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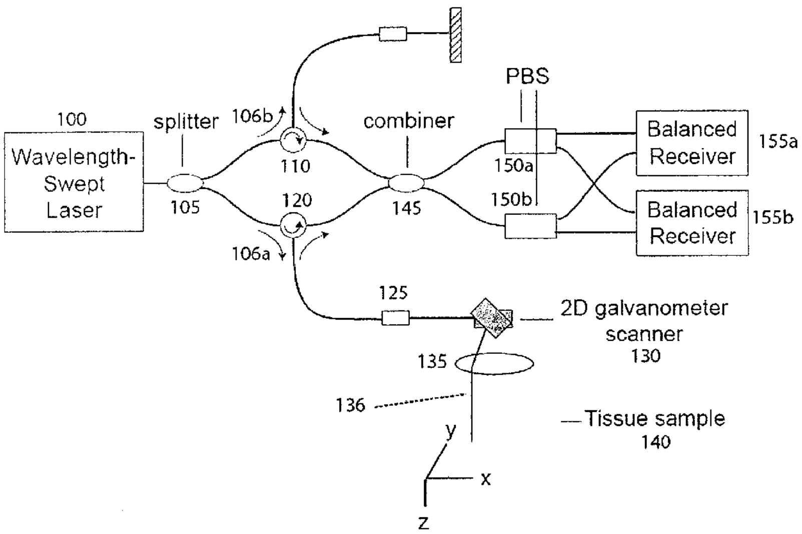

(57) Abstract: Apparatus and method can be provided, whereas a particular radiation which includes at least one first electro-magnetic radiation can be directed to at least one sample and at least one second electro-magnetic radiation can be directed to a reference. The first electro-magnetic radiation having a particular cross-sectional width may be applied to at least one portion of the sample to generate at least one third electro-magnetic radiation. The first electro-magnetic radiation can be provided in the portion along a particular axis for a distance between a multiplier of 0.5 and 100 of the particular cross-sectional width. An interference can be detected between the third electro-magnetic radiation associated with the first electro-magnetic radiation and at least one fourth electro-magnetic radiation associated with the second electro-magnetic radiation. Further, an asymmetrical cross-sectional area of the first electro-magnetic radiation can be provided.

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APPARATUS AND METHODS FOR ENHANCING OPTICAL COHERENCE TOMOGRAPHY IMAGING USING VOLUMETRIC FILTERING TECHNIQUES

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of priority from U.S. Patent Application Serial No. 60/840,213, filed August 25, 2006, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to apparatus and methods for enhancing optical coherence tomography imaging, and more particularly to such apparatus and methods which can enhance the contrast in the optical coherence tomography images using techniques employing three-dimensional (e.g., volumetric) filtering of measured data which may be used to generate these images.

BACKGROUND INFORMATION

A potential of the usage of optical coherence tomography ("OCT") as a diagnostic procedure and technique which is capable of providing high-resolution cross-sectional images of a tissue microstructure to depths of, e.g., 2 mm has been well appreciated. However, in a number of clinical applications, the diagnostic utility of the conventional OCT techniques has been limited by a confounding effect of a speckle noise. This noise, which can be a large magnitude amplitude noise at the size scale of the imaging resolution, can be produced from a coherence ranging technique which may be used to provide a depth sectioning of the evaluated tissue. Certain clinically relevant structures, despite being larger in size than the ~10 mm imaging resolution, may lack a sufficient intrinsic optical scattering contrast relative to the surrounding tissue to be clearly identified through this speckle noise.

The proposed approaches for mitigating the impact of speckle noise can be categorized as either physical compounding methods or digital processing methods. For example, the physical compounding methods generally function by combining multiple, speckle uncorrelated measurements of the same location in the analyzed tissue. The implementation of such methods may require modifications to the imaging system that can complicate a design of the catheter and the design of a minimally-invasive probe. Examples of these physical compounding methods can include angular compounding, frequency compounding, and polarization compounding (e.g., a polarization diversity detection). In contrast, the digital processing methods have conventionally been applied entirely to two-dimensional images using procedures or filters that aim to preferentially remove the speckle noise, while preserving certain features associated with the tissue structures. Such techniques include adaptive filtering, regularization, and wavelet denoising. However, the digital processing methods, unlike the compounding methods, are likely limited to the information content contained within the original speckled image. This, it is important for the digital processing methods to outperform the considerable ability of an experience implementer of the OCT to visually filter the noise and recognize the underlying tissue structures.

Such limitations, however, generally may not apply if the digital processing methods are extended to operate in three-dimensions on volumetric OCT datasets. Certain improvements in OCT imaging speeds have enabled the practical clinical implementation of the volumetric imaging using OCT methods and systems. Thus, there is now an underlying clinical motivation to employ such methods and systems as tools for a comprehensive disease screening. Since these three-dimensional datasets may not be directly visualized, a diagnosis may typically be rendered from one or more images sectioned from the dataset. Preferably, these sectioned images can incorporate measured information both from within the section plane (e.g., in-plane measurements) and from adjacent locations out of the sectioning plane (e.g., out-of-plane measurements).

Indeed, there may be a need to overcome at least some of the deficiencies associated with the conventional arrangements and methods described above. For example, this can be achieved by the volumetric filtering of the dataset prior to the sectioning thereof. Because this exemplary process can increase the information content of the resultant image through inclusion of out-of-plane measurements, substantial enhancement can be achieved.

OBJECTS AND SUMMARY OF EXEMPLARY EMBODIMENTS OF THE INVENTION

To address and/or overcome at least some of the above-described problems and/or deficiencies, exemplary embodiments of apparatus and methods can be provided which can enhance the contrast in the optical coherence tomography images using techniques employing three-dimensional (e.g., volumetric) filtering of measured data which may be used to generate these images.

According to one exemplary embodiment of the present invention, datasets can be filtered in three dimensions such that enhanced images may be generated. In a first exemplary embodiment of the present invention, an asymmetric volumetric median filter can be applied to a three-dimensional OCT dataset prior to imaging the particular section of the tissue. In this exemplary embodiment, the filtering kernel can be larger in the dimension out-of-plane with respect to the image section that the dimensions in-plane. In a second exemplary embodiment of the present invention, an OCT imaging system can be provided which may be configured to produce a dithered beam scanning pattern to enable volumetric imaging to be performed with a high fidelity in the presence of a substantial sample motion. Appropriate filtering of this dataset acquired with the dithered beam allows the generation of an enhanced two-dimensional image.

Thus, an exemplary embodiment of the apparatus and method according to the present invention can be provided for at least such reasons. For example, at least one first fiber arrangement and at least one second fiber arrangement can be provided (each of which having optical transmitting characteristics. The first fiber arrangement can be configured to transmit there through at least one electromagnetic radiation and forward the at least one electromagnetic radiation to at least one sample. The second fiber can be configured to transmit there through at least one electromagnetic radiation received from the sample, and may house therein at least one portion of the first fiber arrangement.

According to another exemplary embodiment of the present invention, the first and second fiber arrangement may each be a fiber. The first and second fibers may be filtered using at least one of the first and second filtering arrangements to prevent at least one portion of each of the respective transmitted and received electromagnetic radiations having particular wavelengths from being forwarded therein. Further, the received electromagnetic radiation can be a Raman radiation associated with the sample.

In addition, according to a particular exemplary embodiment of the present invention, the apparatus and method can be provided, whereas a particular radiation which includes at least one first electro-magnetic radiation can be directed to at least one sample and at least one second electro-magnetic radiation can be directed to a reference. The first electro-magnetic radiation having a particular cross-sectional width may be applied to at least one portion of the sample to generate at least one third electro-magnetic radiation. The first electro-magnetic radiation can be provided in the portion along a particular axis for a distance between a multiplier of 0.5 and 100 of the particular cross-sectional width. An interference can be detected between the third electro-magnetic radiation associated with the first electro-magnetic radiation and at least one fourth electro-magnetic radiation associated with the second electro-magnetic radiation. Further, an asymmetrical cross-sectional area of the first electro-magnetic radiation can be provided.

According to another exemplary embodiment of the present invention, an upper bound of the multiplier can be 50, 60, 70, 80 and/or 90 of the particular cross-sectional width. The first electro-magnetic radiation in the portion can be translated along a further axis which is different from the particular axis. At least one image associated with the at least one portion can be generated as a function of the interference. The first electro-magnetic radiation can be translated in the portion in a sinusoidal pattern, a triangular pattern, a saw-tooth pattern and/or a spiral pattern.

In still another exemplary embodiment of the present invention, the first electro-magnetic radiation may have a particular cross sectional width along a particular axis that can be greater than a further cross-sectional width of the first electro-magnetic radiation along any other axis. The first electro-magnetic radiation may also have a particular cross sectional width along a particular axis that is greater by a factor of at least 2 than a further cross-sectional width of the first electro-magnetic radiation along another axis. In addition, the first electro-magnetic radiation can be translated in the portion along a further axis, and the further axis can be approximately perpendicular to the particular axis. An amplitude profile and/or a phase profile of the first electro-magnetic radiation can be modulated. At least one of a spatial light modulating arrangement, a galvanometer arrangement, acousto-optical modulating arrangement, a wave-guide mode scrambling arrangement, and/or an asymmetric wave-guide arrangement can be provided. The asymmetric wave-guide arrangement can be configured to propagate at least three orthogonal modes of the first electro-magnetic radiation.

