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(54) Title: EYE PIECE AND TUNABLE CHROMATIC DISPERSION COMPENSATOR USING THE SAME

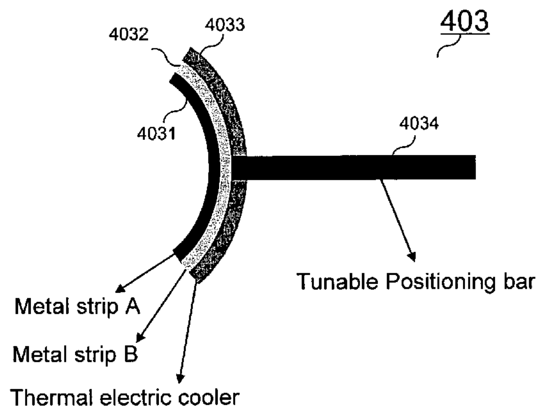

Fig. 4

(57) **Abstract:** An eye piece (403) for use in a tunable chromatic dispersion compensator comprises a first strip (4031) made of a first metal, a second strip (4032) made of a second metal, a heater/cooler (4033), and a tunable positioning bar (4034). The second strip (4032) is attached to the first strip (4031), the heater/cooler (4033) is attached to the second strip (4032) for heating/cooling the first and second strips (4031, 4032), the tunable positioning bar (4034) is attached to the heater/cooler (4033) for keeping the position of the eye piece (403) in the tunable chromatic dispersion compensator, and the first metal and the second metal have different expanding coefficients from each other, so that in response to a change in temperature, the shape of the eye piece (403) is changed from a first shape to a second shape. A tunable chromatic dispersion compensator uses the eye piece (403).

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EYE PIECE AND TUNABLE CHROMATIC DISPERSION COMPENSATOR USING THE SAME

BACKGROUND OF THE INVENTION

FIELD OF INVENTION

The present invention relates to the optical networking field, and in particular to an eye piece and a tunable chromatic dispersion compensator using the eye piece and Planar Lightwave Circuit (PLC) devices, and in the chromatic dispersion compensator, the eye piece is critical for the tunability.

DESCRIPTION OF PRIOR ART

Chromatic dispersion compensation is necessary for optical networks; and tunability is the key for reconfigurable or agile networks. Current tunable methods cannot compensate the chromatic dispersion slope of the optical fiber over a specific wavelength range (e.g. C band), which is an important problem for DWDM systems, though the amount of chromatic dispersion can be tuned.

Conventional chromatic dispersion compensators use specially designed optical fibers, which are expensive, and can not be tuned. Next generation optical networks need cheaper and agile devices, and thus tunability and reconfigurability are desirable. Tunable dispersion compensation is one of the blocking factors for realizing agility of next generation optical networks. Some tunable dispersion compensating modules (DCMs) e.g. Fiber Bragg Grating (FBG) and etalon based DCMs are developed but they are not satisfactory since they are not capable of compensating the dispersion slope of the fiber used for telecommunication (see Reference 1, Christopher R. Doerr, *Optical compensation of system impairments*, 5 – 10 March 2006, OFC 2006).

Fig. 1 shows an optical pulse before entering optical fiber 101 (100), after exiting optical fiber 101 and before entering dispersion compensator 102 (120), and after exiting dispersion compensator 102 (140). An optical pulse consists of different chromatic components. When traveling through a medium e.g. a single mode optical fiber (referring to 101 in Fig. 1), the different components of light have different speeds, so these chromatic components get dispersed after traveling a distance, and the extent of the dispersion is proportional to the traveling distance of the medium (referring to 120 in Fig. 1). The dispersion of different chromatic components causes "distortion" of the shape of the optical pulse thus degrades the transmission performance of the digital networks. Compensation of the chromatic dispersion can restore the "distorted" optical pulse thus improving the transmission performance of the digital networks.

Future optical networks need reconfigurability, this is because the traveling distance needed for the optical pulse may vary with different network configurations, as a result the amount of the dispersion to be compensated should also be reconfigurable, or, tunable.

Particularly, Fig. 2 is a schematic diagram showing the usage of Tunable Chromatic Dispersion Compensator (TCDC) in an agile optical network. As shown in Fig. 2, when changing network transmission configuration from a first configuration A to B to a second configuration A to C by the optical router 201, transmission distance also changes from A-B to A-C, in this case the Tunable Chromatic Dispersion Compensators (TCDCs) 202 are needed to realize reconfigurability.

Fig. 3 shows a schematic overall diagram of the Tunable Chromatic Dispersion Compensator (TCDC) 202. The single channel TCDC 202 mainly consists of a dispersive grating 301, a telescope structure (302 and 303), a single mode waveguide 304 and a tangential coupling grating 305. The dispersive grating 301 disperses the light to a small angle, the telescope structure, which consists of an object lens 302 and an eye piece 303, can magnify this angle by a factor of f_o/f_e, where f_o and f_e are the focal lengths of the object lens and eye piece 303 respectively. Light exiting the eye piece 303 will be coupled to the arc single mode waveguide 304 by the arc tangential coupling grating 305, thus different colors experience different delay after exiting the pigtail, so dispersion is compensated. If the radius of the arc is r, dispersed angle is 2θ, then the maximum dispersion distance able to be compensated is $2r\theta$.

