontal planes, which said same output position in said N horizontal planes lies in one of said vertical planes, thereby having



N distinct modulated wavelengths from said N distinct wavelengths appearing on said N inputs of said each multiplexor, said N inputs of said each multiplexor being in one of said N vertical planes; and

d) multiplexing N modulated wavelengths at N inputs of each of said N multiplexors, thereby having N modulated wavelengths from said N distinct wavelengths at each single output port of said each multiplexor with each of said N modulated wavelengths at each output port being transmitted from a different input port of said N demultiplexors.

5. A method as recited in claim 4, wherein said branch points are Mach-Zehnder filters and said branches are the outputs of said filters. 15
6. A method as recited in claim 4, wherein one of said first subgroups comprises even numbered wavelengths W2, W4, W6, ... which are equally spaced by a frequency spacing 2f and the other of said first subgroups comprises an odd set of wavelengths W1, W3, W5, ... which are equally spaced by frequency spacing 2f. 20
7. A method as recited in claim 4, where two of said second subgroup comprises odd numbered wavelengths separated by frequency spacing 4f. 25
8. A method as recited in claim 4 wherein two of said second subgroups comprises even numbered wavelengths separated by frequency spacing 4f. 30
9. A method as recited in claim 4 wherein each of said x-th subgroups has wavelengths separated by frequency spacing $S_x = 2^x(f)$ where x is an integer and $1 \leq x < n$. 35
10. Adapted to be used in a wavelength division switching network having a central switching fabric (150) which has N demultiplexors (620) with each demultiplexor having one input port (161) and N outputs (W1 - W4), said N outputs for each said demultiplexor lying in a single horizontal plane, said switching fabric thus having N parallel horizontal planes (501 - 524) with N outputs in each of said horizontal planes, said fabric also having N multiplexors (260) with each of said multiplexors having N inputs and one output port, said N inputs laying in a single vertical plane, said switching fabric thus having N parallel vertical planes (505, 506) with N inputs in each of said vertical planes, each input in each vertical plane in optical contact with only one output in only one of said horizontal planes with no two inputs of said each vertical plane in optical contact with outputs on the same horizontal plane of said N 40

horizontal planes, each demultiplexor of said fabric having a tree structure with Mach-Zehnder filters as branch points of said structure with a pair of outputs from each filter being branches of said structure, a method of transmitting from any one of said input ports of demultiplexors to any one of said output ports of said multiplexors, characterized by performing the steps of:

a) for each data stream (A - D) to be transmitted to one of said output ports of said N multiplexors, modulating a particular wavelength of N wavelengths with said each data stream to be transmitted from an input port (161) of one of said N demultiplexors to a selected output port (W1 - W4) of one of said N multiplexors, said particular wavelength corresponding to said input port and said selected output port;

b) multiplexing, for each said input port of said demultiplexors, said N wavelengths, modulated as in step (a), said N wavelengths to be transmitted to N different said output ports of said N multiplexors;

c) demultiplexing N modulated wavelengths, multiplexed in step (b), with one of said demultiplexors into distinct modulated wavelengths by separating said N modulated wavelengths at a first Mach-Zehnder filter of said one demultiplexor into two distinct first subgroups of N/2 modulated wavelengths with each first subgroup being assigned to one of two first branches extending from said first Mach-Zehnder filter, one of said first subgroups having even numbered wavelengths W2, W4, W6, ..., which are equally spaced by a frequency space 2f and the other of said first subgroups equally spaced by frequency spacing 2f, said each first subgroup of N/2 modulated wavelengths being further separated at a corresponding second Mach-Zehnder filter on each one of said first branches into two distinct second subgroups of N/4 modulated wavelengths resulting in four distinct second subgroups with each second subgroup being assigned to one of a pair of second branches extending from a corresponding second branch point, each of said second subgroups having wavelengths which are equally spaced by a frequency space 4f, further separating as above, said second subgroups into equally spaced subgroups with correspondingly wider frequency spacing $S_x = 2^x(f)$ where x is the x-th subgroup, said separating continuing until each n-th subgroup has only one modulated wavelength, with the n-th branches of said one demultiplexor being said N outputs of one each demultiplexor, thereby forming for said one demultiplexor a respective assignment 55



scheme of subgroups to branches with a respective assignment scheme for each other of said demultiplexors being a permutation of said assignment scheme for said one demultiplexor when N modulated wavelengths are demultiplexed as above by each other of said N demultiplexors, the assignment scheme of subgroups to said n-th branches being different for said each other of said demultiplexors, with no two outputs in the same output position of any two of said demultiplexors having the same wavelength assigned thereto, with each subgroup for each assignment scheme still having the same wavelengths therein and with each pair of subgroups assigned to branches extending from a common branch point still being assigned to branches extending from a common branch point, thereby having N distinct modulated wavelengths from said N distinct wavelengths assigned to said N outputs of said each demultiplexor, the modulated wavelength appearing on said each output of said each demultiplexor corresponding to modulated wavelengths assigned thereto, with no two modulated wavelengths from the same wavelength appearing in the same output position of two horizontal planes, thereby having N distinct modulated wavelengths from said N distinct wavelengths in the same output position in said N horizontal planes, which said same output position in said N horizontal planes lies in one of said N vertical planes, thereby having N distinct modulated wavelengths from said N distinct wavelengths appearing on said N inputs of said each multiplexor, said N inputs of said each multiplexor being in one of said N vertical planes; and

d) multiplexing N modulated wavelengths at N inputs of each of said N multiplexors, thereby having N modulated wavelengths from said N distinct wavelengths at each single output port of said each multiplexor with each of said N modulated wavelengths being transmitted from a different input port of said N demultiplexors.