These and other objects, features and advantages of the present invention will become apparent upon reading the following detailed description of embodiments of the invention, when taken in conjunction with the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects, features and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying figures showing illustrative embodiments of the invention, in which:

Fig. 1 is a schematic block diagram of an exemplary embodiment of an optical frequency domain imaging ("OFDI") system according to the present invention which can be used to acquire volumetric datasets;

Fig. 1B is an exemplary irradiation diagram according to one exemplary embodiment of the present invention which in a raster-scanned pattern;

Fig. 1C is an exemplary irradiation diagram according to another exemplary embodiment of the present invention which in a dithered beam scan pattern;

Fig. 2A is an exemplary image which has been unfiltered;

Fig. 2B is an exemplary image set which has been enhanced that can result from the application of the volumetric median filtering procedure with varying kernel sizes in in-plane and out-of-plane dimensions according to another exemplary embodiment of the present invention;

Fig. 2C is a second exemplary image which has been enhanced that can result from the application of the volumetric median filtering procedure according to an exemplary embodiment of the present invention with the kernel size which is similar to the kernel size of Fig. 2A;

Fig. 3A is an exemplary image that is un-enhanced with an application of a dithering beam;

Fig. 3B is an exemplary image that is enhanced by the application of the dithered beam with a first amplitude according to one exemplary embodiment of the present invention;

Fig. 3C is another exemplary image that is enhanced by the application of the dithered beam with a first amplitude according to another exemplary embodiment of the present invention;

Fig. 4A is a depiction of a first exemplary dithered beam scan pattern according to one exemplary embodiment of the present invention;

Fig. 4B is a depiction of a second exemplary dithered beam scan pattern according to another exemplary embodiment of the present invention;

Fig. 4C is a depiction of a third exemplary dithered beam scan pattern according to a further exemplary embodiment of the present invention;

Fig. 5A is an illustration of a symmetric elliptical imaging beam according to one exemplary embodiment of the present invention;

Fig. 5B is an illustration of an asymmetric elliptical imaging beam according to a particular exemplary embodiment of the present invention

Fig. 6A is a front view of a schematic diagram of an exemplary asymmetric waveguide arrangement which can be used for conveying an imaging beam from the imaging system to the sample according to an exemplary embodiment of the present invention;

Fig. 6B is a side view of an exemplary endoscopic optical imaging probe according to an exemplary embodiment of the present invention which can use a fiber shown in Fig. 6A;

Fig. 6C is a top view of the schematic diagram of the probe of Fig. 6B;

Fig. 7 is an operational diagram of an exemplary method for reducing speckle using the rectangular core fiber in combination with a rotating mirror according to one exemplary embodiment of the present invention;

Fig. 8 is an operational diagram of another exemplary method for reducing the speckle using the rectangular core fiber in combination with a linear spatial light modulator according to another exemplary embodiment of the present invention;

Fig. 9 is an operational diagram of an exemplary method for modulating the optical phase/amplitude profile of a rectangular mode fiber according to an exemplary embodiment of the present invention; and

Fig. 10 is a diagram of an exemplary endoscopic imaging arrangement for generating a dithered beam scan using a piezo-actuator to vibrate the fiber end prior to focusing by a lens according to a particular exemplary embodiment of the present invention.

Throughout the figures, the same reference numerals and characters, unless otherwise stated, are used to denote like features, elements, components or portions of the illustrated embodiments. Moreover, while the subject invention will now be described in detail with reference to the figures, it is done so in connection with the illustrative embodiments. It is intended that changes and modifications can be made to the described embodiments without departing from the true scope and spirit of the subject invention as defined by the appended claims.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Figs. 1A shows an illustration of a second-generation optical coherence tomography ("OCT") imaging system based on optical-frequency domain imaging ("OFDI") technology according to an exemplary embodiment of the present invention. The system of Fig. 1A can utilize a wavelength-swept narrowband laser source 100 to record interference fringes as a function of a wavelength using single-element photo-receivers. Although the exemplary system shown in Fig. 1A is described herein as being capable of employing the OFDI techniques, other exemplary embodiments of the methods and arrangements according to the present invention can be equally compatible with other OCT imaging systems, including but not limited to time-domain OCT and spectral-domain OCT techniques.

As shown in Fig. 1A, a light or other electro-magnetic radiation provided from the source 100 can be divided at a splitter 105 into a reference path 106a and a sample path 106b. The sample path 106a can be directed to a sample 140 via an optical circulator 120, a two-dimensional galvanometer mirror 130, and a focusing lens 135. The reference light is directed through the reference path 106b which may be intended to match the optical path length of the sample path 106a. Certain exemplary configurations are known to achieve this functionality, including non-reflective paths and the configuration depicted in Fig. 1A in which a circulator can be used to direct the reference light to a variable delay line 115. The returned reference and sample lights interfere with one another at a combiner 145. The output beams from the combiner 145 may be directed to a first polarization beam splitter (PBS) 150a and a second PBS 150b, the respective outputs of which can be directed to a first balanced receiver 155a and a second balanced receiver 155b.

Conventional processing techniques can be used to convert the measured interference fringes to A-lines that describe the depth-resolved reflectivity in the sample. Exemplary images may be acquired by scanning an imaging beam 136 in two dimensions using a two-dimensional galvanometer mirror 130. For example, arbitrary beam scan patterns in an X-Y plane on a surface of the sample 140 can be generated. As shown in Fig. 1B, volumetric imaging techniques can, for example, be performed by scanning rapidly along the x-dimension, and repeating for various displacements in the y-dimension (160a,160b, 160c, 160d). Alternatively or in addition, the beam can be dithered such that the beam oscillates rapidly in the y-dimension while the beam scans more slowly in the x-dimension 165, as shown in Fig. 1C. Such exemplary scanning techniques can facilitate the recording of the images in three-dimensions, and enable the application of the volumetric filtering techniques.

Fig. 2A illustrates an exemplary single cross-sectional image 190 (in x-z plane) obtained from a dataset using a scan pattern depicted in Fig. 1B without applying the volumetric filtering to illustrate the substantial speckle noise in the baseline image. Figs. 2B and 2C show exemplary OFDI images acquired from a human skin using the scan pattern of Fig. 1B for various sizes of volumetric median filters operating in the in-plane (x-z) and out-of-plane (y) dimensions.

For example, a subset of the image including the boundary of the epidermis and dermis as indicated in Fig. 2A is shown in Fig. 2B without filtering (a left-most image 191) and in the images 192-194 of the upper row for increasing in-plane filter kernel sizes with no out-of-plane filtering. These exemplary results demonstrate the capabilities and limitations of conventional 2D median filtering algorithms. A substantial blurring is provided in these images that accompanies the reduction in the speckle. In the lower row of images 195-197 shown in Fig. 2B, the effect of increasing out-of-plane filter kernel size (with no in-plane filtering) is provided. A clear enhancement in structural visibility without feature blurring can be observed despite the use of filter sizes equivalent to those used in the in-plane results. These exemplary results provide preferable image enhancement results from the use of volumetric filters that are highly asymmetric in size, with minimal filtering in-plane to the image section and substantial filtering out-of-plane. Fig. 2C shows an exemplary cross-sectional image 198 generated based on a combination of in-plane and out-of-plane filtering estimated to produce optimal image enhancement.

Fig. 3A shows exemplary OFDI images 50, 51 generated without a correction thereof by dithered beam scanning (e.g., peak-to-peak dither amplitudes of 0 μm). Figs. 3B and 3C show exemplary images 52, 53 and 54, 55, respectively, that have been enhanced by the application of the dithered beam with different respective amplitudes according to an exemplary embodiment of the present invention. For example, a scan using the dithered beam scan be implemented using a 2-D galvanometer with the y-axis mirror driven with a sinusoidal waveform at 500 Hz and varying amplitudes. With the system A-line rate of, e.g., 10 kHz, a single dither period may contain 20 unique A-lines. An exemplary filtering technique can be performed by assembling the acquired dataset as a single image and applying a 2D median filter. To determine preferable dither amplitudes, measurements of human skin in vivo can be obtained at peak-to-peak dither amplitudes of, e.g., 0 μm to 70 μm in steps of, e.g., 17.5 μm. Exemplary median filtering techniques can be performed over a single dither period yielding an in-plane filter size of, e.g., 5 μm (x-dimension) by, e.g., 7.5 μm (z) and an out-of –plane filter size varying from 0 to 70 μm. Figs. 3B and 3C show the resulting images 52, 53 and 54, 55 for peak-to-peak dither amplitudes of 35 μm, and of 70, respectively.

