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(71) Applicant: CARL ZEISS MEDITEC AG [DE/DE];
Göschwitzer Str. 51 - 52, 07745 Jena (DE).

(72) Inventor: WANG, Yingjian; 1488 Harrington St., Fremont, CA 94539 (US).

(74) Agent: BECK, Bernard; Carl Zeiss AG, Patentabteilung, Carl-Zeiss-Promenade 10, 07745 Jena (DE).

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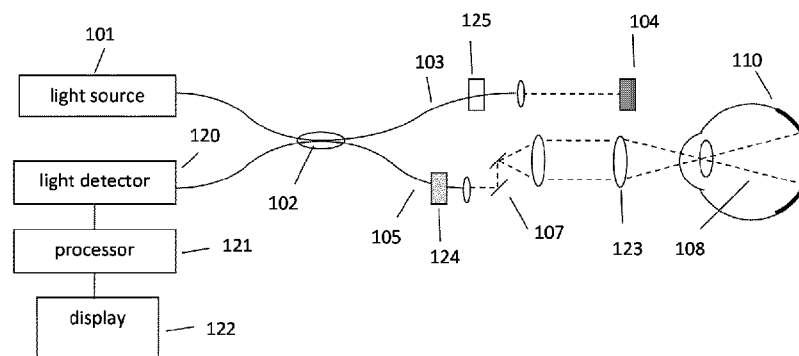
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FIG. 1



(57) Abstract: An apparatus and a method are described which provide a range of second-order chromatic dispersion correction between a reference arm and a sample arm of an optical coherence tomographic system, while minimizing optical path length differences.

**METHODS AND SYSTEMS FOR MODIFYING SECOND-ORDER
CHROMATIC DISPERSION IN OPTICAL COHERENCE
TOMOGRAPHIC SYSTEMS**

5 **TECHNICAL FIELD**

This application presents an apparatus and a method for compensating for second-order chromatic dispersion in optical coherence tomographic systems.

10 **BACKGROUND**

Optical Coherence Tomography (OCT) is a technology for performing high-resolution cross sectional imaging that can provide images of tissue structure on the micron scale in situ and in real time. OCT is a method of interferometry that uses light containing a range of optical frequencies to
15 determine the scattering profile of a sample. The axial resolution of OCT is inversely proportional to the span of optical frequencies used.

In recent years, it has been demonstrated that frequency domain OCT (FD-OCT) has significant advantages in speed and signal to noise ratio
20 as compared to time domain OCT (TD-OCT; Leitgeb et al. 2003; deBoer et al. 2003; Choma et al. 2003).

In FD-OCT, a light source capable of emitting a range of optical frequencies enters an interferometer, the interferometer combines the
25 light returned from a sample with the light from a reference arm, and the intensity of the combined light is recorded as a function of optical frequency to form an interference spectrum. A Fourier transform of the interference spectrum provides the reflectance distribution along the depth within the sample. FD-OCT requires some means to record the
30 interference spectrum, the intensity of light output from the interferometer

as a function of optical frequency. Current methods of FD-OCT can be divided into two categories.

5 In spectral-domain OCT (SD-OCT), a grating or prism or other means is used to disperse the output of the interferometer into its optical frequency components. The intensities of these separated components are measured using an array of optical detectors, each detector receiving an optical frequency or a fractional range of optical frequencies. The set of measurements from these optical detectors forms an interference
10 spectrum (Smith & Dobson 1989). Typically the light source emits a broad range of optical frequencies simultaneously.

Alternatively, in swept-source OCT (SS-OCT), the interference spectrum is recorded by using a source with adjustable optical frequency, with the
15 optical frequency of the source swept through a range of optical frequencies, and recording the interfered light intensity as a function of time during the sweep (US 5321501). FD-OCT efficiently uses the light returned from a range of depths within the sample, as all the returned light contributes to the modulation in the interference spectrum.

20 FD-OCT methods use the fact that interference between light scattered from the sample and the reference beam causes spectral interference fringes, a modulation in the intensity of the combined beam as a function of optical frequency. The spacing of the interference fringes depends on
25 the difference in optical group delay between the light scattered from the sample, and reference light.

OCT determines the position in the sample of a scattering center based on the difference in optical group delay between two optical paths: 1) the
30 path of light scattered from the sample, and 2) a reference optical path.

Most OCT literature refers simply to the difference between sample and reference optical path lengths. However, due to the dispersive nature of not only transmissive optics (such as fibers), but the sample itself, there will be spectral differences introduced between these two optical path lengths, thus effecting the measured signal and its interpretation. Most transmissive optical components generate positive chromatic dispersion. Alternatively, there are some optical components, such as gratings, where the chromatic dispersion is negative.