Patentansprüche

1. Angepaßtes Übertragungsverfahren zur Verwendung innerhalb eines Koppelnetzwerkes, das mit Wellenlängenteilung arbeitet und eine zentrale Vermittlungseinrichtung (150) besitzt, welche N Demultiplexer (620) hat, wobei jeder Demultiplexer einen Eingangsport (161) und N Ausgänge (W1 bis W_n) besitzt, die N Ausgänge von jedem der Demultiplexer in einer einzelnen

Ebene eines ersten Satzes von N sich nicht schneidenden Ebenen (501 bis 504) der Vermittlungseinrichtung liegen, die Vermittlungseinrichtung hat ebenfalls N Multiplexer (260), wobei jeder Multiplexer N Eingänge (W1 bis W_n) und einen Ausgangsport (151) besitzt, die N Eingänge von jedem der Multiplexer in einer einzelnen Ebene eines zweiten Satzes sich nicht schneidender Ebenen (505, 506) der Vermittlungseinrichtung liegen, jeder Eingang von jeder Ebene des zweiten Satzes der Ebenen steht mit nur einem Ausgang in nur einer Ebene des ersten Satzes der Ebenen in optischer Verbindung und niemals stehen zwei Eingänge von jeder der Ebenen aus dem zweiten Satz von Ebenen in optischer Verbindung mit Ausgängen in derselben Ebene aus dem ersten Satz von Ebenen und das Verfahren Übertragungen von jedem beliebigen Eingangsport der Demultiplexer zu jedem beliebigen Ausgangsport der Multiplexer gestattet, dadurch gekennzeichnet, daß die folgenden Schritte ausgeführt werden:

- a) für jede zu einem der Ausgangsports der N Multiplexer zu übertragende Datenfolge (A bis D) wird eine Wellenlänge von N Wellenlängen mit der Datenfolge moduliert, die von einem Eingangsport (161) von einem der N Demultiplexer zu einem Ausgangsport (W1 bis W4) eines aus den N Multiplexern ausgewählten Multiplexers übertragen werden soll, wobei die spezielle Wellenlänge dem Eingangsport und dem ausgewählten Ausgangsport entspricht;
- b) Multiplexen der N Wellenlängen für jeden Eingangsport der Demultiplexer, die entsprechend Schritt (a) moduliert sind und zu N verschiedenen Ausgangsports der N Multiplexer übertragen werden sollen;
- c) Demultiplexen der N modulierten Wellenlängen, die entsprechend Schritt b) gemultiplext worden sind, mit einem der Demultiplexer in getrennte modulierte Wellenlängen durch Trennen der N modulierten Wellenlängen an einem ersten Verzweigungspunkt (30) des einen Demultiplexers in zwei verschiedene erste Untergruppen von N/2 modulierten Wellenlängen, wobei jede erste Untergruppe einem der zwei Zweige zugeordnet ist, die von dem ersten Verzweigungspunkt ausgehen, jede der ersten Untergruppen von N/2 modulierten Wellenlängen wird weiterhin an einem entsprechenden zweiten Verzweigungspunkt (36, 38) auf jedem der ersten Zweige in zwei verschiedene zweite Untergruppen von N/4 modulierten Wellenlängen unterteilt, was vier verschiedene zweite Untergruppen ergibt, wobei jede zweite Untergruppe einem Zweig aus einem Paar zweiter



Zweige zugeordnet ist, die von einem entsprechenden zweiten Verzweigungspunkt ausgehen, wenn nötig werden die zweiten Untergruppen wie oben beschrieben weiterhin unterteilt, bis jede n-te Untergruppe nur noch eine modulierte Wellenlänge besitzt, wobei die n-ten Zweige des einen Demultiplexers die N Ausgänge des besagten Demultiplexers repräsentieren und somit für diesen einen Demultiplexer ein Zuordnungsschema der Untergruppen zu den Zweigen bilden, wobei das entsprechende Zuordnungsschema jedes anderen Demultiplexers eine Permutation des Zuordnungsschemas dieses einen Demultiplexers ist, wenn wie oben beschrieben N modulierte Wellenlängen von jedem anderen der N Demultiplexer entschachtelt werden, das Zuordnungsschema der Untergruppen zu den n-ten Zweigen ist für jeden der Demultiplexer unterschiedlich, wobei niemals zwei Ausgängen mit derselben Position des Ausgangs in jeweils zwei beliebigen Demultiplexern dieselbe Wellenlänge zugeordnet ist, wobei jede Untergruppe in jedem Zuordnungsschema immer dieselben Wellenlängen enthält und wobei jedes Untergruppenpaar, das Zweigen zugeordnet ist, die von einem gemeinsamen Verzweigungspunkt ausgehen, Zweigen zugeordnet bleibt, welche von einem gemeinsamen Verzweigungspunkt ausgehen, wodurch N getrennte modulierte Wellenlängen von den N verschiedenen Wellenlängen erhalten werden, die den N Ausgängen jedes Multiplexers zugeordnet sind, die modulierte Wellenlänge, die an jedem Ausgang jedes Multiplexers erscheint, entspricht der zugeordneten modulierten Wellenlänge, wobei niemals zwei modulierte Wellenlängen aus derselben Wellenlänge erhalten werden, die in derselben Position des Ausgangs von zwei Ebenen des ersten Satzes der N Ebenen erscheinen, wodurch man N verschiedene modulierte Wellenlängen aus den N getrennten Wellenlängen auf derselben Position des Ausgangs in dem ersten Satz der N Ebenen erhält, wobei dieselbe Position des Ausgangs in dem ersten Satz der N Ebenen in einer Ebene des zweiten Satzes von N Ebenen liegt, wodurch man N verschiedene modulierte Wellenlängen aus den N getrennten Wellenlängen erhält, welche an den N Eingängen jedes Multiplexers auftreten und diese N Eingänge jedes Multiplexers in einer Ebene des zweiten Satzes der N Ebenen liegen; und d) Multiplexen von N modulierten Wellenlängen an N Eingängen von jedem der N Multiplexer, wodurch N modulierte Wellenlängen aus den N getrennten Wellenlängen an jedem

einzelnen Ausgangsport jedes einzelnen Multiplexers erhalten werden, wobei jede der N modulierten Wellenlängen an jedem Ausgangsport von einem anderen Eingangsport der N Demultiplexer übertragen wurde.