Figs .4A-4C depict three exemplary dithered scan patterns according to the exemplary embodiments of the present invention. For example, Fig. 4a illustrates an exemplary sinusoidal scan pattern 200 which includes a fast zero-mean modulation in the y-dimension and slow, constant velocity scanning in the x-dimension. Fig. 4B depicts an exemplary spiral scan pattern 205 that can be generated by scanning the x and y dimensions at the same or similar frequency with a 90 degree phase difference while also including a fixed speed slow scanning in the x-dimension. Fig. 4C shows an exemplary diagonal scan pattern 210, in which the y-dimension is driven by a fast saw-tooth pattern and the x-dimension by a slow fixed speed scan. The extent of displacement in the y-dimension may be, for example, approximately 0.5 to 100 times the focused beam cross-sectional width.

Fig. 5A depicts an exemplary symmetric imaging beam profile that can enable imaging of the sample with unequal in-plane and out-of-plane resolution scales. In Fig. 5A, a circular Gaussian beam focus is illustrated, in which the beam profile at a focus 300 is symmetric in the x (scan direction) and y (out-of-plane dimension) dimensions. Fig. 5B shows an exemplary asymmetric imaging beam profile that can enable the imaging of the sample. In Fig. 5B, an asymmetric beam profile 305 with a larger extend in the y-dimension can be used. The beam scan shown in Fig. 5B cab be generated using a combination of spherical and cylindrical focusing optics or the use of a non-circular waveguide as depicted in Figs. 6A-6C.

For example, Fig. 6A shows an exemplary asymmetric waveguide arrangement which can be used for conveying the imaging beam from the imaging system to the sample. For example, a core 400 of this waveguide arrangement (which can be optionally glass optical fiber or photonic band-gap fiber) may have a larger extent in one dimension relative to another dimension. A cladding 405 of the arrangement can be circular as shown in Fig. 6A or asymmetric in shape. As a result, the use of spherical focusing optics to image this beam onto the sample can result in a similarly asymmetric beam profile on the sample.

Fig. 6B shows an exemplary endoscopic optical imaging probe according to the exemplary embodiment of the present invention which can use this fiber that may result in an asymmetric imaging beam profile on the sample. For example, the optical fiber having the asymmetric core 410 can be rotated or placed within an outer drive shaft 425 to increase torque conveyance. At the end of the optical fiber, the light can be expand through a section 411, such as air or amorphous glass and focused by a lens 415, and directed sideways by a prism 420 or a mirror. The lens 415 can produce a focused spot at an approximate distance □r away from the fiber probe. The angular orientation of the fiber is such that the focused beam can be larger in the Z dimension than the x dimension as shown in Fig. 6B. By rotating the fiber or a drive shaft 425, the asymmetric imaging beam can be translate and may facilitate imaging of a hollow organ. Fig. 6C shows the imaging probe from a front view illustrating a tighter focus and a smaller spot size in the x-dimension as compared to the y-dimension.

Fig. 7 shows an operational diagram of an exemplary method for reducing speckle using the rectangular core fiber in combination with a rotating mirror according to one exemplary embodiment of the present invention. Fig. 7 also illustrates an arrangement according to an exemplary embodiment of the present invention which is configured to couple the imaging beam from the system to a proximal end of the rectangular core fiber (e.g., that is used for imaging). For example, the arrangement of Fig. 7 enables that phase and amplitude profile of the imaging beam at the distal end of the fiber to be modulated. In this exemplary arrangement, a fiber asymmetric core 502 can be configured to support multiple optical modes in the dimension of the core with the larger extent. By exciting each mode or different combination of these modes, multiple measurements of reflectivity can be obtained each with a decorrelated speckle noise. The combination of these measurements may enable the speckle-reduced imaging to be performed. As shown in Fig. 7, a Gaussian symmetric input beam 510 can be directed from the imaging system to a galvanometer mirror 515. This mirror 515 may direct the light through a lens 505 to focus onto the core at various transverse positions within the rectangular extent of the core. By tilting the galvanometer mirror 515, the excited phase/amplitude profile of the core can be modulated at the proximal end, and therefore may also be modulated at the distal end. A similar probe design as that shown in Fig. 6B can be used for the endoscopic imaging. For example, a returned light can be recollected through the same or similar optics.

Fig. 8 depicts an operational diagram of an exemplary method for modulating the optical phase/amplitude profile of a rectangular mode fiber according to an exemplary embodiment of the present invention, which may be similar to that described in Fig. 7. Fig. 8 also illustrates another exemplary embodiment of the arrangement which can implement this exemplary method. However, as shown in Fig. 8, a linear spatial light modulator 615 can be instead of the galvanometer mirror 515. For example, an input beam 610 from the system can be passed through the linear spatial light modulator 615 that is capable of rapidly modifying the phase and/or amplitude profile of the beam. This light can be focused through a lens 605 onto a core 602 of a rectangular core fiber 600. Instead of the spatial light modulator 615, an acousto-optic modulator or electro-optic modulator could be used to modify the beam profile.

Fig. 9 illustrates an operational diagram of an exemplary method for modulating the optical phase/amplitude profile of a rectangular mode fiber according to an exemplary embodiment of the present invention. For example, the light in a core 702 passes through a portion of the fiber located between a stiff stationary backing 705 and an actuator 710. An activation of an actuator 710 can produce a downward or upward motion that changes the compressive stresses within the fiber, and can perturb the modal profile. The actuator 710 can optionally be a piezo-electric stack actuator, and the orientation of the core 702 relative to the actuator can be as shown in Fig. 9 or rotated.

Fig. 10 depicts a diagram of an exemplary endoscopic imaging arrangement for generating a dithered beam scan (similar to the pattern shown in Fig. 4A) using a piezo-actuator small diameter endoscopic imaging probe to vibrate the fiber end prior to focusing by a lens according to a particular exemplary embodiment of the present invention. As shown in Fig. 10, an optical fiber 800 can direct an imaging light to the focusing lens 820. A piezo-actuator 805 can be driven with a sinusoidal signal such that the fiber tip vibrates. The light from the fiber can be expanded in an air gap 815, focused by a lens 820, and directed sideways by a prism 825. As a result of the vibrating fiber tip, the focused spot of an imaging beam 830 may oscillate in an indicated dithered pattern 835. A rotation of the entire catheter that is contained within a housing 810 can scan the beam internally, for example, in a hollow cylindrical organ 840.

The foregoing merely illustrates the principles of the invention. Various modifications and alterations to the described embodiments will be apparent to those skilled in the art in view of the teachings herein. Indeed, the arrangements, systems and methods according to the exemplary embodiments of the present invention can be used with imaging systems, and for example with those described in International Patent Application PCT/US2004/029148, filed September 8, 2004, U.S. Patent Application No. 11/266,779, filed November 2, 2005, and U.S. Patent Application No. 10/501,276, filed July 9, 2004, the disclosures of which are incorporated by reference herein in their entireties. It will thus be appreciated that those skilled in the art will be able to devise numerous systems, arrangements and methods which, although not explicitly shown or described herein, embody the principles of the invention and are thus within the spirit and scope of the present invention. In addition, to the extent that the prior art knowledge has not been explicitly incorporated by reference herein above, it is explicitly being incorporated herein in its entirety. All publications referenced herein above are incorporated herein by reference in their entireties.

What Is Claimed Is:

1. An apparatus comprising:

at least one first arrangement configured to provide a particular radiation which includes at least one first electro-magnetic radiation directed to at least one sample and at least one second electro-magnetic radiation directed to a reference;

at least one second arrangement configured to apply the at least one first electro-magnetic radiation having a particular cross-sectional width to at least one portion of the at least one sample to generate at least one third electro-magnetic radiation, wherein the at least one second arrangement is further configured to translate the at least one first electro-magnetic radiation in the at least one portion along a particular axis for a distance between a multiplier of 0.5 and 100 of the particular cross-sectional width; and

at least one third arrangement configured to detect an interference between the at least one third electro-magnetic radiation associated with the at least one first electro-magnetic radiation and at least one fourth electro-magnetic radiation associated with the at least one second electro-magnetic radiation.

2. The apparatus according to claim 1, wherein an upper bound of the multiplier is at least one of 50, 60, 70, 80 or 90 of the particular cross-sectional width.

3. The apparatus according to claim 1, wherein the at least one second arrangement is configured to translate the at least one first electro-magnetic radiation in the at least one portion along a further axis which is different from the particular axis.

4. The apparatus according to claim 1, further comprising at least one fourth arrangement configured to generate at least one image associated with the at least one portion as a function of the interference.

5. The apparatus according to claim 1, wherein the at least one second arrangement is further configured to translate the at least one first electro-magnetic radiation in the at least one portion in at least one of a sinusoidal pattern, a triangular pattern, a saw-tooth pattern or a spiral pattern.

6. The apparatus according to claim 1, wherein the at least one second arrangement is further configured to provide an asymmetrical cross-sectional area of the at least one first electro-magnetic radiation.

