

## Description

The present invention relates to an optical signal processor, and to a method of processing optical data.

In communication systems, spread spectrum techniques have been used, and it is thought that such techniques could offer several advantages in local area networks. In particular, spread spectrum optical communication techniques based on white light interference have been known for some time, and recently these techniques have been used in coherence multiplexed optical fibre sensor systems.

Recently, a spread spectrum technique, referred to as code division multiple access (CDMA) has been described for use with local area networks. In this scheme, each user is assigned orthogonal codes, which results in a substantial increase of the bandwidth of the transmitted signal. However, the bandwidth requirements of this technique can only be supported by wide bandwidth channels such as occur in fibre-optics. This technique also requires wide bandwidth signal processors at the receiver. Conventional receivers for CDMA use electronic processors. However, these are slow when compared with optical systems, and also can be affected by electrical noise. It is desirable to provide an all-fibre and integrated optical processor which could facilitate and permit all-optical processing so that maximum potential of such techniques can be realised.

The paper "Fiber-optic bipolar tap implementation using an incoherent optical source", Optics Letters, vol. 12, no. 9, pages 726-728 describes an optical fibre tap which provides a measure of the intensity of a received signal, any switching being done electronically. Patent Abstracts of Japan, vol. 12, no. 100, page 683 and JP-A-6 223 625 both mention comparing optical signals to reference signals.

The aim of the present invention is to provide a signal processing system, and a method and apparatus for processing optical signals, which obviates or mitigates at least one of the aforementioned problems.

This is achieved by providing an optical processing device for determining matching or mismatching between an optical input signal and a predetermined reference according to claim 1, by further providing an optical processing system for determining matching or mismatching between an optical input signal and a predetermined reference according to claim 3 and by providing a method for determining matching or mismatching between an optical input signal and a predetermined reference according to claim 7.

The invention provides an optical processing element based on at least two optical couplers which are connected so that the principal channels are connected in series with a time delay of a predetermined value in the principal channel between adjacent optical coupling units. The optical coupling units are formed into stages, and the number of optical coupling units per stage determines further coding of each bit of the input optical signal or code sequence. In other words, if the input code is M-bits long, then M optical coupler stages are required to process this code and determine whether the code matches with the pre-set code sequence. Stages can be coupled together to process a sequence of optical pulses corresponding in number to the number of optical coupling stages in the system, and the outputs of the stages are coupled via optical switches to an optical summing device simultaneously to process the coded data and determine whether the processing has resulted in matching or mis-matching of data.

In one embodiment, the data is coded in accordance with a Gold code sequence of M-bits length, and two optical coupling units per stage of M stages are provided in the optical processing system.

The present invention provides an optical processing device for processing an optical input signal to determine matching or mis-matching between the input signal and a predetermined reference, the optical processing device comprising a series of at least two optical couplers each having a principal channel and a coupled channel, the principal channels of the couplers being connected in series with a time delay T between adjacent couplers, where T is the time between successive pulses in the optical input signal, the coupled channels of the couplers being connected in series with a time delay (dT) between adjacent couplers which is minimal in comparison to the time delay T, characterised in that each optical coupler is pre-settable to enable or inhibit optical coupling of an input signal from its principal channel to its coupled channel in accordance with the predetermined reference, the input signal entering the optical processing device via the principal channel of the first in the series of optical couplers, and the output of the optical processing device being taken from the coupled channel of the last of the series of optical couplers, wherein the output of the optical processing device is coupled to optical switch means, the optical switch means being pre-settable to provide an output signal when the optical input thereto exceeds a threshold value.

Preferably, there are two optical couplers whereby, for each optical input, there is provided an optical output signal consisting of two outputs separated by time T.

The invention also provides an optical processing system for determining matching or mis-matching between an optical input signal and a predetermined reference, the system comprising a plurality of optical processing devices, each as defined above, each optical processing device having n optical couplers, the principal channel of each optical processing device being coupled to the principal channel of an adjacent optical processing device by a time delay nT, the outputs of the optical switch means being coupled in parallel to an optical

summing unit, the principal and coupled channels being dimensioned and proportioned such that the outputs of the optical switch means arrive at the summing unit substantially simultaneously, the optical summing unit providing an optical output signal for each optical input signal input into the optical processing system, the optical output signal consisting of  $n$  optical pulses.

Preferably, each optical processing device includes two optical couplers such that each optical input pulse is processed into two output pulses separated by time  $T$ , and the pulses are passed to respective switches from each optical processing device so that the output of the optical processing system consists of a stream of optical pulses, and within said stream one optical pulse represents whether data has been matched or mis-matched and also the level of mis-match.

Preferably, each coupler is programmable to vary the coding selected by the optical processing system. Conveniently, the optical processing system is coupled to synchronising means for synchronising the output pulses with the input pulses to determine whether matching or mis-matching has occurred.

The invention further provides a method of detecting matching or mis-matching between an optical input signal and a predetermined reference, the method comprising the steps of coupling together a plurality of optical processing devices each as defined above, coupling the outputs of the optical switch means in parallel to a summing device, summing the parallel outputs of the optical switch means in the summing device simultaneously to provide a summed output which is representative of pre-set coding of the optical processing devices and pre-set threshold values of the switch means, and monitoring the output to determine whether the input data sequence and the predetermined sequence are matched or mis-matched.

Advantageously, the method further comprises the steps of pre-selecting the coupling ratios in the couplers of each optical processing device to provide a predetermined output code, providing an output from each optical processing device consisting of a sequence of optical output pulses, monitoring the magnitude of one of the optical output pulses of each of said outputs and comparing the monitored value with a pre-set value, and providing a subsequent output depending on the result each of said comparisons.

