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(54) **Tomographic image generation apparatus having modulation and correction device and method of operating the same**

Tomographische Bilderzeugungsvorrichtung mit Modulation und Korrekturvorrichtung und Betriebsverfahren dafür

Appareil de génération d'image tomographique présentant un dispositif de correction et modulation et son procédé de fonctionnement

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Description

BACKGROUND

1. Field

[0001] This application relates to tomographic image generation apparatuses having a modulation and correction device that can generate a more precise tomographic image by increasing a penetration depth in an object and a magnitude of a signal generated from the object, and methods of operating the same.

2. Description of Related Art

[0002] Tomography is a technique for capturing a tomographic image of an object using a penetrating wave. Tomography is used in many fields. Therefore, the demand for obtaining more precise tomographic images is also increased. In particular, in medical fields that are directly related to human life, a technique for generating a more precise tomographic image is an important issue.

[0003] US 2012/0038885 A1 discloses a tomographic image generation apparatus according to the preamble of claim 1.

SUMMARY

[0004] In one general aspect, a tomographic image generation apparatus includes a light source unit configured to emit light to be used for scanning an object; an optical control unit configured to control a direction of propagation of light; an optical coupler configured to divide and combine incident light; a plurality of optical systems optically connected to the optical coupler; and a modulation and correction device configured to modulate and correct the light to be used for scanning the object.

[0005] The light source unit may emit light to be irradiated to an object whose tomographic image is to be captured. The optical control unit may be a device that prevents the light emitted from the light source unit from reentering the light source unit due to reflection by other elements of the apparatus. The optical coupler may be a device that transmits light to the optical systems by dividing light emitted from the light source unit.

[0006] The modulation and correction device may be disposed between the optical control unit and the optical coupler.

[0007] The plurality of optical systems may include a first optical system configured to provide a reference light; and a second optical system configured to irradiate light to the object. The first optical system may be an optical system that receives light from the optical coupler and reflects the light to the optical coupler. This optical system may be connected to the optical coupler. The first optical system may provide a reference light with respect to light to be processed in the second optical system. Accordingly, the first optical system may be a reference optical system with respect to the second optical system.

[0008] The plurality of optical systems may further include a third optical system configured to receive an interference pattern of light generated from the first optical system and light generated from the second optical system. The third optical system may be a device that is connected to the optical coupler and generates tomography information of an organ of the object. The tomography information may be obtained from a combination of lights received from the first and second optical systems through the optical coupler. Additionally, the third optical system may record tomography information of an organ of an object whose tomographic image is to be captured.

[0009] The second optical system may include the modulation and correction device.

[0010] The second optical system may include a spatial light modulator (SLM) configured to modulate light that enters from the optical coupler; a galvanometer configured to reflect light that enters from the SLM to the object and reflect light that enters from the object to the SLM; and an object lens configured to focus light that enters from the galvanometer onto the object.

[0011] The modulation and correction device may be disposed between the second optical system and the optical coupler.

[0012] The modulation and correction device may be disposed between the optical coupler and the first optical system.

[0013] The modulation and correction device may include an optical modulator configured to modulate only light that enters from the optical coupler; and a grating configured to offset diffracted light unnecessarily generated in the optical modulator. The optical modulator may be a device that modulates an amplitude or a frequency of light entering from the optical coupler. The optical modulator may correspond to a grating having a plurality of groves and / or the optical modulator may include a plurality of pixels. Accordingly, light reflected at the optical modulator may have a wavefront that is different from that of light that enters the optical modulator so that light reflected at the optical modulator may have a pattern that is different from that of light that enters the optical modulator. For the optical modulation as described above, pixels located on a region where light enters the optical modulator may be controlled, and through this control, the pattern of incident light may be modulated to be a desired pattern.

[0014] The grating may have a groove density that is the same as a groove density of the optical modulator.

[0015] The grating may have a groove density that is different than a groove density of the optical modulator; and the modulation and correction device may further include a first and lens and a second lens disposed between the optical modulator and the grating and configured to compensate for the difference in groove density between the optical modulator and the grating.

[0016] In the optical modulator, a reflection region of light that enters from the optical coupler may be different from a reflection region of light that enters from the object.

[0017] The optical modulator may be a digital micromirror device (DMD) or a spatial light modulator (SLM).

[0018] The modulation and correction device may include an optical modulator configured to modulate light that enters from the optical coupler; and a grating configured to offset diffracted light unnecessarily generated from the optical modulator.

[0019] The grating may have a groove density that is different from a groove density of the optical modulator; and the modulation and correction device may further include a first lens and a second lens disposed between the optical modulator and the grating and configured to compensate for the difference in groove density between the optical modulator and the grating.

[0020] The first optical system may include a lens corresponding to the first and second lenses.

[0021] The modulation and correction device may be disposed between the optical coupler and the object.

[0022] The optical coupler may be replaced by a beam splitter.

[0023] The tomographic image generation apparatus may be an optical coherence tomography apparatus or an optical coherence tomography microscope.

[0024] In another general aspect, a method of operating a tomographic image generation apparatus includes a light source unit configured to emit light to be used for scanning an object; an optical control unit configured to control a direction of propagation of light; an optical coupler configured to divide and combine incident light; a plurality of optical systems optically connected to the optical coupler; and a modulation and correction device configured to modulate and correct the light to be used for scanning the object and including an optical modulator; the method including performing an optical modulation operation with respect to only light that is reflected to the object using the optical modulator of the modulation and correction device.

[0025] Light that enters the optical modulator from the optical coupler may be incident to a first region of the optical modulator; light that enters the optical modulator from the object may be incident to a second region of the optical modulator; the first and second regions may be separated from each other; and an optical modulation operation may be performed only in the first region.

[0026] The modulation and correction device may be disposed between the optical control unit and the optical coupler.

[0027] The modulation and correction device may be disposed between the optical coupler and the object.

[0028] The tomographic image generation apparatus may include a beam splitter instead of the optical coupler.

[0029] Other features and aspects will be apparent from the following detailed description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

FIG. 1 is a block diagram of an example of a configuration of a tomographic image generation apparatus.

FIG. 2A is a cross-sectional view of an example of a configuration of a second optical system of FIG. 1.

FIG. 2B is a perspective view showing an example of a case when a region where light entering from an optical modulator to an optical coupler is reflected and a region where light entering from an object whose image is to be captured is reflected are different;

FIG. 3 is a cross-sectional view of another example of a configuration of a second optical system of FIG. 1.

FIG. 4 is a cross-sectional view of another example of a configuration of a second optical system of FIG. 1.

FIG. 5 is a cross-sectional view of an example of a configuration of a third optical system of FIG. 1.

FIG. 6 is a cross-sectional view of an example of a configuration of a first optical system of FIG. 1.

FIG. 7 is a cross-sectional view of another example of a configuration of a first optical system of FIG. 1.

FIGS. 8 and 9 are cross-sectional views showing examples of elements of other examples of a tomographic image generation apparatus.