7. A method comprising:

providing a particular radiation which includes at least one first electro-magnetic radiation directed to at least one sample and at least one second electro-magnetic radiation directed to a reference;

applying the at least one first electro-magnetic radiation having a particular cross-sectional width to at least one portion of the at least one sample to generate at least one third electro-magnetic radiation;

translating the at least one first electro-magnetic radiation in the at least one portion along a particular axis for a distance between a multiplier of 0.5 and 100 of the particular cross-sectional width; and

detecting an interference between the at least one third electro-magnetic radiation associated with the at least one first electro-magnetic radiation and at least one fourth electro-magnetic radiation associated with the at least one second electro-magnetic radiation.

8. An apparatus comprising:

at least one first arrangement configured to provide a particular radiation which includes at least one first electro-magnetic radiation directed to at least one sample and at least one second electro-magnetic radiation directed to a reference;

at least one second arrangement configured to apply the at least one first electro-magnetic radiation to at least one portion of the at least one sample to generate at least one third electro-magnetic radiation, wherein the at least one second arrangement is further configured to provide an asymmetrical cross-sectional area of the at least one first electro-magnetic radiation; and

at least one third arrangement configured to detect an interference between the at least one third electro-magnetic radiation associated with the at least one first electro-magnetic radiation and at least one fourth electro-magnetic radiation associated with the at least one second electro-magnetic radiation.

9. The apparatus according to claim 8, wherein the at least one first electro-magnetic radiation has a particular cross sectional width along a particular axis that is greater than a further cross-sectional width of the at least one first electro-magnetic radiation along any other axis.

10. The apparatus according to claim 8, wherein the at least one first electro-magnetic radiation has a particular cross sectional width along a particular axis that is greater by a factor of at least 2 than a further cross-sectional width of the at least one first electro-magnetic radiation along another axis.

11. The apparatus according to claim 10, wherein the at least one second arrangement is further configured to translate the at least one first electro-magnetic radiation in the at least one portion along a further axis, and wherein the further axis is approximately perpendicular to the particular axis.

12. The apparatus according to claim 10, further comprising at least one fourth arrangement configured to modulate at least one of an amplitude profile or a phase profile of the at least one first electro-magnetic radiation.

13. The apparatus according to claim 12, wherein the at least one fourth arrangement includes at least one of a spatial light modulating arrangement, a galvanometer arrangement, acousto-optical modulating arrangement or a wave-guide mode scrambling arrangement.

14. The apparatus according to claim 8, wherein the at least one second arrangement includes at least one asymmetric wave-guide arrangement.

15. The apparatus according to claim 14, wherein the at least one asymmetric wave-guide arrangement is configured to propagate at least three orthogonal modes of the at least one first electro-magnetic radiation.

16. The apparatus according to claim 8, wherein the at least one second arrangement is further configured to translate the at least one first electro-magnetic

radiation in the at least one portion along a particular axis for a distance between a multiplier of 0.5 and 100 of the particular cross-sectional width.

17. A method comprising:

providing a particular radiation which includes at least one first electro-magnetic radiation directed to at least one sample and at least one second electro-magnetic radiation directed to a reference;

applying the at least one first electro-magnetic radiation to at least one portion of the at least one sample to generate at least one third electro-magnetic radiation;

providing an asymmetrical cross-sectional area of the at least one first electro-magnetic radiation; and

detecting an interference between the at least one third electro-magnetic radiation associated with the at least one first electro-magnetic radiation and at least one fourth electro-magnetic radiation associated with the at least one second electro-magnetic radiation.