Preferably, the optical input data sequence comprises a coded sequence of optical input pulses separated by time  $T$ , wherein the output of each optical processing device has a plurality of optical output pulses separated by time  $T$ , wherein each output is compared with a pre-set threshold value to provide a comparator output signal, the comparator output signals being summed in the summing device substantially simultaneously to provide an optical system output which comprises an optical signal having a plurality of optically-summed pulses separated by time  $T$ , and wherein each optically-summed pulse has a magnitude determined by the number of optical processing devices.

Conveniently, the summation of output data is completed when all of the optical processing devices are fully loaded.

Preferably, the output of the summing device comprises a sequence of optical cumulative pulses corresponding to the sum of the outputs of the optical processing devices, and the method further comprises detecting when the first optical cumulative pulse exceeds a pre-set value, triggering monitoring means to monitor the magnitude of the next cumulative pulse, and providing an output indicative of matching or the degree of mis-matching depending on the value of the subsequent measured pulse.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 shows an optical processor having a pair of optical couplers in accordance with an embodiment of the invention;

Figures 2a and 2b show schematically the propagation of a pair of received optical pulses through the optical processor of Figure 1;

Figure 3 shows an optical processor system in accordance with an embodiment of the present invention having  $M$  optical processing stages; and

Figures 4A, 4B and 4C are graphs of light density versus time and display pulses received at the output of terminal O of the embodiment shown in Figure 3.

With reference to Figure 1 of the drawings, there is shown an optical signal processing device 10 for processing an input signal sequence of binary digits represented by light pulses, adjacent ones of which are separated by time  $T$ . For convenience and ease of explanation in this embodiment the input signal consists of two digits separated by time  $T$ . The device 10 comprises an input terminal I and an output terminal O, between which is connected an optical coupler unit 12, having two optical couplers 12A, 12B. Each coupler 12A, 12B comprises a principal channel 14 with input and output ports, and a coupled channel 16 also with input and output ports. The principal and coupled channels 14 and 16 are fibre optic waveguides which are disposed in close proximity within a support block, as is well known in the art, so as to influence the propagation of light from the principal channel to the coupled channel. The couplers 12A, 12B allow the adjustment of optical power passing between the principal and coupled channels 14 and 16. A delay device having a time delay ( $T$ ) equal

to the time between pulses is connected between the output port of the principal channel 14 of the first coupler 12A and the input port of the principal channel 14 of the second coupler 12B. The delay device is formed in the principal channel 14 by a length of waveguide (in this case optical fibre). The output port of the coupled channel 16 of the first coupler 12A is connected to the input port of the coupled channel 16 of the second coupler 12B, a propagation delay  $dT$  being inherent in the connection, and being considerably smaller than the time delay  $T$  of the principal channel 14. The pulsewidth  $pT$  of the binary digits, which are processed by the device 10, is also shorter than the time delay  $T$ .

The output port of the coupled channel 16 of the second coupler 12B is connected to the input port of the principal channel 20 of a switching device 18. The switching device 18 has a switching ratio between its principal channel 20 and its coupled channel 22 which is pre-set to enable or inhibit switching depending on whether the amplitude of the pulse in its principal channel exceeds a threshold value. Each coupler 12A, 12B has a coupling ratio between principal and coupled channels which is pre-set to enable or inhibit coupling to be representative of a binary "1" or binary "0".

The optical pulses to be processed are received at the input terminal I. The binary digits are representative of data which has been coded before transmission using a Gold code sequence. A binary digit pulse in the coded sequence having a value "1" is transmitted as 1,0 and a binary digit pulse having a value "0" is transmitted as 1,1. A "1" is presence of a light pulse, and a "0" indicates the absence of a light pulse. By virtue of this coding, the digits received also represent the address to which binary digits are to be sent.

Figures 2A and 2B schematically illustrate how the device 10 processes a 1,0 and a 1,1 input sequence respectively. The values of the transmitted form of digits match or fail to match the pre-set coupling ratios of the first and second couplers 12A, 12B as will be evident from the following table.

| 25 | <u>Input</u> | Values Assigned to<br>Couplers 12A, 12B<br>by virtue of their<br><u>coupling ratio</u> | <u>Output At O</u> |
|----|--------------|----------------------------------------------------------------------------------------|--------------------|
| 30 | 1, 0         | 1, 0                                                                                   | 1, 0               |
|    | 1, 0         | 1, 1                                                                                   | 1, 1               |
|    | 1, 1         | 1, 0                                                                                   | 1, 1               |
| 35 | 1, 1         | 1, 1                                                                                   | 1, 0               |

Figures 2A (i) to (iii) show an example of mis-match whereby a pulse train 1,0 is received at line input I, but the couplers 12A and 12B represent a 1,1 configured coupler. With reference to Figure 2A (i), at time  $t = 0$  the output at terminal 20 is "1", that is there exists a pulse of light at the terminal 20 because the first received pulse of the pulse train is a "1", and is partly coupled at the coupler 12A from the principal channel 14 to the coupled channel 16 and then to the terminal 20 with a minimal delay  $dT$  due to propagation. After time  $T$  has elapsed, the remainder of the first pulse will have propagated through the principal channel 14 and the delay device  $T$  to the coupler 12B, where it is again partly coupled from the channel 14 to the channel 16 providing an output "1" at the terminal 20. At the same instant, the "0" received at the input I enters the coupler 12A. A "0" is representative of the absence of a light pulse; there being no light coupled in the coupler 12A and the output is "0" which has no effect on the output of the coupler 12B. Thereafter, the output remains a binary "1". After a further time  $T$  (that is, an interval of  $2T$  from receiving the first pulse), the "0" enters the coupler 12B, and the output of the terminal 20 is "0". Over the interval  $2T$  the output is 1,1,0. As we are only interested in the first two digits, the last "0" at the output is redundant, and can be disregarded. So, for a mis-match between the pulse train (1,0) received at the input I and the binary digits (1,1) represented by the coupling ratios of the coupler pair, the output seen at the terminal 20 is 1,1. From the above table, it will be appreciated that this mis-match also occurs for an input 1,1 with a pre-set coupling ratio of 1,0. However, where the input pulse sequence is 1,0 and the coupling ratios of couplers 12A and 12B are "1" and "0" respectively, that is a matching situation, an output of 1,0 is obtained at the terminal 20.

