(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 December 2003 (18.12.2003)

PCT

(10) International Publication Number
WO 03/104867 A1

(51) International Patent Classification[7]: G02B 6/293

(21) International Application Number: PCT/CA03/00863

(22) International Filing Date: 9 June 2003 (09.06.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/386,717 10 June 2002 (10.06.2002) US

(71) Applicant: **LNL TECHNOLOGIES CANADA INC.** [CA/CA]; 400 March Road, Kanata, Ontario K2K 3H4 (CA).

(72) Inventors: **PEARSON, Matt**; 25 Carlisle Circle, RR4, Ashton, Ontario K0A 1B0 (CA). **KRUG, Peter**; 23 Dalecroft Crescent, Nepean, Ontario K2G 5V9 (CA).

(74) Agents: **MITCHELL, Richard, J.** et al.; Marks & Clerk, Station B, P.O. Box 957, Ottawa, Ontario K1P 5S7 (CA).

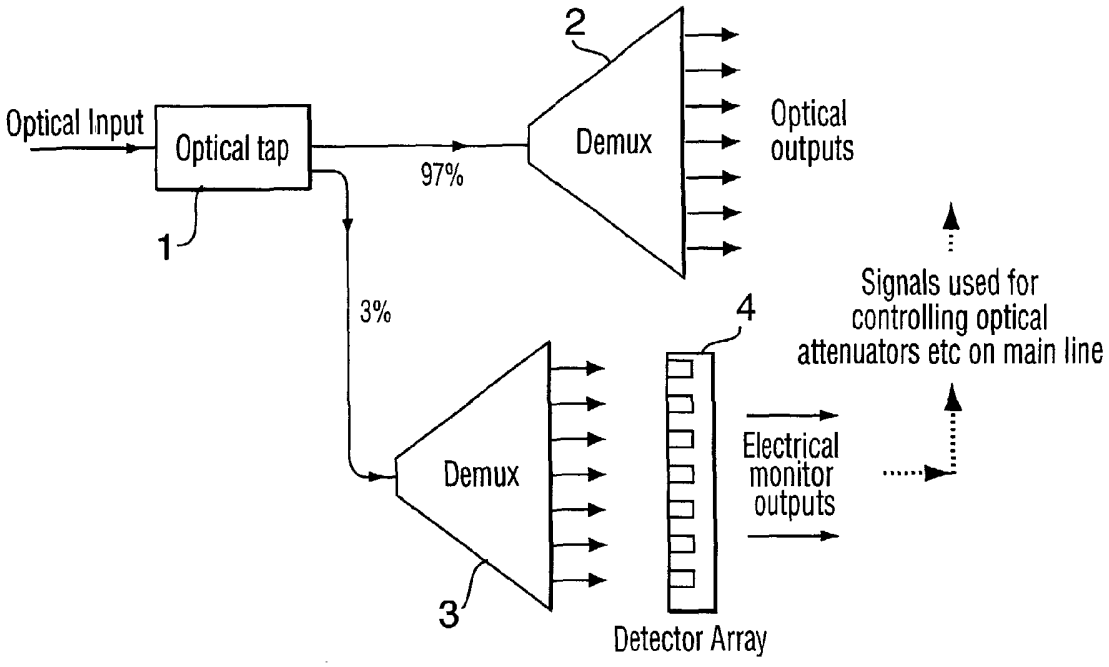
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: OPTICAL CHANNEL MONITORING INTEGRATED IN A DEMULTIPLEXER



(57) Abstract: A method for integrating power monitoring capabilities with passive demultiplexing operations, utilizing the high-order diffraction from an optical diffraction grating. The technique helps avoid insertion loss and polarization dependent loss penalties, and device size penalties, typically incurred with optical taps and multiple diffraction gratings. The technique can also be modified slightly to provide information on channel wavelength and optical signal-to-noise-ratio, as well as channel power.

WO 03/104867 A1

OPTICAL CHANNEL MONITORING INTEGRATED IN A DEMULTIPLEXER

This invention relates to the field of photonics, and in particular to a device for integrating demultiplexing and optical channel monitoring. The invention is applicable to integrated optical components, as well as components based on bulk-optics.