Chromatic dispersion is a property of an optical element that characterizes the degree by which the optical path length through that element varies across a range of optical frequencies. Chromatic dispersion is the result of wavelength components travelling at different phase and/or group velocities in a dispersive medium. Without proper compensation, the phase of the signal varies causing degradation in axial resolution. Due to the nature of most dispersive materials, blue wavelengths of light travel slower in a medium than their red counterparts. Thus a pulse of polychromatic light will be broadened temporally. This temporal shape modification is a function of the degree of second-order (and higher terms as well) in the functional form for chromatic dispersion (discussed in detail hereinbelow).

In the case of chromatic dispersion, there needs to be a distinction between the phase delay and the group delay associated with a given optical path length. OCT is sensitive to the difference in group delay (see, for example, section 2.1 in Fercher et al. 2001). FD-OCT necessarily uses a range of optical frequencies. If the chromatic dispersion is not matched between the two paths, the apparent position of the scattering center depends on the optical frequency used. A mismatch in chromatic dispersion thus broadens the axial resolution of

the OCT as explained by Hitzenger et al. 1999. For this reason, in most FD-OCT systems the chromatic dispersion is closely matched or at least adjusted between sample and reference paths (see, e.g., US6385358, US6615072, US6618152) sometimes through the use of
5 dispersive optical devices (see, e.g., US6282011). Since a perfect match of chromatic dispersion is not simple, it can add cost to the system by requiring tight optical tolerances on the various optical components.

SUMMARY

10 The overall aim of the embodiments presented within the present application is to control the amount of second-order chromatic dispersion difference between the reference and sample paths of an optical coherence tomographic instrument. This is to be accomplished by inserting into either path an apparatus (or optical component) that can
15 nullify or precisely control the difference. The insertion can be performed either manually or via a controller.

DRAWINGS

FIG. 1 is a schematic of an optical coherence tomographic instrument based on frequency-domain technology. Item **124** or Item **125** represent
20 the location of some the various embodiments described in the present application in an optical coherence tomographic system.

FIG. 2 FIG. 2(a) is a schematic of a simple embodiment **201** of the present application using two right triangular prisms **203** and **204** each
25 possessing the same apex angle but being made of different optical glasses. The lateral displacement **205** of the input beam **202** (Δy) onto the entrance surface **207** defines the amount of second-order chromatic dispersion that the beam suffers. The beam shown in FIG. 2(b) enters the compound optic at a different lateral position than that of (a), and
30 thus suffers a different second-order chromatic dispersion. In FIG. 2(c),

the view is of the entrance surface **207** of the compound optic **201**, and illustrates the relationship between (r, Θ) and ΔY and the amount of second-order dispersion compensation in this particular embodiment. The compound optic transforms an input beam of light into an output beam of light and these two beams of light are collinear.

FIG. 3 is a table with basic information (index of refraction and second-order dispersion at two different wavelengths) of two possible glasses, of the many possible combinations available from any of the standard glass catalogs such as those from Schott, Hoya, or Ohara, that when combined and mated as specified in this application produce a constant or near constant optical path length irrespective of lateral entrance position while allowing the variation of second-order dispersion compensation as a function of lateral position. The information depicted was derived from the Schott catalog of glasses.

FIG. 4 depicts one component (one-half) of a rotatable double helical prism, which when mated with its reflected version and with a glass of similar refractivity, but disparate second-order chromatic dispersion, yields compensation in said dispersion, while minimizing optical path lengths irrespective of the rotation angle. The advantage of this particular embodiment is that the optical path length is relatively low, while yielding a large range in second-order chromatic dispersion compensation. An equivalent optic would consist of two circular or annular wedges so attached to form a single geometrically uniform cylinder or 3D annulus, in which a beam of light would enter parallel to the cylindrical or annular axis and encounter two or more optical glasses of similar refractivities, but dissimilar second order chromatic dispersions.

DETAILED DESCRIPTION

A generalized Fourier or Frequency Domain optical coherence tomography (FD-OCT) system used to collect an OCT dataset suitable for use with the present set of embodiments, disclosed herein, is illustrated in FIG. 1. A FD-OCT system includes a light source, **101**, typical sources including but not limited to broadband light sources with short temporal coherence lengths or swept laser sources.

Light from source **101** is routed, typically by optical fiber **105**, to illuminate the sample **110**, a typical sample being tissues at the back of the human eye. The light is scanned, typically with a scanner **107** between the output of the fiber and the sample, so that the beam of light (dashed line **108**) is scanned over the area or volume to be imaged. Light scattered from the sample is collected, typically into the same fiber **105** used to route the light for illumination. Reference light derived from the same source **101** travels a separate path, in this case involving fiber **103** and retro-reflector **104**.