As discussed before, the "maximum compensated dispersion distance" is:

$$2r\theta = 2r \times \arctan\left(\tan(\alpha)\frac{f_o}{f_e}\right)$$

The amount of the compensated dispersion can be tuned by changing the magnification factor of the telescope structure (302 and 303) as shown in Fig. 3. The focal length of the object lens 302 is fixed in this solution, so a deformable mirror with a variable focal length can be used for the eye piece 303. A kind of deformable mirror using piezo-electric actuators is proposed in a publication by Chris R. Doerr (see Reference 2, C. R. Doerr, et. al., *40-Gb/s colorless tunable dispersion compensator with 1000-ps/nm tuning range employing a planar lightwave circuit and a deformable mirror*, 6 – 10 March 2005, OFC 2005).

The present invention is intended to overcome the above problems for "tunable DCMs" for future dynamically reconfigurable optical networks.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an eye piece and a tunable chromatic dispersion compensator using the same which are used for optical networking to overcome the above problems for "tunable DCMs" for future dynamically reconfigurable optical networks.

According to a first aspect of the present invention, an eye piece for use in a tunable chromatic dispersion compensator is proposed, which comprises: a first strip made of a first metal; a second strip made of a second metal, which is attached to the first strip; a heater/cooler which is attached to the second strip for heating/cooling the first and second strips; and a tunable positioning bar which is attached to the heater/cooler for keeping the position of the eye piece in the tunable chromatic dispersion compensator, wherein the first metal and the second metal have different expanding coefficients from each other, so that in response to a change in temperature, the shape of the eye piece is changed from a first shape to a second shape.

Preferably, the first shape is a concave shape the second shape being a convex shape; or the first shape is convex shape the second shape being a concave shape.

Preferably, the first metal has an expanding coefficient smaller than that of the second metal. Alternatively, the first metal has an expanding coefficient larger than that of the second metal.

Preferably, the first metal is suitable to reflect light within a wavelength range for which the chromatic dispersion is to be compensated. Alternatively, the eye piece further comprises a reflection film which is attached onto the first strip and suitable to reflect light within a wavelength range for which the chromatic dispersion is to be compensated.

Preferably, the heater/cooler is a thermal electric cooler.

Preferably, the tunable positioning bar is a piezoelectric transducer or is made of a third metal with large thermal expanding coefficient. More preferably, the third metal is the same as the second metal.

According to a second aspect of the present invention, a tunable chromatic dispersion compensator is proposed, which comprises an eye piece according to the present invention.

Preferably, the tunable chromatic dispersion compensator further comprises: an object lens; an arc tangential coupler; an arc single mode waveguide; and a dispersive grating; wherein inputted light is dispersed to the object lens at the dispersive grating, a focal plane of the object lens is overlapped with the eye piece, the eye piece is located substantially at the center of the arc tangential coupler, and the arc single mode waveguide is parallel to the arc tangential coupler, and the arc tangential coupler couples the light tangentially into the arc single mode waveguide.

Preferably, the tunable chromatic dispersion compensator further comprises a coarse grating, and the dispersive grating is formed by a channel grating array, so that the inputted light is firstly dispersed according to different channels at the coarse grating and then projected onto the channel grating array.

Preferably, the tunable chromatic dispersion compensator further comprises a heater/cooler which is attached onto the channel grating array and is controlled to produce a temperature distribution desired for compensating the chromatic dispersion slope along the channel grating array. More preferably, the temperature distribution is a linear increasing/decreasing temperature distribution along the channel grating.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will be clearer from the following detailed description about the non-limited embodiments of the present invention taken in conjunction with the accompanied drawings, in which:

Fig. 1, which has been described, is a schematic diagram showing the dispersed and restored optical pulses;

Fig. 2, which has been described, is a schematic diagram showing the usage of TCDC in an agile optical network;

Fig. 3, which has been described, shows a schematic overall diagram of the Tunable Chromatic Dispersion Compensator (TCDC);

Fig. 4 shows a tunable eye piece provided according to the present invention in a telescope;

Fig. 5 shows the tangential coupling of the dispersed light from the eye piece (of the telescope) to the single mode waveguide;

Fig. 6 shows a schematic overall diagram of a Multi-channel TCDC;

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Hereunder, the present invention will be described in accordance with the drawings. In the following description, some particular embodiments are used for the purpose of description only, which shall not be understood as any limitation to the present invention but the examples thereof. While it may blur the understanding of the present invention, the conventional structure or construction will be omitted.

