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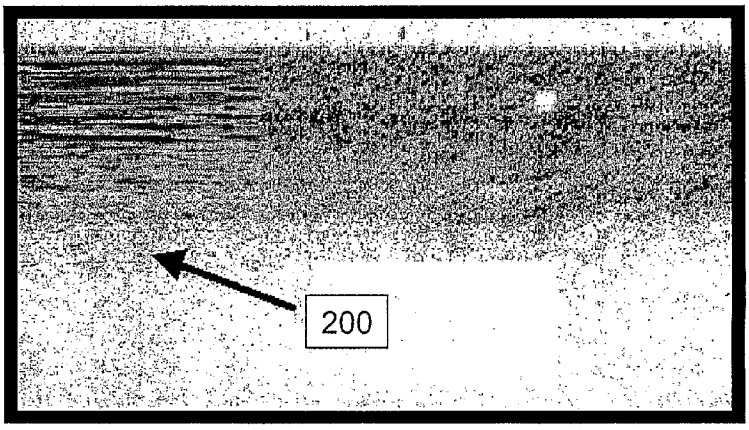
(54) **Title:** ARRANGEMENTS, DEVICES, ENDOSCOPES, CATHETERS AND METHODS FOR PERFORMING OPTICAL IMAGING BY SIMULTANEOUSLY ILLUMINATING AND DETECTING MULTIPLE POINTS ON A SAMPLE



(57) **Abstract:** Devices, arrangements, endoscopes, catheters and methods adapted to propagate at least one electro-magnetic radiation are provided. In particular, a waveguide apparatus specifically configured may be utilized to split the electro-magnetic radiation into a plurality of beams that are intended to illuminate a biological sample, and impart a unique associated characteristics unto each of the beams. The beams may be intended to illuminate a biological sample at distinct locations, and impart a unique associated characteristic unto each of the beams. In addition, a control apparatus may be provided which is configured to control at least one of the fibers and which can be input to the fibers so as to modify the unique associated characteristics of the beams being propagated along the fibers, and thereby modify the characteristics of the distinct locations on the sample.

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ARRANGEMENTS, DEVICES, ENDOSCOPES, CATHETERS AND METHODS FOR PERFORMING OPTICAL IMAGING BY SIMULTANEOUSLY ILLUMINATING AND DETECTING MULTIPLE POINTS ON A SAMPLE

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is based upon and claims the benefit of priority from U.S. Patent Application Serial No. 60/631,539, filed November 29, 2004, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to optical imaging, and more particularly devices and methods which are capable of performing optical imaging by simultaneously illuminating and detecting multiple points on a sample.

BACKGROUND OF THE INVENTION

Endoscopic/catheter-based optical imaging techniques that utilize beam scanning to form an image such as optical coherence tomography and confocal microscopy, may be limited by an inability to rapidly scan a beam along one or two dimensions. The reason for this is that likely the only reliable methods for rapid optical scanning should be performed in free space. In addition, the size of these optical scanners may deter their use in small probes, such as in endoscopes or catheters. The capability to miniaturize the scanning mechanism would likely increase the number of medical applications of optical imaging techniques to include all surfaces of the body, gynecologic applications, probe based applications, and internal organ systems.

U.S. Patent No. 5,321,501 describes optical coherence tomography and U.S. Patent No. 5,161,053 describes confocal microscopy, both of which utilize an optical fiber. However, the conventional methods described in these publications disclose the use of a single focused spot on the sample with an arrangement for scanning such spot. U.S. Patent No. 5,659,642 describes the use of an optical fiber bundle to perform confocal microscopy. However, this publication also describes a switching arrangement for selectively illuminating individual channels. In the disclosure of this U.S. patent, a fiber bundle are used, with all points being

illuminated and detected simultaneously, thereby eliminating the need for a switching mechanism for selectively illuminating certain channels.

Endoscopic confocal microscopy technology has been proposed as a new diagnostic imaging technology capable of providing cellular resolution images in vivo. However, these proposed technology have not been easily realized using a single optical fiber due to the inability to develop a rapid beam scanning mechanism that can reside in a small diameter probe. Other approaches that have been used are selectively illuminating optical fibers in a fiber bundle by scanning a focused beam at the proximal end of a fiber bundle. These approaches have various difficulties due to a beam overlap between channels, thus causing two points to be illuminated simultaneously, which results in cross-talk and aberrations. It would be desirable to use a single fiber to perform endoscopic confocal imaging. If a fiber bundle is used, it may be preferable to illuminate multiple points simultaneously, so that each fiber is illuminated by a unique spot centered on the individual fiber cores.