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2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der erste Satz von Ebenen (501 bis 504) N parallele Ebenen besitzt und daß der zweite Satz von Ebenen (505, 506) N parallele Ebenen besitzt.
3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der erste Satz von Ebenen (501 bis 504) N horizontale Ebenen besitzt und daß der zweite Satz von Ebenen (505, 506) N vertikale Ebenen besitzt.
4. Angepaßtes Übertragungsverfahren zur Verwendung innerhalb eines Koppelnetzwerkes, das mit Wellenlängenteilung arbeitet und eine zentrale Vermittlungseinrichtung (150) besitzt, welche N Demultiplexer (620) hat, jeder Demultiplexer besitzt einen Eingangsport (161) und N Ausgänge (W_1 bis W_n), die N Ausgänge von jedem der Demultiplexer liegen in einer einzelnen horizontalen Ebene, die Vermittlungseinrichtung hat folglich N parallele, horizontale Ebenen (501 bis 504) mit N Ausgängen in jeder der horizontalen Ebenen, die Vermittlungseinrichtung hat ebenfalls N Multiplexer (260), wobei jeder Multiplexer N Eingänge und einen Ausgangsport besitzt, die N Eingänge liegen in einer einzelnen vertikalen Ebene (505, 506), die Vermittlungseinrichtung hat folglich N parallele vertikale Ebenen mit N Eingängen in jeder der vertikalen Ebenen, jeder Eingang in jeder vertikalen Ebene steht in optischer Verbindung mit nur einem Ausgang in nur einer der horizontalen Ebenen, wobei niemals zwei Eingänge von jeder der vertikalen Ebenen in optischer Verbindung mit Ausgängen in derselben horizontalen Ebene von den N horizontalen Ebenen stehen und wobei das Verfahren Übertragungen von jedem beliebigen Eingangsport der Demultiplexer zu jedem beliebigen Ausgangsport der Multiplexer gestattet, dadurch gekennzeichnet, daß die folgenden Schritte ausgeführt werden:
 - a) für jede zu einem der Ausgangsports der N Multiplexer zu übertragende Datenfolge (A bis D) wird eine Wellenlänge von N Wellenlängen mit der Datenfolge moduliert, die von einem Eingangsport (161) von einem der N Demultiplexer zu einem Ausgangsport (W_1 bis W_4) eines aus den N Multiplexern ausgewählten Multiplexers übertragen werden soll, wobei die spezielle Wellenlänge dem Eingangsport und dem ausgewählten Ausgangsport



entspricht;

b) Multiplexen der N Wellenlängen für jeden Eingangsport der Demultiplexer, die entsprechend Schritt (a) moduliert sind und zu N verschiedenen Ausgangsports der N Multiplexer übertragen werden sollen; 5

c) Demultiplexen der N modulierten Wellenlängen, die entsprechend Schritt b) gemultiplext worden sind, mit einem der Demultiplexer in getrennte modulierte Wellenlängen durch Trennen der N modulierten Wellenlängen an einem ersten Verzweigungspunkt (30) des einen Demultiplexers in zwei verschiedene erste Untergruppen von N/2 modulierten Wellenlängen, wobei jede erste Untergruppe einem der zwei Zweige zugeordnet sind, die von dem ersten Verzweigungspunkt ausgehen, jede der ersten Untergruppen von N/2 modulierten Wellenlängen wird weiterhin an einem entsprechenden zweiten Verzweigungspunkt (36, 38) auf jedem der ersten Zweige in zwei verschiedene zweite Untergruppen von N/4 modulierten Wellenlängen unterteilt, was vier verschiedene zweite Untergruppen ergibt, wobei jede zweite Untergruppe einem Zweig aus einem Paar zweiter Zweige zugeordnet ist, die von einem entsprechenden zweiten Verzweigungspunkt ausgehen, wenn nötig werden die zweiten Untergruppen wie oben beschrieben weiterhin unterteilt, bis jede n-te Untergruppe nur noch eine modulierte Wellenlänge besitzt, wobei die n-ten Zweige des einen Demultiplexers die N Ausgänge des besagten Demultiplexers repräsentieren und somit für diesen einen Demultiplexer ein Zuordnungsschema der Untergruppen zu den Zweigen bilden, wobei das entsprechende Zuordnungsschema jedes anderen Demultiplexers eine Permutation des Zuordnungsschemas dieses einen Demultiplexers ist, wenn wie oben beschrieben N modulierte Wellenlängen von jedem anderen der N Demultiplexer entschachtelt werden, das Zuordnungsschema der Untergruppen zu den n-ten Zweigen ist für jeden der Demultiplexer unterschiedlich, wobei niemals zwei Ausgängen mit derselben Position des Ausgangs in jeweils zwei beliebigen Demultiplexern dieselbe Wellenlänge zugeordnet ist, wobei jede Untergruppe in jedem Zuordnungsschema immer dieselben Wellenlängen enthält und wobei jedes Untergruppenpaar, das Zweigen zugeordnet ist, die von einem gemeinsamen Verzweigungspunkt ausgehen, Zweigen zugeordnet bleibt, welche von einem gemeinsamen Verzweigungspunkt ausgehen, wodurch N getrennte modulierte Wellenlängen von den N verschiedenen Wellenlängen erhalten wer-

den, die den N Ausgängen jedes Multiplexers zugeordnet sind, die modulierte Wellenlänge, die an jedem Ausgang jedes Multiplexers erscheint, entspricht der zugeordneten modulierten Wellenlänge, wobei niemals zwei modulierte Wellenlängen aus derselben Wellenlänge erhalten werden, die in derselben Position des Ausgangs von zwei horizontalen Ebenen erscheinen,

wodurch man N verschiedene modulierte Wellenlängen aus den N getrennten Wellenlängen auf derselben Position des Ausgangs in den N horizontalen Ebenen erhält, wobei dieselbe Position des Ausgangs in den N horizontalen Ebenen in einer der vertikalen Ebenen liegt, wodurch man N verschiedene modulierte Wellenlängen aus den N getrennten Wellenlängen erhält, welche an den N Eingängen jedes Multiplexers auftreten und diese N Eingänge jedes Multiplexers in einer der N vertikalen Ebenen liegen; und

d) Multiplexen von N modulierten Wellenlängen an N Eingängen von jedem der N Multiplexer, wodurch N modulierte Wellenlängen aus den N getrennten Wellenlängen an jedem einzelnen Ausgangsport jedes einzelnen Multiplexers erhalten werden, wobei jede der N modulierten Wellenlängen an jedem Ausgangsport von einem anderen Eingangsport der N Demultiplexer übertragen wurde.

