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(54) **SUBMICRON RESOLUTION SPECTRAL-DOMAIN OPTICAL COHERENCE TOMOGRAPHY**

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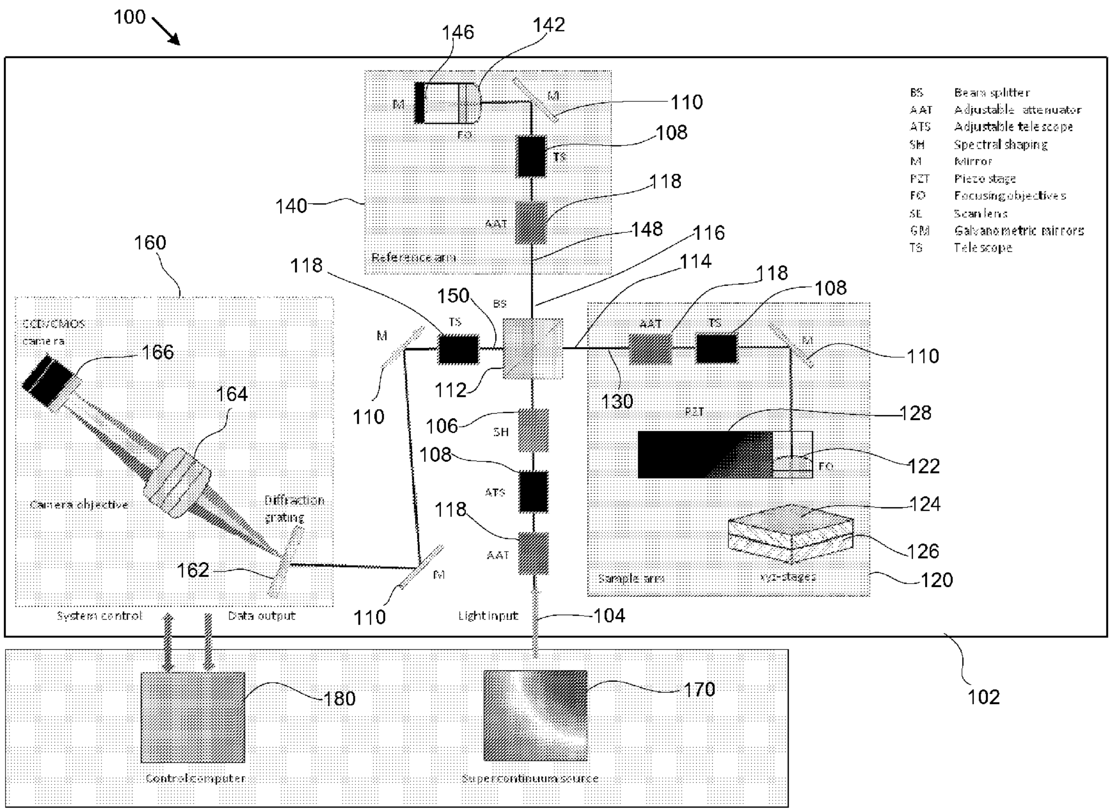
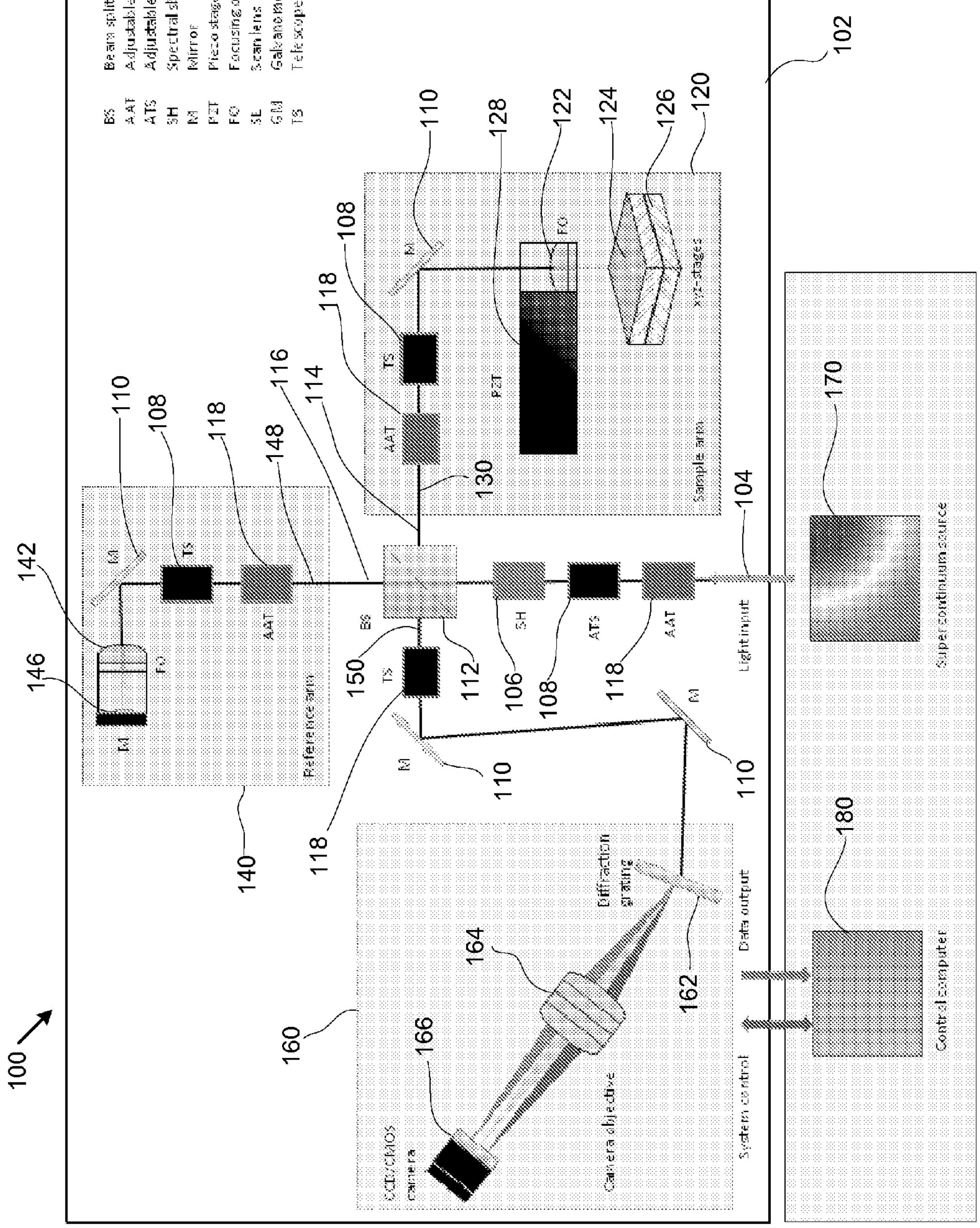
(57) **ABSTRACT**