Optical coherence tomography ("OCT") is an imaging modality that has been implemented in the internal organs of patients using optical fibers. Figure 1 shows an exemplary mechanical and associated optical elements that are common to particular OCT catheter designs. These catheter designs may include an inner core 120, which can may contain a fiber optic element 115 that is coupled to the OCT system at the proximal end 110, 100, and which can focus and redirect the light at the distal end 150. The inner core 120 can rotate or translate to provide one-dimensional motion of the distal optics that serves to scan the beam on the sample. The inner core is enclosed in a transparent sheath 130.

The use of catheters in OCT that utilize motion transduction from a proximal actuator to the distal optics by an inner core is problematic due to artifacts that may occur when friction between the inner core and outer transparent sheath causes non-uniform rotation or linear motion 200. This friction may cause linear artifacts that become more noticeable as the resolution of the imaging technology is increased. As a result, these non-uniform transduction artifacts may prevent the use of this type of catheter when ultra-high resolution OCT (e.g., 1 μm) becomes clinically available. Additional friction due to catheter bending or rotation during the procedure may further exacerbate the problem.

OBJECTS AND SUMMARY OF THE INVENTION

One of the objects of the present invention is to overcome the above-described deficiencies and problems, and provide an exemplary embodiment of a device and arrangement for simultaneously illuminating multiple points on a sample that can be miniaturized and incorporated into a compact probe. Each point on the sample is encoded by frequency using an exemplary embodiment of a frequency encoding method according to the present invention. As a result, frequency analysis of the signal reflected or transmitted through the sample may allow a reconstruction of an image representing the interaction between the energy input and the sample. In addition, by allowing light delivery through a single optical fiber, this device may be also be incorporated into catheters or endoscopes. Other advantages of this exemplary embodiment of the device may include a lack of moving parts, heterodyne detection, and the potential for obtaining cross-sectional images. These properties promote this device for use in performing optical diagnostic imaging in all accessible surfaces of the body. As an example, two technologies that can use and/or incorporate this device are endoscopic confocal microscopy and optical coherence tomography.

Using another exemplary embodiments of the device and method according to the present invention, multiple spots may be illuminated on the sample simultaneously, and can be detected simultaneously, thus possibly eliminating the need for scanning a single spot.

Therefore, exemplary embodiments of devices, arrangements, catheters and methods adapted to propagate at least one electro-magnetic radiation are provided. In particular, a waveguide apparatus specifically configured may be utilized to separate or split the electro-magnetic radiation into a plurality of beams that are intended to illuminate a biological sample, and impart a unique associated characteristic unto each of the beams. The beams may be intended to illuminate a biological sample at distinct locations, and impart a unique associated characteristic unto each of the beams. In addition, a control apparatus may be provided which is configured to control at least one of the fibers and which can be input to the fibers so as to modify the unique associated characteristics of the beams being propagated along the fibers, and thereby modify the characteristics of the distinct locations on the sample.

For example, the waveguide can be a multi-mode waveguide and/or a mirror tunnel. A first illumination arrangement may also be provided that receives the at least one electro-magnetic radiation, and produces a first radiation at least one of within and in a close proximity to the waveguide apparatus. A second illumination arrangement can also be provided that receives which produces a plurality of second radiations based on the first radiation. The second radiations may be approximations of the first radiation, and/or provided at distinct locations on a sample. The first illumination arrangement may include an optical fiber and/or a lens.

According to another exemplary embodiment of the present invention, a further apparatus can be provided which is configured to control the waveguide apparatus so as to modify the unique associated characteristics of the beams. The unique associated characteristics may include path-lengths and/or phases of the respective beams. The further apparatus can control the waveguide apparatus by modifying structural characteristics of the waveguide apparatus. The modification of the structural characteristics of the waveguide apparatus may be asymmetric with respect to a cross-section of the waveguide apparatus. The further apparatus may control the waveguide apparatus by modifying optical characteristics of the waveguide apparatus. The optical characteristics can include a refractive index.