Fig. 4 shows a tunable eye piece 403 provided according to the present invention in a telescope. As shown in Fig. 4, an eye piece 403 is a concave mirror 4031 made of metal A, and is attached onto a strip 4032 made of metal B, the metal A and metal B have different thermal expanding coefficients. For example, the metal A may have a smaller thermal expanding coefficient, and the metal B may have a larger thermal expanding coefficient. For example, the metal A is iron (Fe) and the metal B is copper (Cu), so that when the eye piece 403 is heated, it will be changed from a convex mirror into a concave mirror, and when the eye piece 403 is cooled, it will be changed from a concave mirror into a convex mirror. Alternatively, the metal A may have a larger thermal expanding coefficient, and the metal B may have a smaller thermal expanding coefficient, such as, copper (Cu) for use as the metal A and iron (Fe) for use for the metal B, so that when the eye piece 403 is heated, it will be changed from a concave mirror into a convex mirror, and when the eye piece 403 is cooled, it will be changed from a convex mirror into a concave mirror. Furthermore, it shall be noticed that the metal A (e.g. gold (Au)) or a reflection film (e.g. a gold (Au) film) (not shown) formed thereon is suitable to reflect the light within the wavelength range for which the chromatic dispersion is to be compensated. A TEC (thermal electric cooler) 4033 is attached onto metal stripe B on the opposite side opposite to the metal A. When heated or cooled by the TEC 4033, the focal length of (or, half radius of) the concave mirror will vary due to the different expansions of the metal strip A and metal strip B. When the eye piece 403 is changed from a concave mirror to a convex mirror, the sign of the compensated dispersion will change from positive to negative. A tunable positioning bar 4034 is attached onto the eye piece, which length can be varied by electrical means e.g. PZT (piezoelectric transducer) or thermal means e.g. metal with large thermal expanding coefficient in combination with a TEC. The purpose of the tunable positioning bar 4034 is to keep the telescope structure (302 and 303) as shown in Fig. 3 well tuned, or, in other words, to keep the focal planes of the object lens 302 and the eye piece 303 well overlapped while the focal length of the eye piece 303 is being changed.

Fig. 5 shows the eye piece 503 and the Planar Lightwave Circuit (PLC) devices (5001 – 5005), in which the dispersed light from the eye piece 503 (of the telescope) is tangentially coupled to the single mode waveguide 5004. The tangential coupling grating 5003 is designed to couple the light tangentially, or, in other words, to output light normal to the incident light, so the light exiting the grating 5003 will enter the single mode waveguide 5004 which is parallel to the grating 5003 itself. This kind of grating coupler is reported to have a coupling efficiency of 60 – 70% (see References 3 and 4: F. Van Laere, et. al., *Compact grating couplers between optical fibers and Silicon-on-Insulator photonic wire waveguides with 69% coupling efficiency*, 5 – 10 March 2006, OFC 2006; and Bin Wang, et. al., *Compact slanted grating couplers*, 26 July 2004, Vol. 12, No. 15, Optics Express 3313). Additionally, the relative positioning of the eye piece 503 with respect to the arc tangential coupling grating 5003 as shown in Fig. 5 is that the eye piece 503 is located substantially at the center of the arc, that is, at the radius "r" away from the arc tangential coupling grating 5003, all the time.

Fig. 6 shows a schematic overall diagram of a Multi-channel TCDC. A three-channel TCDC 600 is depicted in Fig. 6. The channel count can be bigger like 40 or more. Compared to the single channel TCDC 202, the difference of a multi-channel TCDC 600 is in that it utilizes a "coarse grating 6001" to disperse the channels from the input light, and the channels will be projected onto a grating array 601 instead of just one grating 301 as in the single channel TCDC 202. The remaining portion of the multi-channel TCDC 600 shares the same design with the single channel TCDC 202. All the gratings on the grating array 601 can diffract the center wavelengths of the channels in parallel. Thus all the channels share the same image area on the focal plane of the telescope structure (302 and 303). The TECs 6002 on the channel grating array 601 can be controlled to produce a desired temperature distribution (gradient), for example, a linear increasing/decreasing temperature distribution, along the grating array 601 which can vary the grating periods to get the slope compensation as needed in telecom systems.

Therefore, according to the present invention, the inventive TCDC may achieve the following technical advantages.

1. Tunable: the amount of the compensated dispersion can be tuned by adjusting the focal length of the eye piece via TEC attached to it. For example, if 2θ = PI/4 and r = 200 mm, then the dispersion length is L = $2r\theta$ = 2 x 200 mm x $\pi/4$ = 0.314 m, assume the velocity of the light in the waveguide is V = $2x10^8$ m/s and the effective bandwidth is B = 0.5 nm, then the amount of the compensated dispersion is CD = L/(BxV) = 0.314/(0.5x2x108) = 3140 ps/nm, the sign of the compensated dispersion is decided by the eye piece, when the eye piece is a concave mirror, the sign is plus, when the eye piece is convex mirror, the sign is minus.

2. Multi-channel operating: suitable for dispersion compensation for DWDM system e.g. an 80-grating array can be designed for an 80 channel DWDM system.

3. Slope compensation, the dispersion slope can be compensated by introducing

a specific temperature distribution (gradient) along the channel grating array, this feature makes the invention more attractive and practical since none of other tunable dispersion compensation method is capable of compensating the dispersion slope according to Reference 1 (Christopher R. Doerr, *Optical compensation of system impairments*, 5 – 10 March 2006, OFC 2006).