FIG. 10 is a cross-sectional view of an example of a modified version of the configuration of FIG. 9.

FIG. 11 is a cross-sectional view showing an example of a beam splitter that is used instead of an optical coupler in a tomographic image generation apparatus.

DETAILED DESCRIPTION

[0031] The following detailed description is provided to assist the reader in gaining a comprehensive understanding of the methods, apparatuses, and/or systems described herein. However, various changes, modifications, and equivalents of the methods, apparatuses, and/or systems described herein will be apparent to one of ordinary skill in the art. The sequences of operations described herein are merely examples, and are not limited to those set forth herein, but may be changed as will be apparent to one of ordinary skill in the art, with the exception of operations necessarily occurring in a certain order. Also, description of functions and constructions that are well known to one of ordinary skill in the art may be omitted for increased clarity and conciseness.

[0032] Throughout the drawings and the detailed description, the same reference numerals refer to the same elements. The drawings may not be to scale, and the relative size, proportions, and depiction of elements in the drawings may be exaggerated for clarity, illustration, and convenience.

[0033] FIG. 1 is a block diagram of an example of a configuration of a tomographic image generation apparatus.

[0034] Referring to FIG. 1, the apparatus includes a light source unit 20, a light control unit / optical control unit 22, and an optical coupler 24. Also, the apparatus includes first, second, and third optical systems 30, 40, and 50 connected to the optical coupler 24. The light source unit 20 emits light to be irradiated to an object whose tomographic image is to be captured. The light source unit 20 may emit coherent light. The light source unit 20 may include a light source that emits coherent light.

[0035] As another example, the light source unit 20 may include a first light source that emits non-coherent light, and an element that transforms the non-coherent light emitted from the first light source to coherent light.

[0036] A light source that is included in the light source unit 20 and emits coherent light may be, for example, a laser diode. The first light source that is included in the light source unit 20 and emits non-coherent light may be, for example, a light-emitting diode (LED). The element that transforms non-coherent light to coherent light may be located between the light source unit 20 and the light control unit / optical control unit 22. Light emitted from the light source unit 20 may have a center wavelength of, for example, 1025 nm, and may have a predetermined bandwidth with the center wavelength at the center of the predetermined bandwidth. The light control unit / optical control unit 22 may be a device that prevents the light emitted from the light source unit 20 from re-entering the light source unit 20 by being reflected by other constituent elements of the apparatus. The optical coupler 24 may be a device that transmits light to the first and second optical systems 30 and 40 by dividing light emitted from the light source unit 20. Also, the optical coupler 24 may be a device that transmits light to the third optical system 50 by combining light entering from the first and second optical systems 30 and 40. The splitting ratio of light divided in the optical coupler 24 to the first and second optical systems 30 and 40 may be different from each other. For example, in the optical coupler 24, an amount of light divided to the second optical system 40 may be greater than an amount of light divided to the first optical system 30. The first optical system 30 may be an optical system that receives light from the optical coupler 24 and reflects the light to the optical coupler 24. This optical system may be connected to the optical coupler 24. The first optical system 30 may provide a reference light with respect to light to be processed in the second optical system 40. Accordingly, the first optical system 30 may be a reference optical system with respect to the second optical system 40. The second optical system 40 receives light from the optical coupler 24. The second optical system 40 may be connected to the optical coupler 24. The second optical system 40 modulates an amplitude or a frequency of light received from the optical coupler 24, and then irradiates the modulated light onto an object whose tomographic image is to be captured. The second optical system 40 transmits light reflected by the object to the optical coupler 24. The object whose tomographic image is to be captured may be an organism that includes a plurality of cells. The object whose tomographic image is to be captured may be a living organ, for example, a skin of a living organ or a surface (an epidermis) of an organ. The third optical system 50 may be a device that is connected to the optical coupler 24 and generates tomography information of an organ of the object. The tomography information may be obtained from a combination of lights received from the first and second optical systems 30 and 40 through the optical coupler 24. Additionally, the third optical system 50 may record tomography information of an organ of an object whose tomographic image is to be captured. Configurations of the first through third optical systems 30, 40, and 50 will be described below.

[0037] FIG. 2A is a cross-sectional view of an example of a configuration of the second optical system 40 of FIG. 1. FIG. 2B is a perspective view showing an example of a case when a region where light entering from an optical modulator 40a to the optical coupler 24 is reflected and a region where light entering from an object 60 whose tomographic image is to be captured is reflected are different.

[0038] Referring to FIG. 2A, the second optical system 40 includes the optical modulator 40a, a first grating 40b, first and second mirrors 40c and 40d, and a first object lens 40e. The optical modulator 40a and the first grating 40b may constitute a modulation and correction device. The first and second mirrors 40c and 40d may be disposed at a predetermined angle relative to each other, and may rotate within a pre-set rotation range with respect to a given center axis. The first and second mirrors 40c and 40d may constitute a galvanometer. At this point, a driving element, for example, a rotation motor (not shown) for driving the first and second mirrors 40c and 40d may be further included. The optical modulator 40a may be a device that modulates an amplitude or a frequency of light (the solid lines) entering from the optical coupler 24. The optical modulator 40a may include a plurality of pixels. The pixels may form an array, and the pixels may have gaps of, for example, approximately 10 μm. The optical modulator 40a may correspond to a grating having a plurality of groves. When a gap between the pixels is approximately 10 μm, the optical modulator 40a may have a groove density corresponding to 100. The groove density denotes a slit density (a number of slits per mm). Each of the pixels performs as a wave source. A wavefront of light (a plane wave) that enters the optical modulator 40a may be newly configured by controlling the pixels of the optical modulator 40a. Accordingly, light (the solid line) reflected at the optical modulator 40a may have a wavefront that is different from that of light that enters the optical modulator 40a. That is, light reflected at the optical modulator 40a may have a pattern that is different from that of light that enters the optical modulator 40a. For the optical modulation as described above, pixels located on a region where light enters the optical modulator 40a may be controlled, and through this control, the pattern of incident light may be modulated to be a desired pattern.

[0039] The optical modulator 40a does not perform an optical modulation operation with respect to light (the dashed line) reflected by the object 60. The optical modulator 40a performs an optical modulation operation with respect to only light (the solid line) that enters from the optical coupler 24.

[0040] More specifically, as depicted in FIG. 2B, light L11 incident to the optical modulator 40a from the optical coupler 24 enters a first region A1 of the optical modulator 40a. The first region A1 is a region where an optical modulation operation is performed. Accordingly, the light L11 incident to the optical modulator 40a from the optical coupler 24 is modulated and is reflected to the first grating 40b.

[0041] Light L22 incident to the optical modulator 40a from the object 60 enters a second region A2 of the optical modulator 40a. The second region A2 is separated from the first region A1. The second region A2 is a region where an optical modulation operation is not performed. Accordingly, the light L22 incident to the optical modulator 40a from the object 60 is reflected to the optical coupler 24 without any optical modulation.

