ALL OPTICAL PROCESSING IN COMMUNICATIONS SYSTEMS

This invention relates to optical processing apparatus and systems, and to methods of processing optical communication signals, and particularly to systems, methods and apparatus for manipulating wavelength division multiplexed optical signals.

Optical fibres are an extremely efficient transmission medium. Presently, the capacity of optical fibre communications systems is limited by certain factors, including the way in which the optical fibre bandwidth is utilised, and the opto-electronic components required to control certain optical communication processing functions.

The first factor, that of bandwidth use, is generally addressed by the use of various multiplexing techniques, for example wavelength division multiplexing (WDM) or optical time division multiplexing (OTDM).

The second factor has been extensively investigated over the past six or seven years, the results being demonstrations of all-optical processing functions in optical fibres and semiconductor optical devices. An optical fibre communications network incorporating only all-optical processing functions would potentially provide communications capacity far beyond that which is currently available in optical fibre communications networks incorporating very much slower opto-electronic processing functions.

In terms of bandwidth usage, WDM networks have received considerable attention in recent years, and are likely to provide optical routing in, for example, a metropolitan or national network, where a large node density makes the simple passive demultiplexing (wavelength filtering) associated with WDM attractive. However, the combination of dispersion and fibre non-linearity potentially restricts the size of WDM networks, or the ability to expand WDM networks, if traditional signalling formats are employed. Therefore, presently OTDM is more likely to find application over wider geographical areas, with a smaller number of higher capacity optical switches, since a single wavelength, multiplexed channel system such as OTDM is not so susceptible to the detrimental effects non-linearity and dispersion as a WDM system, particularly when soliton transmission effects are employed to balance non-linearity against dispersion. Furthermore, gain flatness equalisation or

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pre-emphasis techniques are not an important consideration for single wavelength OTDM systems, whereas such techniques would be an important aspect of the design of a corresponding WDM system, considerably simplifying amplifier (or power) management.

Recognising the problems of scalability associated with WDM communications networks, but at the same time appreciating that WDM has many advantages, for example simple passive demultiplexing, the applicants have considered that in future there might be a need for an all-optical communications network which is potentially able to deal with WDM traffic (eg on a local scale), OTDM traffic (eg on international trunk routes), and soliton traffic (eg on information super-highways). To be effective, such an optical network would also need to be able to convert between any two of the traffic formats employed, otherwise universal interconnection to, and information interchange across, the network would be restricted.

Presently, generation and transmission of WDM, OTDM and soliton optical signalling formats is known and has been widely reported. Also, Lacey, et al. "All optical WDM to TDM transmultiplexer", Electronics Letters, 15 SEPT. 1994, pp 1612-1613, proposes WDM to TDM conversion firstly by splitting the WDM signal into its constituent channels using wavelength selective filters and mixing each channel with a clock pulse in separate respective optical amplifiers. This has the effect that gain compression causes wavelength conversion and reduces the width of the WDM data pulses. Then, each channel is delayed by separate respective optical delay lines having different delays, and finally all the channels are re-multiplexed using an optical coupler. Bigo, et al, "Bit-rate enhancement through optical NRZ-to-RZ conversion and passive time-division multiplexing for soliton transmission systems", Electronics Letters 1994, vol. 30, pp 984-985, proposes using an optical loop mirror as an AND gate for an NRZ data signal and a clock signal to provide NRZ to RZ conversion. Further, Bigo et al. proposes multiplexing a plurality of these AND outputs to provide bit-rate enhancement (TDM).

According to a first aspect, the present invention provides an optical processing apparatus comprising:

a non-linear optical element having input means to receive an optical data input and a clock input, and optical data output means;

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means to filter an optical data output signal received from said optical data output means; and

means to temporally shift different wavelengths in said optical data output signal by different pre-determined amounts.

This apparatus forms the first part of an overall apparatus for carrying out NRZ to RZ conversion.