4. Wide-band, cascadability: unlike other compensation solutions, the present invention has very wide pass-band so can be cascaded in long optical links.

The above embodiments are provided for the purpose of example only, and are not intended to limit the present invention. It is to be understood by those skilled in the art that there may be various modifications or replacements to the embodiments without departing from the scope and the spirit of the present invention, and they shall fall into the scope defined by the appended claims.

Reference List:

Reference 1: Christopher R. Doerr, *Optical compensation of system impairments*, 5 – 10 March 2006, OFC 2006;

Reference 2: C. R. Doerr, et. al., *40-Gb/s colorless tunable dispersion compensator with 1000-ps/nm tuning range employing a planar lightwave circuit and a deformable mirror*, 6 – 10 March 2005, OFC 2005;

Reference 3: F. Van Laere, et. al., *Compact grating couplers between optical fibers and Silicon-on-Insulator photonic wire waveguides with 69% coupling efficiency*, 5 – 10 March 2006, OFC 2006;

Reference 4: Bin Wang, et. al., *Compact slanted grating couplers*, 26 July 2004, Vol. 12, No. 15, Optics Express 3313.

What is claimed is:

1. An eye piece for use in a tunable chromatic dispersion compensator, comprising:

a first strip made of a first metal;

a second strip made of a second metal, which is attached to the first strip;

a heater/cooler which is attached to the second strip for heating/cooling the first and second strips; and

a tunable positioning bar which is attached to the heater/cooler for keeping the position of the eye piece in the tunable chromatic dispersion compensator,

wherein the first metal and the second metal have different expanding coefficients from each other, so that in response to a change in temperature, the shape of the eye piece is changed from a first shape to a second shape.

2. The eyepiece of claim 1, wherein the first shape is a concave shape the second shape being a convex shape; or the first shape is convex shape the second shape being a concave shape.

3. The eye piece for use in the tunable chromatic dispersion compensator according to claim 1, wherein the first metal has an expanding coefficient smaller than that of the second metal.

4 The eye piece for use in the tunable chromatic dispersion compensator according to claim 1, wherein the first metal has an expanding coefficient larger than that of the second metal.

5. The eye piece for use in the tunable chromatic dispersion compensator according to any one of claims 1 – 4, wherein the first metal is suitable to reflect light within a wavelength range for which the chromatic dispersion is to be compensated.

6. The eye piece for use in the tunable chromatic dispersion compensator according to any one of claims 1 – 4, wherein it further comprises a reflection film which is attached onto the first strip and suitable to reflect light within a wavelength range for which the chromatic dispersion is to be compensated.

7. The eye piece for use in the tunable chromatic dispersion compensator according to any one of claims 1 – 6, wherein the heater/cooler is a thermal electric cooler.

8. The eye piece for use in the tunable chromatic dispersion compensator according to any one of claims 1 – 7, wherein the tunable positioning bar is a piezoelectric transducer or is made of a third metal with large thermal expanding coefficient.

9. The eye piece for use in the tunable chromatic dispersion compensator according to claim 8, wherein the third metal is the same as the second metal.

10. A tunable chromatic dispersion compensator, comprising:

an eye piece according to any one of claims 1 – 8.

11. The tunable chromatic dispersion compensator according to claim 10 further comprising:

an object lens;

an arc tangential coupler;

an arc single mode waveguide; and

a dispersive grating;

wherein inputted light is dispersed to the object lens at the dispersive grating, a focal plane of the object lens is overlapped with the eye piece, the eye piece is located substantially at the center of the arc tangential coupler, and the arc single mode waveguide is parallel to the arc tangential coupler, and

the arc tangential coupler couples the light tangentially into the arc single mode waveguide.

12. The tunable chromatic dispersion compensator according to claim 11, wherein it further comprises a coarse grating, and the dispersive grating is formed by a channel grating array, so that the inputted light is firstly dispersed according to different channels at the coarse grating and then projected onto the channel grating array.

13. The tunable chromatic dispersion compensator according to claim 12, wherein it further comprises a heater/cooler which is attached onto the channel grating array and is controlled to produce a temperature distribution desired for compensating the chromatic dispersion slope along the channel grating array.

14. The tunable chromatic dispersion compensator according to claim 13, wherein the temperature distribution is a linear increasing/decreasing temperature distribution along the channel grating.