[0042] The optical modulator 40a may be, for example, a digital micro-mirror device (DMD) or a spatial light modulator (SLM). The DMD includes a plurality of mirrors and each of the micromirrors may perform as a pixel. Since the optical modulator 40a may perform as a grating, a large amount of diffracted light may be generated from the optical modulator 40a. A specific diffracted light of the diffracted lights, for example, a fourth diffracted light, is used for obtaining a tomographic image of the object 60. Accordingly, diffracted lights that are not used for obtaining a tomographic image of the object 60 may be diffracted light unnecessarily generated, and, to remove the diffracted light unnecessarily generated, the second optical system 40 includes the first grating 40b. The first grating 40b may have a groove density (a slit density) that is the same as that of the optical modulator 40a. Therefore, a specific diffracted light generated from the optical modulator 40a enters the object 60 and the diffracted light unnecessarily generated may be offset. Thus, light may be penetrated into a deeper region of the object 60, and thus a clear tomographic image of a corresponding region may be obtained. The first mirror 40c reflects light that is incident from the first grating 40b to the second mirror 40d. An incidence angle of light incident to the second mirror 40d may be controlled by controlling the rotation angle of the first mirror 40c. The second mirror 40d reflects light that enters from the first mirror 40c to the object 60. The reflection angle of light reflected at the second mirror 40d may be controlled by controlling the rotation angle of the second mirror 40d, and, as a result, the incidence angle of light (the solid line) incident to the object 60 may be controlled. The incidence angle of light incident to the object 60 may be controlled by controlling the rotation angles of the first and second mirrors 40c and 40d. Therefore, optical scanning of light with respect to the object 60 may be performed by controlling the rotation angles of the first and second mirrors 40c and 40d. Light (the solid line) reflected at the second mirror 40d is focused on the object 60 through the first object lens 40e. Light (the dashed line) reflected by the object 60 includes tomographic image information of a scanned region of the object 60 and enters the optical coupler 24 sequentially through the first object lens 40e, the second mirror 40d, the first mirror 40c, the first grating 40b, and the optical modulator 40a. Interference occurs between the light that enters the optical coupler 24 from the optical modulator 40a and a reference light that enters from the first optical system 30, and a result of the interference (an interference pattern) is transmitted to the third optical system 50.

[0043] FIG. 3 is a cross-sectional view showing another example of a configuration of the second optical system 40 of FIG. 1. The following description focuses on the differences between the second optical system 40 of FIG. 3 and the second optical system 40 of FIG. 2A. Like reference numerals are used to indicate substantially identical elements.

[0044] Referring to FIG. 3, the second optical system 40 includes a second grating 40h at the position of the first grating 40b in FIG. 2A. The second grating 40h may have a groove density (a slit density) that is different from that of the optical modulator 40a. The second grating 40h may have a groove density smaller than that of the optical modulator 40a, for example, the optical modulator 40a may have a groove density of 400 that corresponds to a fourth diffracted light, and the second grating 40h may have a diffraction density of approximately 300 which is smaller than that of the optical modulator 40a. First and second lenses 40f and 40g are provided in parallel to each other between the optical modulator 40a and the second grating 40h to compensate for a difference in groove density (diffraction density) of the optical modulator 40a and the second grating 40h. The optical modulator 40a, the first and second lenses 40f and 40g, and the second grating 40h constitute a modulation and correction device. The first and second lenses 40f and 40g may be convex lenses and may have focal lengths that are different from each other. For example, the first lens

40f may have a focal length of 30 nm, and the second lens 40g may have a focal length of 40 nm. The optical modulator 40a, the first lens 40f, the second lens 40g, and the second grating 40h may be arranged on the same optical axis. The first and second lenses 40f and 40g may be dual side convex lenses, but tare not limited thereto.

[0045] FIG. 4 is a cross-sectional view of another example of a configuration of the second optical system 40 of FIG. 1.

[0046] Referring to FIG. 4, the second optical system 40 includes a spatial light modulator (SLM) 40i, the first and second mirrors 40c and 40d, and the first object lens 40e. The spatial light modulator 40i reflects light (the solid line) that enters from the optical coupler 24 to the first mirror 40c. The progress of light after the first mirror 40c is the same as the progress described above. After the light is scanned onto the object 60, light (the dashed line) reflected by the object 60 enters the optical coupler 24 via the first object lens 40e, the second mirror 40d, the first mirror 40c, and the spatial light modulator 40i.

[0047] FIG. 5 is a cross-sectional view of an example of a configuration of the third optical system 50 of FIG. 1.

[0048] Referring to FIG. 5, the third optical system 50 includes a third grating 50a, a third lens 50b, and an optical image sensing device 50c. Light L2 that enters from the optical coupler 24 includes information of a tomographic image of a given depth of the object 60, and enters the optical image sensing device 50c sequentially through the third grating 50a and the third lens 50b. The third grating 50a may have a slit density of, for example, 1200 lines/mm. The optical image sensing device 50c recognizes a tomographic image included in the light L2, and may be, for example, a charge-coupled device (CCD).

[0049] FIG. 6 is a cross-sectional view of an example of a configuration of the first optical system 30 of FIG. 1.

[0050] Referring to FIG. 6, the first optical system 30 includes a second object lens 30a and a third mirror 30b which has the same optical axis as the second object lens 30a. The second object lens 30a may be the same object lens 40e of FIG. 2A. Light (the solid line) incident from the optical coupler 24 enters the third mirror 30b through the second object lens 30a. After being reflected by a surface of the third mirror 30b, the light is incident to the optical coupler 24 through the second object lens 30a. An optical path from the optical coupler 24 to the third mirror 30b may be the same as the optical path from the optical coupler 24 to the object 60. Accordingly, a tomographic image corresponding to a predetermined depth of the object 60 may be obtained through an interference pattern of light (a reference light) that is divided with respect to the first optical system 30 and light that is divided with respect to the second optical system 40 to scan the object 60 to a predetermined depth.

[0051] FIG. 7 is a cross-sectional view of another example of a configuration of a first optical system 30 of FIG. 1. The configuration of the first optical system 30 of FIG. 7 corresponds to the second optical system 40 of FIG. 3.

[0052] Referring to FIG. 7, the first optical system 30 includes fourth and fifth lenses 30c and 30d which have the same optical axis, a second object lens 30a, and a third mirror 30b. The fourth and fifth lenses 30c and 30d are arranged between the optical coupler 24 and the second object lens 30a. Light (the solid line) that enters from the optical coupler 24 enters a third mirror 30b through the fourth lens 30c, the fifth lens 30d, and the second object lens 30a, and light (the dashed line) reflected by the third mirror 30b enters the optical coupler 24 sequentially through the second object lens 30a, the fifth lens 30d, and the fourth lens 30c.

[0053] FIG. 8 is a cross-sectional view showing examples of elements of another example of a tomographic image generation apparatus. The following description focuses on the differences between the apparatus of FIG. 1 and the apparatus of FIG. 8. Like reference numerals are used to denote substantially identical elements.