By correctly placing the apparatus, for example, in a metropolitan area network (MAN), standard WDM NRZ signalling can be employed for all traffic within the MAN, whilst long-haul traffic, for example to a second, far-removed MAN can be routed across a soliton supporting communications link, by converting the NRZ format signal to a RZ format in accordance with the present invention, and subsequently to a soliton format signal by a known method. This approach has the advantage that all sources and wavelength converters/switches within each MAN need not necessarily be soliton compatible. Thus, advantageously, existing WDM infrastructure can be maintained, minimising the capital cost of installing the system.

The non-linear optical element preferably comprises a travelling wave semiconductor laser amplifier (TWSLA). In a TWSLA, a strong clock pulse signal is provided, having a pulse repetition rate at least as high as the highest bit-rate WDM channel, which periodically modulates the TWSLA carrier density, imposing cross-phase modulation (XPM) on WDM channels propagating through the amplifier. The result of the XPM is a spectrally-broadened WDM signal wherever the WDM signal is coincident with the clock pulse signal.

When the optical signals are spectrally broadened by XPM in a non-linear element, the apparatus preferably further comprises a cyclic filter downstream of the non-linear element to perform a frequency discrimination function. The cyclic filter eliminates the un-modulated background of the WDM channels so should have regular pass and stop bands, with a good stop band extinction. Suitable filters include Mach Zehnder interferometers, Fabry Perot interferometers and birefringent filters.

One form of suitable cyclic filter is a birefringent fibre incorporating input and output polarisation control. The filter selects the required wavelengths by modifying the polarisations of each WDM channel in the fibre, so that the required

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wavelengths coincide with an output polariser. An arrangement of this type can provide excellent extinction with relatively broad pass-bands. The resulting filtered signal is substantially a WDM RZ, pulse signal representation of the WDM NRZ signal.

A significant advantage of incorporating an non-linear optical element into the apparatus of the present invention is that conversion from NRZ to RZ of all WDM channels is carried out simultaneously in a single element, and that the operating speed is limited by optical non-linearity rather than by the speed of alternative opto-electronic devices.

A significant advantage of using XPM in a TWSLA as the non-linear element is the intrinsic wavelength insensitivity of the TWSLA, and whilst similar XPM effects have been demonstrated in optical fibre, constraints imposed by chromatic dispersion in optical fibres preclude multi-channel operation over a wide wavelength range, although the use of dispersion-flattened fibre may alleviate some of these difficulties.

An alternative non-linear element to a TWSLA is a non-linear optical loop mirror (NOLM). In particular, a NOLM incorporating a semiconductor laser amplifier is preferred since fibre NOLMs may suffer from unwanted dispersion effects and phase matching problems.

A NOLM has an advantage over the method described above that a cyclic filter is not required since the cross-phase modulated signal portions are switched out of a different output from the non-cross-phase modulated signal portions, rather than being combined.

Other non-linear elements which could be used in place of a TWSLA or a NOLM include a polarisation rotation gate, a non-linear Mach Zehnder interference gate, a non-linear directional coupler, or a non-linear Fabry Perot interferometer. This list of alternatives is by no means exhaustive, and does not limit the choice to those alternatives listed. A further alternative, limited in processing speed, is electro-optic modulation using for example electro-absorption modulators to form the pulses.

In a preferred embodiment, the present invention further comprises shift means for temporally shifting each one of the discrete wavelength channels by a

different predetermined amount to provide a wavelength-interleaved time division multiplexed (WITDM) signal.

In this way, a WDM signal (RZ format), is converted to a pseudo-OTDM signal which has the temporal form of an OTDM signal, but not the spectral form (that is, at this stage the signal comprises a series of pulses which sequentially cycle through the different wavelengths of the WDM signal). The formation of a WITDM signal can be an intermediate step towards conversion to an OTDM signal, as described below.

The shift means preferably comprises a dispersive element, which provides a fixed amount of chromatic dispersion to delay each one of the discrete wavelength channels by a different amount, thus producing the WITDM signal.