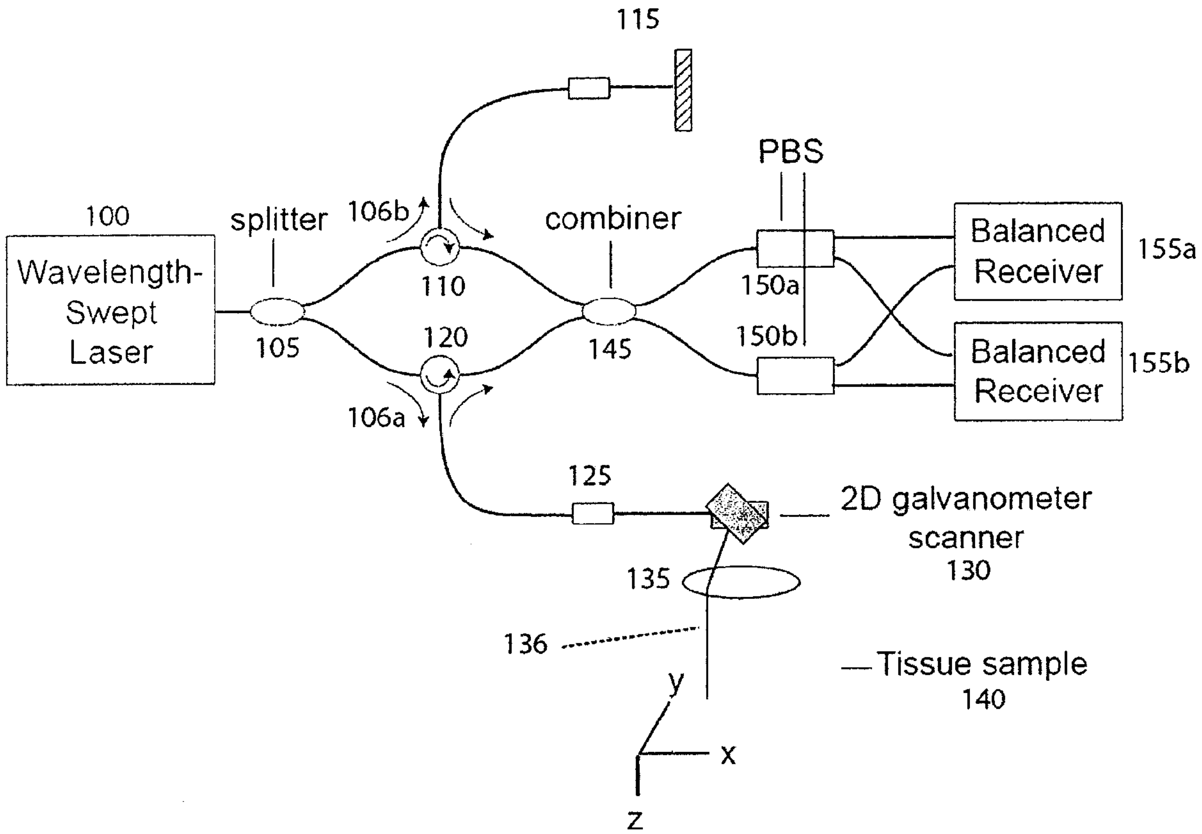

FIG. 1A

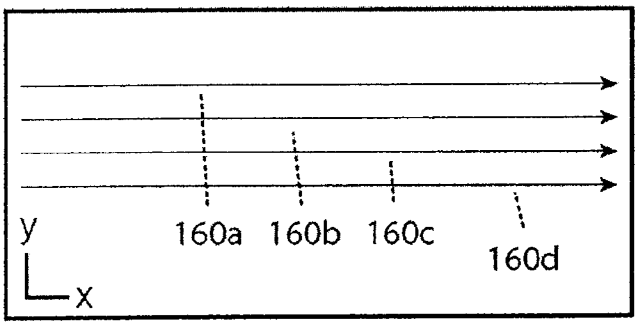

FIG. 1B

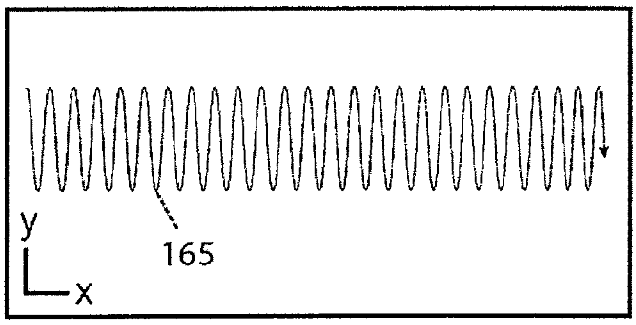

FIG. 1C

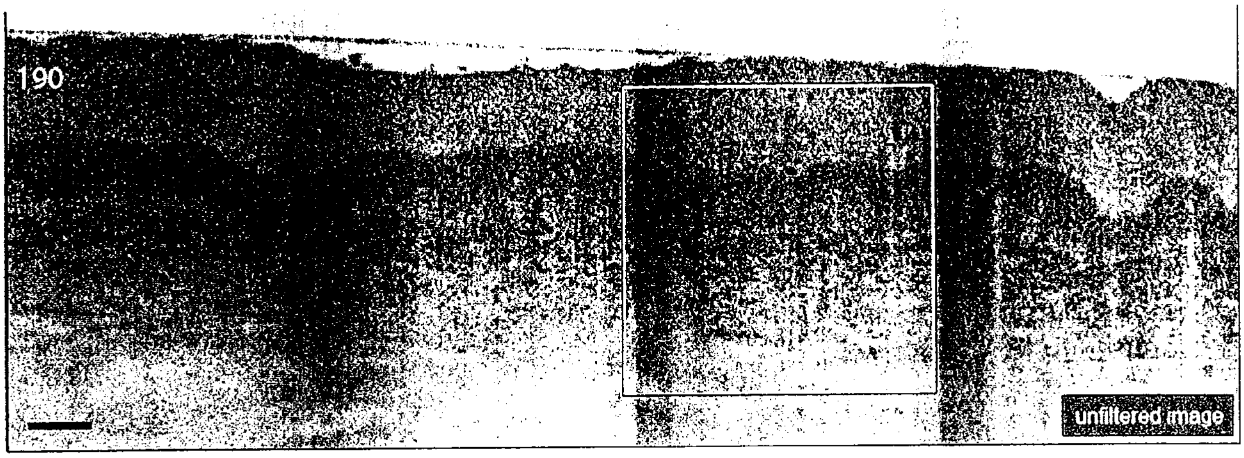

FIG. 2A

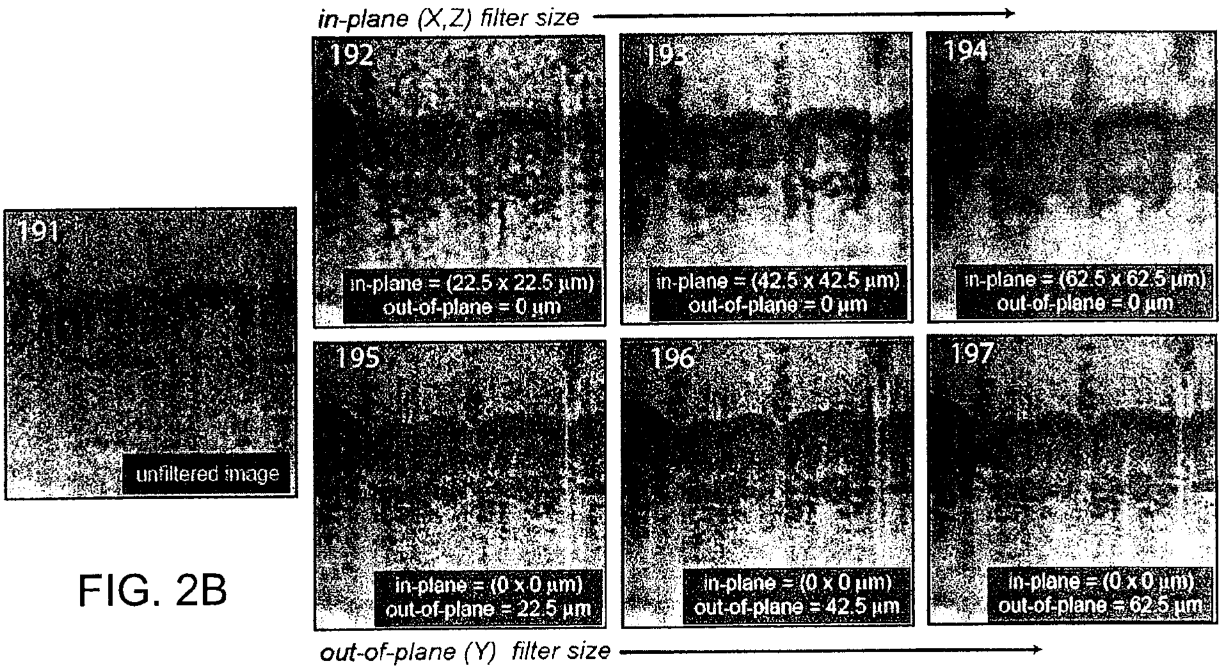

FIG. 2B

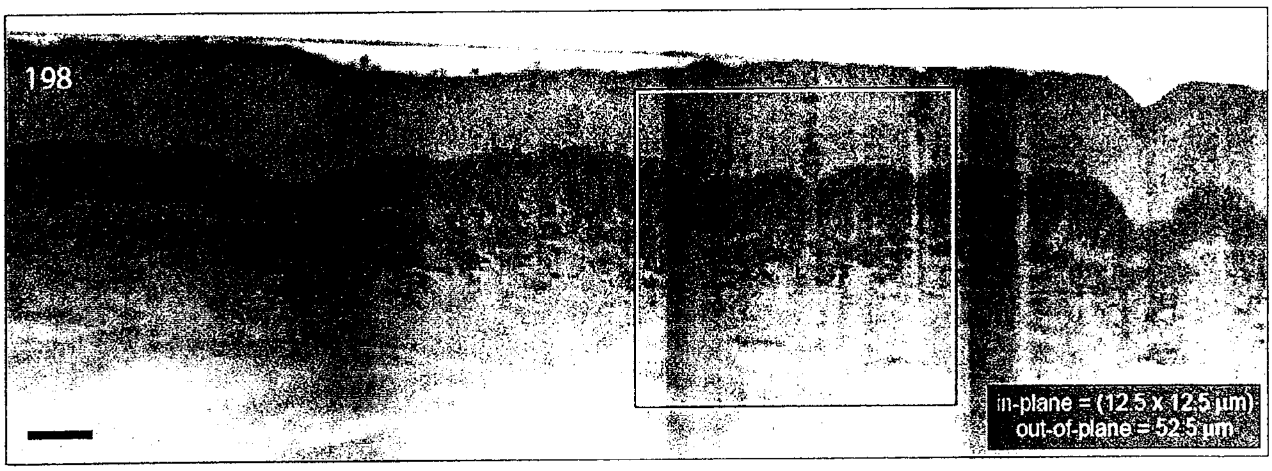

FIG. 2C

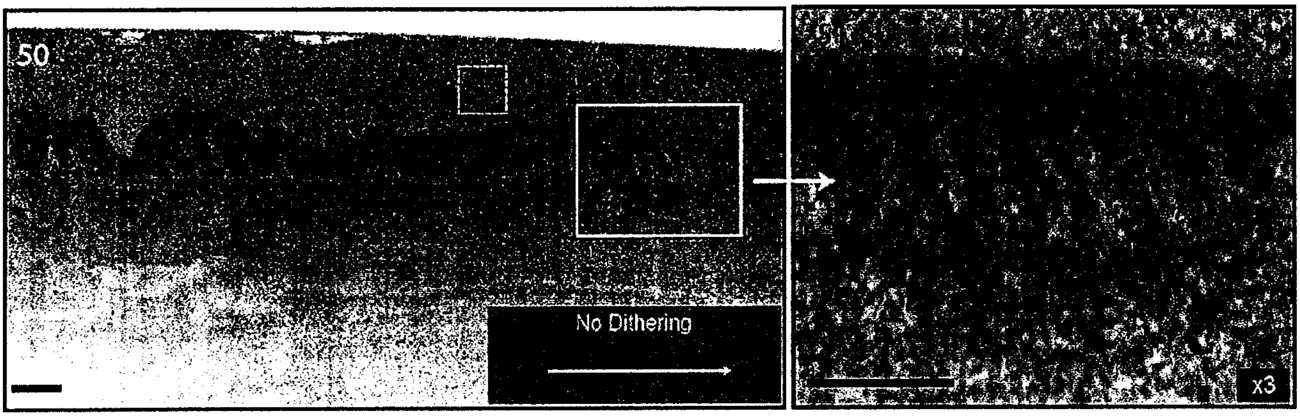

FIG. 3A

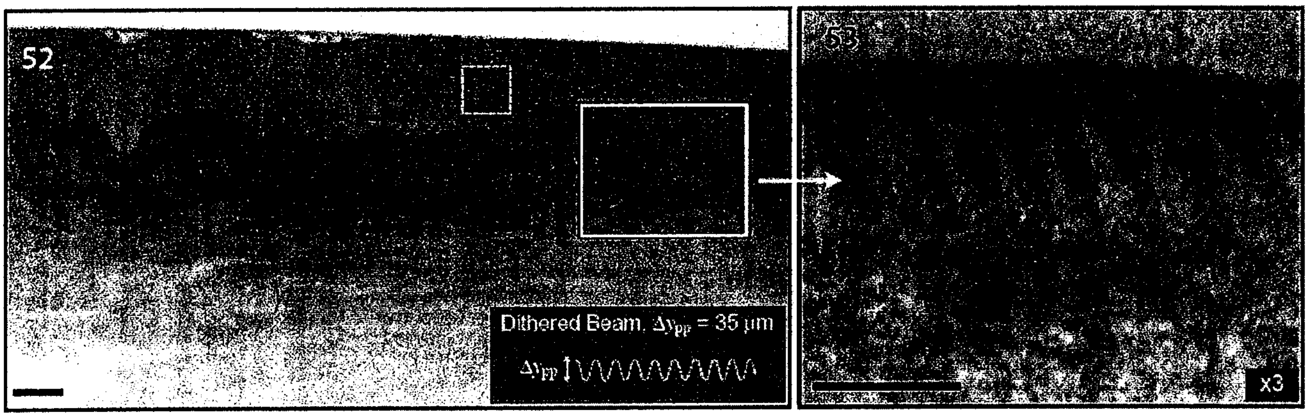

FIG. 3B