[0054] Referring to FIG. 8, the apparatus includes the modulation and correction device of FIG. 2A, that is, the optical modulator 40a and the first grating 40b, between the optical control unit 22 and the optical coupler 24. In the apparatus, light L3 emitted from the optical control unit 22 is reflected at a fourth mirror 70, and then enters the optical modulator 40a. Light L4 modulated in the optical modulator 40a enters the first grating 40b. The modulated light L4 is reflected at the first grating 40b and enters a fifth mirror 72. The configuration of the second optical system 40 of the apparatus of FIG. 8 may be the same as that of the second optical system 40 of FIG. 2A when the optical modulator 40a and the first grating 40b are removed.

[0055] Meanwhile, in FIG. 8, to change an optical path between the optical control unit 22 and the optical modulator 40a, at least one more mirror besides the fourth mirror 70 may be included. That is, at least one mirror besides the fourth mirror 70 may be further included between the optical control unit 22 and the optical modulator 40a.

[0056] Also, at least one mirror besides the fifth mirror 72 may be further included between the first grating 40b and the optical coupler 24.

[0057] FIG. 9 is a cross-sectional view showing examples of elements of another example of a tomographic image generation apparatus. The following description will focus on the differences between the apparatus of FIG. 1 and the apparatus of FIG. 9. Like reference numerals are used to indicate substantially identical elements.

[0058] Referring to FIG. 9, the apparatus includes the fourth and fifth mirrors 70 and 72 between the optical control unit 22 and the optical coupler 24, and includes the modulation and correction device of FIG. 3, that is, the optical modulator 40a, the first and second lenses 40f and 40g, and the second grating 40h, between the fourth and fifth mirrors 70 and 72. Light L3 emitted from the optical control unit 22 is reflected at the fourth mirror

70 and enters the optical modulator 40a. Light L4 modulated at the optical modulator 40a enters the second grating 40h sequentially passing through the first and second lenses 40f and 40g. The light L4 that entered the second grating 40h is reflected at the fifth mirror 72 and enters the optical coupler 24. In the apparatus of FIG. 9, the configuration of the second optical system 40 may be the same as that of the second optical system 40 of FIG. 3 when the optical modulator 40a, the first and second lenses 40f and 40g, and the second grating 40h are removed.

[0059] In FIG. 9, to change an optical path between the optical control unit 22 and the optical modulator 40a, at least one more mirror besides the fourth mirror 70 may be included. That is, at least one mirror besides the fourth mirror 70 may be further included between the optical control unit 22 and the optical modulator 40a.

[0060] Also, at least one mirror besides the fifth mirror 72 may be further included between the second grating 40h and the optical coupler 24.

[0061] FIG. 10 is a cross-sectional view of an example of a modified version of the configuration of FIG. 9.

[0062] Referring to FIG. 10, instead of the fourth mirror 70 of FIG. 9, a light source 25 connected to the optical control unit 22 may be used. Light having a plane wave generated from the light source 25 may enter the optical modulator 40a. The optical control unit 22 and the light source 25 may be connected to each other using an optical transmission medium 23, which may be, for example, an optical fiber.

[0063] Also, a sixth mirror (not shown) may be included between the fifth mirror 72 and the optical coupler 24. At this point, the sixth mirror may reflect light that is reflected by the fifth mirror 72 to the optical coupler 24. At least one mirror besides the fifth mirror 72 and the sixth mirror may be further included between the second grating 40h and the optical coupler 24.

[0064] FIG. 11 is a cross-sectional view of an example of a beam splitter 45 that is used instead of the optical coupler 24 in a tomographic image generation apparatus. Light that enters the beam splitter 45 from the optical control unit 22 is divided with respect to the first and second optical systems 30 and 40. Lights that enter the beam splitter 45 from the first and second optical systems 30 and 40 are combined and transmitted to the third optical system 50. Light that is transmitted to the third optical system 50 from the beam splitter 45 may be transmitted by an optical transmission medium such as an optical fiber.

[0065] In FIG. 11, a modulation and correction device described with reference to FIGS. 8 through 10 may be included between the optical control unit 22 and the beam splitter 45.

[0066] Meanwhile, in the apparatuses of FIGS. 1, 8, and 9, the elements may be spatially separated on the same optical axis, may be connected to each other using an optical transmission medium, or may be configured without an optical transmission medium. The optical transmission medium may be, for example, an optical fiber or a waveguide.

[0067] When the elements are configured without an optical transmission medium, the elements are in a spatially separated state arranged on an optical axis. Accordingly, light emitted from an element, for example, the beam splitter 45, may directly enter another element, for example, the second optical system 40.

[0068] In the examples described above, a tomographic image generation apparatus may be an optical coherence tomography apparatus or an optical coherence tomography microscope.

[0069] While this disclosure includes specific examples, it will be apparent to one of ordinary skill in the art that various changes in form and details may be made in these examples without departing from the scope of the claims. The examples described herein are to be considered in a descriptive sense only, and not for purposes of limitation. Descriptions of features or aspects in each example are to be considered as being applicable to similar features or aspects in other examples. Suitable results may be achieved if the described techniques are performed in a different order, and/or if components in a described system, architecture, device, or circuit are combined in a different manner and/or replaced or supplemented by other components or their equivalents. Therefore, the scope of the disclosure is defined not by the detailed description, but by the claims, and all variations within the scope of the claims are to be construed as being included in the disclosure.

Claims

1. A tomographic image generation apparatus comprising:

a light source unit (20) configured to emit light to be used for scanning an object (60);
an optical control unit (22) optically connected to the light source unit (20) and configured to control a direction of propagation of light;
an optical coupler (24) optically connected to the optical control unit (22) and configured to divide and combine incident light;
a plurality of optical systems (30, 40, 50) optically connected to the optical coupler (24); and
a modulation and correction device optically connected to the optical coupler (24) and configured to modulate and correct the light to be used for scanning the object (60);
the modulation and correction device further **characterized in** comprising
an optical modulator (40a) including a plurality of pixels configured to modulate only light that enters from the optical coupler (24) by controlling pixels located on a region of the optical modulator (40a) where light enters the optical mod-

ulator (40a) from the optical coupler (24); and
a grating (40b, 40h) configured to offset diffracted light unnecessarily generated in the optical modulator (40a).

2. The tomographic image generation apparatus of claim 1, wherein the modulation and correction device is disposed between the optical control unit (22) and the optical coupler (24).

3. The tomographic image generation apparatus of claim 1, wherein the plurality of optical systems (30, 40, 50) comprise:

a first optical system (30) configured to provide a reference light; and
a second optical system (40) configured to irradiate light to the object (60);
wherein the plurality of optical systems preferably further comprise a third optical system (50) configured to receive an interference pattern of light generated from the first optical system (30) and light generated from the second optical system (40).

4. The tomographic image generation apparatus of claim 3, wherein the second optical system (40) comprises the modulation and correction device or wherein the modulation and correction device is disposed between the optical coupler (24) and the first optical system (30).