The dispersive element could comprise a suitable length of standard optical fibre, however a pair of refraction gratings or other dispersive elements could be used instead. However, using a length of standard optical fibre has the advantage that the entire operation of converting from a purely wavelength multiplexed signal to a WITDM signal is achieved in a single optical fibre path. In contrast, in known systems, conversion from WDM to a time division multiplexed format would involve delaying individual channels each by a different amount using different delay lines, and then combining the delayed signals in an optical interleaver. Such systems may be unreliable since optical interleavers typically exhibit poor stability. There is also the greater cost of such systems to consider, compared to the cost of a length of standard optical fibre which can achieve the same effect. The length of optical fibre required is determined by the extent of temporal shifting required between WDM channels, and by the dispersion constant of the optical fibre.

The effect of the dispersion on the pulses in an optical fibre should be considered, and it would appear that lower dispersions would be required to reduce any unwanted temporal broadening, resulting in broad RZ pulses. It is perhaps fortunate, however, that the chirp experienced by pulses formed in a TWSLA can produce pulse compression in standard optical fibre in some circumstances. Thus, preferably, an optical fibre dispersive element both compresses and interleaves the pulses in a preferred scheme.

It will be appreciated that the use of dispersion, for example in a length of optical fibre, as described above, to provide a WITDM signal from a RZ format WDM signal, is not limited to use in accordance with the present invention. Indeed, a WDM signal (RZ format) may be provided by any source and the subsequently formed WITDM signal could be used in accordance with the present invention, or in any other apparatus requiring such a signal.

In a preferred embodiment, the present invention further comprises a second non-linear optical element for converting the WITDM signal to a single wavelength OTDM signal.

This second non-linear optical element can conveniently embody the features of the first non-linear optical element described above.

Therefore, preferably the second non-linear optical element comprises a second TWSLA which operates in a similar fashion to the operation of the first TWSLA, described above. However, in this case, the WITDM signal is arranged to phase-modulate a cw beam, and the cyclic filter is replaced by a bandwidth limiting filter, to isolate the resultant, single wavelength, OTDM signal.

Alternatively, the non-linear element can be any other suitable non-linear element, for example a NOLM or a Mach Zehnder interferometer etc, as before.

In a still further embodiment, the speed of operation of a TWSLA, embodied in the second non-linear stage, can be increased by operating the amplifier in accordance with our co-pending European patent application number 93308066.5 (filed on 11 October 1993), in which a third, pump, beam is injected into the TWSLA to suppress data patterning effects that may otherwise occur due to temporally non-uniform carrier density dynamics. The use of such a pump beam to pin the Fermi level and suppress data patterning, is described in further detail in the application mentioned, the disclosure of which is incorporated herein by reference.

An advantage of the present invention is that extremely spectrally pure data pulses are produced, without the using a high specification pulse source. Normally, a pulse source used for producing OTDM signals requires both spectral purity and temporal stability, and hence is relatively expensive. However, in an apparatus according to the present invention, the clock pulse source needs only to provide pulses which are temporally stable, since the spectral purity is achieved

through the second non-linear element and filter (if necessary) arrangement. Therefore, the light source for the OTDM system can be a relatively cheap DFB laser. Alternatively, if a high speed pulse source is available, a second converter may be used to modulate the pulse stream.

A further advantage of the present invention is that all the active components can be semiconductor components, for example TWSLAs, which allows scope for integration (although development of an on-chip cyclic filter and a dispersive element would be required).

According to further aspects, the present invention also provides methods and systems as described in more detail in the claims.

The present invention will now be described, by way of example only, which reference to the accompanying drawings, of which:

Figure 1 is an experimental system to demonstrate conversion of a four channel WDM signal carrying NRZ data to a WDM signal carrying RZ data;

Figure 2 shows a polarisation filter arrangement used in the system of Figure 1;

Figure 3 shows the stages of spectral broadening for a single NRZ pulse;

Figure 4 shows spectral transformations for four RZ wavelength channels;

Figure 5 shows eye diagrams for the four RZ pulse wave forms;

Figure 6 shows BER measurement comparisons for the system in Figure 1;

Figure 7 is system representation suitable for full WDM to OTDM signal conversion;

Figures 8A to 8G are idealised graphical representations of the signal spectra at points in the system of Figure 7; and

Figures 9A to 9G are idealised graphical representations of the time-varying amplitude signal wave forms at points in the system of Figure 7.

