

(51) International Patent Classification:
G02B 6/34 (2006.01)(21) International Application Number:
PCT/AU2010/000870(22) International Filing Date:
8 July 2010 (08.07.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2009903215 9 July 2009 (09.07.2009) AU(71) Applicant (for all designated States except US): **THE UNIVERSITY OF SYDNEY** [AU/AU]; Parramatta Road, The University of Sydney, New South Wales 2006 (AU).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **YI, Xiaoke** [AU/AU]; C/- University of Sydney Level 5, SIT Building (J12), The University of Sydney, Sydney, New South Wales 2006 (AU). **CHEN, Tong** [AU/AU]; C/- University of Sydney Level 5, SIT Building (J12), The University of Sydney, Sydney, New South Wales 2006 (AU). **HUANG, Thomas** [AU/AU]; C/- University of Sydney Level 5, SIT Building (J12), The University of Sydney, Sydney, New South Wales 2006 (AU). **MINASIAN, Robert** [AU/AU]; C/- University of Sydney Level 5, SIT Building (J12), The University of Sydney, Sydney, New South Wales 2006 (AU).(74) Agent: **SHELSTON IP**; Shelston IP, Level 21, 60 Margaret Street, Sydney, New South Wales 2000 (AU).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) Title: SPECTRUM SLICED PHOTONIC SIGNAL PROCESSOR

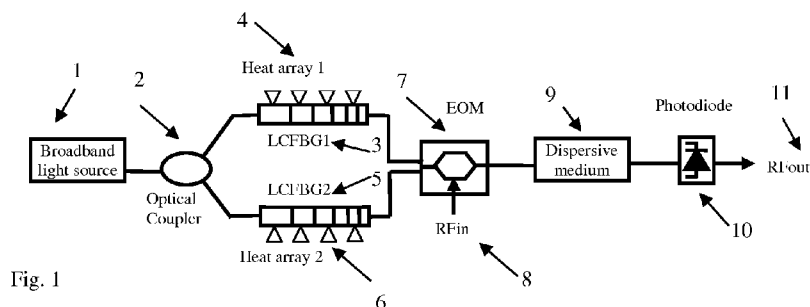


Fig. 1

(57) Abstract: A photonic signal processor providing finite impulse response filtering of an external input signal, the processor including: a photonic signal input having a predetermined wavelength range, a Bragg grating structure interconnected to the photonic signal input and having a series of localised modifications to the periodicity of the grating structure so as to provide a predetermined transmission output window within the stopband of the Bragg grating structure and predetermined wavelength range; a modulator interconnected to the grating structure for modulating the output from the grating structure in accordance with the external signal input; a delay structure for providing a wavelength variable delay to the output from the modulator; an intensity detector interconnected to the delay structure for determining and outputting the intensity of the delay structure output.

- 1 -

Spectrum Sliced Photonic Signal Processor

Field of the Invention

[0001] The present invention relates to the field of optical signal processing of high speed
5 signals such as microwave signals and in particular discloses an optical processor having
a tunable and reconfigurable finite impulse response (FIR) filter topology with bipolar
taps.

Background

[0002] Photonic signal processing using optical delay line structures is a highly powerful
10 technique in processing high speed signals, such as microwave signals, directly in optical
domain because it can overcome the inherent electronic bottlenecks caused by limited
sampling speed in conventional electronics signal processors, such as Digital Signal
Processing (DSP) processors, and also offers attractive features such as tunability, low
loss, large time-bandwidth product and immunity to electromagnetic interference (EMI).
15 Photonic signal processing has particular application in satellite and optical fiber
communications, radio-over-fiber, radioastronomy, radar and warfare systems.

[0003] Spectrum slicing of a broadband light source has been proposed as a low-cost
solution for realizing multiple taps. There have been many reported photonics signal
processor structures. Proposed systems for photonic microwave filtering are discussed in:
20 J. Mora, B. Ortega, J. Capmany, J. L. Cruz, M. V. Andres, D. Pastor, and S. Sales,
"Automatic tunable and reconfigurable fiberoptic microwave filters based on a broadband
optical source sliced by uniform fiber Bragg gratings," Optics Express, vol. 10, pp. 1291-
1298, Nov 04 2002; J. Capmany, D. Pastor, and B. Ortega, "Fibre optic microwave and
millimetre-wave filter with high density sampling and very high sidelobe suppression
25 using subnanometre optical spectrum slicing," Electronics Letters, vol. 35, pp. 494-496,
Mar 18 1999. J. S. Leng, W. Zhang, and J. A. R. Williams, "Optimization of
superstructured fiber Bragg gratings for microwave photonic filters response," IEEE
Photonics Technology Letters, vol. 16, pp. 1736-1738, Jul 2004.

[0004] The aforementioned articles include a discussion of spectrum slicing of amplified
30 spontaneous emission (ASE) from an erbium-doped fiber amplifier (EDFA) using Fabry-

- 2 -

Perot filters or superstructure gratings. These normally have limitations in terms of tunability and weighting adjustment. Mora et al also disclose slicing using mechanical techniques based on the strain tuning of an array of fiber Bragg gratings to change their centre wavelengths. However, this approach requires N gratings for N taps which is
5 inefficient for many taps, and moreover for windowing and sidelobe suppression it requires a multiport optical coupler and an array of variable attenuators which increases the insertion loss and complexity for realizing a large number of filter taps.

Summary

[0005] It is an object of the present invention to provide an improved form of photonic
10 signal processor.

[0006] In accordance with a first aspect of the present invention, there is provided a method of filtering an external input signal, the method including the steps of: (a) providing a photonic signal input having a predetermined wavelength range, (b) filtering the photonic signal input utilising a Bragg grating structure having a series of localised
15 modifications to the periodicity of the grating structure so as to provide a predetermined transmission output window within the stopband of the Bragg grating structure to provide a first filtered output; and (c) utilising the external input signal to modulate the first filtered output so as to provided a modulated output.