Apparatuses and systems for submicron resolution spectral-domain optical coherence tomography (OCT) are disclosed. The system may use white light sources having wavelengths within 400-1000 nanometers, and achieve resolution below 1 μm. The apparatus is aggregated into a unitary piece, and a user can connect the apparatus to a user provided controller and/or light source. The light source may be a supercontinuum source.




BS Beam splitter
AAT Adjustable attenuator
ATS Adjustable telescope
SH Spectral shaping
M Mirror
PZT Piezo stage
FO Focusing objectives
SL Scan lens
GM Galvanometric mirrors
TS Telescope
Reference arm
Sample arm
Light input
Supercontinuum source
Control computer
System control
Data output
Diffraction grating
Camera objective
CCD/CMOS camera
100
102
104
106
108
110
112
114
116
118
120
122
124
126
128
130
140
142
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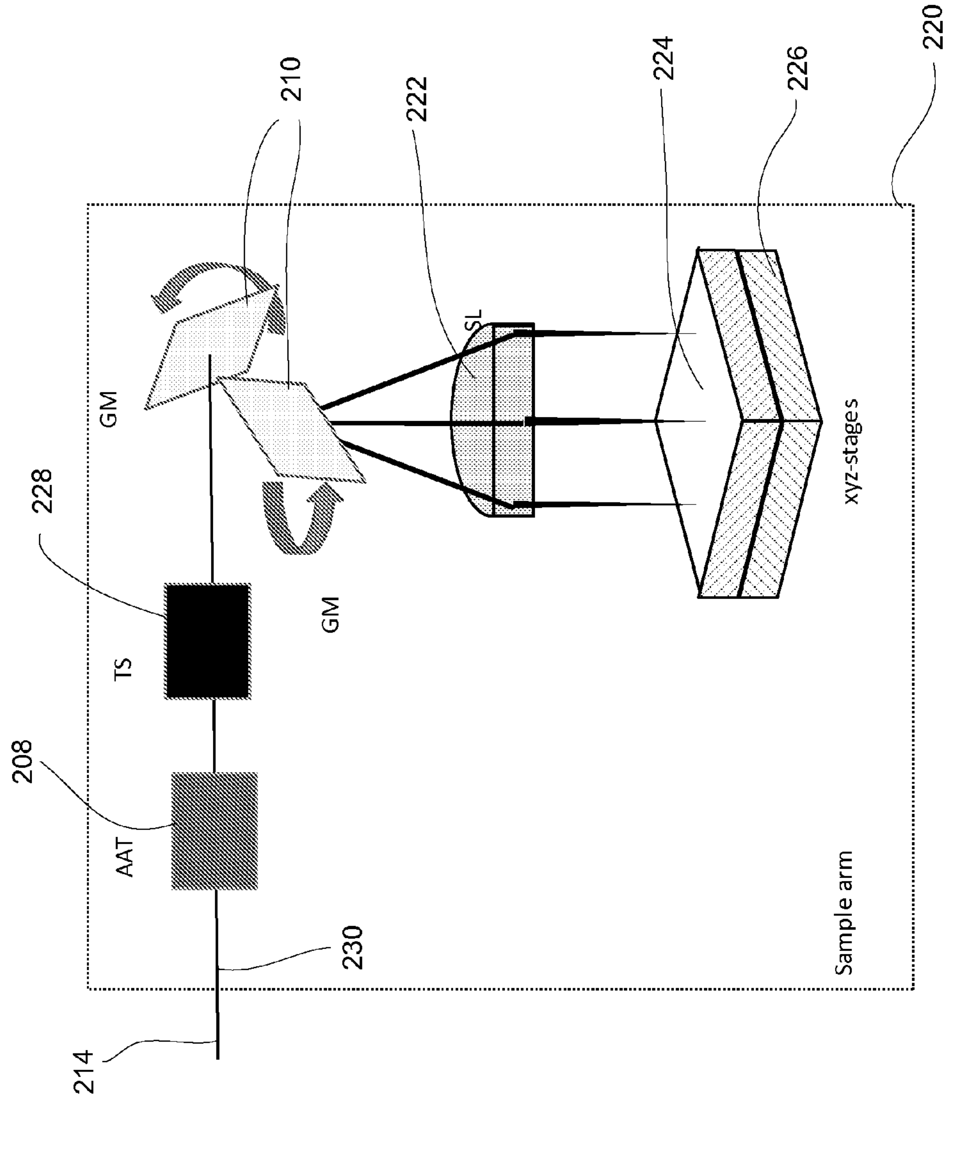
180