Further, the second illumination arrangement can include a further illumination arrangement which is configured to arrange the second radiation in a predetermined pattern on the sample. The predetermined pattern may be approximately circular. The waveguide apparatus can include a plurality of fibers which are configured to transmit the beams. A control apparatus may further be provided that is configured to control the fibers and/or inputs to the fibers so as to modify the unique associated characteristics of the beams being propagated along the fibers, and thereby modify the characteristics of the distinct locations on the sample. Third radiations reflected from the sample may be transmitted back through the waveguide apparatus, and can be based on the second radiation . A reference arm section may be provided that is configured to propagate a portion of the electro-magnetic radiation which is intended to be forwarded to a reference.

According to still another exemplary embodiment of the present invention, a combining apparatus may be provided which combines the third radiation and a fourth radiation returned from the reference arm to produce an interference

radiation. A detection apparatus can be provided which is configured to detect the interference radiation;. Further, a processing apparatus may be provided which is configured to generate data corresponding to the third radiations returning from the distinct locations on the sample based on the interference radiation. The processing apparatus may be further configured to generate an image of at least one portion of the sample based on the data. The electro-magnetic radiation can be generated by a narrowband light source that has a tunable center wavelength. The electro-magnetic radiation may be generated by a broadband light source, and the second radiation returned from the waveguide apparatus and a radiation returned from the reference arm section may be adapted to be received by a spectrometer apparatus. A probe (e.g., a catheter, endoscope and/or laparoscope) may be included which houses the waveguide apparatus.

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:

Figure 1 is a side cut-away view of a conventional OCT catheter;

Figure 2 is an OCT image using the conventional OCT catheter of Figure 1 that is acquired from a subject with Barrett's esophagus, which shows a non-uniform linear motion artifact;

Figure 3 is a schematic side view of a frequency encoded multiple beam OCT system according to one exemplary embodiment of the present invention; with the reference arm mirror potentially moving in a time domain ("TD")-OCT or may remain fixed for a spectral domain ("SD")-OCT or optical frequency domain imaging ("OFDI") techniques;

Figure 4 is a schematic side view of a multiple beam optical imaging system according to another exemplary embodiment of the present invention, which includes a single mode fiber and multiple beam generating element at the distal end of a catheter;

Figure 5 is a schematic side view of a multiple beam optical imaging system according to still another exemplary embodiment of the present invention, which includes a fiber array and multiple beam generating element at a proximal end of the catheter;

Figure 6 is an enlarged schematic view of an exemplary embodiment of a multiple spot generating ("MSG") device according to the present invention that includes two mirrors;

Figure 7 is an enlarged schematic view of another exemplary embodiment of the MSG device that can be used to generate a circumferential scan pattern;

Figure 8 is a side schematic view of an exemplary embodiment of a fiber optic arrangement according to the present invention which can be used for modulating purposes for each separate beamlet on the sample; and

Figure 9 is a side schematic view of another exemplary embodiment of the fiber optic arrangement for synthetic aperture beam scanning.

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 present invention will now be described in detail with reference to the figures, it is done so in connection with the illustrative embodiments.

DETAILED DESCRIPTION

The present invention provides exemplary variations of a catheter paradigm that generally does not scan the beam at the distal end of the catheter, thus eliminating the potential for non-uniform motion artifacts. In a conventional OCT system, one way for conducting OCT can be based on time domain OCT (TD-OCT) scanning.

In thus exemplary procedure, the length of the reference arm in an interferometer 325 is rapidly scanned over a distance corresponding to the imaging depth range (as shown in Figure 3), producing an interference pattern when the path length of the reference arm matches the pathlength to a given scatterer in the sample arm to within the temporal coherence length of the source 310 light. For TD-OCT technique, broad bandwidth light 310 can be input into an interferometer, and spearate

or split into a reference arm 325 and a sample arm 345 arm. The optical path length of the reference arm is scanned by translating the reference arm mirror 320. Light returned from the reference and sample arms 325, 345 combine at the splitter 330. Interference fringes may be detected when the sample arm path length matches the reference arm path length to within the coherence length of the light. The detection of the fringe patterns may allow one axial scan (A-line) to be constructed that maps tissue reflectivity to a given axial or depth location. An image can be generated by repeating this process at successive transverse locations on the sample.