Those skilled in the art recognize that a transmissive reference path can also be used. Collected sample light is combined with reference light, typically in a fiber coupler **102**, to form light interference in a detector **120**.

The output from the detector is supplied to a processor **121**. The results can be stored in the processor or displayed on display **122**. The processing and storing functions may be localized within the OCT instrument or functions may be performed on an external processing unit to which the collected data is transferred. This unit could be dedicated to data processing or perform other tasks which are quite general and not dedicated to the OCT device. The display can also provide a user interface for the instrument operator to control the collection and analysis of the data and receive feedback from the instrument. The interface could contain knobs, buttons, sliders, touch screen or other haptic elements or other data input devices as would be well known to someone skilled in the art.

5 The interference causes the intensity of the interfered light to vary across the spectrum. The Fourier transform of the interference light reveals the profile of scattering intensities at different path lengths, and therefore scattering as a function of depth (z-direction) in the sample.

10 The profile of scattering as a function of depth is called an axial scan (A-scan). A dataset of A-scans measured at neighboring locations in the sample produces a cross-sectional image (slice, tomogram, or B-scan) of the sample. A collection of B-scans collected at different transverse locations on the sample comprises a 3D volumetric dataset. Typically a B-scan is collected along a straight line but B-scans generated from scans of other geometries including circular and spiral patterns are also possible.

15 The sample and reference paths or arms in the interferometer could consist of bulk-optics, fiber-optics, or hybrid bulk-optic systems and could have different architectures such as Michelson, Mach-Zehnder or common-path based designs as would be known by those skilled in the art. Light beam or beam of light as used herein should be interpreted as any carefully directed
20 light path.

25 The present application is aimed at describing a system and a method that compensates for the second-order chromatic dispersions of the reference and/or sample beams of an optical coherence tomographic system via the insertion of an optical component made of two or more optical materials, wherein these materials are chosen to satisfy certain criteria which will be explained hereinbelow. (Within the context of the present application, the use of the terms 'dispersion' and 'chromatic dispersion' will refer to the same physical phenomenon. Moreover, the

terms are used, unless explicitly stated, irrespective of their mathematical representation.)

As discussed previously, there is a strong desire to control the dispersion mismatch between the sample and reference arms in an OCT system.

From a practical perspective, manufacturing tolerances of the dispersion parameters of the optical components involved in the sample and reference paths of the system can cause the total dispersion to be out of range of an adjustment of the relative optical path lengths between the sample and reference arms. Embodiments of the present application bring the dispersion mismatch back into a range where adjustment of the relative optical path lengths of sample and reference arms becomes tractable, while minimizing the optical path length difference if not eliminating it altogether. This can reduce the tolerance demands and hence the costs of some optical components in the system and can provide flexibility in the manufacture and assembly of OCT systems.

The first-order dispersive power of an optical glass is often characterized by the Abbe index or number which is actually the reciprocal of the first-order dispersive power in the visible range, thus indicating that high Abbe numbers correspond to lower first-order dispersive capability. (For an explanation of Abbe indices, see any standard text on lens or optical design, such as Kingslake's 'Lens Design Fundamentals.') The present application concerns not first-order dispersion, but second-order dispersion, which is responsible for the temporal spreading of a pulse of non-monochromatic light.

For the purposes of this application, a compound optic is defined in this application as a consecutive, or linear, or serial combination of two or more optical glasses that are glued, coated, cemented, oiled, or mated

together by any equivalent methodology as would be well known to the appropriately skilled person in the art, such that the total internal reflection between surfaces of adjacent glasses is reduced, frustrated, or eliminated. The distance between adjacent optical glasses in said
5 compound optic should be miniscule enough to eliminate the evanescent wave component, and maximize the transmitted light from one glass to the adjacent one. Also for the purposes of clarification within this application, refractivity is defined as the index of refraction minus one.

10 A simple embodiment of the present application would be the placement of a compound optic **201** as shown in FIG. 2, in either the sample arm (see FIG. 1, item **124**) or the reference arm of an OCT system (see FIG. 1, **125**). The optic **201** includes an entrance surface **207** for a beam of light **202** and an exit surface **208** for the 'transformed' beam of light.

15 (Use of the verb 'transformed' refers to the physical effect that the embodiment has performed on the group delay dispersion of the beam of light.) Moreover, in this particular embodiment, the optical properties of the two glasses in this compound optic are such that the input light beam and the output light beam are collinear.