FIG. 1



214
230
208
AAT
TS
228
GM
GM
210
222
SL
224
226
220
xyz-stages
Sample arm

FIG. 2

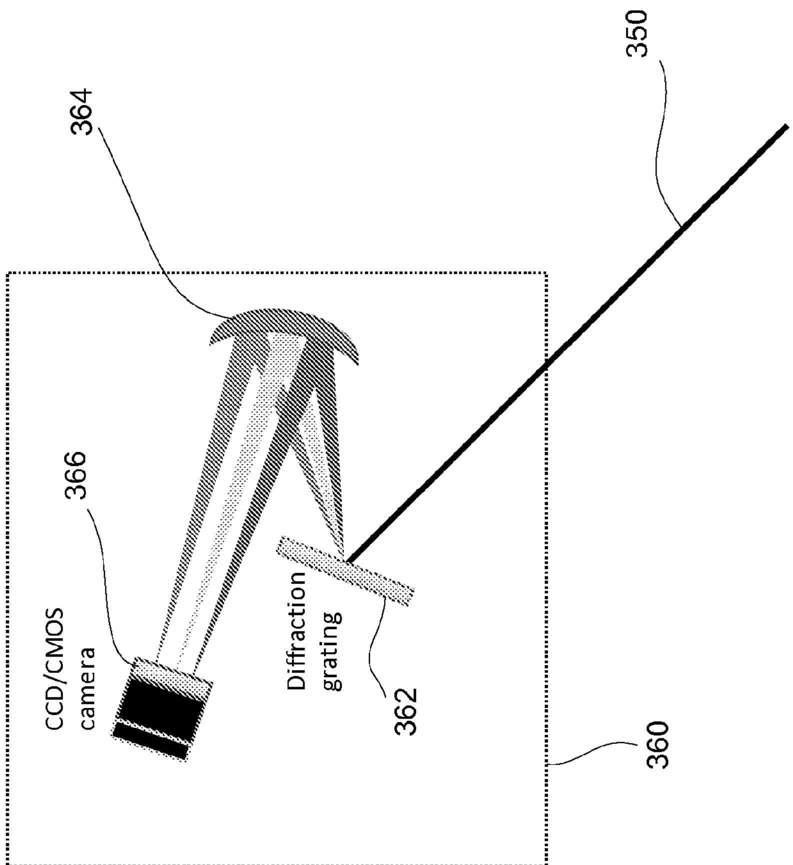


FIG. 3

SUBMICRON RESOLUTION SPECTRAL-DOMAIN OPTICAL COHERENCE TOMOGRAPHY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of priority of U.S. Patent Application No. 61/644,240 to Erkki Alarousu et al. filed on May 8, 2012 and entitled "Submicron Resolution Spectral-Domain Optical Coherence Tomography," which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to optical coherence tomography and more particularly relates to apparatuses and systems for submicron resolution spectral-domain optical coherence tomography using supercontinuum sources.

[0004] 2. Description of the Related Art

[0005] Optical Coherence Tomography (OCT) is a well-known imaging technique in biomedicine capable of optical sectioning of semi-transparent tissues. OCT, which is based on white-light interferometry, is mostly applied in ophthalmology because of its great power in non-invasive retinal and macular imaging.

[0006] OCT is a cross-sectional imaging method offering complete three-dimensional structural reconstruction of an analyzed object. One individual depth scan is referred as an A-scan, which can be treated as an integral over depth dependent reflectivity of the object under measurement. Most common imaging method is B-scan imaging, where several A-scans are combined together to form a cross-sectional image of the object structure called a tomogram. In addition to cross-sectional imaging, OCT is capable of revealing the whole 3D structure of the sample by volume reconstruction.

[0007] A major advantage of OCT over many other imaging techniques is its ability to measure not only almost arbitrary size sample quantitative 3D surface topography but internal 3D volumetric data as well; both at the same time. Very few methods are capable of doing this including: Fluorescence Microscopy, X-ray Tomography, and Electron tomography.