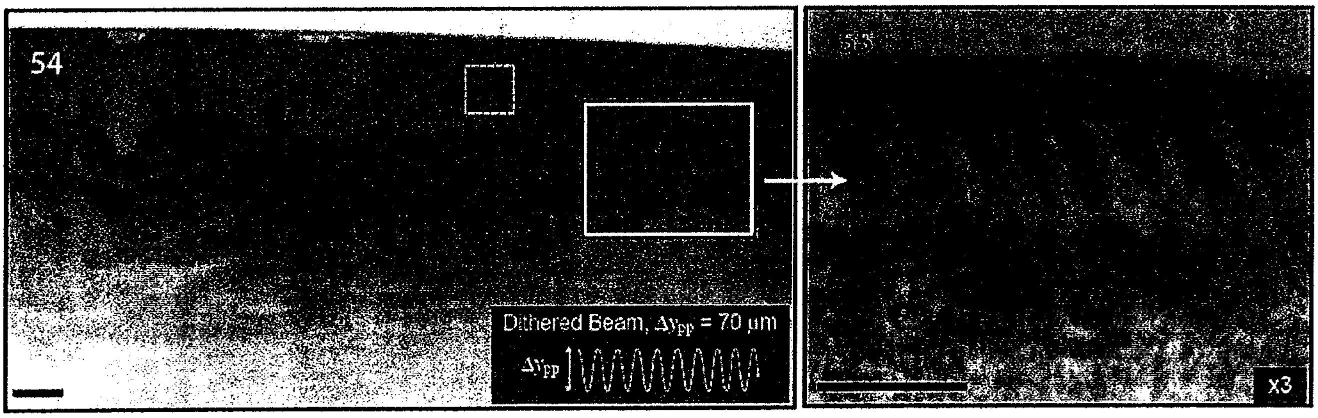

FIG. 3C

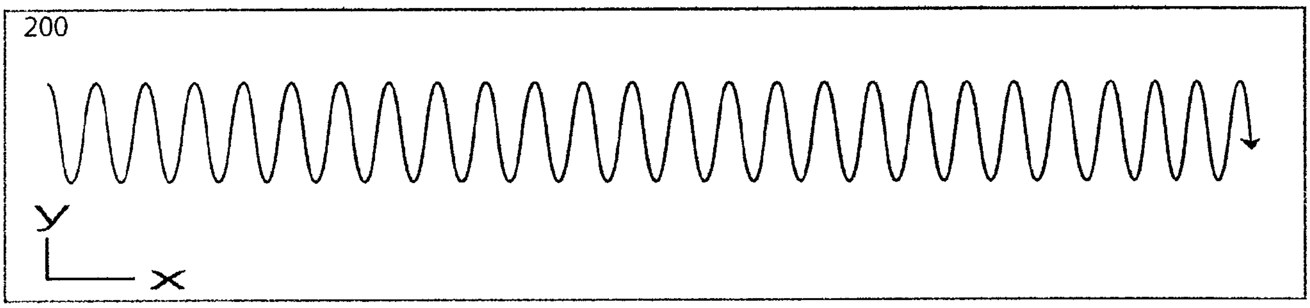

FIG. 4A

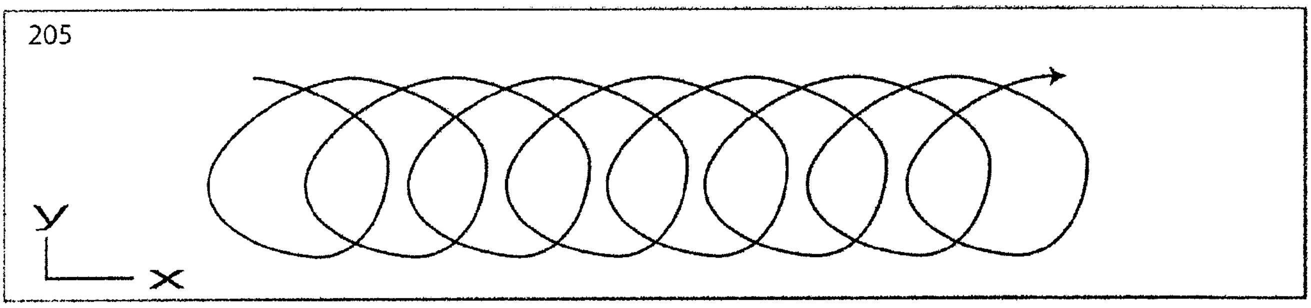

FIG. 4B

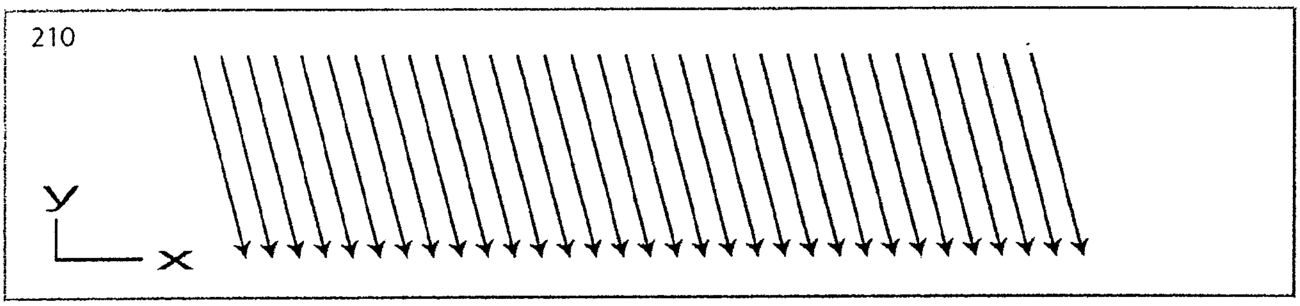

FIG. 4C

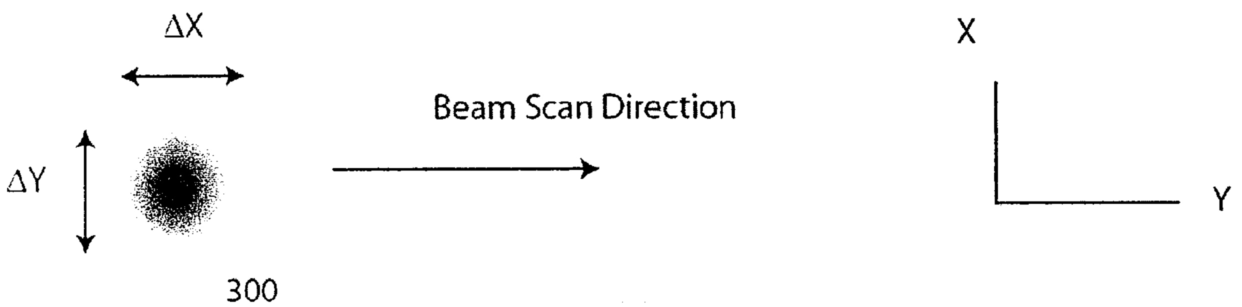
ΔX
Beam Scan Direction
X
ΔY
Y
300

FIG. 5A

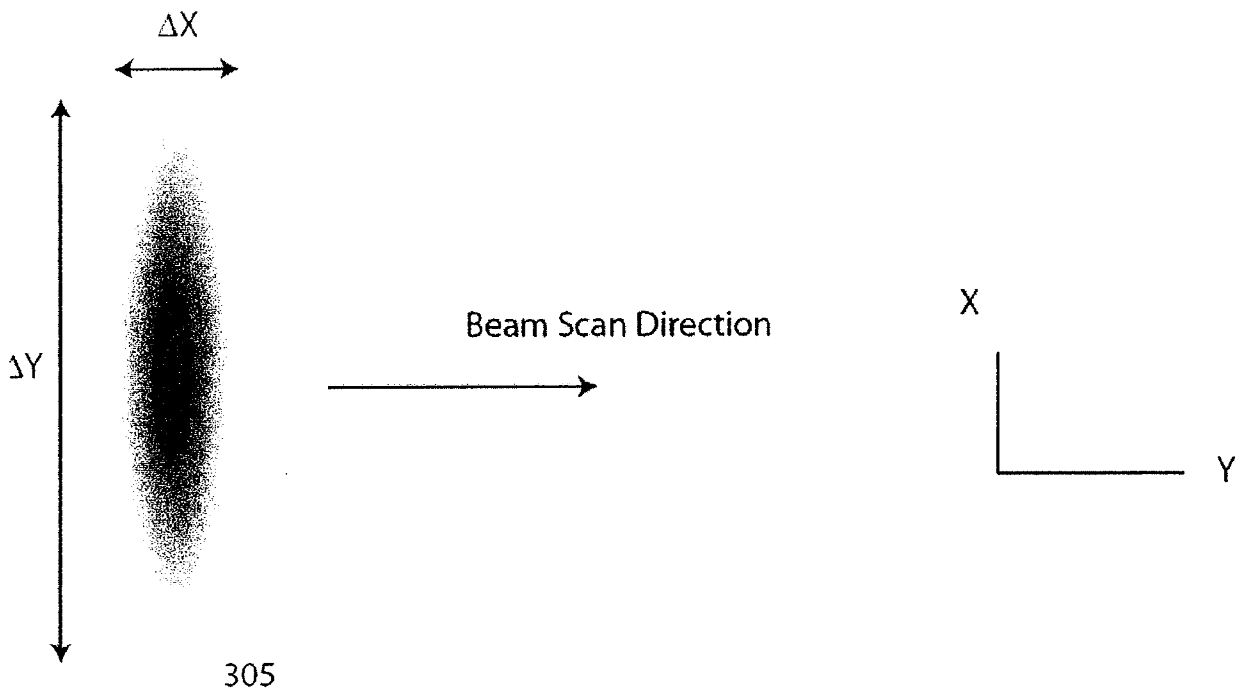
ΔX
Beam Scan Direction
X
ΔY
Y
305

FIG. 5B

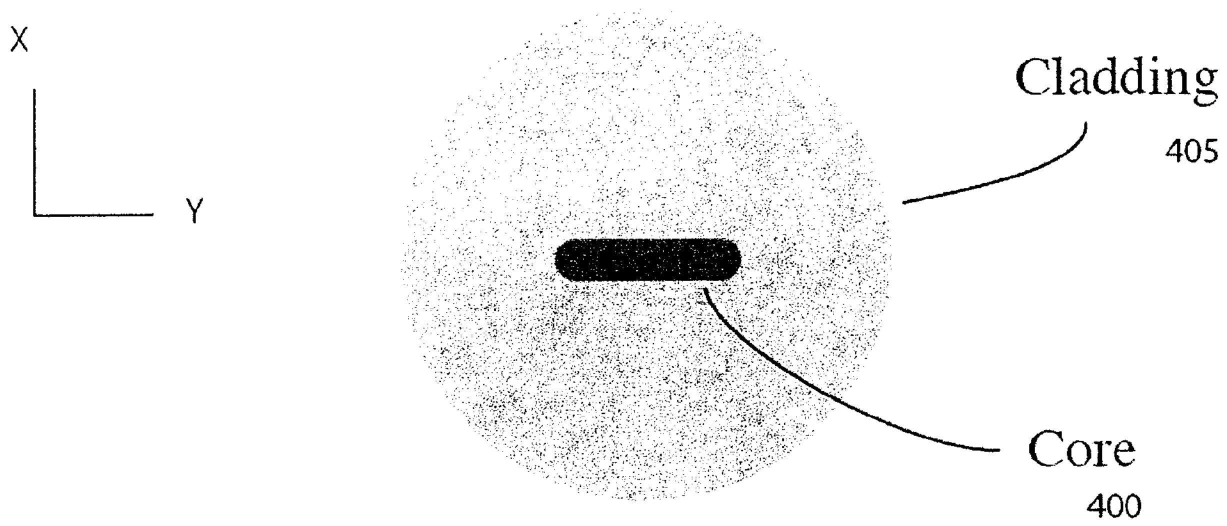