[0007] Preferably, the method further includes the steps of: (d) applying a wavelength
20 variable delay to the modulated output to provide a delayed modulated output; and (e) determining the time varying intensity of the delayed modulated output.

[0008] In accordance with a further aspect of the present invention, there is provided a photonic signal manipulation apparatus, including: a photonic signal input having a predetermined wavelength range, a Bragg grating structure interconnected to the photonic
25 signal input and having a series of localised modifications to the periodicity of the grating structure so as to provide a predetermined transmission output window within the stopband of the Bragg grating structure and predetermined wavelength range; a modulator interconnected to the grating structure for modulating the output from the grating structure in accordance with an external signal input.

- 3 -

[0009] The apparatus includes a delay structure for providing a wavelength variable delay to the output from the modulator; and an intensity detector interconnected to the delay structure for determining and outputting the intensity of the delay structure output.

[0010] The Bragg grating structure preferably can include a first and second chirped
5 Bragg grating on separate interconnected arms with one arm providing a 180 degree phase difference output to the other arm, thereby providing negative coefficient outputs for an optical filter.

[0011] In accordance with a further aspect of the present invention, there is provided a photonic signal processor providing finite impulse response filtering of an external input
10 signal, the processor including: a photonic signal input having a predetermined wavelength range, a Bragg grating structure interconnected to the photonic signal input and having a series of localised modifications to the periodicity of the grating structure so as to provide a predetermined transmission output window within the stopband of the Bragg grating structure and predetermined wavelength range; a modulator interconnected
15 to the grating structure for modulating the output from the grating structure in accordance with the external signal input; a delay structure for providing a wavelength variable delay to the output from the modulator; an intensity detector interconnected to the delay structure for determining and outputting the intensity of the delay structure output.

[0012] The localised modification can be provided by means of localised heating of the
20 Bragg grating structure. Preferably, the localised heating changes the grating period and the refractive index at the localised point thereby introducing a phase shift in the grating at the localised point. More preferably, the manipulation of the phase control is performed by predetermined profile of heating distribution. More preferably still, the localised heating distribution can be individually modified in respect of the selected heat width and
25 heat amount.

[0013] The localised modification can also be provided by localised pressure of the Bragg grating structure. For example, localised strain can change the grating period and the refractive index at the contacting point and split the original grating into two sub-gratings

- 4 -

thereby introducing a phase shift in the grating. The grating position and applied force can be used to control the phase shift.

[0014] The Bragg grating structure preferably can include a first and second chirped Bragg grating on separate interconnected arms with one arm providing a 180 degree
5 phase difference output to the other arm, thereby providing negative coefficient outputs for the finite impulse response filter.

[0015] The localised modification can be variable in intensity and reversible. The Bragg grating structure can be a chirped Bragg grating. The delay structure can comprise a reflection Bragg grating.

10 [0016] In preferred embodiments, the time varying intensity of the delayed modulated output is provided after photodetection. The photonic signal processor can therefore be used to filter an external input signal (RF/Microwave/Millimeter wave) that modulates the first filtered output and the output of the FIR filtering is the signal (RF/Microwave/Millimeter wave) received after photodetection.

15 Brief Description of the Drawings

[0017] Benefits and advantages of the present invention will become apparent to those skilled in the art to which this invention relates from the subsequent description of exemplary embodiments and the appended claims, taken in conjunction with the accompanying drawings, in which:

20 Fig. 1 provides a schematic illustration of a first embodiment;
Fig. 2 is a schematic illustration of an alternative embodiment;
Fig. 3 illustrates the measured spectrum sliced source of the alternative embodiment;
Fig. 4 illustrates the wavelength variation with a change in the heating position for
25 the alternative embodiment;
Fig. 5 illustrates the driving current vs peak power of the sliced source of the alternative embodiment;
Fig. 6 illustrates the frequency response of the filter of the alternative embodiment;

- 5 -

Fig. 7 illustrates the thermal camera output of a fibre heating wire heating a fibre grating;

Fig. 8 illustrates a plot of thermal measurements along a fibre;

Fig. 9 illustrates the resultant spectrum as a result of localised fibre heating; and

5 Fig. 10 illustrates schematically an alternative form of implementation of the preferred embodiment.

Detailed Description

[0018] Preferred embodiments of the invention will now be described, by way of
10 example only, with reference to the accompanying drawings.

[0019] A first embodiment provides a new photonic signal processor based on a thermally controlled spectrum sliced optical source, requiring two identical linearly chirped fiber Bragg gratings (LCFBGs), which readily enables windowing, and can generate multiple taps together with tunability, reconfigurability and low-cost.

15 [0020] The structure of the photonic signal processor is shown in Fig. 1. A broadband optical source 1, whose bandwidth is within the bandwidth of two identical LCFBGs 3, 5, is passed to a 3dB optical coupler 2, which splits the broadband source into two paths. The broadband source can be implemented by an EDFA ASE source followed by a spectrum flattening filter to both flatten the ASE spectrum and suppress the ASE outside
20 of the LCFBGs.

[0021] Two split broadband sources are spectrum sliced by two thermally induced slicing filters based on array-heating LCFBG1 and LCFBG2, respectively. Each LCFBG 3, 5 is locally heated 4,6 at several discrete points along its length to generate desirable wavelengths and magnitudes. The local thermal heating can be from a small thermal
25 head, eg. a fine resistive wire carrying a current and in localized contact with the LCFBG. The heating changes the local refractive index and introduces a phase shift at the contact point, which creates a narrow transmission window within the stopband of the grating.

[0022] Multi-tap WDM spectrum slicing can be obtained by using multiple heating heads to individually control the thermally induced phase shifts at sequential locations along the
30 length of LCFBG, which generates multiple WDM transmission passbands. The two sets of WDM sources are then combined 7 and amplitude modulated with an RF input signal 8

- 6 -

using a dual input electro-optic modulator (EOM) 7 to provide 180° phase difference between two modulation arms and subsequently provide bipolar taps.