[0008] Fluorescence Microscopy, i.e. Confocal Laser Scanning Microscopy (CLSM) and Multiphoton Microscopy (MP), are possible candidates but are limited by the fact that they are based on fluorescence and labeling which complicates the measurement of multimaterial samples like solar cells. Fluorescence Microscopy is used mainly for surface/sub-surface imaging and is limited to thin cross-sections (typically a few μm).

[0009] X-ray Tomography, i.e. Micro Computed Tomography (μCT), exploits X-rays and enables imaging of optically non-transparent objects, but has a drawback of using harmful X-rays, rather slow measurement speed due to angular imaging sequence, invasive sample preparation, and extensive image processing procedure. X-ray Tomography is best suitable for imaging of metal contacts when considering multi-layer structures like solar cells.

[0010] Electron tomography, i.e. 3D Transmission Electron Microscopy (3D-TEM), uses electron beams to image ultrathin objects with sub-nanometer resolution—it gives a superior resolution over all techniques presented here but has drawbacks like limited sample thickness (typically few hundred nanometers), extensive and complicated sample preparation and angular imaging sequence.

[0011] OCT may be implemented in time-domain or spectral-domain. However, time-domain OCT systems have moving parts which limit the speed of the systems. Spectral-domain OCT systems eliminates the requirement to have moving parts in their reference arms, and higher system speed can be achieved. However, achieving ultra-high resolution (such as submicron resolution) remains a challenge for spectral-domain OCT systems. Further, broadband scanning is another challenge for spectral-domain OCT systems.

SUMMARY OF THE INVENTION

[0012] Embodiments of apparatuses and systems for submicron resolution spectral-domain optical coherence tomography (OCT) are presented. The apparatuses and systems may use white light sources having wavelengths of 1000 nanometers or less. The apparatus for submicron resolution spectral-domain OCT is aggregated into a unitary piece, and a user can connect the apparatus to a user provided controller and/or light source. The light source may be a supercontinuum source.

[0013] In one embodiment, the apparatus comprises a sample arm configured to direct a first light beam to a sample and output a sample output beam; a reference arm configured to receive a second light beam and output a reference output beam; a mechanism to combine the sample output beam and the reference output beam to generate a light output; and a spectrometer configured to convert the light output into electrical signals. The first light beam and the second light beam may have wavelengths within a range of 1000 nanometers (nm) or less. In another embodiment, the first light beam and the second light beam may have wavelengths within a range of 400-1000 nanometers.

[0014] In one embodiment, the apparatus further comprises a beam splitter configured to split a light input into the first light beam and the second light beam. The light input may be from a light source such as a supercontinuum source or the like. In one embodiment, the light input may have wavelengths only in the range of 400-1000 nanometers. In another embodiment, the light input comprises a first light component having wavelengths within the range of 400-1000 nanometers and a second light component having wavelengths outside the range of 400-1000 nanometers. In such an embodiment, the apparatus further comprises a spectrum shaping device configured to filter out light within the range of 400-1000 nanometers from the light input, and generate a light beam having wavelengths within the range of 400-1000 nanometers.

[0015] The sample arm of the apparatus may comprise a focusing device configured to adjust a diameter of the first light beam before the first light beam reaches the sample. The focusing device may be movable along a longitudinal axis of the first light beam. The sample arm may further comprise a stage configured to receive the sample, where the stage may be movable along a longitudinal axis of the first light beam.

[0016] In one embodiment, the spectrometer of the apparatus comprises a diffraction grating configured to split the light output into a plurality of light components having different wavelengths. The spectrometer may further comprise a recording device configured to record the plurality of light components as electrical signals. The recording device may be camera, such as a CCD (charge-coupled device) camera, a CMOS (complementary-symmetry metal-oxide-semiconductor) camera, or the like. The spectrometer may also comprise a focusing device (such as a camera objective) configured to adjust the diameter of the light output by the diffraction grating.

[0017] In one embodiment, the mechanism to combine the sample output beam and the reference output beam to generate a light output may comprise one or more reflectors, such as mirrors, splitters, and/or combiners. The reflectors may be configured to change the direction of light beams traveling in the apparatus. The splitter may be configured to split a light beam into two or more light beams. The combiner may be configured to combine two or more light beams into a single light beam.

[0018] In one embodiment, the apparatus may further comprise one or more mechanisms to adjust (e.g. to attenuate or amplify) density of a light beam. Density of a light beam can be adjusted by passing the light beam through one or more attenuators, such as neutral density filters (ND-filters), polarizer-analyzer-combinations, or the like, or by partially reflecting the light beam from an optical surface.

[0019] Systems for submicron resolution spectral-domain OCT are disclosed. In one embodiment, the system comprises a light source configured to output a light input; an apparatus configured to convert a light input into electrical signals; and a controller coupled to the apparatus and configured to receive the electrical signals.

[0020] In one embodiment, the apparatus of the system may be an apparatus described above, where the apparatus comprises a sample arm configured to direct a first light beam to a sample and output a sample output beam; a reference arm configured to receive a second light beam and output a reference output beam; a mechanism to combine the sample output beam and the reference output beam to generate a light output; and a spectrometer configured to convert the light output into electrical signals.