The system of Figure 1 is used to generate a four-channel NRZ format, WDM optical signal, to demonstrate conversion of the signal to a corresponding RZ format signal. In the system of Figure 1, a clock signal comprising equally spaced optical pulses is generated by an external cavity semiconductor laser 110 (1545nm) mode-locked at 10 GHz, with a pulse width of 13ps (assuming a Gaussian pulse shape) and a time-bandwidth product of ~0.45.

Four cw channels (1554.2nm, 1556nm, 1557nm, 1558.4nm) are generated by four cw DFB laser diodes 100. The channels are combined by a 4-to-1 fibre coupler 105 and, for the purposes of demonstration, are modulated with a single 10 Gbit/s 2^7 - 1 PRBS using a lithium niobate ($LiNbO_3$) intensity modulator 130, driven by a suitable pattern generator 160.

The clock and NRZ format data signals are amplified in optical amplifiers 120 and 122, for example erbium doped optical fibre amplifiers, and are fed into a TWSLA 145 through a WDM coupler 140. The clock signal is amplified to around 12dBm, and the NRZ signal is amplified to between 1 to 3dBm. The TWSLA 145 is a bulk device, with a coupling loss of ~6dB per facet. Although a TWSLA provides XPM, any element providing a similar function would be suitable, in this case.

A cyclic filter 150 (described in more detail below, with reference to Figure 2) which is implemented using polarisation rotation in a birefringent fibre, performs a frequency discrimination function downstream of the TWSLA 145 to process all four channels simultaneously. The filter cycle is ~0.7nm, and the extinction ratio is about 30dB. Essentially, the filter 150 removes the unperturbed parts of the data signals (the background components) passing signals that are coincident with, and therefore chirped by, the clock signal.

Finally, a 0.5nm tuneable band pass filter 154 selects one of the four RZ channels, for bit-error-rate (BER) measurement purposes. An error detector 158 compares signals selected by the band pass filter 154 and received by an optical receiver 156, with copies of the signals from the pattern generator 160.

The results of the BER measurements for each of the channels in turn are described below with reference to Figure 6.

With reference to Figure 2, the cyclic filter 150 comprises an input 200 to a combination of a polarisation controller (PC) 210 and a polariser 220. The PC 210 and the polariser 220 are tuned to ensure that an optical signal entering the filter has a well-defined polarisation. The PC 210 is included to enable fine adjustment of the input polarisation.

An optical amplifier 230, downstream of the polariser 220, is included to compensate for signal losses due to the initial polarisation selection stage. Any

form of optical amplifier can be used, although a suitable length of erbium-doped optical fibre is preferred.

The optical signal, having passed through the polarisation selection stage, has a well-defined polarisation. In the filter 150, the periodic spectral shifts imposed on the reference beam by the data pulses in the TWSLA 145 experience a wavelength-dependent polarisation rotation in a birefringent element 250 positioned downstream of the amplifier 230. The birefringent element 250 in this case is a birefringent fibre which has a length of 100m and a polarisation mode dispersion of 10ps. By optimising a polarisation controller 260, which is positioned downstream of the birefringent fibre 250, the spectrally un-shifted component of the wave form is blocked by a polariser 270 positioned downstream of the polarisation controller 260, resulting in the transmission of 10% of the light incident on that polariser. The 10% of the light consists of a train of wavelength-converted pulses, where the pulses effectively correspond to a RZ representation of the original signal.

Other known types of wavelength filtering arrangement can easily replace the cyclic filter arrangement described, for example Mach Zehnder interferometers or Fabry Perot interferometers.

Figure 3 shows the spectral broadening stages of one selected NRZ channel. Trace A represents the un-broadened NRZ channel, trace B represents the NRZ channel spectrally broadened by a clock pulse, and trace C shows the cw component removed by the cyclic filter.

In Figure 4, the spectral peaks at the DFB wavelengths (D_x), with and without the clock wave form, are the unconverted residual NRZ signals which are removed by the cyclic filter when its stop bands are aligned with the peaks.