20 The compound optic **201** would consist of at least two different glasses **203** and **204**, in which the two glasses have similar indices of refraction ($n_1 \approx n_2$), but disparate second-order chromatic dispersions. Equal or similar indices of refraction implies that the optical path length through
25 the optic remains constant or nearly so, but that the second-order chromatic dispersion will depend upon where the light beam has been placed relative to the entrance surface. This point could, for example, be specified by its polar coordinates (r, Θ) as shown in FIG. 2c, where r is the radius from an arbitrary reference point, and Θ is the angle to the

vector defined by $\mathbf{r}$ and the point in question, relative to a zero-point position. This arrangement can be visualized in FIG. 2c, where the plane of the entrance surface **207** is displayed parallel to the plane of the paper. The ΔY variable, in the case of the FIG. 2 configuration of two
5 right triangular prisms, would then be the determining variable in controlling the amount of second-order chromatic dispersion. The compound optic can be shifted laterally relative to the beam to achieve the desired second-order chromatic dispersion. This shifting could be accomplished either manually or automatically based upon a feedback
10 loop built into the system's processor. The compound optic would be adjusted to achieve the desired value of second-order dispersion correction.

Another simple embodiment would be the insertion, into either the
15 reference or sample beams, of a single piece of glass, which compensates for the chromatic dispersion. A set of these glasses or rods, of varying length, thus of varying second-order dispersions, could be available to provide a wide-range of compensation. Manual or automatic insertion of a rod into the appropriate beam can be easily
20 accomplished by techniques readily known by the ordinary skilled person in the art.

Generalized Concepts: Optical Path Length

To conceptualize more generally the aims and embodiments of the
25 present application, further reference is made to the embodiment of FIG. 2, which consists of two cemented right triangular prisms of similar refractivity, but differing second-order chromatic dispersions. If ℓ_1 and ℓ_2 are respectively the path lengths that a light ray travels through the first

prism (with index of refraction n_1), and then the second prism (with index of refraction n_2), then the total optical path length is just

$$OPL = l_1(n_1) + l_2(n_2) \quad \text{Eq. (1)}$$

As l_1 and l_2 are functions of $(\mathbf{r}, \Theta)$, and thus the path length will also be a

5 function of $(\mathbf{r}, \Theta)$. However, if the total path length is a constant, as would be the case of two identical right triangular prisms cemented together, then the only variation in OPL with respect to $(\mathbf{r}, \Theta)$ would be from differing relative indices of refraction of the two component glasses. If, on the other hand, the indices of refraction are the same or nearly so, and in the current embodiment meaning $n_1 \approx n_2$, and $l_1 + l_2 = \text{constant}$,
10 then the OPL is also constant irrespective of the value of $(\mathbf{r}, \Theta)$.

Moreover, similar refractivities of the component glasses aids in substantially reducing internal reflections from the light passing from one
15 surface to another, as is well known by the ordinary skilled person in the art. Furthermore, as the two refractivities are equal, there will be no refraction at the interface of the two glasses.

This technique can then be extended to a plurality of optical path lengths
20 of different dispersive glasses to achieve precise control. Another embodiment would be that of an Amici prism, where three prismatic elements are cemented together. Geometric configurations from the group of prismatoids, helical or arcuate prisms would be viable as well, as would be cylindrical, circular, and triangular prisms.

25 A general equation establishing the same criterium, but with a total of N optical glasses, would be

$$OPL = \sum_{i=1}^N l_i(n_i) = \text{constant} \quad \text{Eq. (2),}$$

Where ℓ_i = the path length through the i th optical glass, with index of refraction = n_i . It can be envisioned that the indices of refraction can vary, even with the condition that Equation (2) can still be honored, by compensating a larger value of the refractivity in a particular glass by
 5 reducing the path length within said glass. This is accomplished by the appropriate geometric design and relative arrangement of the various contributing glasses.

An alternative embodiment to the geometric configuration of two
 10 appropriately mated right triangle prisms or similar, is that of two helical prisms mated together (or annular or circular prisms) so as produce a constant or nearly constant index of refraction, and a large variation in second-order chromatic dispersion. FIG. 4 depicts one half of such a prism. Such a compound optic would then be positioned perpendicular,
 15 or nearly so, to the input beam and would rotate to vary the amount of second-order chromatic dispersion required. The rotation can be manipulated either manually or automatically based upon feedback.

Generalized Concepts: Second-Order Dispersion

20 In order to understand the nature of second-order chromatic dispersion, the nature of chromatic dispersion in general can be characterized as follows, where it is assumed that $k = 2\pi/\lambda$, λ = wavelength of light, and c = speed of light.