5. The tomographic image generation apparatus of claim 3, wherein the second optical system (30) comprises:

spatial light modulator (SLM) (40i) configured to modulate light that enters from the optical coupler (24);
a galvanometer (40c and 40d) configured to reflect light that enters from the SLM (40i) to the object (60) and reflect light that enters from the object (60) to the SLM (40i); and
an object lens (40e) configured to focus light that enters from the galvanometer (40c and 40d) onto the object (60);
wherein the modulation and correction device is preferably disposed between the second optical system (40) and the optical coupler (24).

6. The tomographic image generation apparatus of claim 1, wherein the optical modulator (40a) corresponds to a first grating having a plurality of grooves and the grating (40h) has a groove density that is the same as a groove density of the first grating; or wherein the grating (40h) has a groove density that is different than a groove density of the first grating and the modulation and correction device further comprises a first lens (40f) and a second lens (40g) disposed between the optical modulator (40a) and the grating (40h) and configured to compensate for the difference in groove density between the first grating and the grating (40h).

7. The tomographic image generation apparatus of any one of claims 1to 6, wherein in the optical modulator (40a), a reflection region of light that enters from the optical coupler (24) is different from a reflection region of light that enters from the object (60).

8. The tomographic image generation apparatus of any one of claims 1 to 7, wherein the optical modulator (40a) is a digital micro-mirror device (DMD) including a plurality of micromirrors each performing as a pixel or a spatial light modulator (SLM).

9. The tomographic image generation apparatus of claim 6, wherein the first optical system comprises two lenses corresponding to the first and second lenses.

10. The tomographic image generation apparatus of claim 1, wherein the modulation and correction device is disposed between the optical coupler and the object.

11. The tomographic image generation apparatus of any one of claims 1 to 10, wherein the tomographic image generation apparatus is an optical coherence tomography apparatus or an optical coherence tomography microscope.

12. A method of operating a tomographic image generation apparatus according to any of claims 1 to 11, the method comprising:

performing an optical modulation operation with respect to only light that is directed to the object (60) using the optical modulator (40a) of the modulation and correction device.

13. The method of claim 12, wherein light that enters the optical modulator (40a) from the optical coupler (24) is incident to the first region of the optical modulator (40a); light that enters the optical modulator (40a) from the object (60) is incident to a second region of the optical modulator (40a); the first and second regions are separated from each other; and an optical modulation operation is performed only in the first region.

Patentansprüche

1. Tomographische Bilderzeugungsvorrichtung, umfassend:

eine Lichtquelleneinheit (20), die konfiguriert ist, um Licht für die Verwendung beim Abtasten eines Objekts (60) zu emittieren,
eine optische Steuereinheit (22), die optisch mit der Lichtquelleneinheit (20) verbunden ist und konfiguriert ist, um eine Fortpflanzungsrichtung des Lichts zu steuern,
einen optischen Koppler (24), der optisch mit der optischen Steuereinheit (22) verbunden ist und konfiguriert ist, um einfallendes Licht zu teilen und zu kombinieren,
eine Vielzahl von optischen Systemen (30, 40, 50), die optisch mit dem optischen Koppler (24) verbunden sind, und
eine Modulations- und Korrektureinrichtung, die optisch mit dem optischen Koppler (24) verbunden ist und konfiguriert ist, um das Licht für die Verwendung beim Abtasten des Objekts (60) zu modulieren und zu korrigieren,
wobei die Modulations- und Korrektureinrichtung weiterhin **gekennzeichnet ist durch**:

einen optischen Modulator (40a), der eine Vielzahl von Bildpunkten enthält und konfiguriert ist, um nur von dem optischen Koppler (24) eintretendes Licht zu modulieren, indem er Bildpunkte in einem Bereich des optischen Modulators (40a), in dem Licht von dem optischen Koppler (24) in den optischen Modulator (40a) eintritt, steuert, und
ein Gitter (40b, 40h), das konfiguriert ist, um unnötig in dem optischen Modulator (40a) erzeugtes gebeugtes Licht zu versetzen.

2. Tomographische Bilderzeugungsvorrichtung nach Anspruch 1, wobei die Modulations- und Korrektureinrichtung zwischen der optischen Steuereinheit (22) und dem optischen Koppler (24) angeordnet ist.

3. Tomographische Bilderzeugungsvorrichtung nach Anspruch 1, wobei die Vielzahl von optischen Systemen (30, 40, 50) umfasst:

ein erstes optisches System (30), das konfiguriert ist, um ein Bezugslicht vorzusehen, und
ein zweites optisches System (40), das konfiguriert ist, um Licht zu dem Objekt (60) zu strahlen,
wobei die Vielzahl von optischen Systemen vorzugsweise weiterhin ein drittes optisches System umfasst, das konfiguriert ist, um ein Störungsmuster aus durch das erste optische System (30) erzeugtem Licht und durch das zweite optische System (40) erzeugtem Licht zu empfangen.

4. Tomographische Bilderzeugungsvorrichtung nach Anspruch 3, wobei das zweite optische System (40) die Modulations- und Korrektureinrichtung umfasst oder wobei die Modulations- und Korrektureinrichtung zwischen dem optischen Koppler (24) und dem ersten optischen System (30) angeordnet ist.

5. Tomographische Bilderzeugungsvorrichtung nach Anspruch 3, wobei das zweite optische System (30) umfasst:

einen Raumlichtmodulator (SLM) (40i), der konfiguriert ist, um von dem optischen Koppler (24) eintretendes Licht zu modulieren,
ein Galvanometer (40c und 40d), das konfiguriert ist, um von dem SLM (40i) zu dem Objekt (60) eintretendes Licht zu reflektieren und von dem Objekt (60) zu dem SLM (40i) eintretendes Licht zu reflektieren, und
eine Objektlinse (40e), die konfiguriert ist, um von dem Galvanometer (40c und 40d) eintretendes Licht auf das Objekt (60) zu fokussieren,
wobei die Modulations- und Korrektureinrichtung vorzugsweise zwischen dem zweiten optischen System (40) und dem optischen Koppler (24) angeordnet ist.

6. Tomographische Bilderzeugungsvorrichtung nach Anspruch 1, wobei der optische Modulator (40a) einem ersten Gitter mit einer Vielzahl von Vertiefungen entspricht, wobei das Gitter (40h) eine Vertiefungsdichte aufweist, die gleich der Vertiefungsdichte des ersten Gitters ist, oder wobei das Gitter (40h) eine Vertiefungsdichte aufweist, die sich von der Vertiefungsdichte des ersten Gitters unterscheidet, wobei in diesem Fall die Modulations- und Korrektureinrichtung weiterhin eine erste Linse (40f) und eine zweite Linse (40g) umfasst, die zwischen dem optischen Modulator (40a) und dem Gitter (40h) angeordnet sind und konfiguriert sind, um die Differenz in der Vertiefungsdichte zwischen dem ersten Gitter und dem Gitter (40h) zu kompensieren.