Figures 2B (i) to (iii) show an example of matching wherein the output obtained at the terminal 20 is not 1,0. In this example, the coupling ratio of the couplers 12A, 12B represent 1,1 and the input pulse train is 1,1. With reference to Figure 2B (i), at time  $t = 0$ , the output of the terminal 20 is a "1", because the first received pulse is a "1", and is partly coupled by the coupler 12A from the principal channel 14 to the coupled channel

16, and then passes to the terminal 20 with minimal propagation delay  $dT$ . In Figure 2B (ii), after time  $T$ , the remainder of the uncoupled light pulse has propagated through the principal channel 14 and the delay device 16 to the coupler 12B, where it is again partly coupled from the channel 14 to the channel 16 because the coupling ratio of coupler 12B represents a binary "1". Simultaneously, the second received pulse train enters the coupler 12A. It is also partly coupled from the channel 14 to the channel 16 by virtue of the coupler 12A coupling ratio; and, because the propagation delay  $dT$  of the channel 16 is minimal compared with the delay  $T$  in the channel 14, the pulse in the channel 16 propagates to the coupler 12B. Therefore, at the terminal 20, a pulse having the effective value of "2" exists, because at the same time part of the pulse received in the coupler 12B has been 5 coupled to the channel 16. As described above, the switching device 18 has a switching ratio which is pre-set to enable switching when the amplitude of the pulse at the terminal 20 is greater than a pre-set threshold (for example 1.5) i.e. between 1 and 2. Consequently, the output pulse having an 0 effective value of 2 is "dumped" on to the line 22 of the switch 18, and a "0" is present at the output.

After a further delay  $T$ , as seen in Figure 2B (iii), the second received "1" propagates through the principal channel 14 and the delay device 16 to the coupler 12B where it is partly coupled to the channel 16. However, as mentioned above with reference to Figure 2A, we are only interested in the first two digits, so this output is 1, 0 which is to be expected for matching. It will be appreciated that the switching device 18 will not "dump" any of the other outputs because no other output will exceed the threshold value.

An embodiment of an optical signal processor is shown in Figure 3, wherein there is provided an optical signal processor 30 having  $M$  processing devices  $10_1, 10_2, \dots, 10_M$ , where  $M$  is the length of the coded sequence, for processing  $M$  pairs of first and second pulses as mentioned in the Figure 1 embodiment. The pairs of each of the adjacent pairs of pulses are each separated by a time interval  $2T$ . Each of the processing devices  $10_1, 10_2, \dots, 10_M$  has a respective coupler unit  $12_1, 12_2, \dots, 12_M$ , each having a pair of couplers 12A, 12B, each as described in the Figure 1 embodiment and having respective input and output terminals. The principal channels of the coupler pairs are connected in series via a time delay  $2T$  except for the input to the first coupler unit  $12_1$ , and the output of the last coupler pair unit  $12_M$ . The output of each of the coupled channels 16 is connected to a respective switch element  $18_1, 18_2, \dots, 18_M$  of the type hereinbefore described. It will be appreciated that the length a channel with the  $2T$  delay is physically longer than the channel having a  $T$  delay. Switches  $18_1, 18_2, \dots, 18_M$  have outputs  $21_1, 21_2, \dots, 21_M$  which are connected in parallel to form  $M$  inputs of an  $M$ -to-one summing device 24. The length of each of the waveguides is dimensioned so that pulses in each channel arrive at the summing device 24 at the same time. The output of the summing device 24 is connected to the output terminal O at which the output signal is checked for matching as will be later described in detail.

Reference is now made to Figures 4A to 4C of the accompanying drawings. When the processor is fully loaded (i.e. when the first digit reaches the last coupler pair  $12_M$ )  $M$  pairs of digits are simultaneously processed in the  $M$  processing devices  $10_1, 10_2, \dots, 10_M$ , and the sum of all the couplers in the  $M$  coupler units  $12_1, 12_2, \dots, 12_M$  is  $M$  for a perfect match. That is, for four stages the output is 4,0 as seen in Figure 4A (the match is  $4 \times (1,0)$ ). Figure 4B depicts the output at terminal O for a total mis-match; and, in this case, the output is 4, 4 which is formed by the sum of four mis-matches, that is  $4 \times (1,1)$ .

Figure 4C depicts the output in the case of a partial mis-match; and, in this case, the output seen at terminal O is 4,X where X is some value between 0 and 4.

As indicated above, the aforementioned outputs shown in Figures 4A, 4B and 4C are obtained by adding all of the outputs of the  $M$  coupler units  $12_1, 12_2, \dots, 12_M$  in the summing device 24. For the input code sequence described, two signals of interest are present at the output separated by time  $T$ . In the optical processing system shown, the first signal is always a pulse of intensity  $M$ , and hence its magnitude can be disregarded for the purpose of determining matching or mis-matching. It will be understood that the magnitude of the second pulse varies, and this pulse can be used to indicated matching, total mis-matching or partial mis-matching of the input code sequence. Thus, the second pulse is used as the sole indication of whether matching or mis-matching has occurred.

In the embodiment shown, detection is carried out by first detecting the pulse of magnitude  $M$ , in this case a magnitude of 4, and the detection of this pulse is used to trigger a detector so that, after a time  $T$  has elapsed, the magnitude of the next pulse detected will indicate whether the system is matched or mis-matched. This is achieved by setting a threshold value so that the first pulse of value  $M = 4$  exceeds a threshold, and triggers a detector circuit so that, after a time  $T$ , the next signal can be detected to determine matching or mis-matching. Detection is achieved using a photodetector which monitors the output sequence, and which indicates that the pulse after the maximum pulse contains the matching information. An advantage of this method is that there is no need to synchronise pulse detection with the timing of pulses input to the optical processing system. The detection device will enable the pulse to be monitored to be converted from light to voltage using, for example, a photodiode and then observed electronically on an oscilloscope or the like with a degree of mis-match being readily quantifiable.