25 Chromatic dispersion of orders higher than that of the first order is obtainable through a Taylor series expansion of the wavenumber, k , (change in spectral phase per unit length) as a function of the angular frequency centered about central frequency, ω_0 , of the median or mean frequency of the input light):

$$k(\omega) = k_0 + \frac{1}{1!} \left(\frac{dk}{d\omega} \right) (\omega - \omega_0) + \frac{1}{2!} \left(\frac{d^2k}{d\omega^2} \right) (\omega - \omega_0)^2 + \frac{1}{3!} \left(\frac{d^3k}{d\omega^3} \right) (\omega - \omega_0)^3 + \dots \quad \text{Eq. (3)}$$

The first term in this equation, k_0 , has no influence on the temporal shape of the propagated pulse but only on the phase shift.

5

The second, linear term, generates only a time delay of the pulse propagating through the medium, thus does not affect the temporal shape. Moreover, it is just the inverse of the group velocity.

$$v_g^{-1} = \left(\frac{dk}{d\omega} \right) \quad \text{Eq. (4)}$$

Its physical meaning is that the time, t_g , is needed to cover the distance, ℓ , by the spectral component moving with group velocity, v_g .

10

The third term in the above expansion (the second-order dispersion) will distort the pulse shape, as the blue wavelength light will travel slower than light with red wavelengths in most commonly available optical glasses. Thus a narrow pulse of polychromatic light will be broadened as a result of different group velocities. This second-order term contains the second-order dispersion or group delay dispersion per unit length. Thus the group delay dispersion is just the group velocity dispersion times the path length within the medium.

15

20

The coefficient of the third term would be a function of the medium or material and thus dependent upon the amount of material through which

the pulse travels. The coefficient factor of the second-order term is defined to be:

$$\alpha \sim \frac{1}{2!} \left(\frac{d^2 k}{d\omega^2} \right), \text{ Eq. (5)}$$

and its units are sec^2/m . It is the derivative of the inverse of the group velocity, v_g , with respect to angular frequency. For example, the group delay dispersion of silica is $+36 \text{ fsec}^2/\text{mm}$ at 800nm , or $-26 \text{ fsec}^2/\text{mm}$ at 1.5 microns . Zero group delay dispersion is located at about 1.27 microns . The units of the group delay dispersion can also be expressed in sec^2/km or $\text{sec}/\text{m}/\text{Hz}$ or $\text{sec}/\text{Hz}/\text{m}$ or $\text{microns}^2/\text{mm}$.

If an embodiment of just two different glasses that are combined into a compound optic is considered, then the total second-order dispersion will be just the addition of the amounts of second-order dispersion for each glass suffered by the light multiplied by the path lengths through that particular glass.

The second useful guideline is then

$$\alpha_1(l_1) + \alpha_2(l_2) = \alpha_T = \text{total 2}^{\text{nd}}\text{-order dispersion, Eq. (6)}$$

Thus the equivalent generalized formula for a coefficient factor of a compound optic comprised of a plurality of optical glasses would be:

$$\alpha_T = \sum_{i=1}^N l_i(\alpha_i) \quad \text{Eq. (7),}$$

where there are N optical glasses in the compound optic, and the i^{th} component (i^{th} optical glass) possesses an index of refraction of n_i , a second-order dispersion coefficient, α_i , and the path length of this material in which the light beam traverses is l_i . As the amount of path length through a particular optical glass is dependent upon (r, Θ) , thus the total

amount of second-order dispersion is also dependent upon (r, Θ) .
Mechanically positioning the light beam onto a certain place on the
entrance surface of the dispersion compensator will then achieve the
desired second-order chromatic dispersion.

5

The use of glasses with high refractivities minimizes the length of the
transmissive material through which the beam traverses: in other words
high refractivities compensate for lower path lengths. The use of at least
two dispersive (non-zero α) transmissive materials with relatively large

10

differences in α will permit a large range in second-order dispersion
compensation.

15

For each component in a double prism, or in any multi-component or
compound optic, its individual contribution will depend upon the path
length multiplied by the dispersive power of the particular glass used
over that path length. A low dispersive material can be used but will
necessarily be coupled with a longer path length to achieve a desired
dispersion compensation. A high dispersive material can be used over a
shorter (comparatively) path length. This is true irrespective of the
nature of the dispersion, second-order, third-order, etc.

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25

In FIG. 3, basic optical characteristics of two possible glasses from the
Schott glass catalog (internet available) are given. They have similar
refractivities at the wavelengths of interest (840 and 1060 nm) but
disparate second-order dispersions. These two glasses used in the
compound optic depicted in FIG. 2, will produce a nearly uniform optical
path length for the relevant wavelengths irrespective of the lateral
position of the input beam. In addition, due to the differences in second-
order chromatic dispersions, passage through a compound optic

comprising prisms of two glasses, will yield a different second-order dispersion dependent upon the lateral location of the input beam as shown in FIG. 2.