5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß die Verzweigungspunkte Mach-Zehnder-Filter sind und daß die Zweige durch die Ausgänge dieser Filter repräsentiert werden. 35
6. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß eine der ersten Untergruppen die geradzahlig numerierten Wellenlängen W₂, W₄, W₆ ... umfaßt, welche sich durch den gleichmäßigen Frequenzabstand 2f unterscheiden und daß die andere der Untergruppen den ungeradzahlig Satz von Wellenlängen umfaßt, welche sich ebenfalls durch den gleichmäßigen Frequenzabstand 2f unterscheiden. 40
7. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß zwei der zweiten Untergruppen ungeradzahlig numerierte Wellenlängen umfassen, die durch einen Frequenzabstand von 4f voneinander getrennt sind. 45
8. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß zwei der zweiten Untergruppen geradzahlig numerierte Wellenlängen umfassen, die durch einen Frequenzabstand von 4f voneinander getrennt sind. 50



9. Verfahren nach Anspruch 3, dadurch gekennzeichnet, daß jede der x-ten Untergruppen Wellenlängen umfaßt, die durch einen Frequenzabstand von $S_x = 2^x(f)$ voneinander getrennt sind, wobei x eine ganze Zahl ist, mit $1 \leq x < n$. 5
10. Angepaßtes Übertragungsverfahren zur Verwendung innerhalb eines Koppelnetzwerkes, das mit Wellenlängenteilung arbeitet und eine zentrale Vermittlungseinrichtung (150) besitzt, welche N Demultiplexer (620) hat, jeder Demultiplexer besitzt einen Eingangsport (161) und N Ausgänge (W1 bis W4), die N Ausgänge von jedem der Demultiplexer liegen in einer einzelnen horizontalen Ebene, die Vermittlungseinrichtung hat folglich N parallele, horizontale Ebenen (501 bis 504) mit N Ausgängen in jeder der horizontalen Ebenen, die Vermittlungseinrichtung hat ebenfalls N Multiplexer (260), wobei jeder Multiplexer N Eingänge und einen Ausgangsport besitzt, die N Eingänge liegen in einer einzelnen vertikalen Ebene, die Vermittlungseinrichtung hat folglich N parallele vertikale Ebenen (505, 506) mit N Eingängen in jeder der vertikalen Ebenen, jeder Eingang in jeder vertikalen Ebene steht in optischer Verbindung mit nur einem Ausgang in nur einer der horizontalen Ebenen, wobei niemals zwei Eingänge von jeder der vertikalen Ebenen in optischer Verbindung mit Ausgängen in derselben horizontalen Ebene von den N horizontalen Ebenen stehen, jeder Demultiplexer der Vermittlungseinrichtung besitzt eine Baumstruktur mit Mach-Zehnder-Filtern als Verzweigungspunkte dieser Struktur, wobei die Zweige dieser Struktur durch Ausgangspaare von jedem Filter dargestellt werden und wobei das Verfahren Übertragungen von jedem beliebigen Eingangsport der Demultiplexer zu jedem beliebigen Ausgangsport der Multiplexer gestattet, dadurch gekennzeichnet, daß die folgenden Schritte ausgeführt werden: 10
- a) für jede zu einem der Ausgangsports der N Multiplexer zu übertragende Datenfolge (A bis D) wird eine Wellenlänge von N Wellenlängen mit der Datenfolge moduliert, die von einem Eingangsport (161) von einem der N Demultiplexer zu einem Ausgangsport (W1 bis W4) eines aus den N Multiplexern ausgewählten Multiplexers übertragen werden soll, wobei die spezielle Wellenlänge dem Eingangsport und dem ausgewählten Ausgangsport entspricht; 15
- b) Multiplexen der N Wellenlängen für jeden Eingangsport der Demultiplexer, die entsprechend Schritt (a) moduliert sind und zu N verschiedenen Ausgangsports der N Multiplexer übertragen werden sollen; 20
- c) Demultiplexen der N modulierten Wellenlängen, die entsprechend Schritt b) gemultiplext worden sind, mit einem der Demultiplexer in getrennte modulierte Wellenlängen durch Trennen der N modulierten Wellenlängen an einem ersten Mach-Zehnder-Filter des einen Demultiplexers in zwei verschiedene erste Untergruppen von N/2 modulierten Wellenlängen, wobei jede erste Untergruppe einem der zwei Zweige zugeordnet ist, die von dem ersten Mach-Zehnder-Filter ausgehen, eine der ersten Untergruppen hat die geradzahlig numerierten Wellenlängen W2, W4, W6, ..., welche sich durch einen Frequenzabstand von $2f$ gleichmäßig voneinander unterscheiden und die andere der ersten Untergruppen besteht aus den ungeradzahlig nummerierten Wellenlängen, welche sich ebenfalls durch den gleichmäßigen Frequenzabstand $2f$ unterscheiden, jede der ersten Untergruppen von N/2 modulierten Wellenlängen wird weiterhin an einem entsprechenden zweiten Mach-Zehnder-Filter auf jedem der ersten Zweige in zwei verschiedene zweite Untergruppen von N/4 modulierten Wellenlängen unterteilt, was vier verschiedene zweite Untergruppen ergibt, wobei jede zweite Untergruppe einem Zweig aus einem Paar zweiter Zweige zugeordnet ist, die von einem entsprechenden zweiten Verzweigungspunkt ausgehen, jede der zweiten Untergruppen besteht aus Wellenlängen, welche sich durch einen Frequenzabstand von $4f$ gleichmäßig voneinander unterscheiden, die zweiten Untergruppen werden wie oben beschrieben weiterhin in Untergruppen unterteilt, deren Wellenlängen einen gleichmäßigen, entsprechend weiteren Frequenzabstand von $S_x = 2^x(f)$ aufweisen, wobei x die x-te Untergruppe repräsentiert, diese Unterteilung wird so lange fortgesetzt, bis jede n-te Untergruppe nur noch eine modulierte Wellenlänge besitzt, wobei die n-ten Zweige des einen Demultiplexers die N Ausgänge des besagten Demultiplexers repräsentieren und somit für diesen einen Demultiplexer ein entsprechendes Zuordnungsschema der Untergruppen zu den Zweigen bilden, wobei das entsprechende Zuordnungsschema jedes anderen Demultiplexers eine Permutation des Zuordnungsschemas dieses einen Demultiplexers ist, wenn wie oben beschrieben N modulierte Wellenlängen von jedem anderen der N Demultiplexer entschachtelt werden, das Zuordnungsschema der Untergruppen zu den n-ten Zweigen ist für jeden der Demultiplexer unterschiedlich, wobei niemals zwei Ausgängen mit derselben Position des Ausgangs in jeweils zwei beliebigen Demultiplexern diesel-