[0021] In one embodiment, the light source may be a supercontinuum source. The light source may be configured to output a light having wavelengths only within the range of 400-1000 nanometers or 1000 nanometers or less. Alternatively, the light source may be configured to output a light comprising a first light component having wavelengths within a range of 400-1000 nanometers and a second light component having wavelengths outside the range of 400-1000 nanometers. In such an embodiment, the system further comprises a spectrum shaping device configured to filter out light within the range of 400-1000 nanometers from the light input, and generate a light beam having wavelengths within the range of 400-1000 nanometers.

[0022] In one embodiment, the apparatus is aggregated into a unitary piece. The apparatus may be detachable from the light source and controller.

[0023] The controller of the system may be configured to control the movement of a focusing device which is movable along a longitudinal axis of a light beam, the movement of a stage configured to receive the sample, where the stage is movable along a longitudinal axis of the first light beam, the recording of a light beam as electrical signals by a recording device, and/or storage of the electrical signals. The recording device may be a camera or the like.

[0024] The term "coupled" is defined as connected, although not necessarily directly, and not necessarily mechanically. The terms "a" and "an" are defined as one or more unless this disclosure explicitly requires otherwise.

[0025] The term "substantially" and its variations are defined as being largely but not necessarily wholly what is specified as understood by one of ordinary skill in the art, and in one non-limiting embodiment "substantially" refers to ranges within 10%, preferably within 5%, more preferably within 1%, and most preferably within 0.5% of what is specified.

[0026] The terms "comprise" (and any form of comprise, such as "comprises" and "comprising"), "have" (and any form of have, such as "has" and "having"), "include" (and any form of include, such as "includes" and "including") and "contain" (and any form of contain, such as "contains" and "containing") are open-ended linking verbs. As a result, a method or device that "comprises," "has," "includes" or "contains" one or more steps or elements possesses those one or more steps or elements, but is not limited to possessing only those one or more elements. Likewise, a step of a method or an element of a device that "comprises," "has," "includes" or "contains" one or more features possesses those one or more features, but is not limited to possessing only those one or more features. Furthermore, a device or structure that is configured in a certain way is configured in at least that way, but may also be configured in ways that are not listed.

[0027] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description that follows may be better understood. Additional features and advantages will be described hereinafter, which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. The novel features which are believed to be characteristic of embodiments of the present invention, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the embodiments of the present application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] For a more complete understanding of the present application, reference is now made to the following descriptions taken in conjunction with the accompanying drawings.

[0029] FIG. **1** is a block diagram illustrating one embodiment of a system for submicron resolution spectral-domain optical coherence tomography (OCT), according to certain aspects of the present disclosure.

[0030] FIG. **2** is a block diagram illustrating one embodiment of a sample arm for a system for submicron resolution spectral-domain OCT, according to certain aspects of the present disclosure.

[0031] FIG. **3** is a block diagram illustrating one embodiment of a spectrometer for a system for submicron resolution spectral-domain OCT, according to certain aspects of the present disclosure.

DETAILED DESCRIPTION

[0032] Various features and advantageous details are explained more fully with reference to the nonlimiting embodiments that are illustrated in the accompanying drawings and detailed in the following description. Descriptions of well known starting materials, processing techniques, components, and equipment are omitted so as not to unnecessarily obscure the invention in detail. It should be understood, however, that the detailed description and the specific examples, while indicating embodiments of the invention, are given by way of illustration only, and not by way of limitation. Various substitutions, modifications, additions, and/or rearrangements within the spirit and/or scope of the underlying inventive concept will become apparent to those having ordinary skill in the art from this disclosure.

Background

[0033] An OCT measurement system usually consists of a Michelson interferometer illuminated by a low-coherent light source, like a supercontinuum source, or a superluminescent diode (SLD) operating at near infrared (NIR) region. Coherence length defines the depth resolution of the OCT system: the broader the spectrum the better the depth resolution. It is beneficial to use ultra-violet-visible wavelengths due to the fact that the best resolution is achieved in that range. A supercontinuum source is an ideal source as it emits light from 400-2000 nanometers (nm), and submicron depth resolution can be achieved.

[0034] In addition to width of the spectrum, the shape of the spectrum is also important: the more complex the spectrum, the more complex the autocorrelation function of the interferometer, which lowers the quality of the acquired images and causes false interpretation of scattering sites inside the sample due to side lobes in the autocorrelation function. However, depth and transversal resolutions are not linked to each other. Depth resolution is defined solely by the light source and transversal resolution by the optics thus being limited by diffraction like in conventional microscopy.

[0035] In an OCT system, a sample to be investigated is placed in one arm of the interferometer: the measurement i.e. sample arm. The light beam is reflected or scattered from the sample depending on the various optical properties of the material layers in the sample. In time-domain systems, the longitudinal profile of reflectivity versus depth (A-scan) is obtained by translating the mirror in the reference arm and synchronously recording the interfering beams at the output of the interferometer. A fringe pattern is evident at the detector only when the optical path length difference in the interferometer arms is less than the coherence length of the light source. Mirror translation is also used to shift the signal to a certain Doppler frequency to enable removal of noise outside the pass band caused by environmental disturbances, light source fluctuations, vibrations on the system, etc.