It will be appreciated that various modifications may be made to the optical processing system and method hereinbefore described without departing from the scope of the invention. In particular, Figure 3 shows a modification to the embodiment hereinbefore described in which the matching and mis-matching can be detected using processor, shown in broken outline and generally indicated by reference numeral 25, which consists of a delay device 26 having an optical coupler pair 26A, 26B, the principal channel of which is coupled to the output of the summing device 24. The principal channel output of the delay device 26 is coupled to the input of a switching device 28 of the same type as switching devices 18<sub>1</sub>, 18<sub>2</sub> ..... 18<sub>M</sub>. The optical couplers 26A, 26B of the delay device 26 each have a 50% coupling ratio. This means that, for an input pulse of magnitude  $n$ , the output of the first optical coupler 26A is  $n/2$ ; and, when this is passed to the second coupler 26B, the output is  $n/4$ . When a second pulse of zero magnitude is received, for a perfect match, the output from the second coupler 26B consists of  $n/4 + 0$  because there is no output from the second matching pulse. The output  $n/4$  is fed to the switching device 28 and passes straight through when there is a perfect match between the input data and the sequence programmed into the processor.

In the case of a total mis-match, that is for two pulses of  $n$  separated by time  $T$  being received from the output of the summing device 26, the output from the second coupler 26B is  $n/4$ . However, the output corresponding to the second pulse is also  $n/4$  because of the 50% coupling ratio of each coupler. Therefore, the output at time  $t + T$  is  $n/2$  ( $n/4 + n/4$ ), and this is dumped by the switch 28. The threshold of the switch 28 is set such that, for any output greater than  $n/4$ , it is dumped, so that only an output indicative of a match is passed straight through the switch.

A further modification to the method of detecting whether matching or mis-matching has occurred, is to synchronise a detector at an output of the summing device 24 such that the detector is switched to detect the pulse of interest at an interval equal to the sum of all the time delays of the processor, not including time delay 26 if the unit 25 is connected to the summing device. The pulse of interest is, of course, the pulse which indicates whether there is total matching, total mis-matching or partial mis-matching of the input signal in the optical processing system.

This interval is given by the formula:

$$[(n - 1) M - (M - 1)n] T$$

Where  $M$  is the number of processing devices

$T$  is the time interval between successive pulses, and

$n$  is the number of optical units per processing device.

This means that, for each input pulse after the time interval given by the above formula, the switch is synchronised to detect whether matching or mis-matching has occurred for the input data. However, the aforedescribed method of using the first received pulse of amplitude  $M$  as a trigger for sampling the next pulse is preferred because of its simplicity.

It will be appreciated that, by virtue of the pre-transmission coding of data, any number of pulses may be used to process an input binary pulse, for example, in each processing device 10<sub>1</sub>, 10<sub>2</sub> ..... 10<sub>M</sub> three or more optical couplers could be used to process (translate) each input pulse into three or more output pulses. The number of couplers in each processing device 10<sub>1</sub>, 10<sub>2</sub> ..... 10<sub>M</sub>, determines the number of pulses per input binary digit. The expression  $N = nM$  determines the total number of pulses ( $N$ ) received by the processor where  $n$  is the number of optical couplers per processing device 10<sub>1</sub>, 10<sub>2</sub> ..... 10<sub>M</sub>, and  $M$  is the number of processing devices. Processing such data to determine matching or mis-matching may be carried out as described above. It will be understood that, in such an optical processing system, a serially-connected principal channel is provided and the coupled channels of each of the stages are connected in parallel to switching units which can be pre-set to pass selected outputs to a summing device in a manner as hereinbefore described.

It will also be understood that each of the processing devices 10<sub>1</sub>, 10<sub>2</sub> ..... 10<sub>M</sub> is separated by time  $nT$ , where  $n$  is an integer and is the number of couplers per processing device, and that the optical waveguide used to create the time delay  $nT$  can be a long length of optical fibre coiled onto a drum or the like. In addition, the Gold code sequence can be replaced by any suitable code which has a large number of orthogonal sequences, and which has an auto-correlation function as large as possible and a cross-correlation function as small as possible.

A signal processor as hereinbefore described can be formed using discrete optical components or as a single integrated optical device. The principal advantage of an optical processing unit is speed of operation and immunity to noise. The optical processor has application in local area networks where a large number of assignable addresses are required.

In particular, it will be understood that the application in local area networks is to select a particular stream of data out of many such streams. Thus, the matching or mis-matching performed by the optical processing system will enable signals having the correct header codes to be correctly selected. It will also be appreciated that the optical processing system hereinbefore described can be organised to increase or decrease the num-

ber of processing devices, and the particular coding selected by the optical processing system can be varied by using individual couplers which are programmable. Therefore, the processing devices in a particular optical processing system can be reconfigured by external programming to vary the coding sequence to match that of the input code and thus select a particular input signal of corresponding data. Such re-programming of the optical processing system can be done remotely from a central processing unit, or this could be achieved locally if it was known which particular code was to be received by the local station.

It will be also appreciated that the programmable device may be controlled electrically, optically or acoustically. Electrical control is preferred, and includes an electro-optical substrate, such as lithium niobate, which allows an electrical signal to be applied to the coupler and the optical properties of the coupler to be set. This can result in a change in coupling ratio from an enable condition (that is, coupling) to an inhibit condition (that is, no-coupling) or vice-versa.