In an optical telecommunications network based on dense wavelength division multiplexing (DWDM), several closely-spaced wavelength channels are multiplexed onto a single optical fiber and transmitted to another system node where the channels are demultiplexed and detected individually. It is very important in DWDM networks to monitor the power in each wavelength channel, as well as other channel information, such as wavelength and optical signal to noise ratio (OSNR), which can vary significantly from channel to channel due to wavelength-dependent amplification or loss.

This monitoring is often performed at system nodes immediately before the main signal is demultiplexed. This is typically accomplished by tapping a small fraction of the signal (1% to 5%) off the main transmission line before the demultiplexer. These two signals, the "main" signal and the "monitoring" signal, are then sent to separate demultiplexers and separated into their individual wavelengths. The monitoring channels pass to a detector array for measuring the power in each channel, while the main signals split into individual optical fibers for coupling to their individual receivers or, for example, variable optical attenuators. This typical functionality is illustrated in Fig. 1. An input signal is input to an optical tap 1, which splits the signal into a first portion containing 97% of the light that goes to a demultiplexer 2 providing the optical outputs. The tap passes 3% of the light to a demultiplexer 3 that provides outputs that a detected by a detector array 4.

A key product focus for integrated optic and bulk-optic component manufacturers is integration of multiple functions into a single module. For example, it would generally be desirable to integrate an optical demultiplexer with an optical channel monitor, including the 1% optical tap. Such a device would accomplish the functionality illustrated in Fig. 1.

One major difficulty with this approach is that in integrated optics, optical taps often exhibit a polarization dependent loss (PDL), a major problem for all telecommunications components. Also, it is difficult to manufacture even a single optical demultiplexer on a single chip. The functionality demonstrated in Fig. 1 requires two demultiplexers.

Furthermore, all of the components need to be individually temperature controlled. Integrating three building blocks into a common device results in a large device that is difficult to manufacture and has potential PDL problems.

According to the present invention there is provided a device for integrating demultiplexing and optical channel monitoring, comprising a diffraction grating; an input waveguide providing an optical input to said diffraction grating; a first set of output waveguides providing optical outputs to said diffraction grating at a predetermined order of diffraction; and a second set of output waveguides providing monitor outputs to said diffraction grating at another order of diffraction different from said predetermined order of diffraction.

The extra order of diffraction is normally higher than the predetermined order of diffraction providing the optical outputs. In a preferred embodiment a further set of waveguides are provided to receive a further order of diffraction. These can be used for measuring, for example, inter-channel noise.

This invention thus describes a method for integrating the functions of optical demultiplexing and optical tapping, in order to manufacture the functionality demonstrated in Fig. 1, but with the use of no optical tap, and with only a single optical demultiplexer. Also, the invention does not generally induce any additional optical loss to the system, and in fact can operate without tapping the typical 1%-5% off the main optical fiber. It can also substantially eliminate the polarization dependent loss that can often accompany an optical tap.

The invention is applicable to integrated optics, but also to devices based on bulk-optic diffraction gratings.

In a broad aspect, therefore, the invention uses the light diffracted into higher orders of the grating, which is typically just the source of insertion loss in the device. This light that is diffracted into higher orders is a fixed percentage of the incoming light, and is precisely the same wavelength as the main signal, and contains the same information as the main signal, albeit at a much lower intensity.

The light can be collected and sent to a detector array, which after calibration with a known source can provide information such as the optical power in each channel of the

system. Virtually all demultiplexers rely on a diffractive element, and virtually all diffractive elements diffract light into higher orders. Designers typically try to minimize the amount of light diffracted into higher orders (to minimize optical loss in the main signal), but it is extremely difficult to eliminate entirely, making the invention suitable for a wide array of applications. This includes Echelle Grating demultiplexers, Arrayed Waveguide Grating demultiplexers, and bulk optic diffraction grating demultiplexers.

The monitor outputs, i.e. those positioned to collect the light from higher orders, can be positioned on the channel grid and monitor the channels at channel center, in the same way as the light from the main signal is collected at the demultiplexer output. However, with a slight modification to the above design, the monitor outputs can be positioned off-center, or be composed of a split-waveguide output, which means different orders can be received to deduce different information about the main optical signal. This type of information could include the monitoring of channel wavelength, and optical signal to noise ratio, as well as channel power.