In conventional OCT techniques, one single spot may be illuminated on the sample at one time. According to an exemplary embodiment of the present invention, instead, multiple beams 370 can be focused by the distal optics simultaneously illuminating one transverses dimension on the sample 360. Each distinct beam or spot on the sample 360 can be encoded by frequency in a manner such that frequency analysis of the interferometric signal provides reconstruction of the entire OCT image. Another advantage of this exemplary OCT paradigm is that the reference arm path length scanning can be performed at a much slower rate, thus allowing conventional mechanical path length scanning techniques to produce OCT images at real time frame rates.

Exemplary System Overview

A side schematic view of an exemplary embodiment of a system according to the present invention is shown in Figures 4 and 5. For example, each device can include an irradiation source 400, 500, a sample path (impacting the sample 460. 560) and a reference path (impacting a reference 410, 510) and a detector 470, 570. A catheter 430 of Figure 4 may contain a single optical fiber 435 with the multiple spot generating ("MSG") device 440 at the distal end of the catheter. Alternatively, the MSG device 580 of Figure 5 may be placed at the proximal end of the catheter 530, illuminating an optical fiber array 535. Multiple points 450, 550 are thus illuminated on the sample 460, 560.

Multiple Spot Generating ("MSG") Device

An enlarged view of a schematic diagram of one exemplary embodiment of the MSG device according to the present invention is shown in Figure

6. A beam emitted from an optical fiber 600 diverges by focusing it to a spot by a lens 610 at the input to a mirror tunnel or optical waveguide 630, 640. A lens at the opposite end 650 of the mirror tunnel images virtual sources or beamlets along a one-dimensional line. Light is reflected from the sample 660, and returns along its conjugate path. The exemplary embodiment of the optical system according to the present invention provides a confocal rejection of out-of-focus light, due to the aperture of the fiber.

Due to the geometry of this exemplary optical device, light that forms each beamlet (I_n) 670 bounces off one of the mirrors n times. This same beamlet reflects off of the opposite mirror n-1 times. If one or both mirrors 630, 640 are moved using an electromechanical actuator, such as a piezoelectric transducer, each distinct beamlet can be imparted a phase shift, $n\nu_d$, where ν_d is the Doppler shift imparted by a double-passed reflection off one moving mirror:

$$\nu_d = \frac{4v}{\lambda}.$$

Heterodyne detection of the signal returned from the probe can allow a simultaneous measurement of the Doppler shifted frequencies $0, \nu_d, 2\nu_d..n\nu_d$. The reflectivity from each point can be determined using a tapped bandpass filter or ramped frequency mixing demodulation. The bandwidth of the signal must be no greater than $1/2\,\nu_d$ to avoid aliasing.

Brief Description of Components of Exemplary Device of Figure 6

1. Lens 610: GRIN, cylindrical, plano-convex, convex-convex, drum, ball, asphere, multiple element. Asymmetric holographic diffuser.
2. Mirrors 630 and/or 640: Dielectric, omnidirectional mirrors, uncoated metal
3. Mirror motion mechanism 635: Piezoelectric transducer, cantilever.
4. Lens 650: GRIN (OCT), plano-convex, convex-convex, drum, ball, asphere, multiple element (confocal).

Conjugate Symmetry

The exemplary two-mirror system described above with reference to Figure 6 has conjugate symmetry properties. Positive and negative beamlets of the same order may have the same Doppler shift if both mirrors are synchronous and have identical modulation frequencies. Discrimination of positive and negative orders may be accomplished by modulating the two mirrors 630, 640 with different phases and performing phase sensitive detection. Alternatively, each positive and negative order may be discriminated by frequency interleaving by modulating each mirror at a different frequency.

Alternative mirror configurations

1. Two mirror (N=2) device can create a one-dimensional array of beamlets.
2. Triangular mirror tunnel (N=3) can create a two-dimensional hexagonal array of beamlets.
3. Rectangular array (N=4) can create a rectilinear array of beamlets.
4. Higher orders (N=5,6) can create more complex two-dimensional patterns.
5. Cylindrical waveguide may produce orders of rings on the sample.