### Claims

1. An optical processing device (10) for processing an optical input signal to determine matching or mis-matching between the input signal and a predetermined reference, the optical processing device comprising a series of at least two optical couplers (12A, 12B) each having a principal channel (14) and a coupled channel (16) the principal channels of the couplers being connected in series with a time delay  $T$  between adjacent couplers, where  $T$  is the time between successive pulses in the optical input signal, the coupled channels of the couplers being connected in series with a time delay ( $dT$ ) between adjacent couplers which is minimal in comparison to the time delay  $T$ , characterised in that each optical coupler is pre-settable to enable or inhibit optical coupling of an input signal from its principal channel to its coupled channel in accordance with the predetermined reference, the input signal entering the optical processing device via the principal channel of the first in the series of optical couplers, and the output of the optical processing device being taken from the coupled channel of the last of the series of optical couplers, wherein the output of the optical processing device is coupled to optical switch means (18), the optical switch means being pre-settable to provide an output signal when the optical input thereto exceeds a threshold value.
2. An optical processing device as claimed in claim 1, wherein there are two optical couplers (12A, 12B) whereby, for each optical input pulse, there is provided an optical output signal consisting of two outputs separated by time  $T$ .
3. An optical processing system for determining matching or mis-matching between an optical input signal and a predetermined reference, the system comprising a plurality of optical processing devices ( $10_1, 10_2, \dots, 10_M$ ) each as claimed in claim 1 or claim 2, each optical processing device having  $n$  optical couplers (12A, 12B), the principal channel (14) of each optical processing device being coupled to the principal channel (14) of an adjacent optical processing device by a time delay  $nT$ , the outputs of the optical switch means ( $21_1, 21_2, \dots, 21_M$ ) being coupled in parallel to an optical summing unit (24), the principal and coupled channels being dimensioned and proportioned such that the outputs of the optical switch means arrive at the summing unit substantially simultaneously, the optical summing unit providing an optical output signal for each optical input signal input into the optical processing system, the optical output signal consisting of  $n$  optical pulses.
4. An optical processing system as claimed in claim 3, wherein each coupler (12A, 12B) is programmable to vary the coding selected by the optical processing system.
5. An optical processing system as claimed in claim 3 or claim 4, wherein each optical processing device ( $10_1, 10_2, \dots, 10_M$ ) includes two optical couplers (12A, 12B) such that each optical input pulse is processed into two output pulses separated by time  $T$ , and the pulses are passed to respective switches ( $18_1, 18_2, \dots, 18_M$ ) from each optical processing device so that the output of the optical processing system consists of a stream of optical pulses, and within said stream one optical pulse represents whether data has been matched or mis-matched and also any level of mis-match.
6. An optical processing system as claimed in any one of claims 3 to 5, wherein the optical processing system is coupled to synchronising means for synchronising the output pulses with the input pulses to determine whether matching or mis-matching has occurred.



ber of processing devices, and the particular coding selected by the optical processing system can be varied by using individual couplers which are programmable. Therefore, the processing devices in a particular optical processing system can be reconfigured by external programming to vary the coding sequence to match that of the input code and thus select a particular input signal of corresponding data. Such re-programming of the optical processing system can be done remotely from a central processing unit, or this could be achieved locally if it was known which particular code was to be received by the local station.

It will be also appreciated that the programmable device may be controlled electrically, optically or acoustically. Electrical control is preferred, and includes an electro-optical substrate, such as lithium niobate, which allows an electrical signal to be applied to the coupler and the optical properties of the coupler to be set. This can result in a change in coupling ratio from an enable condition (that is, coupling) to an inhibit condition (that is, no-coupling) or vice-versa.

### Claims

1. An optical processing device (10) for processing an optical input signal to determine matching or mis-matching between the input signal and a predetermined reference, the optical processing device comprising a series of at least two optical couplers (12A, 12B) each having a principal channel (14) and a coupled channel (16) the principal channels of the couplers being connected in series with a time delay  $T$  between adjacent couplers, where  $T$  is the time between successive pulses in the optical input signal, the coupled channels of the couplers being connected in series with a time delay ( $dT$ ) between adjacent couplers which is minimal in comparison to the time delay  $T$ , characterised in that each optical coupler is pre-settable to enable or inhibit optical coupling of an input signal from its principal channel to its coupled channel in accordance with the predetermined reference, the input signal entering the optical processing device via the principal channel of the first in the series of optical couplers, and the output of the optical processing device being taken from the coupled channel of the last of the series of optical couplers, wherein the output of the optical processing device is coupled to optical switch means (18), the optical switch means being pre-settable to provide an output signal when the optical input thereto exceeds a threshold value.
2. An optical processing device as claimed in claim 1, wherein there are two optical couplers (12A, 12B) whereby, for each optical input pulse, there is provided an optical output signal consisting of two outputs separated by time  $T$ .
3. An optical processing system for determining matching or mis-matching between an optical input signal and a predetermined reference, the system comprising a plurality of optical processing devices ( $10_1, 10_2, \dots, 10_M$ ) each as claimed in claim 1 or claim 2, each optical processing device having  $n$  optical couplers (12A, 12B), the principal channel (14) of each optical processing device being coupled to the principal channel (14) of an adjacent optical processing device by a time delay  $nT$ , the outputs of the optical switch means ( $21_1, 21_2, \dots, 21_M$ ) being coupled in parallel to an optical summing unit (24), the principal and coupled channels being dimensioned and proportioned such that the outputs of the optical switch means arrive at the summing unit substantially simultaneously, the optical summing unit providing an optical output signal for each optical input signal input into the optical processing system, the optical output signal consisting of  $n$  optical pulses.
4. An optical processing system as claimed in claim 3, wherein each coupler (12A, 12B) is programmable to vary the coding selected by the optical processing system.
5. An optical processing system as claimed in claim 3 or claim 4, wherein each optical processing device ( $10_1, 10_2, \dots, 10_M$ ) includes two optical couplers (12A, 12B) such that each optical input pulse is processed into two output pulses separated by time  $T$ , and the pulses are passed to respective switches ( $18_1, 18_2, \dots, 18_M$ ) from each optical processing device so that the output of the optical processing system consists of a stream of optical pulses, and within said stream one optical pulse represents whether data has been matched or mis-matched and also any level of mis-match.
6. An optical processing system as claimed in any one of claims 3 to 5, wherein the optical processing system is coupled to synchronising means for synchronising the output pulses with the input pulses to determine whether matching or mis-matching has occurred.