Figures 3 and 4 show that the spectral broadening is asymmetric, being biased to the longer wavelength side due to the gain recovery mechanism in the TWSLA 145. Because of the asymmetry in spectrum, it is possible to remove the un-broadened parts with only ~5dB insertion loss for the broadened signals. The alignment of the four wavelengths with respect to the filter pass bands is realised by a fine tuning of both the temperature and bias current of the DFBs 100.

Figure 5, shows eye diagrams for all four wavelength channels. As can be seen, the diagrams do not show patterning effects, which are completely

suppressed by the strong clock signal. The pulse widths of the converted RZ signals are ~15ps (assuming Gaussian pulse shape) which is very close to the clock pulse width of ~13ps.

To demonstrate the low noise characteristics of the converted RZ signals, BER measurements are carried out for all four channels, the results of which are shown in Figure 6. The receiver 156 sensitivity (@BER = 10^{-9}) spread among the 4 channels is ~1.5 dB, and there is no noticeable error floor at BER = 10^{-11}, illustrating the excellent performance of the scheme.

Figure 7 illustrates a system suitable for converting four NRZ optical signals at different wavelengths into a single OTDM channel.

In the system, a clock signal comprising equally spaced optical pulses is generated by an external cavity semiconductor laser 710 (1545nm) mode-locked at 10 GHz, with a pulse width of 13ps (assuming Gaussian pulse rate) and a time-bandwidth product of ~0.45.

Four WDM format NRZ channels (1554.2nm, 1556nm, 1557nm, 1558.4nm) are generated by four cw DFB laser diodes 700, which produce beams which are modulated by individual modulators 730 (to model four separate wavelength channels). The four channels are combined by a 4 to 1 WDM fibre coupler 705. The combined signal is then preferably passed into an optical element 708 which simulates the effects of an optical communications link, for example by dispersing and attenuating the signal. In practice, a link may be thousands of kilometres long, and may include one or more stages of amplification, signal regeneration, and/or switching. Thus, the parameters of the element 708 may be varied to simulate different link parameters. The element 708 may comprise combinations of different types of optical fibre, dispersive elements and maybe loop mirrors, however, the actual arrangement depends on the effects to be simulated. For the purposes of demonstration, optical element 708 may be omitted from the system altogether.

The clock and NRZ format WDM data signals are amplified in erbium doped optical fibre amplifiers 720 and 722 which provide the necessary signal levels for subsequent stages: the clock signal is amplified to around 12dBm and the NRZ format signal between 1 to 3dBm. The signals are then fed into a TWSLA

745 through a WDM coupler 740. The TWSLA 745 is a bulk device, with a coupling loss of ~6dB per facet.

A cyclic filter 750 (described above, with reference to Figure 2), which is implemented using polarisation rotation in a birefringent fibre, performs a frequency discrimination function downstream of the TWSLA 745 to process all four channels simultaneously. The filter cycle is ~0.7nm, and the extinction ratio is about 30dB. Essentially, the filter 750 removes the unperturbed part of the data signals (the background component) passing signals that are coincident with, and therefore chirped by, the clock signal.

The output of the cyclic filter 750 is dispersed by a dispersive element 760, this element being a length of standard optical fibre. For WDM channels 1.4nm apart, 25ps delay between adjacent channels requires 17.8ps/nm of dispersion, which is provided by around 1km of standard optical fibre. Alternatively, any length of suitably dispersive optical fibre, which provides the required amount of dispersion, could be used.

The dispersed signal is amplified by an amplifier 726 and is fed into a second TWSLA 770, through a WDM coupler 765, along with a cw reference signal amplified by an amplifier 724 and originating from an optically amplified DFB semiconductor laser 772. The WDM pulse stream is amplified to a mean optical power of +12dBm and the co-propagating cw reference signal is amplified to a mean optical power of 4.9dBm.

Optionally, a separate optically amplified counter-propagating (or co-propagating) cw DFB pump beam is injected into the second TWSLA 770, from a DFB semiconductor laser 775, to suppress the data patterning effects that might otherwise occur due to temporally non-uniform carrier density dynamics.