[0023] The output of the modulator is launched into a dispersive delay line 9 before being detected by a photodetector 10. The amplitude response of the microwave photonic filter is given by:

$$|H(\omega_m)| = R \left| \sum_{i=1}^N B_i W_i e^{j\omega_m \Delta t (i-1)} \right| \quad \text{Eqn (1)}$$

[0024] where ω_m is the angular modulation frequency, and $B_i W_i$ is the filter coefficient corresponding to i^{th} wavelength. B_i is the tap polarity parameter, where B_i is 1 for taps corresponding to wavelengths entering from the upper input port via grating 3 of the EOM, and -1 for light entering the lower port via lower grating 5. W_i is the optical power of the i^{th} sliced source, and the factor R represents the dispersion induced RF distortion. The basic time delay of the filter is given by $\Delta t = D \Delta \lambda$ where D is the group delay of the dispersive medium, $\Delta \lambda$ is the wavelength spacing of the optical source, and the free spectral range (FSR) of the filter is $FSR = 1 / \Delta t$.

[0025] The amplitude of the spectrum slices can be controlled by adjusting the heating level of the thermal head, thus changing the filter weights (W_i) and reconfiguring the transfer function of the transversal microwave photonic filter. As the thermally induced phase shift occurs at the location of the heating points on LCFBG, the wavelength spacing of the sliced source ($\Delta \lambda$) can be adjusted by moving the heating point along the grating. This will change the FSR of the filter and consequently realizes tunability. Finally, if the induced temperatures are less than 570 K, the phase shifts in the grating are reversible, which gives the flexibility to implement tunable and reconfigurable microwave photonic filter by tuning the position and amount of the heat applied.

[0026] The operation and structure of the grating 5 and heaters 6 provide the ability to achieve spectrum slices for negative coefficients of the RF filter. Since spectrum slices for positive taps and negative taps have different central wavelengths, and the amplitude of each spectrum slice is designed according to the targeted filter coefficients, locations of

- 7 -

the heaters can be different for each arm with the temperatures of the heaters controlled according to the required positive or negative coefficients. The dual input electro-optical modulator provides electrical to optical conversion and 180° phase difference between two modulation arms thereby providing the negative coefficients.

- 5 [0027] Alternative embodiments are possible. For example, other modulator configurations such as two modulators with opposite slopes DC-biases configuration can also be used in the design to replace the dual-input EOM. The structure uses two single-input single-output modulators which are operated at positive and negative slope of the signal's transfer function. The arrangement can be similar to that disclosed in: J.
10 Capmany, D. Pastor, A. Martinez, B. Ortega, and S. Sales, "Microwave photonic filters with negative coefficients based on phase inversion in an electro-optic modulator," Optics Letters, vol. 28, pp. 1415-1417, Aug 15 2003.

- [0028] Further, alternative embodiments are possible. For example Fig. 2 illustrates an alternative prototype filtering structure containing only one LCFBG arm. A broadband
15 ASE source 21 is spectrum sliced by a thermally induced slicing filter based on linear chirped fiber Bragg grating (LCFBG1 22) which is locally heated at several discrete points along its length. It is then amplitude modulated using an electro-optic modulator (EOM) 23, and is subsequently launched into a dispersive delay line (LCFBG2 24), via circulator 25 before being detected by a photodetector 26 and a corresponding signal
20 output as RFout.

- [0029] The local heating can be from a small thermal head, for example, a fine resistive wire carrying a current and in contact with the grating LCFBG1 22 which again changes the local refractive index and introduces a phase shift at the contact point, which creates a narrow transmission window within the stopband of the grating. Multi-tap WDM
25 spectrum slicing is obtained by using multiple heating heads to individually control the thermally induced phase shifts at sequential locations along the length of LCFBG1 22, which generates multiple WDM transmission passbands. The broadband source bandwidth or the LCFBG2 bandwidth is chosen to be within the bandwidth of LCFBG1 in order to suppress the ASE outside of the slicing filter. The amplitude response of the

- 8 -

filter will be in accordance with the previously discussed equation 1, with all positive coefficients ($B_i = 1$).

Experiments and results

[0030] A prototype was constructed in accordance with the arrangement of Fig. 2. The LCFBG1 22 had 96% reflectivity, 211ps/nm group delay slope, and 4.6nm bandwidth. Four thermal heads made from NiCr wire were vertically placed on LCFBG1 to heat the grating at four points. The location of each thermal head can be precisely tuned and the width of the heat region of a single thermal head, estimated from diameter of the wire, was about 100 μ m. The current passing through each thermal head can be independently controlled using a variable current source, which in turn controlled the temperature change at each heating point. Heat sinks can be used in the fibre region between neighbouring resistance wires to reduce unwanted thermal feed through.

[0031] A high power ASE source with 4nm bandwidth was used as source, which operated within the bandwidth of LCFBG1 22. By heating all the thermal heads, a four channel spectrum sliced source with uniform amplitude and wavelength separation of 0.78nm as shown in Fig. 3 was obtained. The measurement resolution was 10pm. The distance between neighboring thermal heads was 15.6mm. The small interchannel oscillations are caused by the Fabry-Perot cavity formed in LCFBG1 22, which can be reduced by using grating with higher reflectivity.

[0032] Fig. 4 shows the relation between the slice wavelength and the heating position, which was obtained by scanning a thermal head along the whole bandwidth of LCFBG1 22. The line 41 in Fig. 4 has 0.5nm/cm slope. The linear relationship allows the slice wavelength to be chosen by selecting the position of thermal head on the grating. The realized prototype spectrum sliced source had a wavelength resolution of <10pm, enabling precise control of the basic time delay (Δt) for the targeted FSR and for realizing tunability of the photonic filter.

[0033] Adjustment of coefficients (W_i) of the microwave photonic filter can be obtained by changing the driving current of the thermal head. By fine tuning the location of the

- 9 -

thermal head, the thermal induced wavelength shifting during adjustment of the magnitude of spectrum slices can also be overcome. Fig. 5 shows the peak power of the sliced source increases with driving current until the heat level reaches to give π phase shift at a current of 0.2A. The relation is nearly linear when the driving current is within
 5 the range of 0.06A to 0.17A.