7. A method of detecting matching or mis-matching between an optical input signal and a predetermined reference, the method comprising the steps of coupling together a plurality of optical processing devices (10) each as claimed in claim 1 or claim 2, coupling the outputs ( $21_1, 21_2 \dots 21_M$ ) of the optical switch means ( $18_1, 18_2, \dots 18_M$ ) in parallel to a summing device (24), summing the parallel outputs of the optical switch means in the summing device simultaneously to provide a summed output which is representative of pre-set coding of the optical processing devices and pre-set threshold values of the switch means, and monitoring the output to determine whether the input data sequence and the predetermined sequence are matched or mis-matched.
8. A method as claimed in claim 7, further comprising the steps of pre-selecting the coupling ratios in the couplers (12A, 12B) of each optical processing device (10) to provide a predetermined output code, providing an output from each optical processing device consisting of a sequence of optical output pulses, monitoring the magnitude of one of the optical output pulses of each of said outputs and comparing the monitored value with a pre-set value, and providing a subsequent output depending on the result each of said comparisons.
9. A method as claimed in claim 7, wherein the optical input data sequence comprises a coded sequence of optical input pulses separated by time T, wherein the output of each optical processing device has a plurality of optical output pulses separated by time T, wherein each output is compared with a pre-set threshold value to provide a comparator output signal, the comparator output signals being summed in the summing device (24) substantially simultaneously to provide an optical system output which comprises an optical signal having a plurality of optically-summed pulses separated by time T, and wherein each optically-summed pulse has a magnitude determined by the number of optical processing devices.
10. A method as claimed in any one of claims 7 to 9, wherein the summation of output data is completed when all of the optical processing devices are fully loaded.
11. A method as claimed in any one of claims 7 to 10, wherein the output of the summing device (24) comprises a sequence of optical cumulative pulses corresponding to the sum of the outputs of the optical processing devices (10), and the method further comprises detecting when the first optical cumulative pulse exceeds a pre-set value, triggering monitoring means (25) to monitor the magnitude of the next cumulative pulse, and providing an output indicative of matching or the degree of mis-matching depending on the value of the subsequent measured pulse.

## Patentansprüche

1. Optische Prozessorvorrichtung (10) für die Verarbeitung eines optischen Eingangssignals, um die Übereinstimmung oder Nicht-Übereinstimmung zwischen dem Eingabesignal und einer vorgegebenen Referenz zu ermitteln, welche Prozessorvorrichtung eine Reihe von wenigstens zwei optischen Richtkopplern (12A, 12B), jeweils mit einem Hauptkanal (14) und einem gekoppelten Kanal (16) umfaßt, wobei die Hauptkanäle der Koppler mit einer Zeitverzögerung T zwischen benachbarten Kopplern in Reihe verbunden sind, wobei T die Zeit zwischen aufeinanderfolgenden Pulsen im optischen Eingabesignal ist, wobei die gekoppelten Kanäle der Koppler mit einer Zeitverzögerung ( $dT$ ) zwischen benachbarten Kopplern in Reihe verbunden sind, die im Vergleich zur Zeitverzögerung T minimal ist, dadurch gekennzeichnet, daß  
 Jeder optische Richtkoppler voreinstellbar ist, um die optische Kopplung eines Eingangssignals von seinem Hauptkanal in den gekoppelten Kanal gemäß der vorgegebenen Referenz zu ermöglichen oder zu sperren, wobei das Eingabesignal über den Hauptkanal des ersten in der Reihe von optischen Richtkopplern in die optische Prozessorvorrichtung eintritt und die Ausgabe der optischen Prozessorvorrichtung vom gekoppelten Kanal des letzten aus der Reihe von optischen Richtkopplern abgenommen wird, wobei die Ausgabe der optischen Prozessorvorrichtung an ein optisches Schaltmittel (18) gekoppelt ist, das voreinstellbar ist, um ein Ausgabesignal zu liefern, wenn seine optische Eingabe einen Schwellwert überschreitet.
2. Optische Prozessorvorrichtung nach Anspruch 1, mit zwei optischen Richtkopplern (12A, 12B), wodurch für jeden optischen Eingabepuls ein optisches Ausgabesignal erzeugt wird, das aus zwei Ausgaben mit dem Zeitabstand T besteht.