FIG. 6A

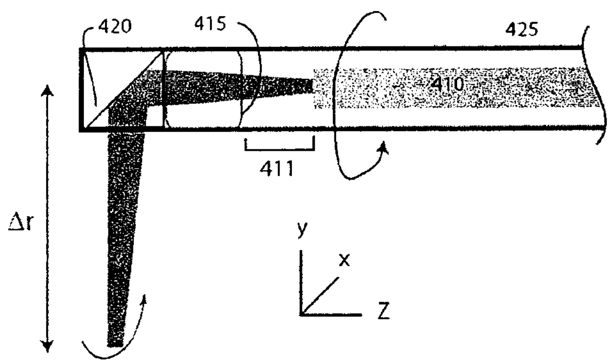

FIG. 6B

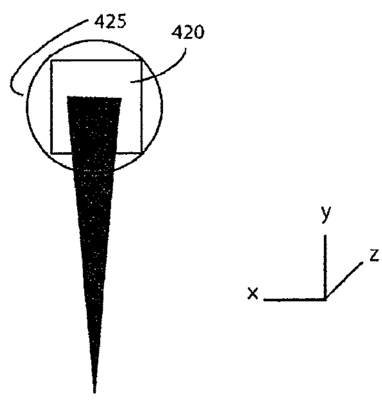

FIG. 6C

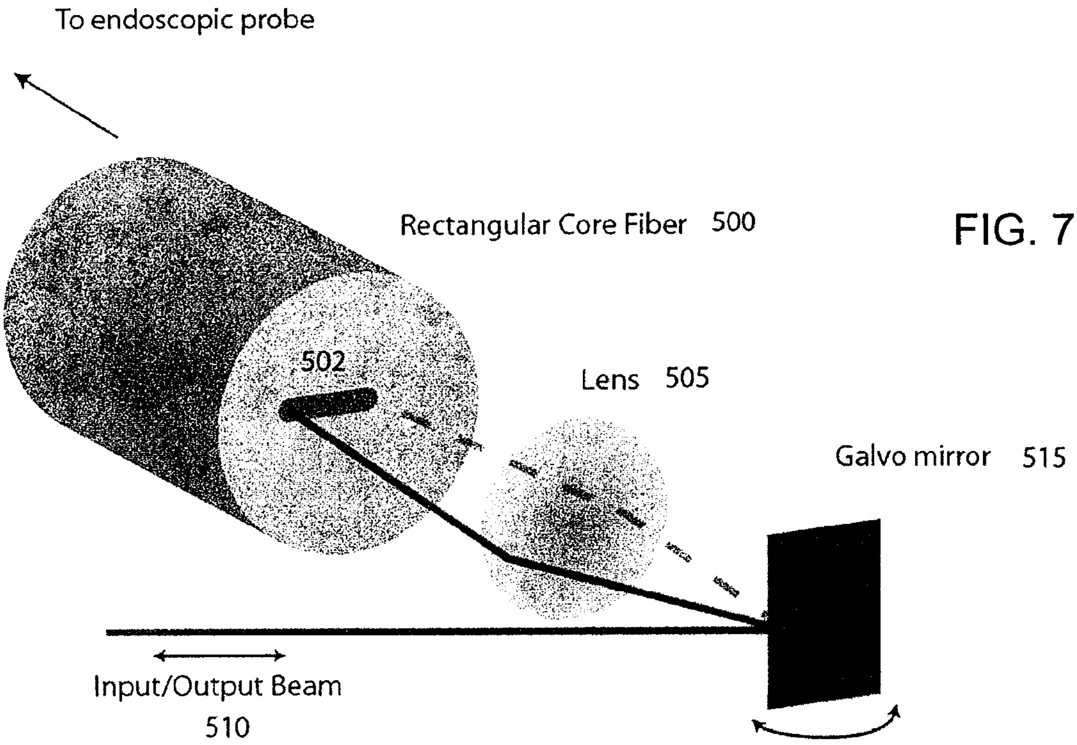
To endoscopic probe
Rectangular Core Fiber 500
502
Lens 505
Galvo mirror 515
Input/Output Beam
510

FIG. 7

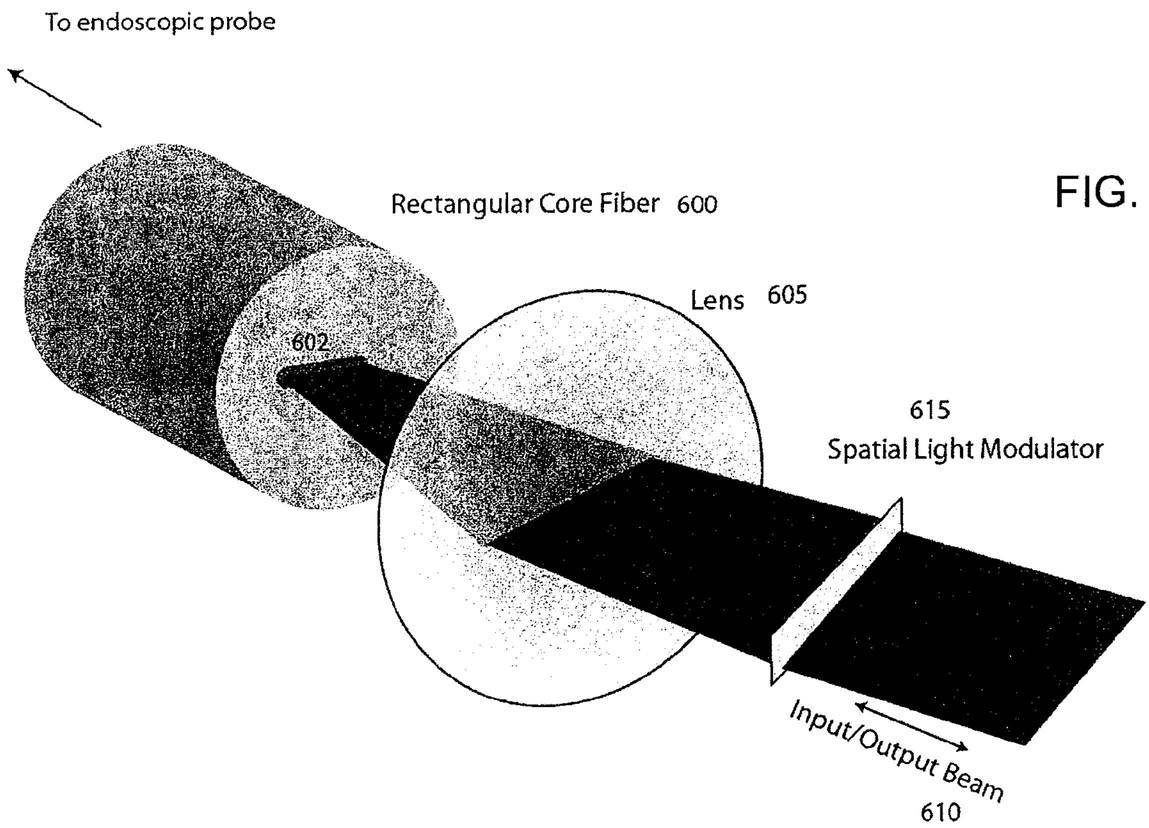
To endoscopic probe
Rectangular Core Fiber 600
Lens 605
602
615
Spatial Light Modulator
Input/Output Beam
610