5 The simplest implementation of the embodiments presented in this application would be that the second-order dispersion compensation would occur in the field during installation. This can be a manual adjustment. More sophisticated implementations would be those in which the amount of second-order dispersion compensation would be
10 under processor control, thus the dispersion compensating optic itself would be on a motorized stage.

While it would be expected that such embodiments as described in the present application remain stable with time regarding optical properties,
15 an OCT system might, over time, alter its optical properties slightly. Thus an ability to re-calibrate the system automatically under processor control would be expected.

It may also be desirable to separately manufacture the OCT engine from
20 other components of an overall ophthalmic system, such as the patient interface responsible for delivering the OCT light to the sample. In different clinical applications, different types of patient interfaces can be use including but not limited to, endoscopes, slit lamps, handheld devices, and dedicated OCT interfaces with head and chinrests. In
25 addition, OCT is sometimes used in multi-modality systems where secondary imaging modalities such as fundus cameras are combined with OCT imaging to provide a clinician with multiple diagnostic modes. In these cases, a portion of the sample arm of the OCT system might be part of the other component and the rest of the OCT system is connected
30 to that component via free space or an optical fiber. Here it would be

especially important to have the ability to adjust an optical component to match the dispersion in the sample and reference arms of the OCT system, especially if the two systems are manufactured in different locations and not combined until installation in a clinical or surgical (e.g.,
5 microscopes) setting.

Prior to insertion into an optical coherence tomographic instrument, any optic which is designed to compensate for second-order chromatic dispersion, can be in situ calibrated in advance, such that, e.g., the
10 variation of the amount of second-order chromatic dispersion with $(\mathbf{r}, \Theta)$ or ΔY is well-known prior to final installation.

The positioning can be accomplished manually or under control of a controller.

15 Although various applications and embodiments that incorporate the teachings of the present invention have been shown and described in detail herein, those skilled in the art can readily devise other varied embodiments that still incorporate these teachings.

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CLAIMS

1. An apparatus, comprising:
a compound optic with an entrance surface and an exit surface
comprising a plurality of optical glasses, in which a light beam is
5 subjected to minimal deflection between entrance and exit surfaces and
at least one optical property of the light beam is altered.

2. An apparatus as recited in claim 1, in which said altered optical
property is that of second-order chromatic dispersion.

3. An apparatus as recited in claim 1, in which said altered optical
property is that of a group delay dispersion.

4. An apparatus as recited in any one of claims 1 – 3, in which the
15 spectral composition of the light beam is polychromatic.

5. An apparatus as given in any one of claims 1 – 4, in which a
light beam impinging anywhere on said entrance surface encounters the
same optical path length upon exiting the exit surface.

6. An apparatus as given in any one of claims 1 - 5, in which a
point on said entrance surface for said beam of light determines the
amount of second-order chromatic dispersion suffered by said light
beam.

7. An apparatus as recited in any one of the preceding claims, in
which each of the plurality of glasses possesses a geometric
25 configuration from the group of prismatoids.

8. An apparatus as recited in claim 1, further comprising:
a first optic with a first entrance surface and a first exit surface for a
beam of light;
a second optic with a second entrance surface and a second exit surface
5 for said beam of light, in which the first exit surface of the first optic is
mated with the second entrance surface of the second optic to frustrate
total-internal-reflection, and the location of said beam of light impinging
upon the first entrance surface of said first optic determines the total
amount of second-order chromatic dispersion said beam of light will
10 suffer.

9. An apparatus as recited in claim 8, in which the first optic and
the second optic each are selected from the group consisting of helical
prisms, arcuate prisms, cylindrical prisms, annular prisms, triangular
15 prisms, and right triangular prisms.

10. An optical coherence tomographic (OCT) system, comprising:
a light source for generating a radiation beam;
a divider for splitting the beam along separate sample and reference
20 paths;
a scanner located in the sample path for scanning the beam over the
sample;
a detector for receiving interfered light returned from both the sample
and reference paths;
25 a processor for analyzing signals generated by the detector; and
a dispersion control module located in one of the sample or reference
paths, said module having an entrance face and an exit face, said
module being formed from first and second materials each with different
second order dispersion characteristics, said module being configured so
30 that the variations in the location where the beam enters the entrance

face varies the relative percentage of the first and second materials traversed by the beam before it exits the exit face such that by changing the location where the beam enters the entrance face, the level of second order dispersion provided by the module can be varied.