3. Optisches Prozessorsystem zum Bestimmen der Übereinstimmung oder Nicht-Übereinstimmung eines optischen Eingangssignals mit einer vorgegebenen Referenz, das eine Mehrzahl optischer Prozessorvorrichtungen ( $10_1, 10_2, \dots, 10_M$ ) jeweils nach Anspruch 1 oder Anspruch 2 umfaßt, wobei jede optische Prozessorvorrichtung n optische Richtkoppler (12A, 12B) umfaßt, wobei der Hauptkanal (14) einer jeden optischen Prozessorvorrichtung mit dem Hauptkanal (14) einer benachbarten optischen Prozessorvorrichtung über eine Zeitverzögerung nT verbunden ist, wobei die Ausgänge der optischen Schaltmittel ( $21_1, 21_2, \dots, 21_M$ ) parallel an eine optische Summationseinheit (24) gekoppelt sind, wobei die Hauptkanäle und die gekoppelten Kanäle so bemessen und proportioniert sind, daß die Ausgaben der optischen Schaltmittel die Summationseinheit im wesentlichen gleichzeitig erreichen, wobei die optische Summationseinheit ein optisches Ausgangssignal für jedes in das optische Prozessorsystem eingegebene Eingangssignal erzeugt und das optische Ausgangssignal aus n optischen Pulsen besteht.
4. Optisches Prozessorsystem nach Anspruch 3, bei dem jeder Koppler (12A, 12B) programmierbar ist, um die vom optischen Prozessorsystem gewählte Codierung zu verändern.
5. Optisches Prozessorsystem nach Anspruch 3 oder Anspruch 4, bei dem jede optische Prozessorvorrichtung ( $10_1, 10_2, \dots, 10_M$ ) zwei optische Richtkoppler (12A, 12B) enthält, so daß jeder optische Eingabepuls zu zwei Ausgabepulsen mit dem Zeitabstand T verarbeitet wird und die Pulse von jeder optischen Prozessorvorrichtung zu entsprechenden Schaltern ( $18_1, 18_2, \dots, 18_M$ ) weitergegeben werden, so daß die Ausgabe des optischen Prozessorsystems aus einem Strom optischer Pulse besteht, und daß in dem Strom ein optischer Puls die Übereinstimmung oder Nicht-Übereinstimmung von Daten sowie ein Maß der Nicht-Übereinstimmung angibt.
6. Optisches Prozessorsystem nach einem der Ansprüche 3 bis 5, das an Synchronisierungsmittel gekoppelt ist, um die Ausgabepulse mit den Eingabepulsen zu synchronisieren, um zu ermitteln, ob Übereinstimmung oder Nicht-Übereinstimmung aufgetreten ist.
7. Verfahren zur Erfassung der Übereinstimmung oder Nicht-Übereinstimmung zwischen einem optischen Eingangssignal und einer vorgegebenen Referenz, mit den Schritten des Aneinanderkoppelns einer Mehrzahl optischer Prozessorvorrichtungen (10) nach Anspruch 1 oder Anspruch 2, Parallelkoppeln der Ausgaben ( $21_1, 21_2, \dots, 21_M$ ) der optischen Schaltmittel ( $18_1, 18_2, \dots, 18_M$ ) an eine Summationsvorrichtung (24), simultanes Summieren der parallelen Ausgaben der optischen Schaltmittel in der Summationsvorrichtung, um eine summierte Ausgabe zu erzeugen, die für eine voreingestellte Codierung der optischen Prozessorvorrichtungen und voreingestellte Schwellwerte der Schaltmittel repräsentativ ist, und Überwachen der Ausgabe, um zu bestimmen, ob die Eingabedatenfolge und die vorgegebene Folge übereinstimmen oder nicht.
8. Verfahren nach Anspruch 7, zusätzlich mit den Schritten der Vorwahl der Kopplungsverhältnisse in den Kopplern (12A, 12B) jeder optischen Prozessorvorrichtung (10), um einen vorgegebenen Ausgabecode zu erzeugen, Erzeugen einer Ausgabe einer jeden optischen Prozessorvorrichtung, die aus einer Folge optischer Ausgabepulse besteht, Überwachen der Stärke eines der optischen Ausgabepulse jeder dieser Ausgaben und Vergleichen des überwachten Werts mit einem voreingestellten Wert, und Erzeugen einer darauffolgenden Ausgabe in Abhängigkeit vom Ergebnis eines jeden Vergleichs.
9. Verfahren nach Anspruch 7, bei dem die optische Eingabedatenfolge eine codierte Folge optischer Eingabepulse mit dem Zeitabstand T umfaßt, wobei die Ausgabe jeder optischen Prozessorvorrichtung eine Mehrzahl optischer Ausgabepulse mit dem Zeitabstand T umfaßt, wobei jede Ausgabe mit einem voreingestellten Schwellwert verglichen wird, um ein Komparatorausgangssignal zu erzeugen, die Komparatorausgangssignale in der Summationsvorrichtung (24) im wesentlichen gleichzeitig summiert werden, um eine Ausgabe des optischen Systems zu erzeugen, die ein optisches Signal mit einer Mehrzahl optisch summierter Pulse mit dem Zeitabstand T umfaßt und wobei jeder optisch summierte Puls eine durch die Anzahl optischer Prozessorvorrichtungen bestimmte Stärke hat.
10. Verfahren nach einem der Ansprüche 7 bis 9, bei dem die Summation der Ausgabedaten beendet wird, wenn alle optischen Prozessorvorrichtungen vollständig geladen sind.
11. Verfahren nach einem der Ansprüche 7 bis 10, bei dem die Ausgabe der Summationsvorrichtung (24) eine Folge von kumulativen optischen Pulsen umfaßt, die der Summe der Ausgaben der optischen Prozessorvorrichtungen (10) entsprechen, und bei dem das Verfahren außerdem umfaßt: Erfassen, wann der erste



kumulative optische Puls einen voreingestellten Wert überschreitet, Auslösen von Überwachungsmitteln (25) zur Überwachung der Stärke des nächsten kumulativen Pulses und Erzeugen einer die Übereinstimmung oder den Grad der Nicht-Übereinstimmung anzeigenden Ausgabe in Abhängigkeit vom Wert des nachfolgenden gemessenen Pulses.