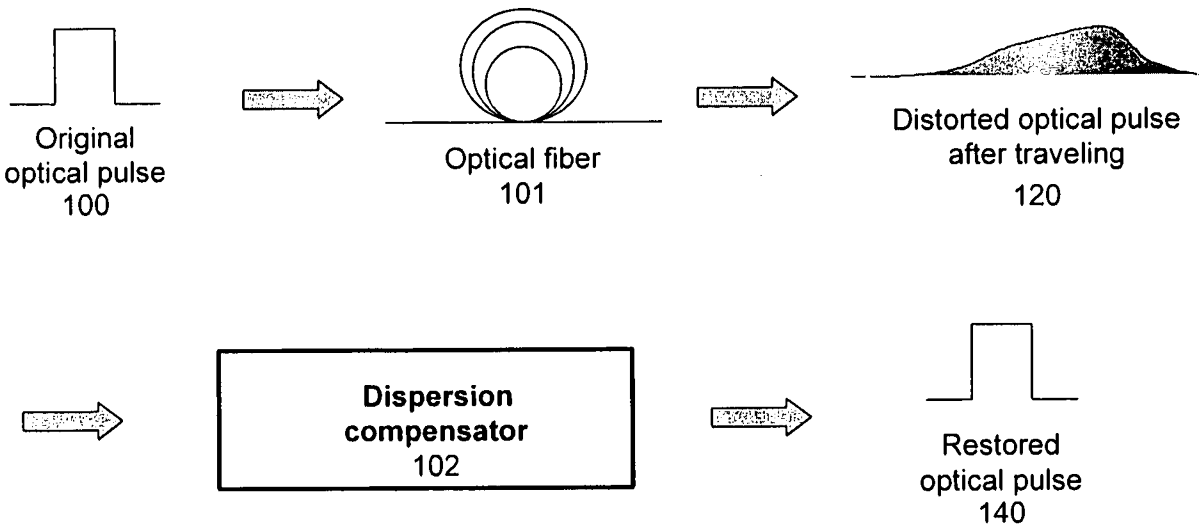

Original
optical pulse
100
Optical fiber
101
Distorted optical pulse
after traveling
120
Dispersion
compensator
102
Restored
optical pulse
140

Fig. 1

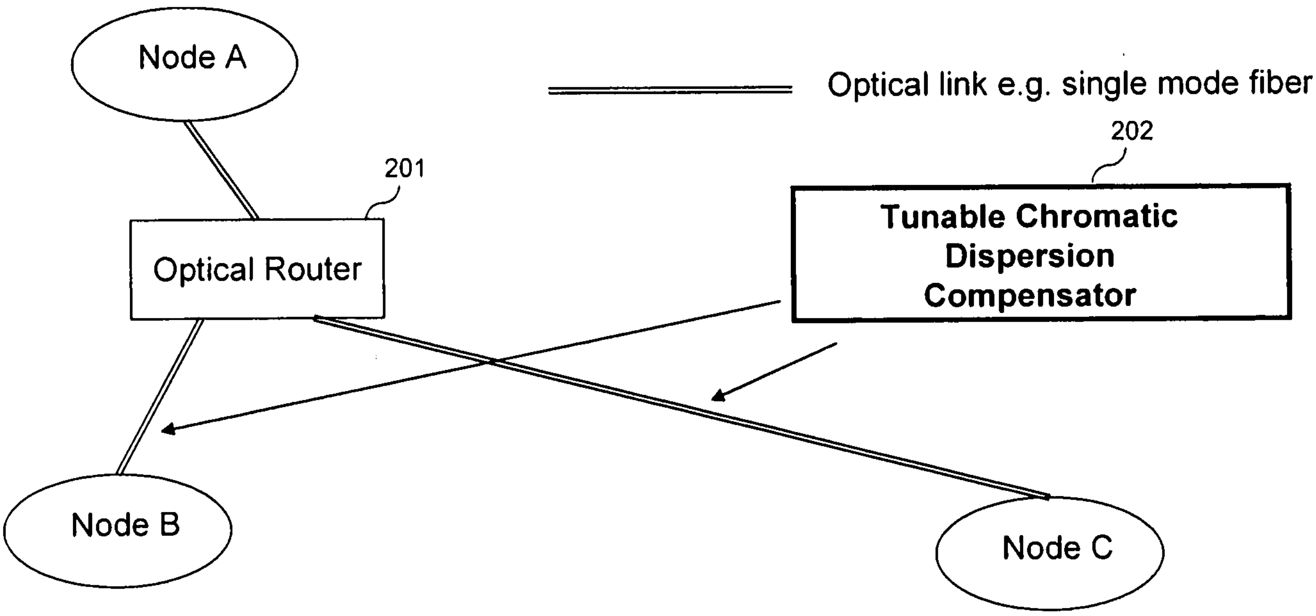

Node A
Optical link e.g. single mode fiber
202
201
Optical Router
Tunable Chromatic
Dispersion
Compensator
Node B
Node C