längen, die entsprechend Schritt b) gemultiplext worden sind, mit einem der Demultiplexer in getrennte modulierte Wellenlängen durch Trennen der N modulierten Wellenlängen an einem ersten Mach-Zehnder-Filter des einen Demultiplexers in zwei verschiedene erste Untergruppen von N/2 modulierten Wellenlängen, wobei jede erste Untergruppe einem der zwei Zweige zugeordnet ist, die von dem ersten Mach-Zehnder-Filter ausgehen, eine der ersten Untergruppen hat die geradzahlig numerierten Wellenlängen W2, W4, W6, ..., welche sich durch einen Frequenzabstand von $2f$ gleichmäßig voneinander unterscheiden und die andere der ersten Untergruppen besteht aus den ungeradzahlig nummerierten Wellenlängen, welche sich ebenfalls durch den gleichmäßigen Frequenzabstand $2f$ unterscheiden, jede der ersten Untergruppen von N/2 modulierten Wellenlängen wird weiterhin an einem entsprechenden zweiten Mach-Zehnder-Filter auf jedem der ersten Zweige in zwei verschiedene zweite Untergruppen von N/4 modulierten Wellenlängen unterteilt, was vier verschiedene zweite Untergruppen ergibt, wobei jede zweite Untergruppe einem Zweig aus einem Paar zweiter Zweige zugeordnet ist, die von einem entsprechenden zweiten Verzweigungspunkt ausgehen, jede der zweiten Untergruppen besteht aus Wellenlängen, welche sich durch einen Frequenzabstand von $4f$ gleichmäßig voneinander unterscheiden, die zweiten Untergruppen werden wie oben beschrieben weiterhin in Untergruppen unterteilt, deren Wellenlängen einen gleichmäßigen, entsprechend weiteren Frequenzabstand von $S_x = 2^x(f)$ aufweisen, wobei x die x-te Untergruppe repräsentiert, diese Unterteilung wird so lange fortgesetzt, bis jede n-te Untergruppe nur noch eine modulierte Wellenlänge besitzt, wobei die n-ten Zweige des einen Demultiplexers die N Ausgänge des besagten Demultiplexers repräsentieren und somit für diesen einen Demultiplexer ein entsprechendes Zuordnungsschema der Untergruppen zu den Zweigen bilden, wobei das entsprechende Zuordnungsschema jedes anderen Demultiplexers eine Permutation des Zuordnungsschemas dieses einen Demultiplexers ist, wenn wie oben beschrieben N modulierte Wellenlängen von jedem anderen der N Demultiplexer entschachtelt werden, das Zuordnungsschema der Untergruppen zu den n-ten Zweigen ist für jeden der Demultiplexer unterschiedlich, wobei niemals zwei Ausgängen mit derselben Position des Ausgangs in jeweils zwei beliebigen Demultiplexern diesel-



be Wellenlänge zugeordnet ist, wobei jede Untergruppe in jedem Zuordnungsschema immer dieselben Wellenlängen enthält und wobei jedes Untergruppenpaar, das Zweigen zugeordnet ist, die von einem gemeinsamen Verzweigungspunkt ausgehen, Zweigen zugeordnet bleibt, welche von einem gemeinsamen Verzweigungspunkt ausgehen, wodurch N getrennte modulierte Wellenlängen von den N verschiedene Wellenlängen erhalten werden, die den N Ausgängen jedes Multiplexers zugeordnet sind, die modulierte Wellenlänge, die an jedem Ausgang jedes Multiplexers erscheint, entspricht der zugeordneten modulierten Wellenlänge, wobei niemals zwei modulierte Wellenlängen aus derselben Wellenlänge erhalten werden, die in derselben Position des Ausgangs von zwei horizontalen Ebenen erscheinen, wodurch man N verschiedene modulierte Wellenlängen aus den N getrennten Wellenlängen auf derselben Position des Ausgangs in den N horizontalen Ebenen erhält, wobei dieselbe Position des Ausgangs in den N horizontalen Ebenen in einer der vertikalen Ebenen liegt, wodurch man N verschiedene modulierte Wellenlängen aus den N getrennten Wellenlängen erhält, welche an den N Eingängen jedes Multiplexers auftreten und diese N Eingänge jedes Multiplexers in einer der N vertikalen Ebenen liegen; und d) Multiplexen von N modulierten Wellenlängen an N Eingängen von jedem der N Multiplexer, wodurch N modulierte Wellenlängen aus den N getrennten Wellenlängen an jedem einzelnen Ausgangsport jedes einzelnen Multiplexers erhalten werden, wobei jede der N modulierten Wellenlängen von einem anderen Eingangsport der N Demultiplexer übertragen wurde.