[0034] A microwave photonic filter was constructed by using LCFBG2 24, having a dispersion of 320ps/nm, as the dispersive delay line. Fig. 6 shows the measured RF responses of the filter. An RF filter with 4GHz FSR and uniform weighting and equal wavelength spacing (0.78nm) was demonstrated; an RF filter with windowing function
 10 [0.6 1 1 0.6] which was realized by adjusting the driving current of the thermal head to control the power of the sliced source, demonstrated about 20dB sidelobe suppression; and finally an RF filter with a different FSR of 6GHz, obtained by adjusting the location of the thermal head to relocate optical wavelengths of the sliced source to a wavelength spacing of 0.52nm.

15 [0035] In a further experimental analysis, localized heating was conducted utilising a NiCr wire. In this arrangement, the relative optical power of the output spectrum slice was increased with driving current until a heat level was reached which gave a π phase shift. Fig. 7 illustrates a 2-D heat distribution from a thermal camera when a NiCr wire with a diameter of 100 μ m was utilised to locally heat a linearly chirped grating to generate a π
 20 phase shift. The grating utilized had greater than 99.9% reflectivity, 150ps/nm group delay slope and 6nm bandwidth.

[0036] The sectional heat distribution along the fiber grating was also obtained and is shown in Fig. 8. The y-axis is the recorded temperature and x-axis shows the relative heating distance along the grating. It can be seen that the heat shows a Gaussian
 25 distribution profile and the maximum required heat to create an approximately π phase shift is 60 degree Celcius.

[0037] The interchannel oscillations caused by the F-P cavity can be neglected due to the usage of high reflective gratings. The usage of high reflective grating reduces the

- 10 -

interchannel oscillations and narrows the bandwidth of the sliced source, which ease the dispersion induced RF degradation effect consequently.

[0038] The resulting spectrum sliced source obtained by locally heating a linearly chirped fiber Bragg gratings at 4 discrete locations is shown in Fig. 9 which clearly illustrates the
5 resulting transmission windows. As noted previously, the grating had greater than 99.9% reflectivity, 150ps/nm group delay slope and 6nm bandwidth.

[0039] Other forms of localized manipulation of the grating structure are possible. For example, Fig. 10 illustrates a similar arrangement to Fig. 1, however, in this case, the localized change is implemented by a localized strain applied to the grating. The localized
10 change can be implemented by applying a localized pressure but means of a piezoelectric ceramic or a mechanical pressing device to the gratings 74, 76, thereby providing a stretch of compression to the grating to generate a requisite optical phase shift.

Interpretation

[0040] Reference throughout this specification to “one embodiment” or “an embodiment”
15 means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined
20 in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

[0041] Similarly it should be appreciated that in the above description of exemplary embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of
25 streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims

- 11 -

following the Detailed Description are hereby expressly incorporated into this Detailed Description, with each claim standing on its own as a separate embodiment of this invention.

[0042] Furthermore, while some embodiments described herein include some but not
5 other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

[0043] Furthermore, some of the embodiments are described herein as a method or
10 combination of elements of a method that can be implemented by a processor of a computer system or by other means of carrying out the function. Thus, a processor with the necessary instructions for carrying out such a method or element of a method forms a means for carrying out the method or element of a method. Furthermore, an element described herein of an apparatus embodiment is an example of a means for carrying out
15 the function performed by the element for the purpose of carrying out the invention.

[0044] In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

20 [0045] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

25 [0046] In the claims below and the description herein, any one of the terms comprising, comprised of or which comprises is an open term that means including at least the elements/features that follow, but not excluding others. Thus, the term comprising, when used in the claims, should not be interpreted as being limitative to the means or elements or steps listed thereafter. For example, the scope of the expression a device comprising A
30 and B should not be limited to devices consisting only of elements A and B. Any one of the terms including or which includes or that includes as used herein is also an open term

- 12 -

that also means including at least the elements/features that follow the term, but not excluding others. Thus, including is synonymous with and means comprising.

[0047] Similarly, it is to be noticed that the term coupled, when used in the claims, should not be interpreted as being limitative to direct connections only. The terms "coupled" and "connected," along with their derivatives, may be used. It should be understood that these terms are not intended as synonyms for each other. Thus, the scope of the expression a device A coupled to a device B should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other devices or means. "Coupled" may mean that two or more elements are either in direct physical or electrical contact, or that two or more elements are not in direct contact with each other but yet still co-operate or interact with each other.

[0048] Although the present invention has been described with particular reference to certain preferred embodiments thereof, variations and modifications of the present invention can be effected within the spirit and scope of the following claims.

- 13 -

We Claim:

1. A method of filtering an external input signal, the method including the steps of:
 - (a) providing a photonic signal input having a predetermined wavelength range,
 - (b) filtering the photonic signal input utilising a Bragg grating structure having a
5 series of localised modifications to the periodicity of the grating structure so as to provide a predetermined transmission output window within the stopband of the Bragg grating structure to provide a first filtered output; and
 - (c) utilising the external input signal to modulate the first filtered output so as to
provided a modulated output.
- 10 2. A method as claimed in claim 1, further comprising the steps of:
 - (d) applying a wavelength variable delay to the modulated output to provide a
delayed modulated output; and
 - (e) determining the time varying intensity of the delayed modulated output.
- 15 3. A photonic signal manipulation apparatus, including:
 - a photonic signal input having a predetermined wavelength range,
 - a Bragg grating structure interconnected to the photonic signal input and having a
series of localised modifications to the periodicity of the grating structure so as to provide
20 a predetermined transmission output window within the stopband of the Bragg grating
structure and predetermined wavelength range;
 - a modulator interconnected to the grating structure for modulating the output from
the grating structure in accordance with an external signal input;
- 25 4. An apparatus as claimed in claim 3 further comprising:
 - a delay structure for providing a wavelength variable delay to the output from the
modulator; and
 - an intensity detector interconnected to the delay structure for determining and
outputting the intensity of the delay structure output.