In a further aspect the invention provides a method of performing demultiplexing and optical channel monitoring, comprising the steps of directing an optical input signal containing multiple channels to a diffraction grating; receiving reflected and diffracted signals at a first set of output waveguides providing optical outputs at a predetermined order of diffraction; and receiving reflected and diffracted signals at a second set of output waveguides providing monitor outputs at another order of diffraction different from said predetermined order of diffraction.

The invention will now be described in more detail, by way of examples, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic drawing showing the functionality required for integrating optical demultiplexing with optical channel monitoring;

Figure 2 is a practical layout of an Echelle Grating demultiplexer designed with monitor outputs positioned at the foci of the higher-order diffraction; and

Fig. 3 is a practical layout of an Arrayed Waveguide Grating (AWG) demultiplexer designed with monitor outputs positioned at both the order n+1 and order n-1 foci (The

n+1 and n-1 outputs can be off-grid in order to monitor extra information beyond just power, such as wavelength and OSNR).

In the embodiment of the invention shown in Figure 3, the components are integrated into a single integrated device. An optical signal 10 consisting of many different wavelength channels is input to the input waveguide at A. Optical signal 10 travels through the input waveguide 11, and then spreads out laterally to fill the echelle diffraction grating 12 at B. The diffraction grating 12 reflects and diffracts the light back to a first set of several different output waveguides 13, located at C, based on wavelength. This is termed the order *n* of the diffracted light.

At the same time, a small fraction of the main signal is reflected and diffracted into a higher order, termed "order *n*+1", which is focused onto a second set of monitor output waveguides 14 at position D. Positions C and D are located at the foci of the diffraction grating for their respective orders.

The main optical signal is routed off the chip from C to positions E, where it is coupled to an array of optical fibers.

The monitoring signal is routed off the chip from D to position F, where it is coupled to an array 15 of optical detectors.

This configuration has several advantages. The single device shown in Fig. 2 accomplishes the functionality illustrated in Fig. 1, but is a single component, versus the three components illustrated in Fig. 1. This leads to enormous reductions in assembled device cost. The main optical signal is demultiplexed with no significant additional loss or PDL from an optical tap. This results in improved performance at the system-level as well. The monitoring signal is created from the higher-order diffraction, with no additional PDL from an optical tap, and no fiber coupling between separate components.

The single device shown in Fig. 2 replaces the three components illustrated in Fig. 1, and combines them onto a small optical chip. This also reduces the footprint and improves the reliability of the completed module. The optical chip illustrated in Fig. 2 can be temperature controlled using a single heater/cooler. The use of separate demultiplexers, as illustrated in Fig. 1, implies roughly twice the power consumption of the new invention. The invention leads to a significant reduction in power requirements.

In the embodiment of Fig. 3 an optical signal 10 consisting of many different wavelength channels is input to the input waveguide 11 at A. The device operation is identical to that described in Example No. 1, with the main optical signal being demultiplexed and output through order n. However, in this example there are also monitor output waveguides 16 positioned to collect light of order n+1, as well as n-1. The monitor output waveguides 14 for order n+1 can be identical to those described in Example No. 1, positioned on-grid at channel center, and provide information on the power in each channel. The monitor outputs for order n-1, however, can be positioned off-grid, e.g. between channels, and provide information on the inter-channel noise.

The outputs can also be designed so that the ratio between complementary detectors is a known function of wavelength, which allows the device to monitor the wavelength of each channel. This can be accomplished, for example, by using the technique described in US patent No. 6,339,662, entitled "Wavelength stabilized planar waveguide optical devices incorporating a dispersive element", the contents of which are herein incorporated by reference, or by other similar techniques.

The advantages of this configuration include all the advantages listed for Example No. 1. In addition, wavelength / OSNR measurements are made possible with no moving parts. Typically, wavelength and OSNR monitoring techniques often involve devices with moving parts such as tunable filters, which often exhibit reliability issues and have very slow scan times. The invention described here allows the monitoring of a signal at several positions on or off grid, all measured simultaneously. This results in a device with no moving parts, with a very fast scan time.

The integrated photonics devices can be made using silica technology in a manner known *per se*.

It will be appreciated by one skilled in the art that many other variants of the invention are possible within the scope of the appended claims.

We claim:

1. A device for integrating demultiplexing and optical channel monitoring, comprising:

a diffraction grating;

an input waveguide providing an optical input to said diffraction grating;

a first set of output waveguides providing optical outputs to said diffraction grating at a predetermined order of diffraction; and

a second set of output waveguides providing monitor outputs to said diffraction grating at another order of diffraction different from said predetermined order of diffraction.