[0036] In spectral-domain systems, interfering beams are guided to a diffraction grating which diffracts the beam via objective to CCD or CMOS line scan camera. No reference arm translation is needed; reflectivity versus depth (A-scan) is obtained by Fourier transforming the spectral interference. Diffraction grating coupled to a line scan camera forms a spectrometer which measures the spectrum of light equidistant in λ-space. However, depth dependent reflectivity is obtained via discrete Fourier transform in k-space ($k=2\pi/\lambda$, nonlinear relation) that means a linear interpolation must be performed to get the spectrum evenly sampled. Zero-filling technique must be applied before the interpolation to avoid shoulders around the peaks at greater depths. In both methods, the final image is formed by measuring several adjacent A-scans and then combining them together in software like Matlab, Paraview, Amira or Avizo for tomogram reconstruction or 3D volumetric rendering.

[0037] Spectral domain system offers increased sensitivity and speed over time domain systems since it measures all the photons returning from the sample simultaneously. In addition, numerical dispersion compensation can be performed instead of using extra optics in the reference arm. Dispersion compensation is crucial when using super broadband light sources like supercontinuum sources. Dispersion decreases the resolution as a function of depth dramatically even with a thin samples (in the order of tens of micrometers).

Systems and Apparatuses

[0038] FIG. **1** illustrates one embodiment of a system **100** for submicron resolution spectral-domain optical coherence tomography (OCT). In one embodiment, the system **100** may offer a spatial resolution below 1 μm. The system **100** may comprise a light source **170**, an apparatus **102**, and a controller **180**. The apparatus **102** may comprise a sample arm **120**, a reference arm **140** and a spectrometer **160**.

[0039] The light source **170** may be a supercontinuum laser source, superluminescent diode (SLD) source, or other kind of laser source. The light source **170** may be configured to generate a light input **104**. The light input **104** may have low coherence. The light input **104** may be white light comprising a plurality of components with different wavelengths. In one embodiment, the light input **104** have wavelengths only within the range of 400-1000 nm. In another embodiment, the light input **104** comprises a first light component having wavelengths within the range of 400-1000 nm and a second light component having wavelengths outside the range of 400-1000 nm.

[0040] In one embodiment, the apparatus **102** may be aggregated into a unitary piece. The apparatus **102** may be configured to be detachable from the light source **170** and the controller **180**. For example, the apparatus **102** may be aggregated in a ready-to-use box, and a user can connect a user provided light source and controller to the apparatus **102**.

[0041] In one embodiment, the apparatus **102** may be configured to receive a light input **104** from the light source **170**. The apparatus **102** may further comprise a spectrum shaping device **106** configured to filter out undesired light components of the light input **104** and generate a light beam with light components having wavelengths in a desired range. For example, when the light input **104** comprises a first component having wavelengths within the range of 400-1000 nm and a second component having wavelengths outside the range of 400-1000 nm, the spectrum shaping device **106** may filter out the second component and keep the first component of the light input to generate a light beam having wavelengths only within the range of 400-1000 nm.

[0042] In one embodiment, the apparatus **102** comprises one or more magnifying devices **108** configured to adjust a diameter of a light input. The magnifying device **108** may increase or decrease the diameter of a light input. In certain embodiments, the magnifying device **108** is a telescope. In some embodiments, apparatus **102** may comprise one or more mechanisms to adjust intensity of a light beam. Intensity of a light beam can be adjusted by passing the light beam through one or more attenuators, such as neutral density filters (ND-filters), polarizer-analyzer-combinations, or the like, or by partially reflecting the light beam from an optical surface. In the depicted embodiment, apparatus **102** comprises one or more attenuators **118** configured to adjust an intensity of a light beams, such as light input **104**. Attenuators **118** may be adjustable such that a light output of attenuators **118** has a target light intensity. Apparatus **102** may further comprise a beam splitter **112** configured to split a light input into two or more light beams. For example, beam splitter **112** can split a light input into a first light beam **114** and a second light beam **116**. It should be understood that the order of the spectrum shaping device **106**, magnifying device **108**, attenuators **118**, and/or other components of the apparatus **102** may be exchangeable.

[0043] In one embodiment, the sample arm **120** of apparatus **102** may be configured to receive a first light beam **114**. The first light beam **114** is white light comprising a plurality of light components with different wavelengths. The first light beam may have wavelengths only within the range of 1000 nanometers (nm) or less. In one embodiment, the first light beam **114** may have wavelengths only within the range of 400-1000 nm.

[0044] The sample arm **120** may comprise an attenuator **118** configured to adjust the intensity of the first light beam **114**. The sample arm **120** may further comprise one or more minors **110** configured to adjust the direction of the first light beam **114**. The sample arm **120** may also comprise a focusing device **122** configured to adjust the diameter of the first light beam **114**. The focusing device **122** may further be configured to adjust a direction of the first light beam **114** such that the beam reaches a sample **124**. The focusing device **122** may be configured to be movable, for example, along a longitudinal axis of the first light beam **114**, or of the first light beam **114** with a direction adjusted by the mirror **110**. For example, the focusing device **122** may be coupled to a support stage **128**, which is configured to be movable.