Fig. 2

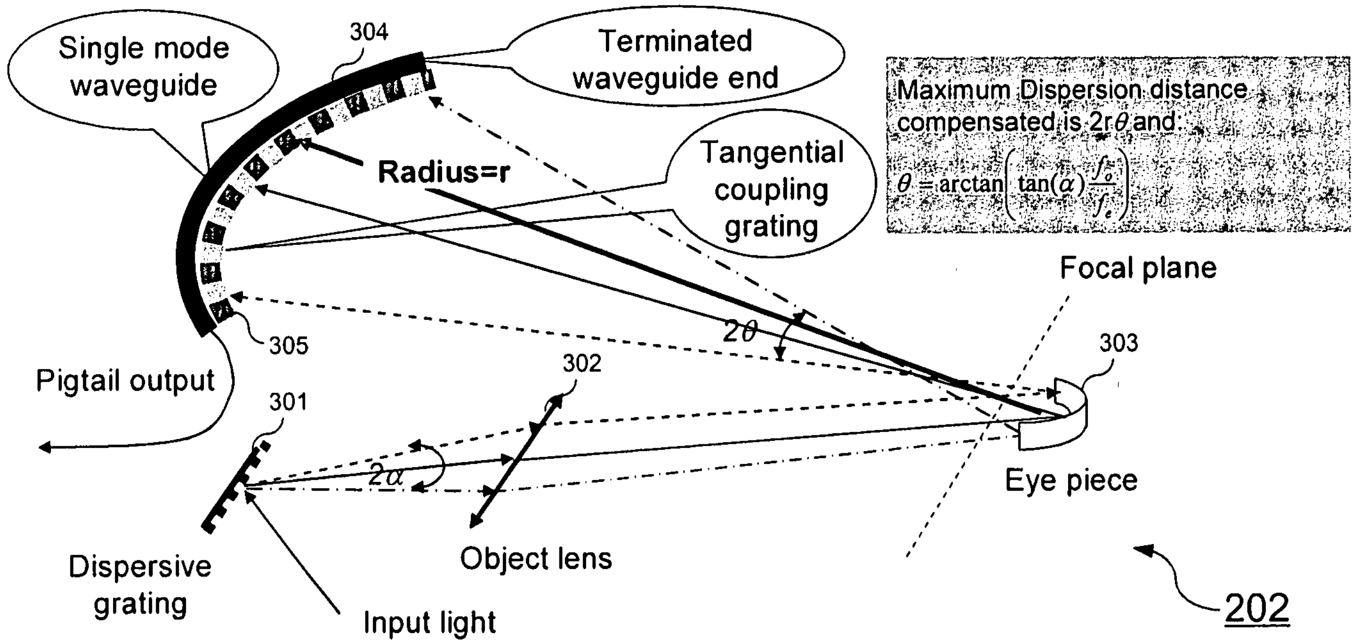

Single mode waveguide
304
Terminated waveguide end
Maximum Dispersion distance compensated is 2rθ and:
$\theta = \arctan\left(\tan(\alpha)\frac{f_o}{f_e}\right)$
Radius=r
Tangential coupling grating
Focal plane
2θ
303
305
Pigtail output
302
301
2α
Eye piece
Dispersive grating
Object lens
Input light
202