FIG. 8

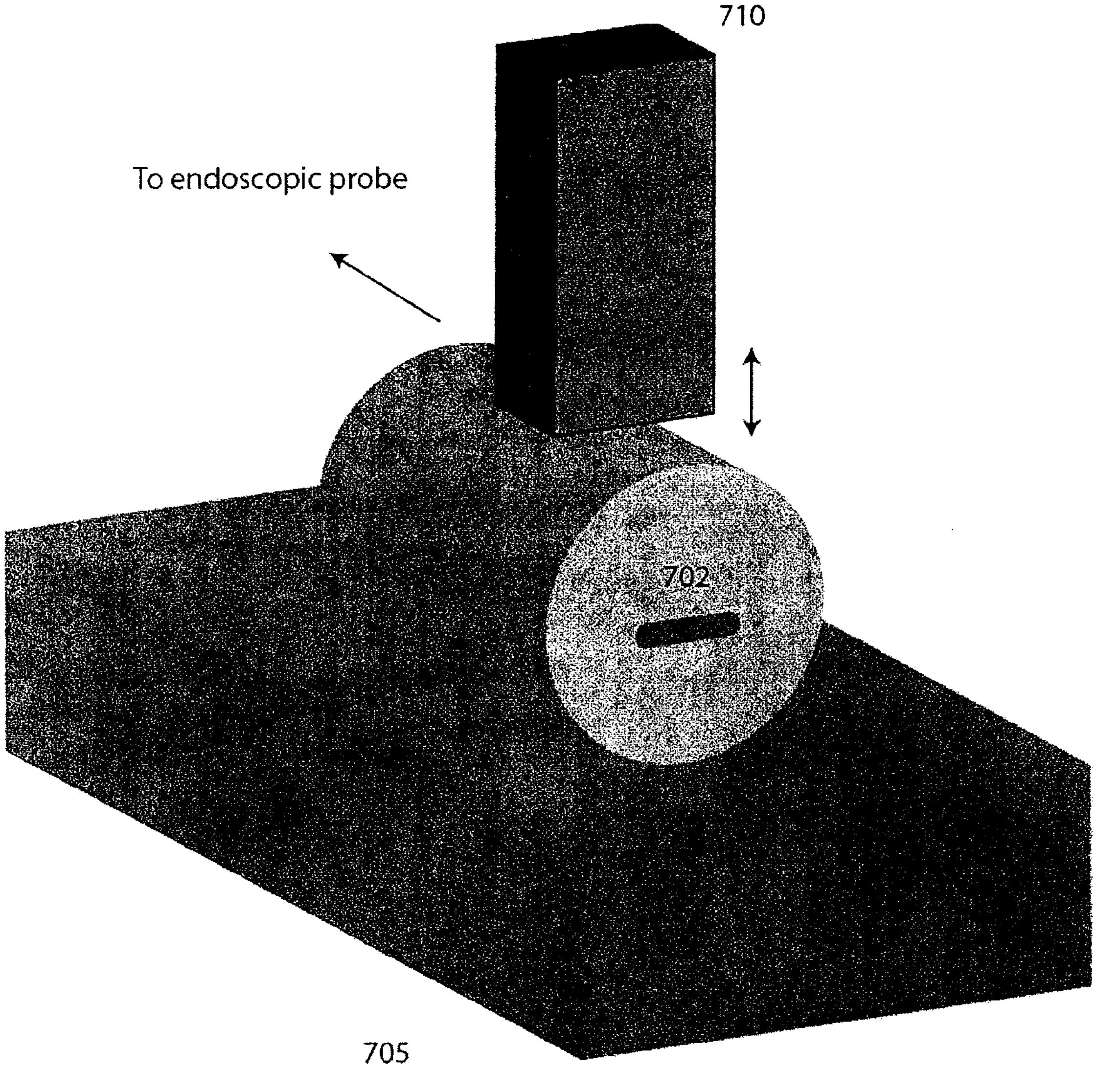

FIG. 9

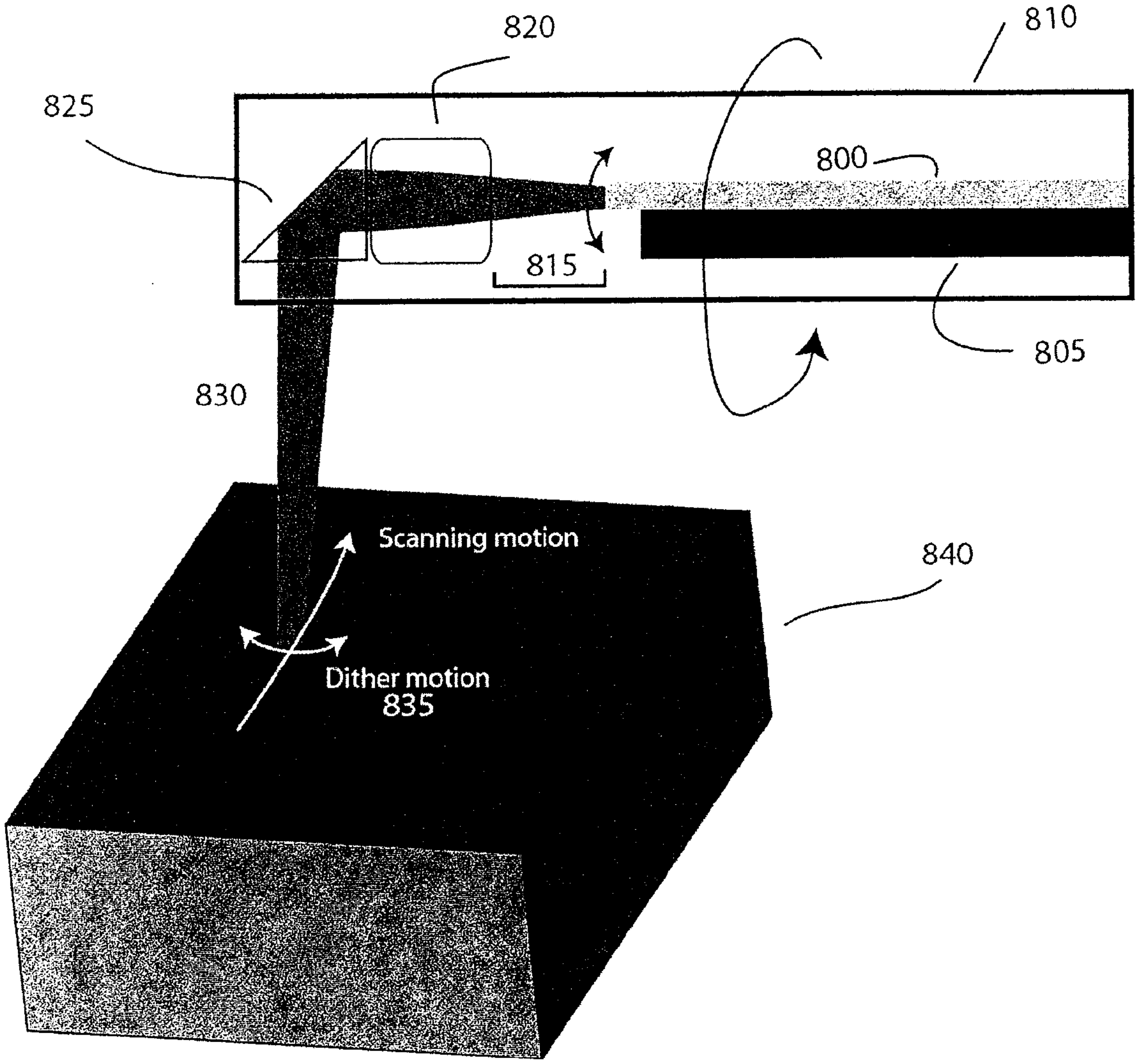
820
810
825
800
815
805
830
Scanning motion
840
Dither motion
835

FIG. 10