2. A device as claimed in claim 1, wherein said another order of diffraction is higher than said predetermined order of diffraction.

3. A device as claimed in claim 1 or 2, further comprising a third set of outputs at a further order of diffraction different from said predetermined order of diffraction and said another order of diffraction, said third set of outputs providing monitor outputs to said diffraction grating.

4. A device as claimed in claim 3, wherein said further order of diffraction is lower than said predetermined order of diffraction.

5. A device as claimed in claim 4, wherein said predetermined order of diffraction is order n, said another order of diffraction is order n+1, and said further order of diffraction is order n-1.

6. A device as claimed in claim 3, wherein said second set of output waveguides are positioned at channel locations, and said third set of waveguides are positioned at between-channel locations to provide information on inter-channel noise.

7. A device as claimed in any of claims 1 to 6, further comprising a detector array coupled to said second set of waveguides.

8. A device as claimed in claim 7, wherein said diffraction grating is an echelle grating.

9. A device as claimed in claim 8, which is in the form of an integrated optical device.

10. A method of performing demultiplexing and optical channel monitoring, comprising the steps of:

directing an optical input signal containing multiple channels to a diffraction grating;

receiving reflected and diffracted signals at a first set of output waveguides providing optical outputs at a predetermined order of diffraction; and

receiving reflected and diffracted signals at a second set of output waveguides providing monitor outputs at another order of diffraction different from said predetermined order of diffraction.

11. A method as claimed in claim 10, wherein said another order of diffraction is higher than said predetermined order of diffraction.

12. A method as claimed in claim 11, wherein reflected and diffracted signals are received at a third set of outputs at a further order of diffraction different from said predetermined order of diffraction and said another order of diffraction, said third set of outpus providing monitor outputs to said diffraction grating.

13. A method as claimed in claim 12, wherein said further order of diffraction is lower than said predetermined order of diffraction.

14. A method as claimed in claim 13, wherein said predetermined order of diffraction is order n, said another order of diffraction is order n+1, and said further order of diffraction is order n-1.

15. A method as claimed in claim 12, wherein said second set of output waveguides are positioned at channel locations, and said third set of waveguides are positioned at between-channel locations to provide information on inter-channel noise.