Fig. 3

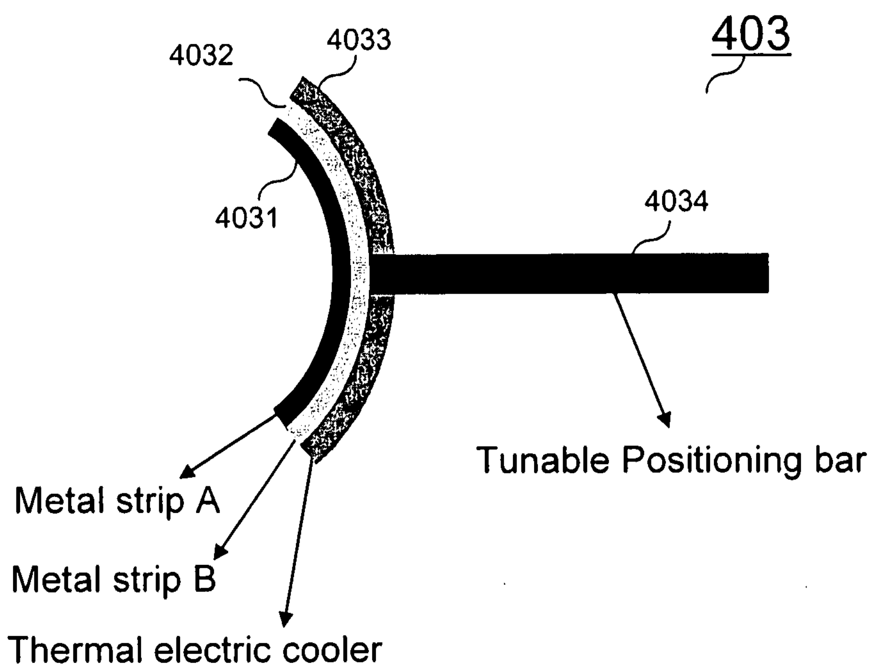
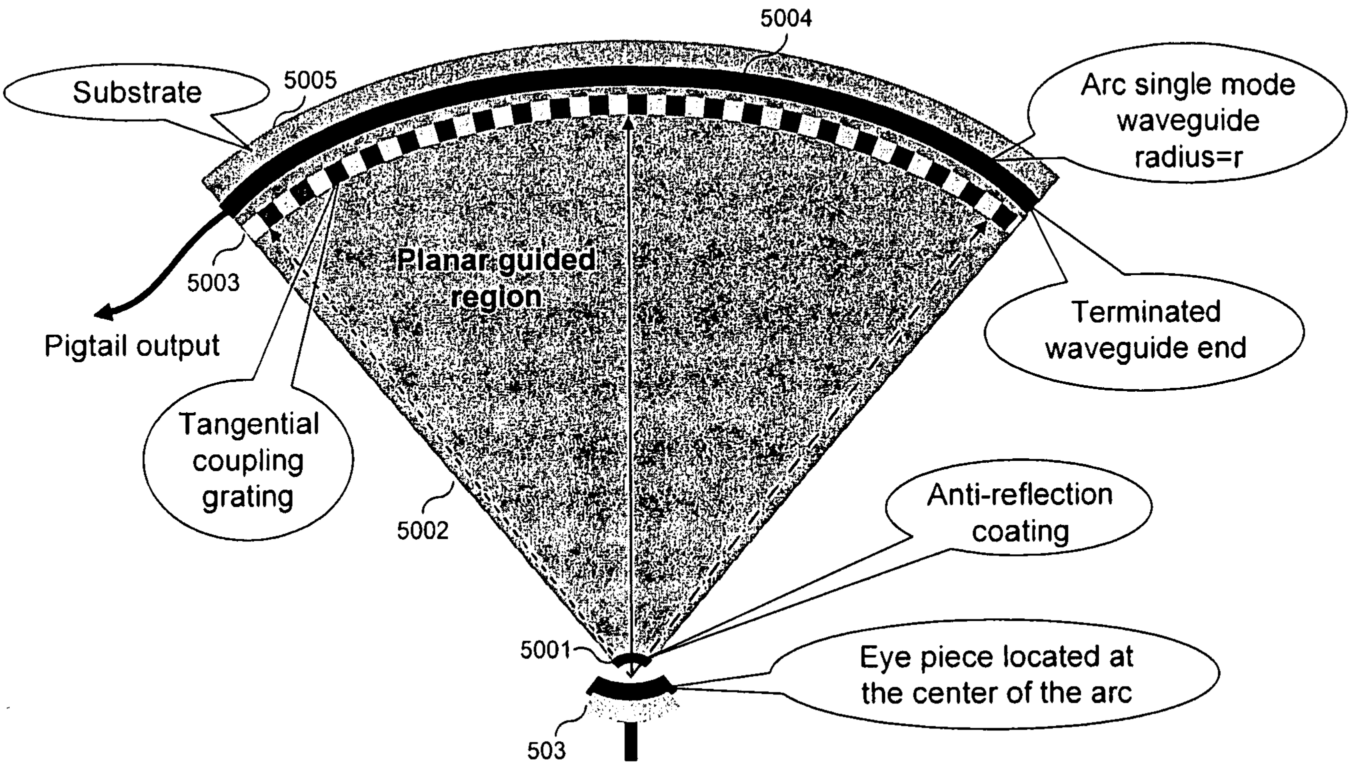
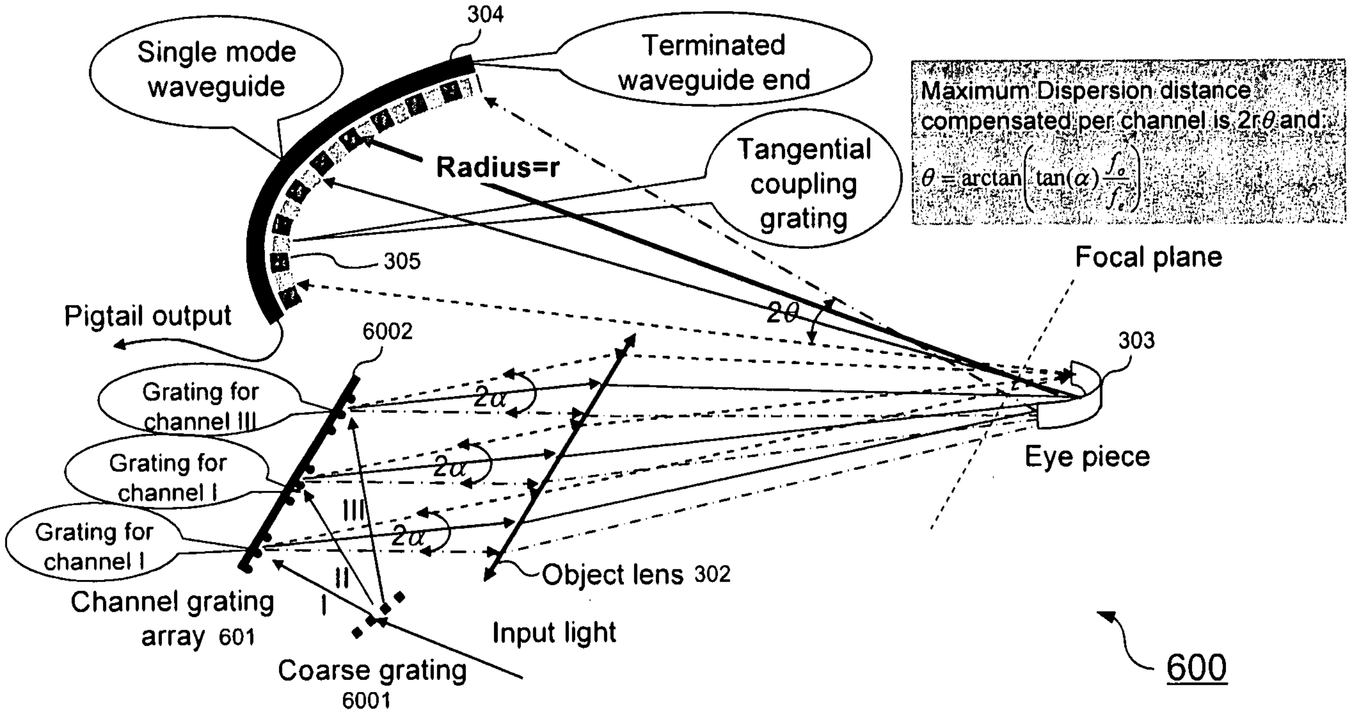