7. Tomographische Bilderzeugungsvorrichtung nach einem der Ansprüche 1 bis 6, wobei sich in dem optischen Modulator (40a) der Reflexionsbereich des von dem optischen Koppler (24) eintretenden Lichts von dem Reflexionsbereich des von dem Objekt (60) eintretenden Lichts unterscheidet.

8. Tomographische Bilderzeugungsvorrichtung nach einem der Ansprüche 1 bis 7, wobei der optische Modulator (40a) eine digitale Mikrospiegeleinrichtung (DMD) ist, die eine Vielzahl von Mikrospiegeln enthält, die jeweils als ein Bildpunkt oder ein Raumlichtmodulator (SLM) dienen.

9. Tomographische Bilderzeugungsvorrichtung nach Anspruch 6, wobei das erste optische System zwei Linsen in Entsprechung zu den ersten und zweiten Linsen umfasst.

10. Tomographische Bilderzeugungsvorrichtung nach Anspruch 1, wobei die Modulations- und Korrektureinrichtung zwischen dem optischen Koppler und dem Objekt angeordnet ist.

11. Tomographische Bilderzeugungsvorrichtung nach einem der Ansprüche 1 bis 10, wobei die tomographische Bilderzeugungsvorrichtung eine optische Kohärenztomographievorrichtung oder ein optisches Kohärenztomographiemikroskop ist.

12. Verfahren zum Betreiben einer tomographischen Bilderzeugungsvorrichtung gemäß einem der Ansprüche 1 bis 11, wobei das Verfahren umfasst:

Durchführen einer optischen Modulationsoperation nur in Bezug auf Licht, das zu dem Objekt (60) gerichtet ist, unter Verwendung des optischen Modulators (40a) der Modulations- und Korrektureinrichtung.

13. Verfahren nach Anspruch 12, wobei das von dem optischen Koppler (24) in den optischen Modulator (40a) eintretende Licht auf den ersten Bereich des optischen Modulators (40a) einfällt und das von dem Objekt (60) in den optischen Modulator (40a) eintretende Licht auf einen zweiten Bereich des optischen Modulators (40a) einfällt, wobei die ersten und zweiten Bereiche voneinander getrennt sind und eine optische Modulationsoperation nur in dem ersten Bereich durchgeführt wird.

Revendications

1. Appareil de génération d'image tomographique comprenant :

une unité de source de lumière (20) configurée pour émettre de la lumière destinée à être utilisée pour balayer un objet (60) ;
une unité de commande optique (22) reliée optiquement à l'unité de source de lumière (20) et configurée pour commander la direction de propagation de la lumière ;
un coupleur optique (24) relié optiquement à l'unité de commande optique (22) et configuré pour diviser et combiner la lumière incidente ;
une pluralité de systèmes optiques (30, 40, 50) reliés optiquement au coupleur optique (24) ; et
un dispositif de modulation et de correction relié optiquement au coupleur optique (24) et configuré pour moduler et corriger la lumière destinée à être utilisée pour balayer l'objet (60) ;
le dispositif de modulation et de correction étant **caractérisé en outre en ce qu'**il comprend
un modulateur optique (40a) incluant une pluralité de pixels, configuré pour moduler uniquement la lumière qui entre depuis le coupleur optique (24) en commandant les pixels situés sur une région du modulateur optique (40a) où la lumière entre dans le modulateur optique (40a) depuis le coupleur optique (24) ; et
un réseau (40b, 40h) configuré pour décaler la lumière diffractée générée inutilement par le modulateur optique (40a).

2. Appareil de génération d'image tomographique selon la revendication 1, dans lequel le dispositif de modulation et de correction est disposé entre l'unité de commande optique (22) et le coupleur optique (24).

3. Appareil de génération d'image tomographique selon la revendication 1, dans lequel la pluralité de systèmes optiques (30, 40, 50) comprend :

un premier système optique (30) configuré pour fournir une lumière de référence ; et
un deuxième système optique (40) configuré pour rayonner la lumière vers l'objet (60) ;
dans lequel les systèmes optiques de la pluralité de systèmes optiques comprennent en outre de préférence un troisième système optique (50) configuré pour recevoir un motif d'interférence de lumière générée par le premier système optique (30) et de lumière générée par le deuxième système optique (40).

4. Appareil de génération d'image tomographique selon la revendication 3, dans lequel le deuxième système optique (40) comprend le dispositif de modulation et de correction ou dans lequel le dispositif de modulation et de correction est disposé entre le coupleur optique (24) et le premier système optique (30).

5. Appareil de génération d'image tomographique selon la revendication 3, dans lequel le deuxième système optique (30) comprend :

un modulateur spatial de lumière (SLM) (40i) configuré pour moduler la lumière qui entre depuis le coupleur optique (24) ;
un galvanomètre (40c et 40d) configuré pour réfléchir la lumière qui entre dans l'objet (60) depuis le SLM (40i) et pour réfléchir la lumière qui entre dans le SLM (40i) depuis l'objet (60) ; et
un objectif (40e) configuré pour focaliser la lumière qui entre dans l'objet (60) depuis le galvanomètre (40c et 40d) ;
dans lequel le dispositif de modulation et de correction est disposé de préférence entre le deuxième système optique (40) et le coupleur optique (24).

6. Appareil de génération d'image tomographique selon la revendication 1, dans lequel le modulateur optique (40a) correspond à un premier réseau comportant une pluralité de rainures et le réseau (40h) présente une densité de rainures qui est la même que la densité de rainures du premier réseau ; ou dans lequel le réseau (40h) présente une densité de rainures qui est différente de la densité de rainures du premier réseau et le dispositif de modulation et de correction comprend en outre une première lentille (40f) et une seconde lentille (40g) disposées entre le modulateur optique (40a) et le réseau (40h) et configurées pour compenser la différence de densité de rainures entre le premier réseau et le réseau (40h).

7. Appareil de génération d'image tomographique selon l'une quelconque des revendications 1 à 6, dans lequel, dans le modulateur optique (40a), une région de réflexion de la lumière qui entre depuis le coupleur optique (24) est différente d'une région de réflexion de la lumière qui entre depuis l'objet (60).

8. Appareil de génération d'image tomographique selon l'une quelconque des revendications 1 à 7, dans lequel le modulateur optique (40a) est un dispositif à micro-miroirs numérique (DMD) incluant une pluralité de micro-miroirs fonctionnant chacun comme un pixel ou un modulateur spatial de lumière (SLM).

9. Appareil de génération d'image tomographique selon la revendication 6, dans lequel le premier système optique comprend deux lentilles correspondant aux première et seconde lentilles.

10. Appareil de génération d'image tomographique selon la revendication 1, dans lequel le dispositif de modulation et de correction est disposé entre le coupleur optique et l'objet.

11. Appareil de génération d'image tomographique selon l'une quelconque des revendications 1 à 10, dans lequel le dispositif de génération d'image tomographique est un dispositif de tomographie par cohérence optique ou un microscope à tomographie par cohérence optique.