The second TWSLA 770 is a polarisation insensitive bulk-layer device with a peak wavelength of 1.54μm, operating with a DC bias current of 200mA. A filter element 780 positioned downstream of the TWSLA 770, comprises a tuneable band pass filter and polariser which is used to eliminate the residual amplified spontaneous emission and to define the polarisation of the reference signal at the output of the TWSLA 770. The filter 780 is typically similar to the cyclic filter 150 described above with reference to Figure 2. However, for this filter, emphasis is placed on a single accurate pass band and strong rejection about

the required output signal wavelength, rather than on four equally efficient pass and rejection bands.

Figures 8A to 8G represent the spectra of the pulsed clock signal (designated CL) and the four wavelength channels (designated W, X, Y, Z) present at corresponding locations A to G on Figure 7. As can be seen, the four channels (W = 1554.2nm, X = 1555.6nm, Y = 1557nm and Z = 1558.4nm) in Figure 8B are wavelength broadened, as represented in Figure 8C, by the pulse clock signal (1545nm) shown in Figure 8A. Figures 8D and 8E show the channels having been stripped of their cw background component by the filtering. Figure 8F represents the four channels after wavelength conversion by the cw reference signal in the second TWSLA 770, to a single wavelength OTDM signal. Figure 8G represents the resultant OTDM signal at 1545nm, after the cw background of the reference signal has been filtered away.

Figures 9A to 9G represent the time-varying characteristics of the clock and four channels (designated cl,w,x,y,z) which correspond to the same points A to G on Figure 7. Figure 9A represents pulsed clock signal. Figure 9B represents a data pattern superimposed onto all four channels (all data patterns are the same for each channel for the sake of clarity). Figure 9C represents the output of the first TWSLA 745 which comprises components of the data pattern and the clock pulse signals. The figure shows an idealised superposition of wave forms where the signals coincide, which in practice would more closely resemble a disturbance, or glitch, in the data pattern. The output of the filter 750 is represented in Figure 9D. It can be seen in this figure that all but the perturbed (cross-phase modulated) portions of the wave form are filtered out, leaving a pulse train corresponding to a RZ representation of the original NRZ signal.

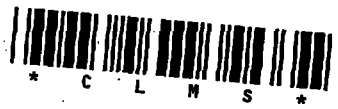
The effect of the dispersive element 760 to disperse each wavelength channel by a different amount is shown in Figure 9E, where the WDM RZ pulse train is converted to interleaved pulses w, x, y, z at the different channel wavelengths. This pulse pattern remains the same throughout the remaining system, wherein only the spectral compositions of the pulses vary in accordance with Figures 8A to 8D.

As the skilled person will appreciate, the systems in Figures 1 and 7 relate only to possible ways of carrying out the present invention. Particularly, the non-

linear elements described could be realised by alternative devices or arrangements of devices other than TWSLAs which provide a similar effect, for example NOLMs. In fact, the devices described in each stage of the invention (the non-linear element, the dispersive element, and the second non-linear element) can each be realised in a variety of ways, without falling outside the bounds of the present invention.

Also, all signal levels, signal frequencies, repetition rates and device bias currents etc, are provided by way of example, and are not essential features of the present invention.

Furthermore, it will be appreciated by the skilled person that the type of optical amplification (if any), and the exact positioning of optical amplification stages in the systems described, depends entirely on the arrangements and types of devices used, and as such is not an essential aspect of the present invention.



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CLAIMS

1. An optical processing apparatus comprising:

a non-linear optical element having input means to receive an optical data input and a clock input, and optical data output means;

means to filter an optical data output signal received from said optical data output means; and

means to temporally shift different wavelengths in said optical data output signal by different pre-determined amounts.

2. An apparatus according to claim 1, wherein the filter means includes a birefringent fibre.

3. An apparatus according to either claim 1 or claim 2, wherein said shift means comprises a dispersive element for providing chromatic dispersion.

4. An apparatus according to claim 3, wherein said shift means comprises a length of optical fibre.

5. An apparatus according to any one of the preceding claims, further comprising means to input an optical data signal and means to input an optical clock signal, the power of the optical clock signal being substantially higher than the power of the optical data signal.

6. An apparatus according to any one of claims 1 to 5, further comprising a second non-linear optical element having means to receive said optical data output signal and a clock input signal, and having an optical data output means.