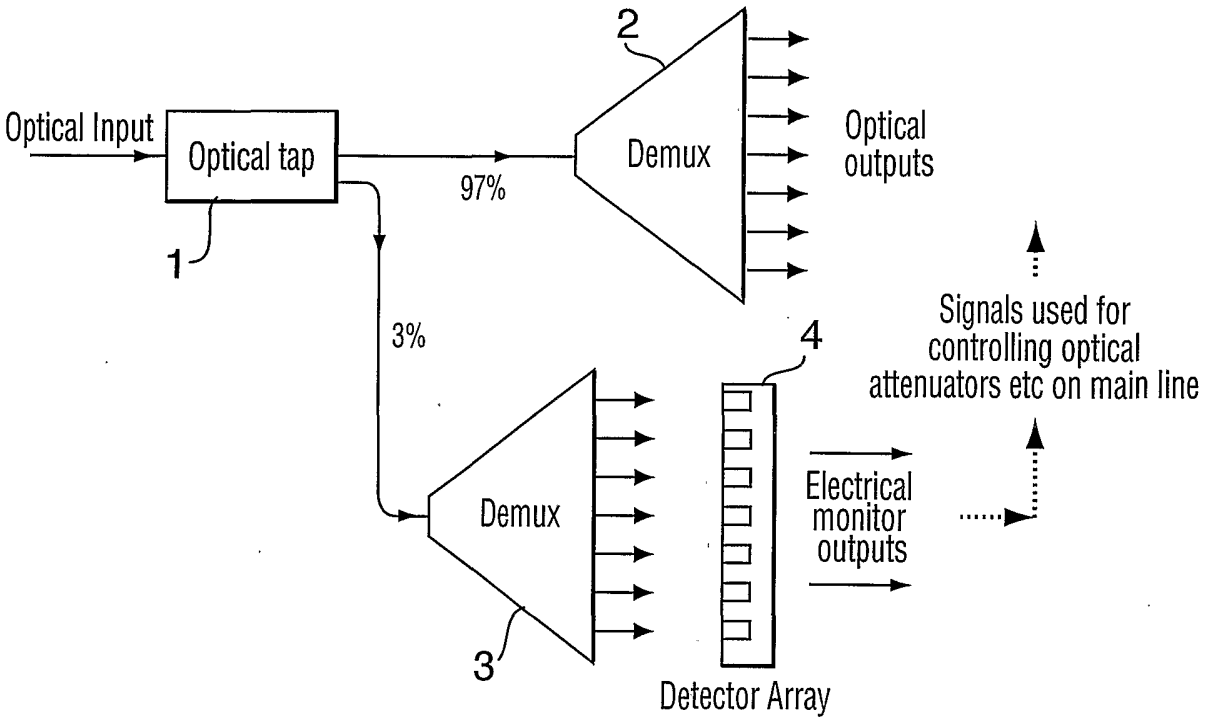

Optical Input
Optical tap
1
97%
2
Demux
Optical outputs
3%
4
Signals used for controlling optical attenuators etc on main line
Demux
3
Electrical monitor outputs
Detector Array

FIG. 1

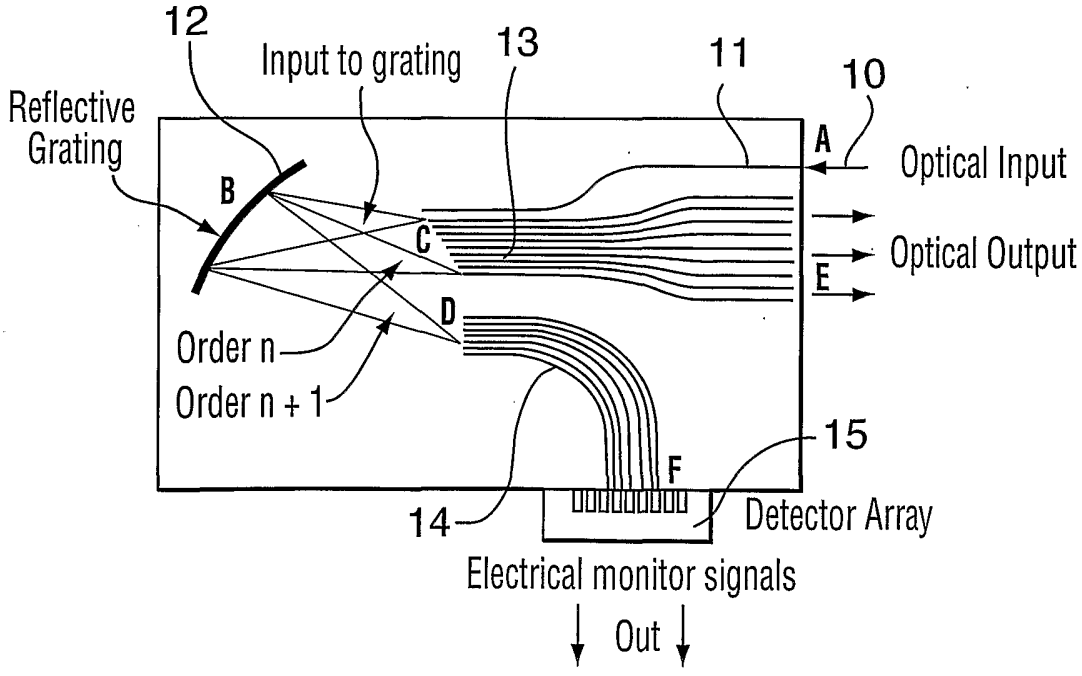

12
Input to grating
13
11
10
Reflective Grating
A
Optical Input
B
C
Optical Output
E
D
Order n
Order n + 1
15
F
14
Detector Array
Electrical monitor signals
Out