5

11. An OCT system as recited in claim 10, in which the refractivities of the first and second materials are substantially identical.

10

12. A method for controlling group delay dispersion of a light beam in an optical coherence tomographic (OCT) system with a sample arm and a reference arm, comprising:
positioning into said light beam two or more optical glasses each with a disparate second-order chromatic dispersion and a common refractivity.

15

13. A method as recited in claim 12, in which the two or more optical glasses have prismatic geometric shapes.

20

14. A method as recited in claim 13, in which the prismatic geometric shapes are selected from the group consisting of: triangular prisms, helical prisms, arcuate prisms, cylindrical prisms, and annular prisms.

25

15. A method as recited in any one of claims 12-14, further comprising:
inserting said two or more optical glasses into said sample arm of said OCT system.

16. A method as recited in any one of claims 12-15, further comprising:

inserting said two or more optical glasses into said reference arm of said OCT system.

5 17. A method as recited in either of claims 15 or 16, in which the inserting is performed manually.

18. A method as recited in either of claims 15 or 16, in which the inserting is performed under control of a controller.

10

FIG. 1

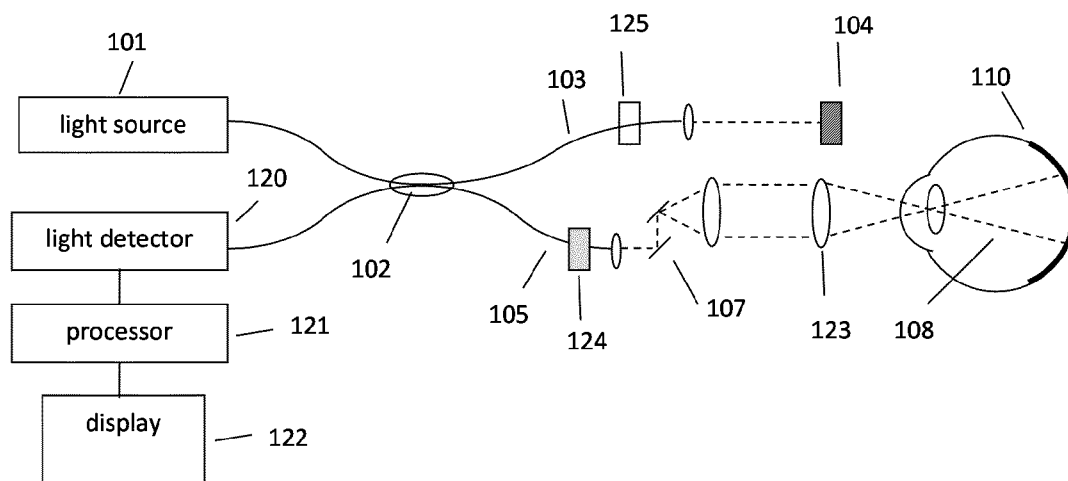


FIG. 2

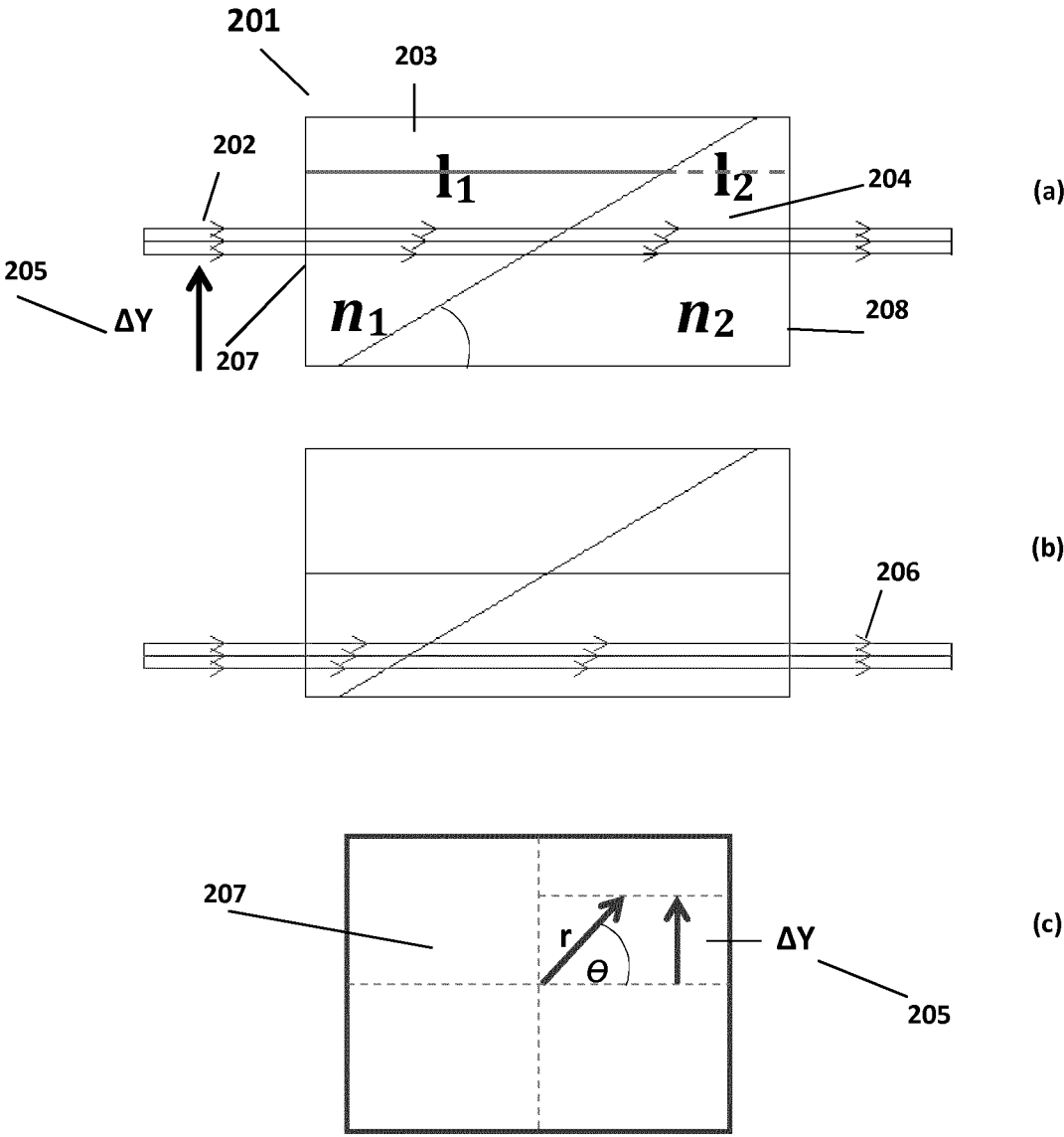
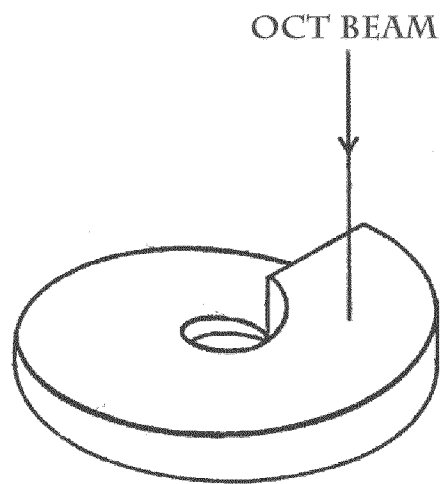


FIG. 3

Schott Glass	Refractive Index @840nm	Second-order dispersion @840nm [$\mu\text{m}^2/\text{mm}$]	Refractive Index @1060nm	Second-order dispersion @1060nm [$\mu\text{m}^2/\text{mm}$]