The use of N=2 mirrors may have the advantage that the aspect ratio can be maintained at 1:1. In addition, this exemplary configuration allows the illumination of a two-dimensional area, which is particularly well suited for endoscopic confocal microscopy. Disadvantages of two-dimensional illumination may include an increased complexity of the detection mechanism and an increased high reflectivity requirements for the mirror coatings.

Exemplary Embodiment of Device (with N=2 configuration)

Using a mirror separation (d) of 10 μm, a mirror length, L, of 2.0 mm, and a input divergence angle of 100°, a total of 520 points may be simultaneously illuminated and detected using the exemplary embodiment of the present invention. Assuming a mirror reflectivity of 0.997, the maximum double-pass accumulated loss at the edge of the scan would be 6.0 dB. Specifying dielectric coatings that provide maximal reflection at the higher angles may minimize this loss.

Endoscopic Confocal Applications

For example, N=2 configurations may be used in conjunction with SECM for providing the slow scan axis of SECM. The exemplary MSG device (with N=2) can also be used to provide the fast scan axis for endoscopic confocal microscopy. One beneficial option can be the use of N > 2 configurations, which may provide the entire two-dimensional scan.

Cross Talk

Cross talk can occur every (2M+1) pixels on the sample. Modulating M mirrors can allow interleaving of the cross-talk frequencies. Since cross talk exists between (2M++) illumination spots on the sample, increasing N and modulating all N=M mirrors allows increasing separation of the cross-talk channels with increasing N and M. For example, for N = M= 2, cross talk occurs for spots that are 4 spot diameters from each other. If N = M is increased to 3, cross-talk occurs for spots that are 6 diameters from each other. Cross talk may also be reduced by increasing spot-spot separation or illuminating 1/N of the mirror tunnel and modulating only one mirror.

MSG spot symmetry

When MSG illumination is in the center of the exemplary MSG device, identical frequency shifts and path length variations occur symmetrically around the center of the MSG. In order to avoid spot order ambiguity, these planes of symmetry must be broken. One way for breaking this symmetry is to illuminate the MSG device at a location slightly offset from the center. Another way of breaking this symmetry may be to utilize mirrors of slightly different lengths or angulation.

Electro-Optical Exemplary Embodiments of Device

In the above descriptions, the use of a hollow, mirror-based waveguide has been described for generating multiple spots on the sample. An alternative exemplary embodiment of the present invention can use a silicon/glass/crystal waveguide, which would also produce the self-imaging effect. The waveguide may also contain an electro-optic material where a voltage applied to the crystal would change the extraordinary and ordinary refractive indices in such a manner as to

modulate the phase of the different spot orders independently. This may have the same effect as physically modulating the mirror distances.

Optical Coherence Tomography Applications

In standard axial (depth) priority scan OCT, the MSG device can be used to provide the slow scan axis within the OCT probe. This can allow for imaging at the distal end of the OCT probe, eliminating artifacts such as binding and non-uniform rotational defects ("NURD") found using a cable to transduce motion from the proximal to distal ends of the catheter/endoscope probe.

Since the MSG device is capable of rapid imaging, the priority of OCT can be modified from axial to transverse. This exemplary variant of the present invention can greatly diminish the requirements of the rapidly scanning optical delay line ("RSOD"), which could increase scan speeds of OCT systems significantly.

Exemplary OCT Circumferential Imaging Catheter Design

An incorporation of a spatially varying directional grating 760 could allow circumferential OCT imaging with an elimination of non-uniform motion (as shown in the enlarged schematic view of the exemplary MSG device of Figure 7). This grating may take a line or two-dimensional array of Doppler encoded beamlets and maps this pattern into a circle 770. The application of this exemplary technique may be desirable for OCT imaging of coronary arteries. Another exemplary embedment of the present invention that enables the circumferential imaging with the MSG device includes the insertion of a helical mirror in place of the custom grating 760 of Figure 7.