[0045] In one embodiment, the sample arm **120** may comprise a sample stage **126** configured to receive a sample **124**. The sample stage **126** may be configured to be movable. For example, sample stage may be movable along a longitudinal axis of the first light beam **114**, or of the first light beam **114** with a direction adjusted by the mirror **110**. Sample stage **126** may be also configured to be movable in a direction substantially perpendicular to a longitudinal axis of the first light beam **114**, or of the first light beam **114** with a direction adjusted by the mirror **110**. The first light beam **114** may be reflected by the sample **126** in the sample arm **120**, which outputs a sample output beam **130**. According to certain aspects of the present disclosure, it should be understood that all optical devices, such as minors, focusing devices, beam splitters, beam attenuators, magnifying objects, or the like, are bidirectional.

[0046] In one embodiment, the reference arm **140** of apparatus **102** may be configured to receive a second light beam **116**. The second light beam **116** is white light comprising a plurality of light components with different wavelengths. The second light beam may have wavelengths only within the range of 1000 nanometers (nm) or less. In one embodiment, the second light beam **116** may have wavelengths only within the range of 400-1000 nm. The focusing device **142** and reflecting device **146** may be configured to be movable together along the longitudinal axis of the second light beam **116**, with a direction adjusted by one or more mirrors **110**.

[0047] In one embodiment, the reference arm **140** may comprise an attenuator **118** configured to adjust the intensity of the second light beam **116**. The reference arm **140** may further comprise one or more minors **110** configured to adjust a direction of the second light beam **116**. The reference arm **140** may also comprise a focusing device **142** configured to adjust a diameter of the second light beam **116**. The focusing device **142** may be fixed or movable. The reference arm **140** may further comprise a reflecting device **146** configured to adjust a direction of the second light beam **116**. The reference arm **140** output a reference output beam **148**.

[0048] The sample output beam **130** and the reference output beam **148** are combined to generate a light output **150**. In one embodiment, the sample output beam **130** and the reference output beam **148** are combined at splitter **112**. In another embodiment, the sample output beam **130** and the reference output beam **148** may be combined at a light combiner. One of ordinary skill in the art will recognize other methods and/or devices to combine the sample output beam **130** and the reference output beam **148** are combined. In one embodiment, the attenuators **118** and focusing devices **108** are configured such that the sample output beam **130** and the reference output beam **148** have substantially similar light intensities. The light output **150** may be directed into the spectrometer **160**, e.g. by one or more mirrors **110**.

[0049] In one embodiment, the spectrometer **160** comprises a diffraction grating **162** configured to split the light output **150** into a plurality of light components having different wavelengths. In one embodiment, the spectrometer **160** further comprises a recording device **166** configured to record the plurality of light components as electrical signals. The recording device **166** may be a camera, such as a CCD camera, a CMOS camera, or the like. The spectrometer **160** may further comprise a camera objective **164** configured to adjust the direction of the plurality of light components output by the diffraction grating **162**. In one embodiment, the camera objective **164** may comprise a plurality of convex and/or concave lens arraigned in a certain order.

[0050] In one embodiment, the controller **180** is configured to receive and/or store the electrical signals from the recording device **166**. The controller **180** may be further configured to control the recording of the light output **150**, e.g., by the recording device **166**, as electrical signals, movements of the sample stage **126** and/or focusing device **122**, focusing device **124**, and/or reflecting device **146**, direction of the mirrors **110**, the attenuators **108**, the spectrum shaping device, or the like.

[0051] The controller **180** may be a general-purpose computer, a tablet computer, or the like. The controller **180** may further comprise a processor configured to perform certain operations on the electrical signals received from the apparatus **102**. For example, the controller may amplify, quantize, and/or filter the electrical signals, and/or perform (inverse) Fourier transform on the electrical signals.

[0052] FIG. **2** illustrates one embodiment of a sample arm **220** for a system for submicron resolution spectral-domain OCT. The sample arm **220** is configured to receive a light beam **214** and output a sample output beam **230**. The sample arm **220** may comprise a scanning lens **222** configured to adjust a direction and/or diameter of a light beam **214** such that the light beam **214** can reach a sample **224**, which may be hosted by a sample stage **226**. The scanning lens **222** may be fixed, or movable. In one embodiment, the sample arm **220** comprises one or more Galvanometric minors **210** configured to adjust direction of a light beam **214**. For example, the Galvanometric minors **210** may direct a light beam **214** to a certain direction so that the light beam can engage a target area of the scanning lens **222**. The Galvanometric mirrors **210**

is further configured to movable and/or rotatable, such that a light beam **214** is directed to a target direction.

[0053] FIG. **3** illustrates one embodiment of a spectrometer **360** for a system for submicron resolution spectral-domain OCT. The spectrometer **360** is configured to receive a light beam **350**, and record the light as electrical signals. In one embodiment, the spectrometer **360** may comprise a diffracting grating **362** and/or a recording device **366**, such as those described in FIG. **1**. The spectrometer **360** may further comprise a spherical mirror **364** configured adjust the directions of a plurality of light components output by the diffraction grating **362**.

[0054] All of the methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the apparatus and methods of this invention have been described in terms of preferred embodiments, it will be apparent to those of skill in the art that variations may be applied to the methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit and scope of the invention. In addition, modifications may be made to the disclosed apparatus and components may be eliminated or substituted for the components described herein where the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope, and concept of the invention as defined by the appended claims.