7. An apparatus according to claim 6 further comprising pass-band filter means to filter an optical data output signal received from the optical data output means of the second non-linear optical element.

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8. An apparatus according to any one of the preceding claims, wherein at least one of the non-linear optical elements provides an optical AND function of a clock signal and a multiple-wavelength data signal.

9. An apparatus according to any one of the preceding claims, wherein at least one of the non-linear optical elements comprises a semiconductor laser amplifier.

10. An apparatus according to any one of the preceding claims, wherein at least one of the non-linear optical elements includes an optical loop mirror.

11. An apparatus according to any one of the preceding claims, wherein at least one of the non-linear optical elements comprises an electro-optic modulator having an electrical clock input means.

12. An apparatus according to any one of claims 6 to 10 further comprising means to input the clock input signal to the second optical non-linear element, the power of said clock input signal being substantially greater than the power of the optical data output signal received by the second optical non-linear element.

13. A method of processing an optical signal comprising the steps of:

introducing a first input signal into a non-linear optical device, said signal comprising a plurality of discrete wavelength data channels; and

introducing a second input signal into the non-linear optical device, said signal having a frequency at least as high as the highest data rate data channel,

wherein the input signals are arranged such that the non-linear optical device provides an output signal including perturbed data signal portions resulting from cross phase modulation of the first and second signals.

14. A method according to claim 13, wherein the non-linear optical device comprises a semiconductor optical amplifier.

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15. A method according to claim 13 or claim 14, wherein the first input signal comprises a plurality of discrete wavelength non-return to zero data channels.

16. A method according to claim 15, wherein the second input signal comprises a stream of clock pulses.

17. A method according to claim 16, wherein the power of the first input signal is arranged to be substantially smaller than the power of the second input signal, thereby determining that the output signal comprises perturbed spectral components of the first input signal.

18. A method according to any one of claims 13 to 17, wherein the perturbed spectral components substantially represent an AND function of the two input signals.

19. A method according to any one of claims 13 to 18, including the further step of filtering the output signal to remove any unperturbed spectral components.

20. A method according to any one of claims 17 to 19, including the further step of temporally shifting each one of the discrete wavelength components of the output signal to provide a signal having the temporal form of a time division multiplexed signal.

21. A method according to claim 20, using chromatic dispersion to provide the temporal shifts.

22. A method according to either claim 20 or claim 21, including the further step of introducing the resultant optical data signal into a second non-linear optical device along with a clock signal having a period substantially the same as the period of the resultant signal, said clock signal arranged to have a substantially smaller power level than said resultant signal, whereby the second non-linear optical device provides an optical output signal including perturbed clock signal portions resulting from cross phase modulation of the data and clock signals.

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23. A method according to claim 22, including arranging the second non-linear optical device to receive a cw control beam to fix the Fermi level of the device at a pre-determined level.

24. A method according to either claim 22 or claim 23, including the further step of filtering the optical output signal with a narrow pass-band filter to remove substantially all unperturbed spectral components.

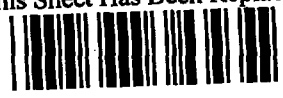
25. A method of producing a multiple channel return to zero data signal from a multiple channel non-return to zero data signal, said method comprising:

introducing a multiple channel non-return to zero data signal into a non-linear optical device;

introducing a clock signal having a repetition frequency at least as high as the highest data rate non-return to zero channel into the device; and

arranging the respective signal power levels to provide an output data signal including perturbed data signal portions resulting from cross phase modulation of the data and clock signals, thereby providing an output data signal comprising spectral components corresponding to a return to zero representation of the non-return to zero data channels.

26. An optical processing system for converting an input optical data signal comprising a plurality a discrete wavelength non-return to zero data channels to an output optical data signal comprising a single wavelength time division multiplexed signal, said system comprising:

a first non-linear optical device arranged to receive the input signal and a first clock signal and to provide an output optical return to zero signal representation of the original non-return to zero signal, said input signal comprising a plurality of discrete wavelength non-return to zero data channels having a relatively low optical power and said clock signal comprising a pulse train having a frequency at least as high as the highest data rate data channel and a relatively high optical power;

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