Alternate Exemplary Embodiment of MSG Device

Another exemplary embodiment of the MSG device according to the present invention, as shown in Figure 8, can include a single fiber input 800 provided into a star coupler 810 or multiple fibers 820 arranged such that each fiber received a separate Doppler frequency. The Doppler frequencies may be applied using piezoelectric fiber stretchers, electro-optic or acustooptic modulators 830. Each individual fiber can then be directed to focus a single spot on the sample 850 by distal optics 855, each unique spot encoded by frequency.

Synthetic aperture beam scanning for OCT and confocal microscopy

Another exemplary embodiment for use with OCT or confocal imaging according to the present invention that excludes a transverse scanning mechanism may use a one- or two-dimensional fiber array 935 where the phase of light in each fiber could be controlled 930 or 960 (as shown in Figure 9). An arrangement for controlling the phase of light in each fiber can include mechanical manipulation of the individual fibers (e.g. piezoelectric transducers) or phase control of each fiber at the input of the array (e.g. via liquid crystal spatial light modulator). By controlling the phase of each individual channel, the output from each fiber can interfere with the outputs from other fibers in order to create a focus or multiple foci 950 on the sample, which can then be scanned. A circumferential scan can be conducted by insertion of a diffractive optic or helical mirror distal to the fiber bundle face at the end of the catheter/endoscope.

Detection

A high sensitivity may be achieved through the use of heterodyne detection. If the reference arm 410 is modulated, the interference of light from the sample arm and the reference arm will also be modulated. High signal to noise ratios may be then achieved by lock-in detection on the reference arm modulation frequency. Frequency domain techniques such as SD-OCT and OFDI can also be utilized that would detect different spectral interference fringe frequencies for different spot orders, as a result of their different path length traveled through the MSG.

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 any OCT system, OFDI system or other imaging systems, and for example with those described in U.S. Provisional Patent Appn. No. 60/514,769 filed October 27, 2003, and International Patent Application No. PCT/US03/02349 filed on January 24, 2003, 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.

CLAIMS

1. An arrangement adapted to propagate at least one electro-magnetic radiation, comprising:

a waveguide apparatus specifically configured to split the at least one electro-magnetic radiation into a plurality of beams that are intended to illuminate a biological sample, and impart a unique associated characteristic unto each of the beams.

2. The arrangement according to claim 1, wherein the waveguide apparatus is at least one of a multi-mode waveguide, a multi-mode optical fiber or a mirror tunnel.

3. The arrangement according to claim 1, further comprising:

a first illumination arrangement that receives the at least one electro-magnetic radiation, and produces a first radiation at least one of within or in a close proximity to the waveguide apparatus; and

a second illumination arrangement that receives at least one second radiation based on the first radiation.

4. The arrangement according to claim 3, wherein the at least one second radiation is an approximation of the first radiation.

5. The arrangement according to claim 3, wherein the at least one second radiation is provided at one or more distinct locations on a sample.

6. The arrangement according to claim 3, wherein the first illumination arrangement includes an optical fiber.

7. The arrangement according to claim 6, wherein the first illumination arrangement further includes a lens.

8. The arrangement according to claim 3, further comprising a further apparatus which is configured to control the waveguide apparatus so as to modify the unique associated characteristics of the beams.

9. The arrangement according to claim 8, wherein the unique associated characteristics include at least one of path-lengths or phases of the respective beams.

10. The arrangement according to claim 8, wherein the further apparatus controls the waveguide apparatus by modifying structural characteristics of the waveguide apparatus.

11. The arrangement according to claim 10, wherein the modification of the structural characteristics of the waveguide apparatus is asymmetric with respect to a cross-section of the waveguide apparatus.

12. The arrangement according to claim 8, wherein the further apparatus controls the waveguide apparatus by modifying optical characteristics of the waveguide apparatus.

13. The arrangement according to claim 11, wherein the optical characteristics includes a refractive index.

14. The arrangement according to claim 11, wherein the second illumination arrangement includes a further illumination arrangement which is configured to arrange the second radiation in a predetermined pattern on the sample.

15. The arrangement according to claim 14, wherein the predetermined pattern is approximately circular.

16. The arrangement according to claim 5, wherein the waveguide apparatus includes a plurality of fibers which are configured to transmit the beams.

17. The arrangement according to claim 16, further comprising a control apparatus configured to control at least one of the fibers or inputs to the fibers so as to modify

the unique associated characteristics of the beams being propagated along the fibers, and thereby modify the characteristics at the distinct locations on the sample.