N-SF57	1.821	9.131	1.820	6.305
N-LASF41	1.820	4.917	1.813	3.248

FIG. 4



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/070414

A. CLASSIFICATION OF SUBJECT MATTER INV. A61B3/10 G01B9/02 G02B26/06 G02B26/08 ADD.		
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) A61B G01B 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 practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2010 171194 A (UNIV ELECTRO COMMUNICATIONS) 5 August 2010 (2010-08-05) the whole document	1-9
X	----- HUI WANG ET AL: "Ultrahigh-resolution optical coherence tomography at 1.15 m using photonic crystal fiber with no zero-dispersion wavelengths", OPT. EXPRESS, vol. 15, no. 06, 19 March 2007 (2007-03-19), pages 3085-3092, XP55155971,	10
A	the whole document ----- -/--	11
☒ 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 "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
3 December 2014		18/12/2014
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Gomez, Adriana

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/070414

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	R. E. SHERRIFF: "Analytic expressions for group-delay dispersion and cubic dispersion in arbitrary prism sequences", JOURNAL OF THE OPTICAL SOCIETY OF AMERICA B, vol. 15, no. 3, 1 March 1998 (1998-03-01), page 1224, XP55156039, ISSN: 0740-3224, DOI: 10.1364/JOSAB.15.001224 the whole document -----	1-18

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Information on patent family members

International application No

PCT/EP2014/070414

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		JP 2010171194 A	05-08-2010