30

- 14 -

5. An apparatus as claimed in claim 3 wherein the localised modification is provided by means of localised heating of the Bragg grating structure.

6. An apparatus as claimed in claim 5 wherein the localised heating changes the refractive index at the localised point thereby introducing a phase shift in the grating at the localised point.

7. An apparatus as claimed in claim 6 wherein the manipulation of the phase control is performed by predetermined profile of heating distribution.

10

8. An apparatus as claimed in claim 7 wherein localised heating distribution can be individually modified from selected heating width and heat.

9. An apparatus as claimed in claim 5 wherein the degree of heating controls the amplitude of a Bragg transmission window and the location of the heating controls the wavelength of the transmission window.

10. An apparatus as claimed in claim 3 wherein the localized modification is provided by means of localized pressure applied to the Bragg grating structure.

20

11. An apparatus as claimed in any previous claim 3 to claim 10 wherein the Bragg grating structure includes a first and second chirped Bragg grating on separate interconnected arms with one arm providing a 180 degree phase difference output to the other arm, thereby providing negative coefficient outputs for an optical filter.

25

12. An apparatus as claimed in any previous claim 3 to claim 11 wherein the localised modification is variable in intensity and reversible.

13. An apparatus as claimed in any previous claim 3 to claim 12 wherein said Bragg grating structure is a chirped Bragg grating.

30

- 15 -

14. An apparatus as claimed in any previous claim 3 to claim 13 wherein said the predetermined wavelength range is covered by:

- (a) a single long chirped Bragg grating
- (b) or a cascade of multiple chirped Bragg grating

5

15. An apparatus as claimed in any previous claim 3 to claim 14 wherein the delay structure comprises a reflection Bragg grating.

16. A photonic signal processor providing finite impulse response filtering of an external input signal, the processor including:
- a photonic signal input having a predetermined wavelength range,
 - a Bragg grating structure interconnected to the photonic signal input and having a series of localised modifications to the periodicity of the grating structure so as to provide a predetermined transmission output window within the stopband of the Bragg grating structure and predetermined wavelength range;
 - a modulator interconnected to the grating structure for modulating the output from the grating structure in accordance with the external signal input;
 - a delay structure for providing a wavelength variable delay to the output from the modulator;
 - an intensity detector interconnected to the delay structure for determining and outputting the intensity of the delay structure output.
- 10
- 15
- 20