18. The arrangement according to claim 5, wherein third radiations reflected from the sample are transmitted back through the waveguide apparatus, and are based on the second radiation .

19. The arrangement according to claim 18, further comprising:

a reference arm section configured to propagate a portion of the at least one electro-magnetic radiation that is intended to be forwarded to a reference.

20. The arrangement according to claim 19, further comprising:

a first apparatus which combines the third radiation and a fourth radiation returned from the reference arm to produce an interference radiation;

a second apparatus which is configured to detect the interference radiation; and

a third apparatus which is configured to generate data corresponding to the third radiations returning from the distinct locations on the sample based on the interference radiation.

21. The arrangement according to claim 20, wherein the processing apparatus is further configured to generate an image of at least one portion of the sample based on the data.

22. The arrangement according to claim 5, further comprising a radiation receiving arrangement which is adapted to receive third radiations reflected from the sample which are based on the second radiation .

23. The arrangement according to claim 3, wherein the at least one electro-magnetic radiation is generated by a narrowband light source that has a tunable center wavelength.

24. The arrangement according to claim 23, wherein the at least one electro-magnetic radiation is generated by a broadband light source, and wherein a third radiation reflected from the sample that is associated with the second radiation and a further radiation returned from the reference arm section are adapted to interfere with one another and be received by a spectrometer apparatus.

25. The arrangement according to claim 1, further comprising a probe which houses the waveguide apparatus.

26. The arrangement according to claim 25, wherein the probe is at least one of a catheter, an endoscope or a laparoscope.

27. The arrangement according to claim 1, wherein the arrangement is at least one of a probe, an endoscope or a catheter.

28. An arrangement adapted to propagate at least one electro-magnetic radiation, comprising:

a waveguide apparatus specifically configured to separate the at least one electro-magnetic radiation into a plurality of beams that are intended to illuminate a biological sample at distinct locations, and impart a unique associated characteristic unto each of the beams, wherein the waveguide apparatus includes a plurality of fibers which are configured to transmit the beams; and

a control apparatus configured to control at least one of the fibers and inputs to the fibers so as to modify the unique associated characteristics of the beams being propagated along the fibers, and thereby modify the characteristics of the distinct locations on the sample.

29. An arrangement adapted to propagate at least one electro-magnetic radiation, comprising:

a waveguide apparatus specifically configured to separate the at least one electro-magnetic radiation into a plurality of beams that are intended to illuminate a biological sample at a single location, wherein the waveguide apparatus includes a plurality of fibers which are configured to transmit the beams; and

a control apparatus configured to control at least one of the fibers and inputs to the fibers so as to modify at least one of unique associated characteristics of the beams being propagated along the fibers, and thereby to illuminate the single location on the sample, wherein the single location is determined by the unique associated characteristics of the beams.

30. A method for propagating at least one electro-magnetic radiation, comprising:

separating the at least one electro-magnetic radiation into a plurality of beams that are intended to illuminate a biological sample using a waveguide apparatus, the waveguide apparatus being specifically configured to impart a unique associated characteristic unto each of the beams.