Revendications

1. Adapté pour une utilisation dans un réseau de commutation à répartition en longueurs d'onde ayant une structure de commutation centrale (150) qui a N démultiplexeurs (620), chaque démultiplexeur ayant un port d'entrée (161) et N sorties (W1 - Wn), lesdites N sorties pour chacun desdits démultiplexeurs se trouvant dans un seul plan d'un premier ensemble de N plans non sécants (501-504) de ladite structure de commutation, ladite structure ayant également N multiplexeurs (260), chacun desdits N multiplexeurs ayant N entrées (W1 - Wn) et un port de sortie (151), lesdites N entrées de chacun desdits multiplexeurs se trouvant dans un seul plan d'un deuxième ensemble de N plans non sécants

(505, 506) de ladite structure de commutation, chaque entrée dans chaque plan dudit deuxième ensemble de plans étant en contact optique avec uniquement une sortie dans seulement un dudit premier ensemble de plans sans que deux entrées dudit chaque plan dudit deuxième ensemble de plans soient en contact optique avec des sorties sur le même plan dudit premier ensemble de plans, procédé de transmission à partir de l'un quelconque desdits ports d'entrée de démultiplexeurs jusque sur l'un quelconque desdits ports de sortie desdits multiplexeurs, caractérisé en ce qu'il comprend les étapes de:

- a) pour chaque débit de données (A - D) à transmettre sur un desdits ports de sortie desdits N multiplexeurs, moduler une longueur d'onde particulière de N longueurs d'onde avec ledit chaque débit de données à transmettre depuis un port d'entrée (161) sur l'un desdits N démultiplexeurs jusque sur un port de sortie (W1 - W4) d'un multiplexeur sélectionné parmi lesdits N multiplexeurs, ladite longueur d'onde particulière correspondant audit port d'entrée et audit port de sortie sélectionné;
- b) multiplexer, pour chacun desdits ports d'entrée desdits démultiplexeurs, lesdites N longueurs d'onde, modulées comme dans l'étape a), lesdites N longueurs d'onde à transmettre sur N différents desdits ports de sortie desdits N multiplexeurs;
- c) démultiplexer N longueurs d'onde modulées, multiplexées à l'étape b), avec un desdits démultiplexeurs en longueurs d'onde distinctes en séparant lesdites N longueurs d'onde modulées à un premier point de branchement (30) dudit un démultiplexeur en deux premiers sous-groupes distincts de N/2 longueurs d'onde modulées, chaque premier sous-groupe étant attribué à un de deux premiers branchements se prolongeant à partir dudit premier point de branchement, ledit chaque premier sous-groupe de N/2 longueurs d'onde modulées étant en outre séparé à un deuxième point de branchement correspondant (36, 38) sur chacun desdits premiers branchements en deux deuxième sous-groupes distincts de N/4 longueurs d'onde modulées donnant finalement quatre deuxième sous-groupes distincts, chaque deuxième sous-groupe étant attribué à l'un d'une paire de deuxième branchements se prolongeant à partir d'un deuxième point de branchement correspondant, encore séparer, si besoin est, lesdits deuxième sous-groupes comme ci-dessus jusqu'à ce que chaque énième sous-groupe ait uniquement une longueur d'onde modulée, les énièmes branche-



ments dudit un démultiplexeur étant lesdites N sorties dudit un démultiplexeur, formant de ce fait pour un dit démultiplexeur un schéma d'attribution de sous-groupes à des branches avec un schéma d'attribution respectif pour chaque autre desdits démultiplexeurs qui est une permutation dudit schéma d'attribution pour ledit un démultiplexeur lorsque N longueurs d'onde modulées sont démultiplexées comme ci-dessus par chaque autre desdits N démultiplexeurs, le schéma d'attribution de sous-groupes auxdites énièmes branches étant différent pour chacun desdits démultiplexeurs, sans que deux sorties dans la même position de sortie de deux quelconques desdits démultiplexeurs aient la même longueur d'onde qui leur soit attribuée, chaque sous-groupe de chaque schéma d'attribution y ayant encore les mêmes longueurs d'onde, et chaque paire de sous-groupes attribués à des branches se prolongeant à partir d'un point de branchement commun tout en étant encore attribués à des branches se prolongeant à partir d'un point de branchement commun, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes attribuées auxdits N sorties dudit chaque démultiplexeur, la longueur d'onde apparaissant sur ladite chaque sortie dudit chaque démultiplexeur correspondant aux longueurs d'onde modulées qui lui sont attribuées, sans que deux longueurs d'onde modulées provenant de la même longueur d'onde apparaissent dans la même position de sortie de deux plans dudit premier ensemble de N plans, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes dans la même position de sortie dans ledit premier ensemble de N plans, ladite même position de sortie dans ledit premier ensemble de N plans se trouvant dans un plan dudit deuxième ensemble de N plans, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes qui apparaissent sur lesdites N entrées dudit chaque multiplexeur, lesdites N entrées dudit chaque multiplexeur étant dans un plan dudit deuxième ensemble de N plans; et d) multiplexer N longueurs d'onde modulées à N entrées de chacun desdits N multiplexeurs, ce qui fait qu'il y a N longueurs d'onde modulées à partir desdites N longueurs d'onde distinctes à chaque port de sortie unique dudit chaque multiplexeur, chacune desdites longueurs d'onde modulées N à chaque port de sortie étant transmise à partir d'un port d'entrée différent desdits N démultiplexeurs.