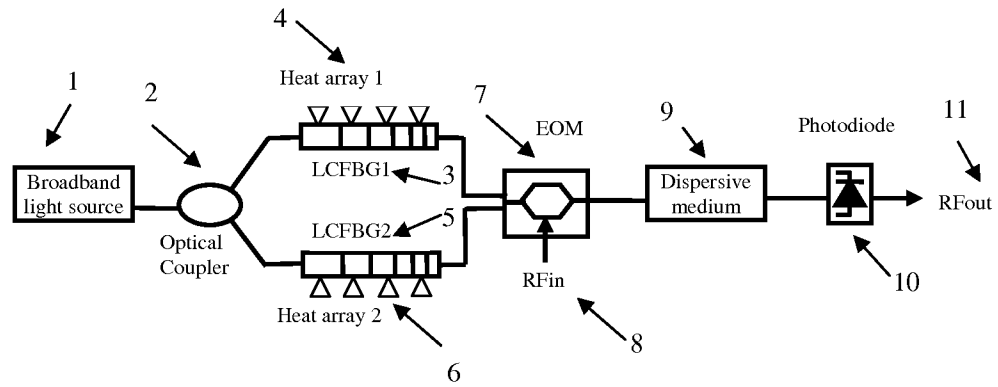


Fig. 1

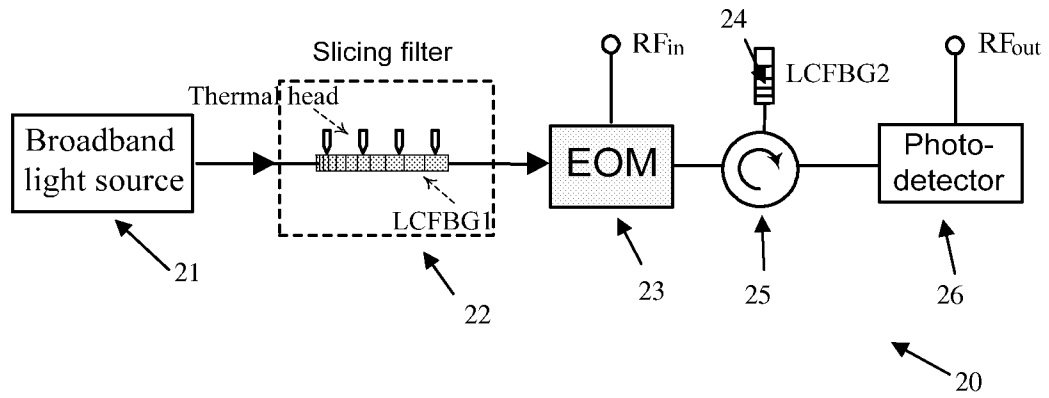


Fig. 2

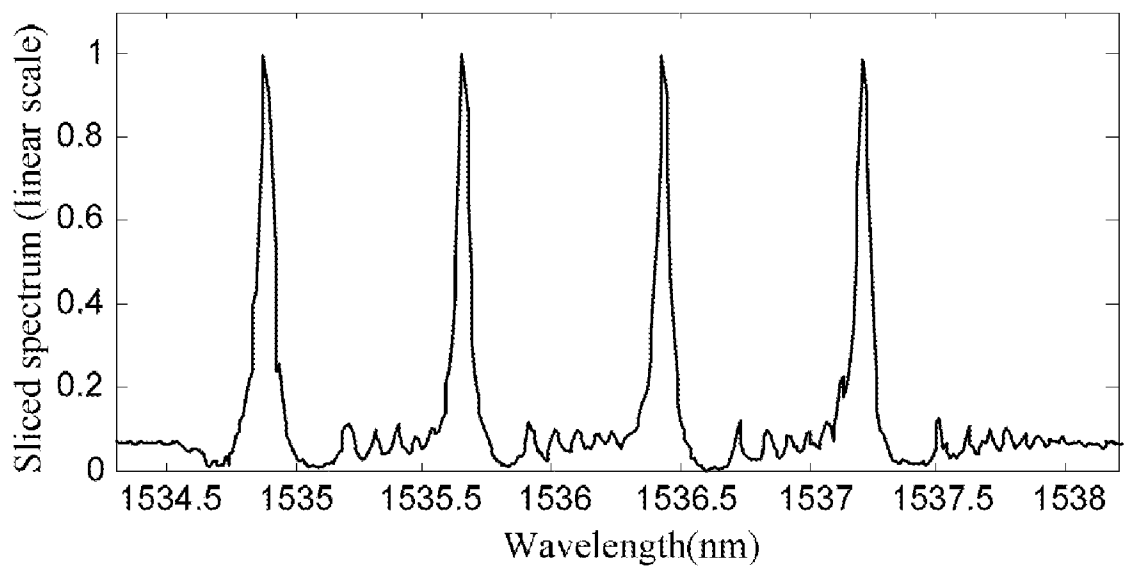


Fig. 3

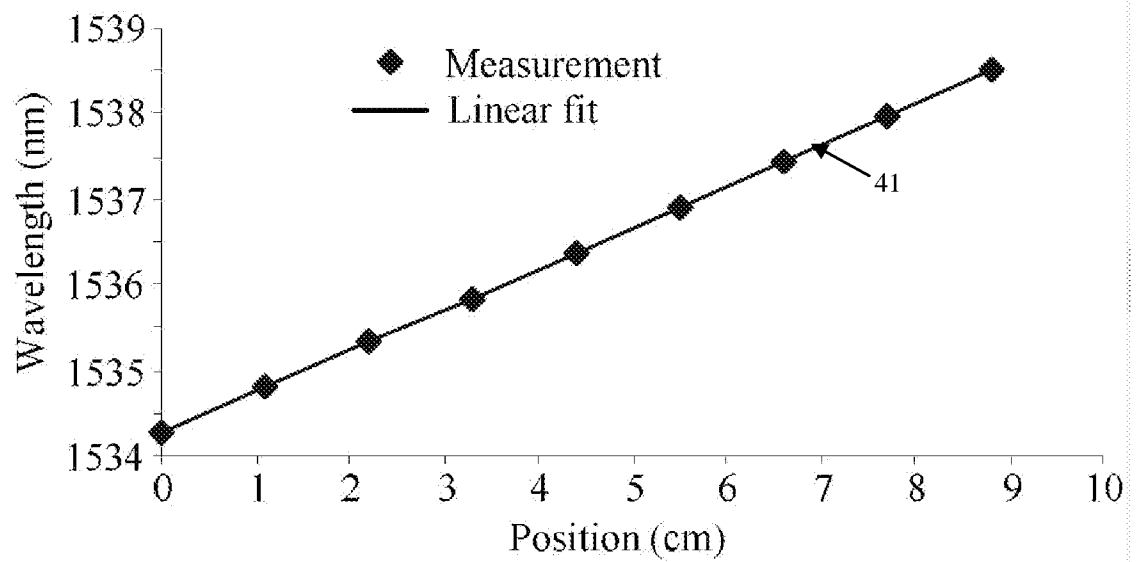


Fig. 4

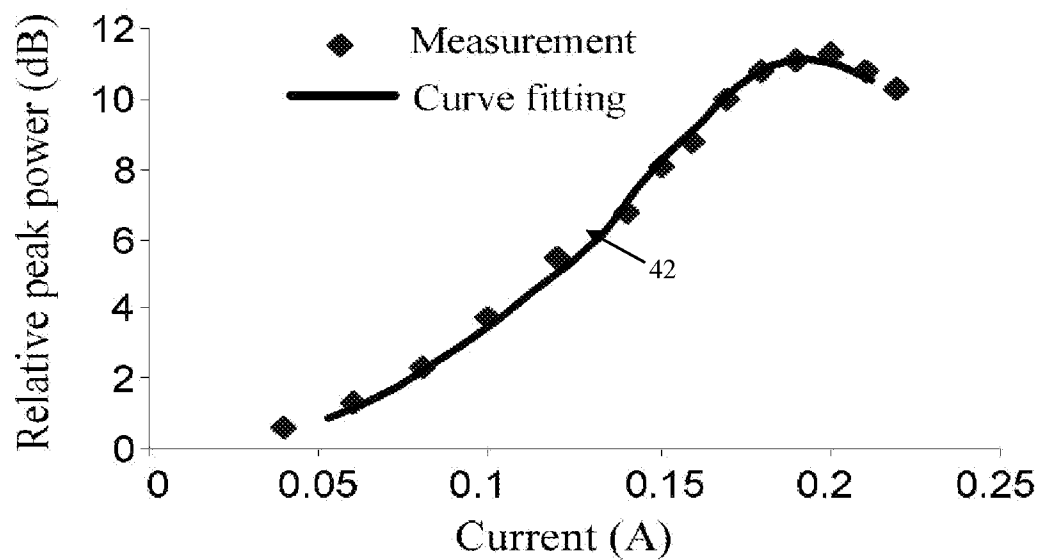


Fig. 5

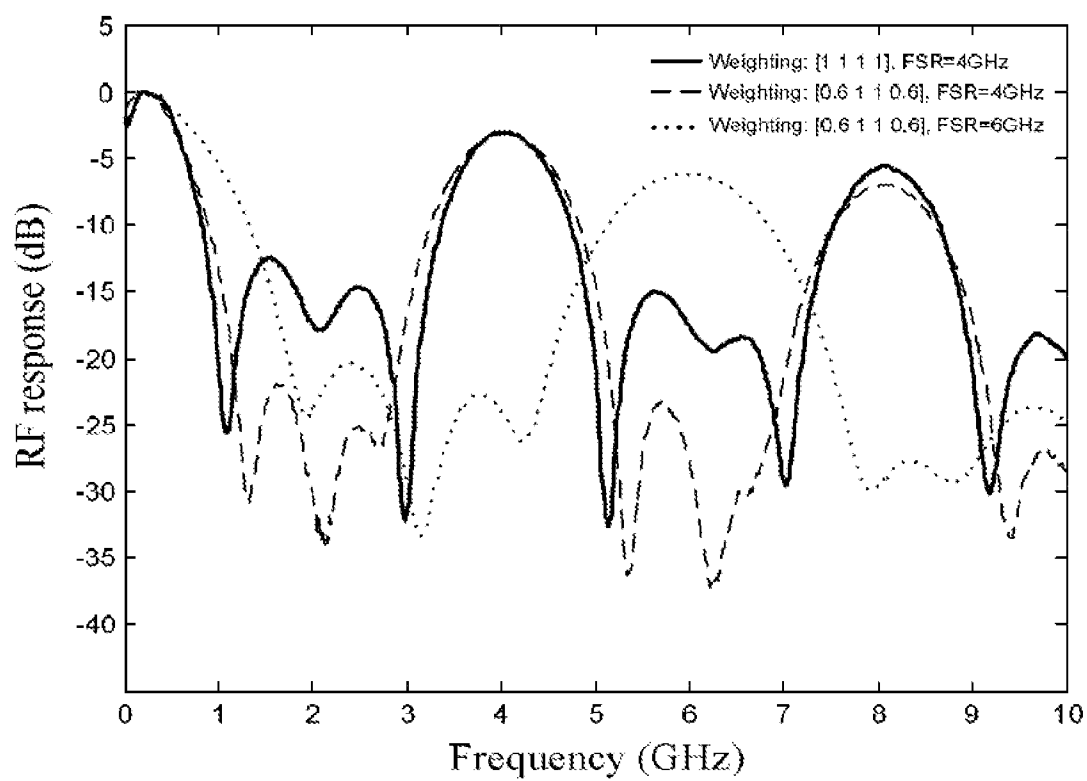
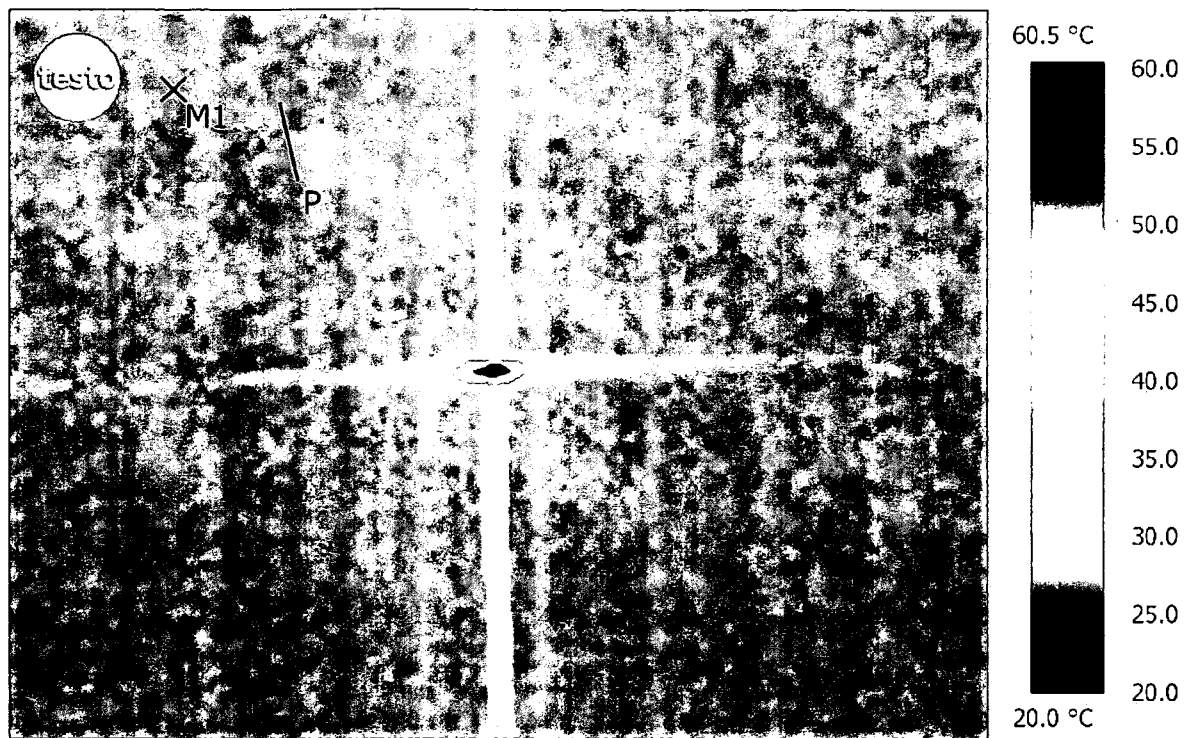


Fig. 6



The heat distribution along the grating is also obtained and is shown in the following figure. The x-axis is the recorded temperature and y-axis shows the relative heating distance along the grating. It can be seen that the heat shows a Gaussian distribution profile and the maximum required heat to create a closed to 180 phase shift is 60 degree.