403
4032
4033
4031
4034
Tunable Positioning bar
Metal strip A
Metal strip B
Thermal electric cooler

Fig. 4



5004
Substrate
5005
Arc single mode waveguide radius=r
Planar guided region
5003
Pigtail output
Terminated waveguide end
Tangential coupling grating
5002
Anti-reflection coating
5001
Eye piece located at the center of the arc
503

Fig. 5



304
Single mode waveguide
Terminated waveguide end
Maximum Dispersion distance compensated per channel is $2r\theta$ and:
$\theta = \arctan\left(\tan(\alpha)\frac{f_o}{f_e}\right)$
Tangential coupling grating
Radius=r
305
Focal plane
Pigtail output
2θ
6002
303
Grating for channel III
2α
Grating for channel I
2α
Eye piece
III
Grating for channel I
2α
Object lens 302
II
Channel grating array 601
I
Input light
Coarse grating 6001
600

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2008/000053

A. CLASSIFICATION OF SUBJECT MATTER

See the extra sheet

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

IPC: G02B6 H04B10 G02B5

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

WPI EPODOC PAJ CNPAT

TODC TCDC ODC tunable variable chang??? vary??? deformable dispers??? chromatic aberratio chromaticaberratio compensat??? eliminat??? heat??? cool??? chill??? temperature expansion 2d coefficient expansion 2d ratio expansion 2d factor expanding coefficient eye piece eye lens eyepiece ocular ocular lens ocular glass sighting piece telescope binocular

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN1828352A (LUCENT TECHNOLOGIES INC) 06 Sep. 2006 (06.09.2006) page 3, line 21-page 5, line 2, figs. 1-3	1-14
A	EP1278081A2 (FUJITSU LTD) 22 Jan. 2003 (22.01.2003) paragraphs 0024-0057, figs. 6-14	1-14
A	JP2002-72034A (HITACHI CABLE LTD) 12 Mar. 2002 (12.03.2002) paragraphs 0009-0025, fig. 1	1-14
A	US2006/0203344A1 (FUJITSU LTD) 14 Sep. 2006 (14.09.2006) the whole	1-14
A	US4875766A (MITSUBISHI ELECTRIC CORP) 24 Oct. 1989 (24.10.1989) the whole	1-14

☒ Further documents are listed in the continuation of Box C. ☒ See patent family 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 application or patent but published on or after the international filing date

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"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
07 Oct. 2008 (07.10.2008)	**30 Oct. 2008 (30.10.2008)**
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer LIU, Wenzhi Telephone No. (86-10)62085752

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2008/000053

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN1982201A (FRAUNHOFER GES FOERDERUNG ANGEWANDTEN EV) 20 Jun. 2007 (20.06.2007) the whole	1-14
A	JP2005-37709A (MITSUBISHI ELECTRIC CORP) 10 Feb. 2005 (10.02.2005) the whole	1-14

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2008/000053

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN1828352A	06.09.2006	EP1698922A2	06.09.2006
		JP2006243736A	14.09.2006
		US2006198577A1	07.09.2006
		US7174063B2	06.02.2007
		INCHE200600373A	07.09.2006
EP1278081A2	22.01.2003	JP2003029168A	29.01.2003
		US2003016908A1	23.01.2003
		US6832020B2	14.12.2004
		US2005041921A1	24.02.2005
		US7197211B2	27.03.2007
JP2002-72034A	12.03.2002	none	
US2006/0203344A1	14.09.2006	US7262913B2	28.08.2007
		EP1703307A1	20.09.2006
		JP2006251609A	21.09.2006
US4875766A	24.10.1989	DE3723245A	21.01.1988
		DE3723245C2	19.01.1995
		JP63025601A	03.02.1988
		JP63041801A	23.02.1988
		JP63041802A	23.02.1988
		JP6075121B	21.09.1994
		JP1951190C	10.07.1995
		JP63089801A	20.04.1988
		JP63089802A	20.04.1988
		JP63089803A	20.04.1988
CN1982201A	20.06.2007	US2007165297A1	19.07.2007
		DE102006059091A1	26.07.2007
JP2005-37709A	10.02.2005	none	

INTERNATIONAL SEARCH REPORT

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A.CLASSIFICATION OF SUBJECT MATTER:

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