What is claimed is:

1. An apparatus for optical coherence tomography, comprising:
- a sample arm configured to direct a first light beam to a sample and output a sample output beam, the first light beam having wavelengths within a range of 1000 nanometers or less;
- a reference arm configured to receive a second light beam and output a reference output beam, the second light beam having wavelengths within the range of 1000 nanometers or less;
- a mechanism to combine the sample output beam and the reference output beam to generate a light output; and
- a spectrometer configured to convert the light output into electrical signals.

2. The apparatus of claim **1**, aggregated into a unitary piece.

3. The apparatus of claim **1**, the first light beam and the second light beam having wavelengths within a range of 400-1000 nanometers.

4. The apparatus of claim **1**, further comprising a beam splitter configured to split a light input into the first light beam and the second light beam.

5. The apparatus of claim **4**, the light input being generated by a supercontinuum source.

6. The apparatus of claim **4**, the light input comprising a first light component having wavelengths within a range of 400-1000 nanometers and a second light component having wavelengths outside the range of 400-1000 nanometers.

7. The apparatus of claim **6**, further comprising a spectrum shaping device configured to generate a light beam from the light input, the light beam having wavelengths within the range of 400-1000 nanometers.

8. The apparatus of claim **4**, wavelengths of the light input being within a range of 400-1000 nanometers.

9. The apparatus of claim **1**, the sample arm comprising a focusing device configured to adjust a diameter of the first light beam before the first light beam reaches the sample.

10. The apparatus of claim **9**, the focusing device configured to be movable along a longitudinal axis of the first light beam.

11. The apparatus of claim **1**, the sample arm comprising a sample stage configured to receive the sample, the sample stage configured to be movable.

12. The apparatus of claim **11**, the sample stage configured to be movable along a longitudinal axis of the first light beam.

13. The apparatus of claim **11**, the sample stage configured to be movable in a direction substantially perpendicular to a longitudinal axis of the first light beam.

14. The apparatus of claim **1**, the spectrometer comprising a diffraction grating configured to split the light output into a plurality of light components having different wavelengths.

15. The apparatus of claim **14**, the spectrometer further comprising a recording device configured to record the plurality of light components as electrical signals.

16. A system for optical coherence tomography comprising:
- a light source configured to output a light input;
- an apparatus comprising:
  - a sample arm configured to direct a first light beam to a sample and output a sample output beam, the first light beam generated from the light input and having wavelengths within a range of 1000 nanometers or less;
  - a reference arm configured to receive a second light beam and output a reference output beam, the second light beam generated from the light input and having wavelengths within the range of 1000 nanometers or less;
  - a mechanism to combine the sample output beam and the reference output beam to generate a light output; and
  - a spectrometer configured to convert the light output into electrical signals; and
- a controller coupled to the apparatus and configured to receive the electrical signals.

17. The system of claim **16**, the apparatus aggregated into a unitary piece.

18. The system of claim **17**, the apparatus detachable from the light source and controller.

19. The system of claim **16**, the first light beam and the second light beam having wavelengths within a range of 400-1000 nanometers.

20. The system of claim **16**, further comprising a beam splitter configured to split the light input into the first light beam and the second light beam.

21. The system of claim **16**, the light source being a supercontinuum source.

22. The system of claim **16**, the light input comprising a first light component having wavelengths within a range of 400-1000 nanometers and a second light component having wavelengths outside the range of 400-1000 nanometers.

23. The system of claim **22**, further comprising a spectrum shaping device configured to generate a light beam from the light input, the light beam having wavelengths within the range of 400-1000 nanometers.

24. The system of claim **16**, wavelengths of the light input being within a range of 400-1000 nanometers.

25. The system of claim **16**, the sample arm comprising a focusing device configured to adjust a diameter of the first light beam before the first light beam reaches the sample.

26. The system of claim **25**, the focusing device configured to be movable along a longitudinal axis of the first light beam.

27. The system of claim **26**, the controller further configured to control a movement of the focusing device.

28. The system of claim **16**, the sample arm comprising a sample stage configured to receive the sample, the sample stage configured to be movable.

29. The system of claim **16**, the sample stage configured to be movable along a longitudinal axis of the first light beam.

30. The system of claim **16**, the sample stage configured to be movable in a direction substantially perpendicular to a longitudinal axis of the first light beam.

31. The system of claim **16**, the controller further configured to control a movement of the stage.

32. The system of claim **16**, the spectrometer comprising a diffraction grating configured to splitting the light output into a plurality of light components having different wavelengths.

33. The system of claim **32**, the spectrometer further comprising a recording device configured to record the plurality of light components as electrical signals.

34. The system of claim **33**, the controller further configured to control the recording device.

35. The system of claim **33**, the recording device comprising a camera.

36. The apparatus of claim **1**, in which the reference arm comprises a reflecting device configured to adjust a diameter of the second light beam.

37. The apparatus of claim **36**, in which the reference arm is configured to be moveable along a longitudinal axis of the second light beam.

38. The apparatus of claim **37**, in which the reference arm further comprises a focusing device configured to be movable with the reflecting device.

39. The apparatus of claim **36**, in which the reference arm comprises at least one mirror configured to adjust a direction of the second light beam.

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