Fig. 7

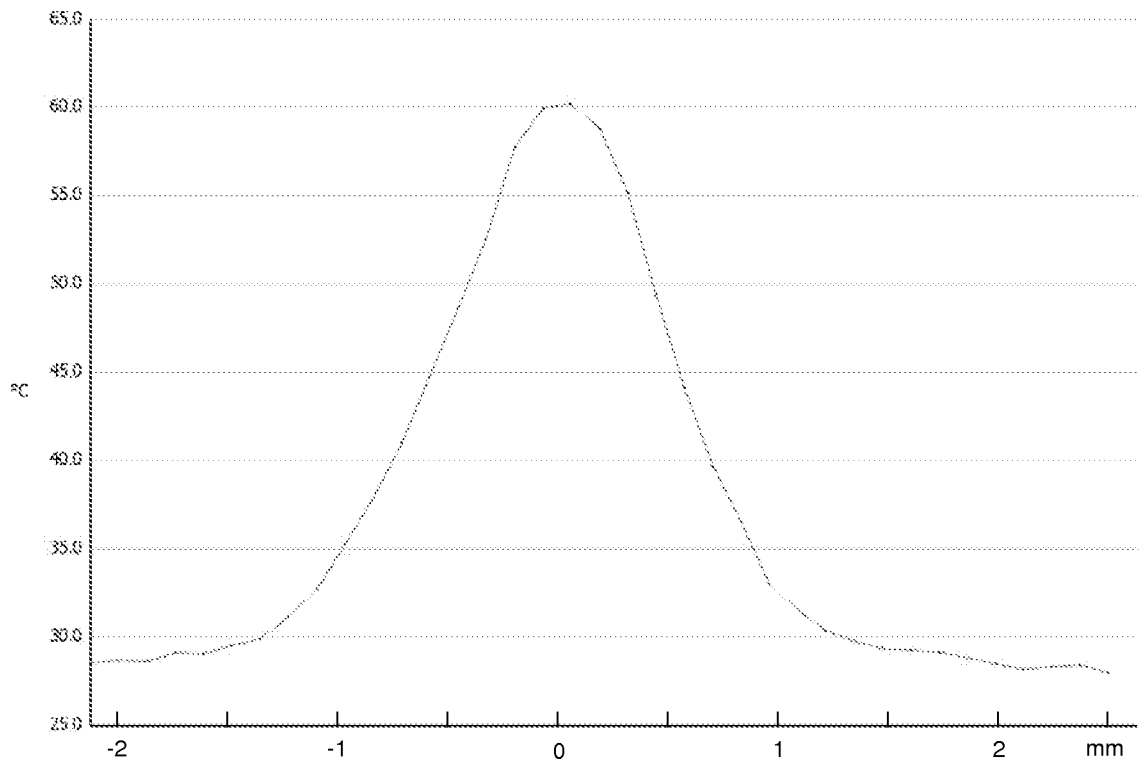
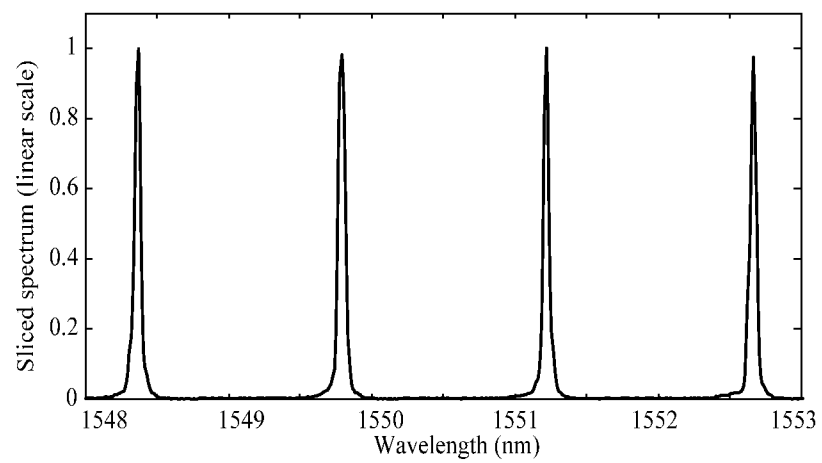


Fig. 8



Measured spectrum sliced source with four induced transmission windows

Fig. 9

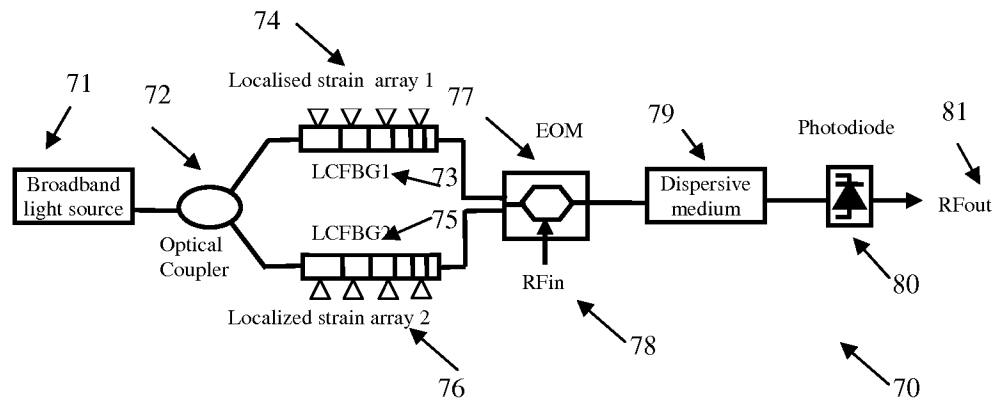


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2010/000870

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

G02B 6/34 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI (Keywords: Grating, Bragg, Modulate, Period, Local, heat, Pressure, Arm, Delay and similar terms)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/0196048 A1 (GALVANAUSKAS et al.) 23 August 2007 See figures 1, 3, 31 and 32; paragraphs 56-60, 93-94	1-16
A	US 5748312 A (KERSEY et al.) 5 May 1998 See abstract and figures	1-16
A	WO 2003/103192 A1 (E.I. DU PONT DE NEMOURS AND COMPANY) 11 December 2003 See abstract and figures	1-16
A	WO 2006/072759 A2 (ASTON UNIVERSITY) 13 July 2006 See abstract and figures	1-16



Further documents are listed in the continuation of Box C



See patent family annex

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 25 August 2010	Date of mailing of the international search report 30 AUG 2010
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer MATTHEW FELLEW AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2041

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2010/000870

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report			Patent Family Member		
US	2007196048	NONE			
US	5748312	NONE			
WO	03103192	CN 1656716 US 6728445	EP 1508208	US 2003223687	
WO	2006072759	EP 1836516 US 7580184	GB 2422021	US 2008204859	
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.					
END OF ANNEX					