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## Revendications

1. Un dispositif de traitement optique (10) servant à traiter un signal d'entrée optique afin de déterminer une concordance ou une discordance entre le signal d'entrée et une référence prédéterminée, le dispositif de traitement optique comprenant une série d'au moins deux coupleurs optiques (12A, 12B) comprenant chacun un canal principal (14) et un canal couplé (16), les canaux principaux des coupleurs étant reliés en série avec un retard de temps  $T$  entre coupleurs adjacents, où  $T$  est le temps compris entre les impulsions successives dans le signal d'entrée optique, les canaux couplés des coupleurs étant reliés en série avec un retard de temps ( $dT$ ) entre coupleurs adjacents qui est minimal par rapport au retard de temps  $T$ , caractérisé en ce que chaque coupleur optique est réglable au préalable pour permettre ou empêcher un couplage optique du signal d'entrée à partir de son canal principal vers son canal couplé conformément à la référence prédéterminée, le signal d'entrée entrant dans le dispositif de traitement optique par l'intermédiaire du canal principal du premier des coupleurs optiques de la série, et la sortie du dispositif de traitement optique étant prise au canal couplé du dernier de la série de coupleurs optiques, la sortie du dispositif de traitement optique étant couplée à un moyen commutateur optique (18), le moyen commutateur optique étant réglable au préalable de manière à produire un signal de sortie lorsque l'entrée optique qui y parvient dépasse une valeur de seuil.
2. Un dispositif de traitement optique selon la revendication 1, dans lequel il existe deux coupleurs optiques (12A, 12B), grâce à quoi il est produit, pour chaque impulsion d'entrée optique, un signal de sortie optique consistant en deux sorties optiques séparées par un temps  $T$ .
3. Un système de traitement optique servant à déterminer une concordance ou une discordance entre un signal d'entrée optique et une référence prédéterminée, le système comprenant une série de dispositifs de traitement optiques ( $10_1, 10_2, \dots 10_M$ ) conformes chacun à la revendication 1 ou à la revendication 2, chaque dispositif de traitement optique comprenant des coupleurs optiques (12A, 12B), le canal principal (14) de chaque dispositif de traitement optique étant couplé au canal principal (14) d'un dispositif de traitement optique adjacent par un retard de temps  $nT$ , les sorties des dispositifs commutateurs optiques ( $21_1, 21_2, \dots 21_M$ ) étant couplés en parallèle à une unité de sommation optique (24), les canaux principaux et couplés étant dimensionnés et proportionnés d'une manière telle que les sorties des moyens commutateurs optiques arrivent de façon sensiblement simultanée à l'unité de sommation, l'unité de sommation produisant un signal de sortie optique pour chaque entrée de signal d'entrée optique dans le système de traitement optique, ce signal de sortie optique consistant en  $n$  impulsions optiques.
4. Un système de traitement optique selon la revendication 3, dans lequel chaque coupleur (12A, 12B) est programmable de façon à provoquer une variation du codage choisi par le système de traitement optique.
5. Un système de traitement optique selon la revendication 3 ou la revendication 4, dans lequel chaque dispositif de traitement optique ( $10_1, 10_2, \dots 10_M$ ) inclut deux coupleurs optiques (12A, 12B) tels que chaque impulsion d'entrée optique est traitée en deux impulsions de sortie séparées par un temps  $T$ , et les impulsions sont envoyées à partir de chaque dispositif de traitement optique vers des commutateurs respectifs ( $18_1, 18_2, \dots 18_M$ ) de sorte que la sortie du système de traitement optique consiste en un train d'impulsions optiques, et une impulsion optique dudit train indique si la donnée est en concordance ou est en discordance, ainsi que tout niveau de discordance.
6. Un système de traitement optique selon l'une quelconque des revendications 3 à 5, dans lequel le système de traitement optique est couplé à un moyen de synchronisation afin de synchroniser les impulsions de sortie avec les impulsions d'entrée de manière à déterminer s'il s'est produit une concordance ou une discordance.
7. Un procédé de détection de concordance ou de discordance entre un signal d'entrée optique et une référence la prédéterminée, le procédé comprenant les étapes consistant à coupler entre eux une série de dispositifs de traitement optiques (10), conformes chacun à la revendication 1 ou à la revendication 2,



coupler les sorties ( $21_1, 21_2, \dots 21_M$ ) des moyens commutateurs optiques ( $18_1, 18_2, \dots 18_M$ ) en parallèle à un dispositif de sommation (24), sommer simultanément dans le dispositif de sommation les sorties parallèles des moyens commutateurs optiques afin de produire une sortie sommée qui est représentative d'un codage préétabli des dispositifs de traitement optiques et de valeurs préétablies de seuil des moyens commutateurs, et surveiller la sortie afin de déterminer si la séquence de donnée d'entrée et la séquence prédéterminée sont en concordance ou en discordance.

8. Un procédé selon la revendication 7, comprenant en outre les étapes consistant à choisir au préalable les rapports de couplage des coupleurs (12A, 12B) de chaque dispositif de traitement optiques (10) afin de produire un code de sortie prédéterminé, produire à partir de chaque dispositif de traitement optique une sortie consistant en une séquence d'impulsions de sorties optiques, surveiller l'amplitude de chacune des impulsions de sorties optiques de chacune desdites sorties et comparer la valeur surveillée avec une valeur préétablie, et produire une sortie ultérieure qui dépend du résultat de chacune desdites comparaisons.
9. Un procédé selon la revendication 7, dans lequel la séquence de donnée d'entrée optique comprend une séquence codée d'impulsions d'entrée optiques séparées par un temps T, dans lequel la sortie de chaque dispositif de traitement optique comprend une série d'impulsions optiques de sortie séparées par un temps T, dans lequel chaque sortie est comparée à une valeur de seuil préétablie afin de réaliser un signal de sortie de comparateur, les signaux de sortie des comparateurs étant sommés dans le dispositif de sommation (24) de façon sensiblement simultanée afin de réaliser une sortie de système optique qui comprend un signal optique incluant une série d'impulsions optiquement sommées, séparées par un temps T, et dans lequel l'amplitude de chaque impulsion optiquement sommée est déterminée par le nombre de dispositifs de traitement optiques.
10. Un procédé selon l'une quelconque des revendications 7 à 9, dans lequel la sommation de donnée de sortie est achevée lorsque tous les dispositifs de traitement optiques sont complètement chargés.
11. Un procédé selon l'une quelconque des revendications 7 à 10, dans lequel la sortie du dispositif de sommation (24) comprend une séquence d'impulsions optiques cumulatives correspondant à la somme des sorties des dispositifs de traitement optiques (10), et le procédé comprend en outre une détection de l'instant où la première impulsion optique cumulative dépasse une valeur préétablie, un déclenchement d'un moyen de surveillance (25) pour surveiller l'amplitude de l'impulsion cumulative suivante, et la production d'une sortie indicative de la concordance ou du degré de discordance selon la valeur de l'impulsion ultérieure mesurée.