FIG. 2

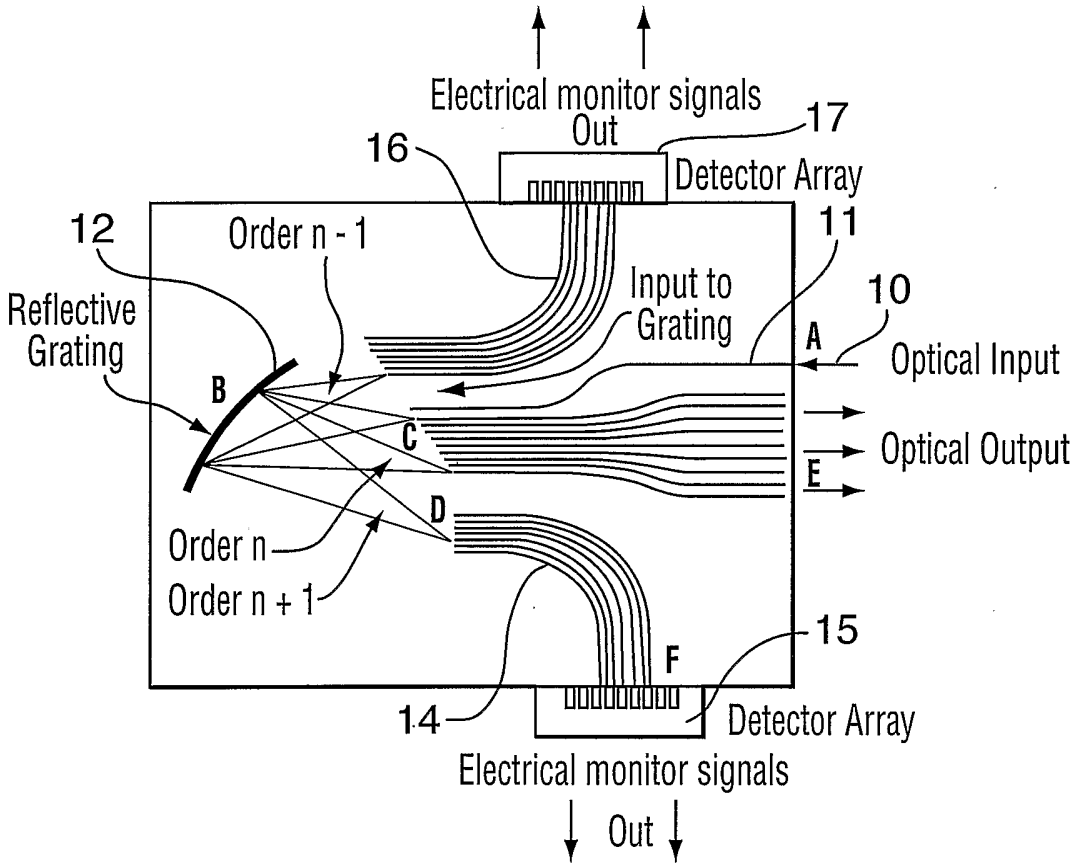

Electrical monitor signals
Out
17
16
Detector Array
12
Order n - 1
11
Input to
Grating
10
Reflective
Grating
A
Optical Input
B
C
Optical Output
E
D
Order n
Order n + 1
15
F
14
Detector Array
Electrical monitor signals
Out

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 03/00863

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/293

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)
IPC 7 G02B

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

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

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/057875 A1 (KANEKO TAROU) 16 May 2002 (2002-05-16) abstract; figure 1 paragraphs '0097!,'0103!,'0104!,'0135!; figure 15	1-7
Y		12-15
X	US 5 748 815 A (HAMEL ANDRE ET AL) 5 May 1998 (1998-05-05) abstract; figures 5,6 column 5, line 47 -column 7, line 52	1,2,8-11
Y		12-15
X	US 6 389 201 B1 (URINO YUTAKA) 14 May 2002 (2002-05-14) abstract; figures 1,2	1,2

-/--

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

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"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)

"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

"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

"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

"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.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 September 2003	02/10/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Riblet, P

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 803 115 A (CIT ALCATEL) 29 June 2001 (2001-06-29) abstract; figures 1,2	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 03/00863

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002057875 A1	16-05-2002	JP 2002148459 A	22-05-2002
US 5748815 A	05-05-1998	FR 2738432 A1	07-03-1997
		EP 0762161 A1	12-03-1997
US 6389201 B1	14-05-2002	JP 3346751 B2	18-11-2002
		JP 2001116938 A	27-04-2001
FR 2803115 A	29-06-2001	FR 2803115 A1	29-06-2001
		EP 1113595 A1	04-07-2001
		JP 2001235639 A	31-08-2001
		US 2001005438 A1	28-06-2001