12. Procédé de fonctionnement d'un appareil de génération d'image tomographique selon l'une quelconque des revendications 1 à 11, le procédé comprenant :

l'exécution d'une opération de modulation optique uniquement vis-à-vis de la lumière qui est dirigée vers l'objet (60) en utilisant le modulateur optique (40a) du dispositif de modulation et de correction.

13. Procédé selon la revendication 12, dans lequel la lumière qui entre dans le modulateur optique (40a) depuis le coupleur optique (24) est incidente sur la première région du modulateur optique (40a) ; la lumière qui entre dans le modulateur optique (40a) depuis l'objet (60) est incidente sur une seconde région du modulateur optique (40a) ; les première et seconde régions sont séparées l'une de l'autre et une opération de modulation optique est effectuée uniquement dans la première région.

FIG. 1

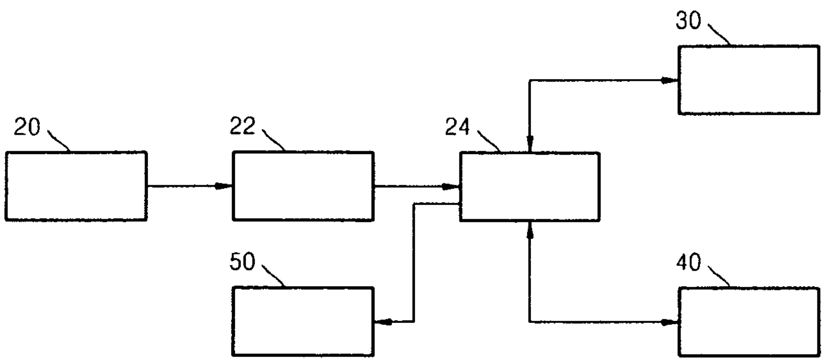


FIG. 2A

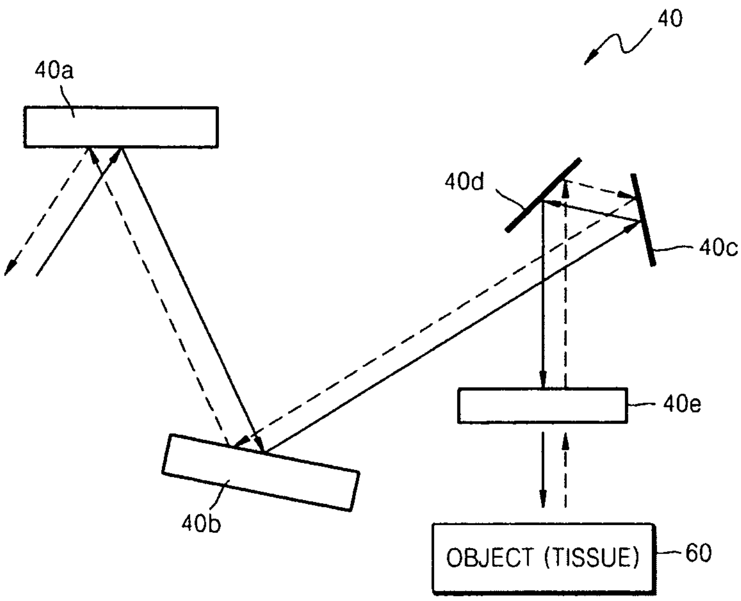


FIG. 2B

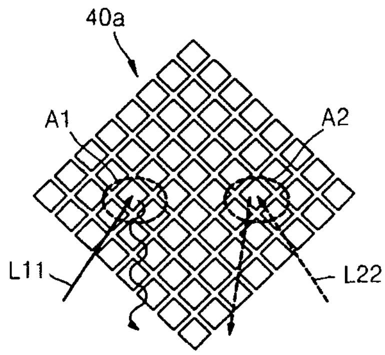


FIG. 3

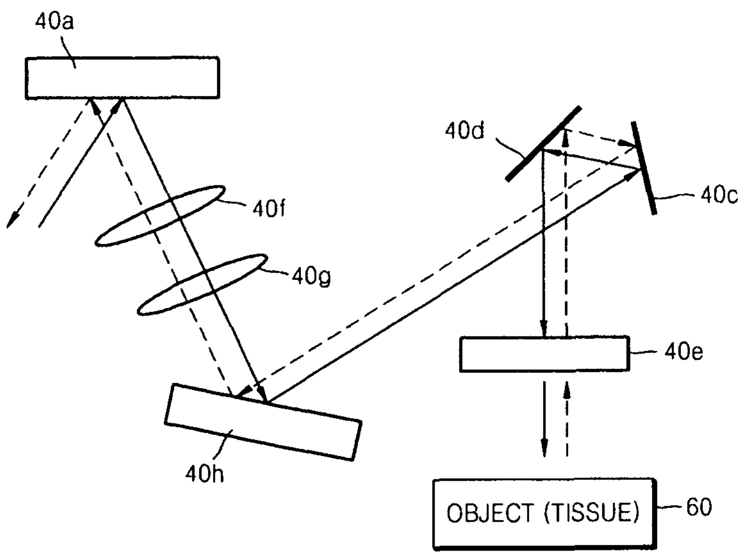