2. Procédé selon la revendication 1, dans lequel ledit premier ensemble de plans (501 - 504) a N plans parallèles et ledit deuxième ensemble de plans (505, 506) a N plans parallèles.
3. Procédé selon la revendication 1, dans lequel ledit premier ensemble de plans (501 - 504) a N plans horizontaux et ledit deuxième ensemble de plans (505, 506) a N plans verticaux.
4. Adapté pour une utilisation dans un réseau de commutation à répartition en longueurs d'onde ayant une structure de commutation centrale (150) qui a N démultiplexeurs (620), chaque démultiplexeur ayant un port d'entrée (161) et N sorties (W1 - W4), lesdites N sorties pour chacun desdits multiplexeurs se trouvant dans un seul plan horizontal, ladite structure de commutation ayant ainsi N plans horizontaux parallèles (501 - 504) avec N sorties dans chacun desdits plans horizontaux, ladite structure ayant aussi N multiplexeurs (260), chacun desdits multiplexeurs ayant N entrées et un port de sortie, lesdites N entrées se trouvant dans un seul plan vertical (505, 506), ladite structure ayant ainsi N plans verticaux parallèles avec N entrées dans chacun desdits plans verticaux, chaque entrée dans chaque plan vertical étant en contact optique avec uniquement une sortie dans seulement un desdits plans horizontaux sans que deux entrées dudit chaque plan vertical soient en contact optique avec des sorties sur le même plan horizontal desdits N plans horizontaux, procédé de transmission depuis l'un quelconque desdits ports d'entrée de démultiplexeurs jusque sur l'un quelconques desdits ports de sortie desdits multiplexeurs, caractérisé en ce qu'il comprend les étapes suivantes:
 - a) pour chaque débit de données (A - D) à transmettre sur un desdits ports de sortie desdits N multiplexeurs, moduler une longueur d'onde particulière de N longueurs d'onde avec ledit chaque débit de données à transmettre depuis un port d'entrée (161) de l'un desdits N démultiplexeurs, sur un port de sortie (W1 - W4) d'un multiplexeur sélectionné parmi lesdits N multiplexeurs, ladite longueur d'onde particulière correspondant audit port d'entrée et audit port de sortie sélectionné;
 - b) multiplexer, pour chacun desdits ports d'entrée desdits démultiplexeurs, lesdites N longueurs d'onde, modulées comme dans l'étape a) lesdites N longueurs d'onde à transmettre sur N différents desdits ports de sortie desdits N multiplexeurs;
 - c) démultiplexer N longueurs d'onde modulées, multiplexées à l'étape b), avec un des-



dits démultiplexeurs en longueurs d'onde distinctes en séparant lesdites N longueurs d'onde modulées à un premier point de branchement (30) dudit un démultiplexeur en deux premiers sous-groupes distincts de N/2 longueurs d'onde modulées, chaque premier sous-groupe étant attribué à un de deux premiers branchements se prolongeant à partir dudit premier point de branchement, ledit chaque premier sous-groupe de N/2 longueurs d'onde modulées étant en outre séparé à un deuxième point de branchement correspondant (36, 38) sur chacun desdits premiers branchements en deux deuxièmes sous-groupes distincts de N/4 longueurs d'onde modulées donnant finalement quatre deuxièmes sous-groupes distincts, chaque deuxième sous-groupe étant attribué à l'un d'une paire de deuxièmes branchements se prolongeant à partir d'un deuxième point de branchement correspondant, encore séparer, si besoin est, lesdits deuxièmes sous-groupes comme ci-dessus jusqu'à ce que chaque énième sous-groupe ait uniquement une longueur d'onde modulée, les énièmes branchements dudit un démultiplexeur étant lesdites N sorties dudit un démultiplexeur, formant de ce fait pour un dit démultiplexeur un schéma d'attribution de sous-groupes à des branches avec un schéma d'attribution respectif pour chaque autre desdits démultiplexeurs qui est une permutation dudit schéma d'attribution pour ledit un démultiplexeur lorsque N longueurs d'onde modulées sont démultiplexées comme ci-dessus par chaque autre desdits N démultiplexeurs, le schéma d'attribution de sous-groupes auxdites énièmes branches étant différent pour chacun desdits démultiplexeurs, sans que deux sorties dans la même position de sortie de deux quelconques desdits démultiplexeurs aient la même longueur d'onde qui leur soit attribuée, chaque sous-groupe de chaque schéma d'attribution y ayant encore les mêmes longueurs d'onde, et chaque paire de sous-groupes attribués à des branches se prolongeant à partir d'un point de branchement commun tout en étant encore attribués à des branches se prolongeant à partir d'un point de branchement commun, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes attribuées auxdits N sorties dudit chaque démultiplexeur, la longueur d'onde modulée apparaissant sur ladite chaque sortie dudit chaque démultiplexeur correspondant aux longueurs d'onde modulées qui lui sont attribuées, sans que deux longueurs d'onde mo-

dulées provenant de la même longueur d'onde apparaissent dans la même position de sortie de deux plans horizontaux, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes dans la même position de sortie dans lesdits N plans horizontaux, ladite même position de sortie dans lesdits N plans horizontaux se trouvant dans un desdits plans verticaux, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes qui apparaissent sur lesdites N entrées dudit chaque multiplexeur, lesdites N entrées dudit chaque multiplexeur étant dans un desdits N plans verticaux N, et d) multiplexer N longueurs d'onde modulées à N entrées de chacun desdits N multiplexeurs, ce qui fait qu'il y a N longueurs d'onde modulées à partir desdites N longueurs d'onde distinctes à chaque port de sortie unique dudit chaque multiplexeur, chacune desdites longueurs d'onde modulées N à chaque port de sortie étant transmise à partir d'un port d'entrée différent desdits N démultiplexeurs.

5. Procédé selon la revendication 4, dans lequel lesdits points de branchement sont des filtres Mach-Zehnder et lesdites branches sont les sorties desdits filtres.
6. Procédé selon la revendication 4, dans lequel l'un desdits premiers sous-groupes comprend des longueurs d'onde de numérotation paire W2, W4, W6, ... qui sont espacées de façon égale par un intervalle de fréquence 2f, et l'autre desdits premiers sous-groupes comprend un groupe impair de longueurs d'onde W1, W3, W5, ... qui sont espacées de façon égale par un intervalle de fréquence 2f.
7. Procédé selon la revendication 4, dans lequel deux desdits deuxièmes sous-groupes comprennent des longueurs d'onde de numérotation impaire séparées par un intervalle de fréquence 4f.
8. Procédé selon la revendication 4, dans lequel deux desdits deuxièmes sous-groupes comprennent des longueurs d'onde de numérotation paire séparées par un intervalle de fréquence 4f.
9. Procédé selon la revendication 4, dans lequel chacun desdits xième sous-groupes a des longueurs d'onde séparées par un intervalle de fréquence $S_x = 2^x(f)$, où x est un nombre entier et $1 \leq x < n$.
10. Adapté pour une utilisation dans un réseau de commutation à répartition en longueurs d'onde