FIG. 4

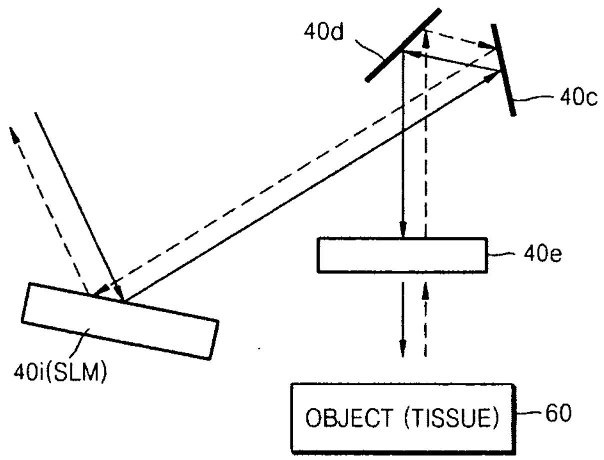


FIG. 5

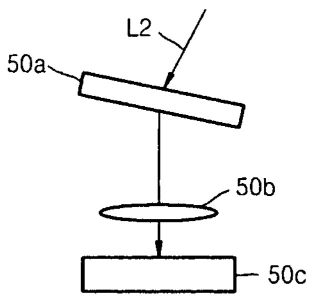


FIG. 6

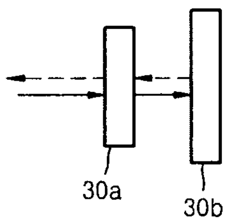


FIG. 7

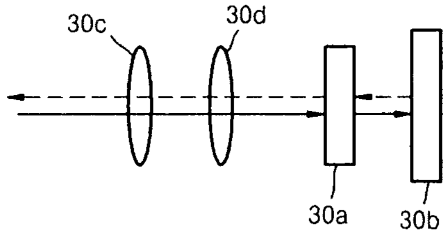


FIG. 8

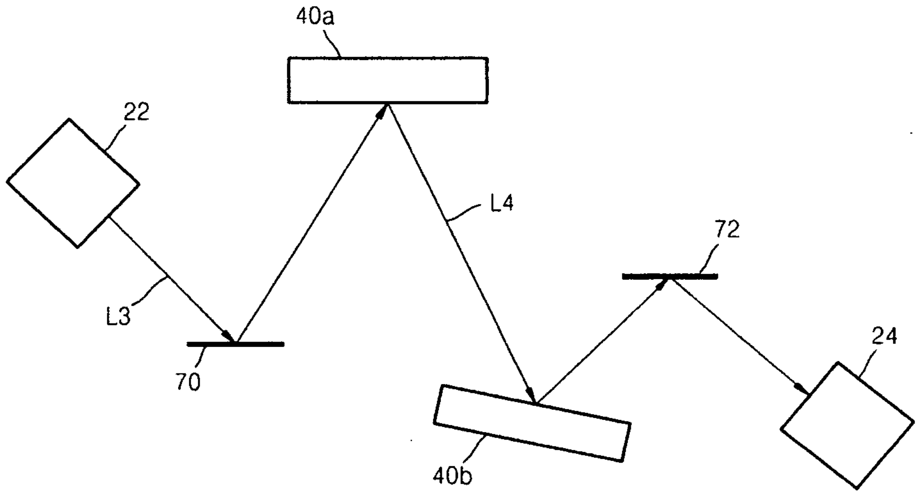


FIG. 9

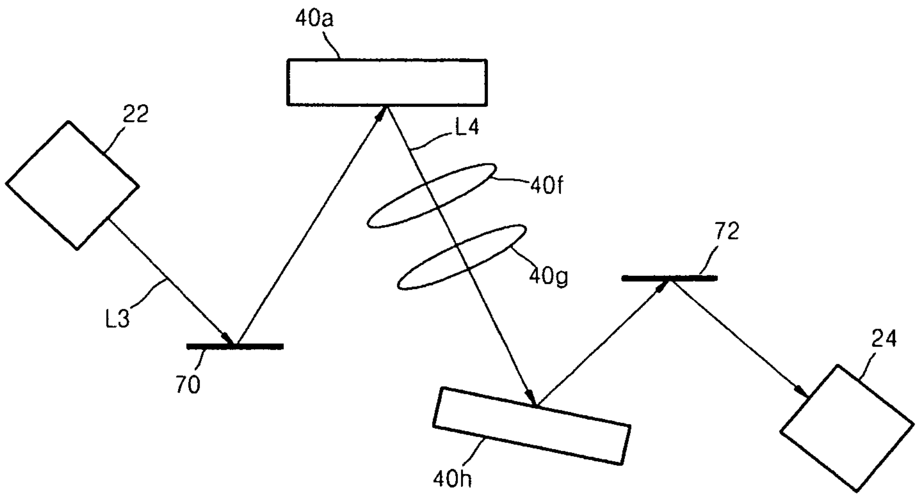


FIG. 10

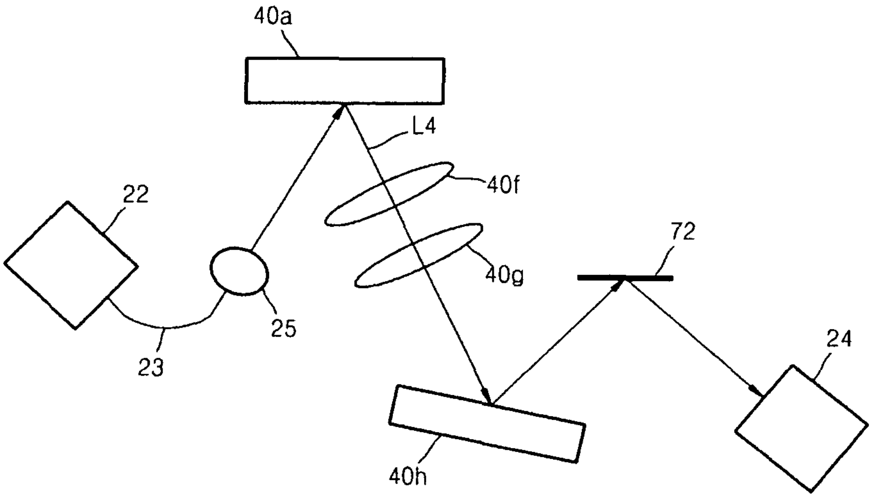
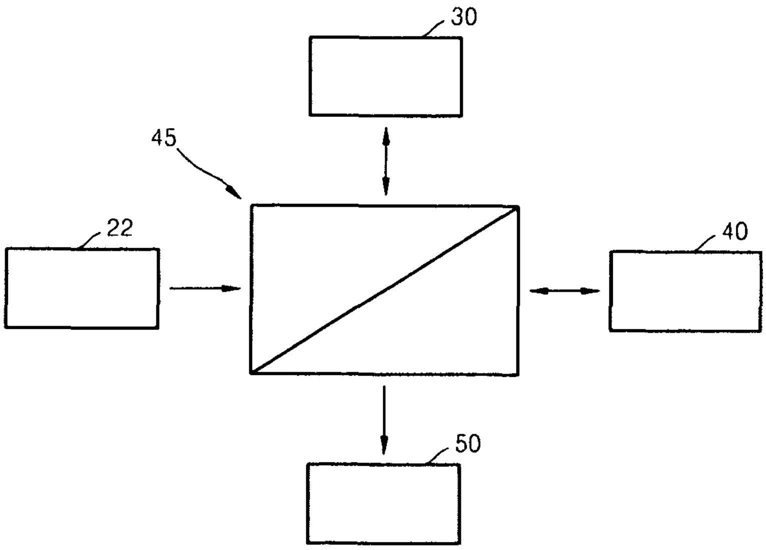


FIG. 11



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20120038885 A1 **[0003]**

专利名称(译)	具有调制和校正装置的断层图像产生装置及其操作方法
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公开(公告)日	2015-07-08
申请号	EP2013181509
申请日	2013-08-23
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申请(专利权)人(译)	三星电子有限公司 韩国高等学院科技
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其他公开文献	EP2700352A1
外部链接	Espacenet

摘要(译)

断层图像生成装置包括光源单元，该光源单元被配置为发射用于扫描物体的光;光控制单元，被配置为控制光的传播方向;光耦合器，被配置为分离和组合入射光;光学连接到光耦合器的多个光学系统;调制和校正装置，被配置为调制和校正用于扫描物体的光。调制和校正装置可以设置在光学控制单元和光学耦合器之间，或者可以包括在光学系统中，该光学系统将光照射到多个光学系统中的物体上。调制和校正装置可以仅调制反射到物体的光。

FIG. 1

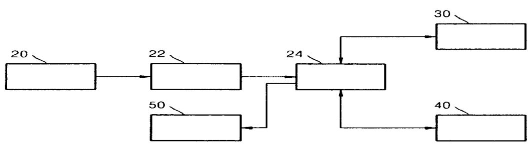

FIG. 2A