ayant une structure de commutation centrale (150) qui a N démultiplexeurs (620), chaque démultiplexeur ayant un port d'entrée (161) et N sorties (W1 - W4), lesdites N sorties pour chacun desdits multiplexeurs se trouvant dans un seul plan horizontal, ladite structure de commutation ayant ainsi N plans horizontaux parallèles (501 - 504) avec N sorties dans chacun desdits plans horizontaux, ladite structure ayant aussi N multiplexeurs (260), chacun desdits multiplexeurs ayant N entrées et un port de sortie, lesdites N entrées se trouvant dans un seul plan vertical, ladite structure ayant ainsi N plans verticaux parallèles (505, 506) avec N entrées dans chacun desdits plans verticaux, chaque entrée dans chaque plan vertical étant en contact optique avec uniquement une sortie dans seulement un desdits plans horizontaux sans que deux entrées dudit chaque plan vertical soient en contact optique avec des sorties sur le même plan horizontal desdits N plans horizontaux, chaque démultiplexeur de ladite structure ayant une structure arborescente avec des filtres Mach-Zehnder comme points de branchement de ladite structure, une paire de sortie provenant de chaque filtre étant des branches de ladite structure, procédé de transmission depuis l'un quelconque desdits ports d'entrée de démultiplexeurs jusque sur l'un quelconque desdits ports de sortie desdits multiplexeurs, caractérisé en ce qu'il comprend les étapes suivantes:

- a) pour chaque débit de données (A - D) à transmettre sur un desdits ports de sortie desdits N multiplexeurs, moduler une longueur d'onde particulière de N longueurs d'onde avec ledit chaque débit de données à transmettre depuis un port d'entrée (161) de l'un desdits N démultiplexeurs, sur un port de sortie sélectionné (W1 - W4) d'un desdits N multiplexeurs, ladite longueur d'onde particulière correspondant audit port d'entrée et audit port de sortie sélectionné;
- b) multiplexer, pour chacun desdits ports d'entrée desdits démultiplexeurs, lesdites N longueurs d'onde, modulées comme dans l'étape a), lesdites N longueurs d'onde à transmettre sur N différents desdits ports de sortie desdits N multiplexeurs;
- c) démultiplexer N longueurs d'onde modulées, multiplexées à l'étape b), avec un desdits démultiplexeurs en longueurs d'onde distinctes en séparant lesdites N longueurs d'onde modulées à un premier filtre Mach-Zehnder dudit un démultiplexeur en deux premiers sous-groupes distincts de N/2 longueurs d'onde modulées, chaque premier sous-groupe étant attribué à un de deux premiers branchements se prolongeant à partir

dudit premier filtre Mach-Zehnder, un desdits premiers sous-groupes ayant des longueurs d'onde de numérotation paire W2, W4, W6, ..., qui sont espacées de façon égale par un intervalle de fréquence 2f, et l'autre desdits premiers sous-groupes étant espacé de façon égale par un intervalle de fréquence 2f, ledit chaque premier sous-groupe de longueurs d'onde modulées N/2 étant en outre séparé à un deuxième filtre Mach-Zehnder correspondant sur chacun desdits premiers branchements en deux deuxièmes sous-groupes distincts de N/4 longueurs d'onde modulées donnant finalement quatre deuxièmes sous-groupes distincts, chaque deuxième sous-groupe étant attribué à l'un d'une paire de deuxièmes branchements se prolongeant à partir d'un deuxième point de branchement correspondant, chacun desdits deuxièmes sous-groupes ayant des longueurs d'onde qui sont espacées de façon égale par un intervalle de fréquence 4f, encore séparer, comme ci-dessus, lesdits deuxièmes sous-groupes en sous-groupes d'espacements égaux avec un intervalle de fréquence plus large $S_x = 2^x(f)$, où x est le xième sous-groupe, ladite séparation se poursuivant jusqu'à ce que chaque énième sous-groupe ait seulement une longueur d'onde modulée, les énièmes branchements dudit un démultiplexeur étant lesdites N sorties de chaque démultiplexeur, formant de ce fait pour un dit démultiplexeur un schéma d'attribution de sous-groupes à des branches avec un schéma d'attribution respectif pour chaque autre desdits démultiplexeurs qui est une permutation dudit schéma d'attribution pour ledit un démultiplexeur lorsque N longueurs d'onde modulées sont démultiplexées comme ci-dessus par chaque autre desdits N démultiplexeurs, le schéma d'attribution de sous-groupes auxdites énièmes branches étant différent pour chaque autre desdits démultiplexeurs, sans que deux sorties dans la même position de sortie de deux quelconques desdits démultiplexeurs aient la même longueur d'onde qui leur soit attribuée, chaque sous-groupe de chaque schéma d'attribution y ayant encore les mêmes longueurs d'onde, et chaque paire de sous-groupes attribués à des branches se prolongeant à partir d'un point de branchement commun tout en étant encore attribués à des branches se prolongeant à partir d'un point de branchement commun, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes attribuées auxdites N sorties dudit chaque démultiplexeur, la longueur d'onde



modulée apparaissant sur ladite chaque sortie dudit chaque démultiplexeur correspondant aux longueurs d'onde modulées qui lui sont attribuées, sans que deux longueurs d'onde modulées provenant de la même longueur d'onde apparaissent dans la même position de sortie de deux plans horizontaux, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes dans la même position de sortie dans lesdits N plans horizontaux, ladite même position de sortie dans lesdits N plans horizontaux se trouvant dans un desdits N plans verticaux, ce qui fait qu'il y a N longueurs d'onde modulées distinctes à partir desdites N longueurs d'onde distinctes qui apparaissent sur lesdites N entrées dudit chaque multiplexeur, lesdites N entrées dudit chaque multiplexeur étant dans un desdits N plans verticaux, et

d) multiplexer N longueurs d'onde modulées à N entrées de chacun desdits N multiplexeurs, ce qui fait qu'il y a N longueurs d'onde modulées à partir desdites N longueurs d'onde distinctes à chaque port de sortie unique dudit chaque multiplexeur, chacune desdites N longueurs d'onde modulées à chaque port de sortie étant transmise à partir d'un port d'entrée différent desdits N démultiplexeurs.

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