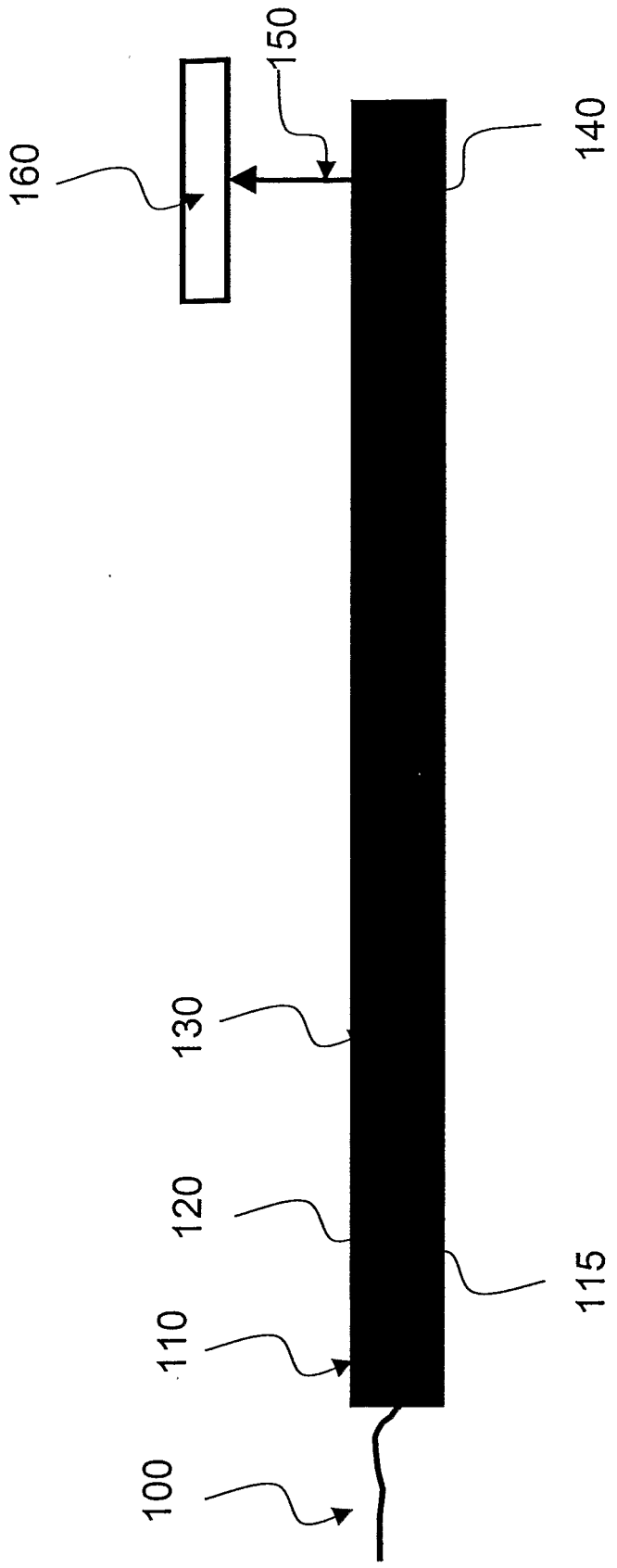

FIGURE 1 PRIOR ART

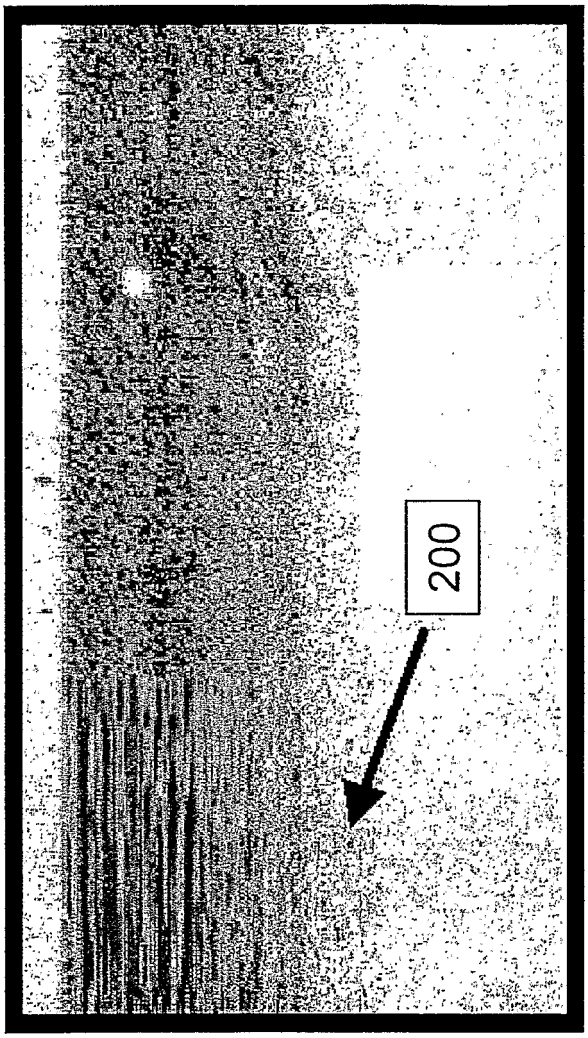

FIGURE 2

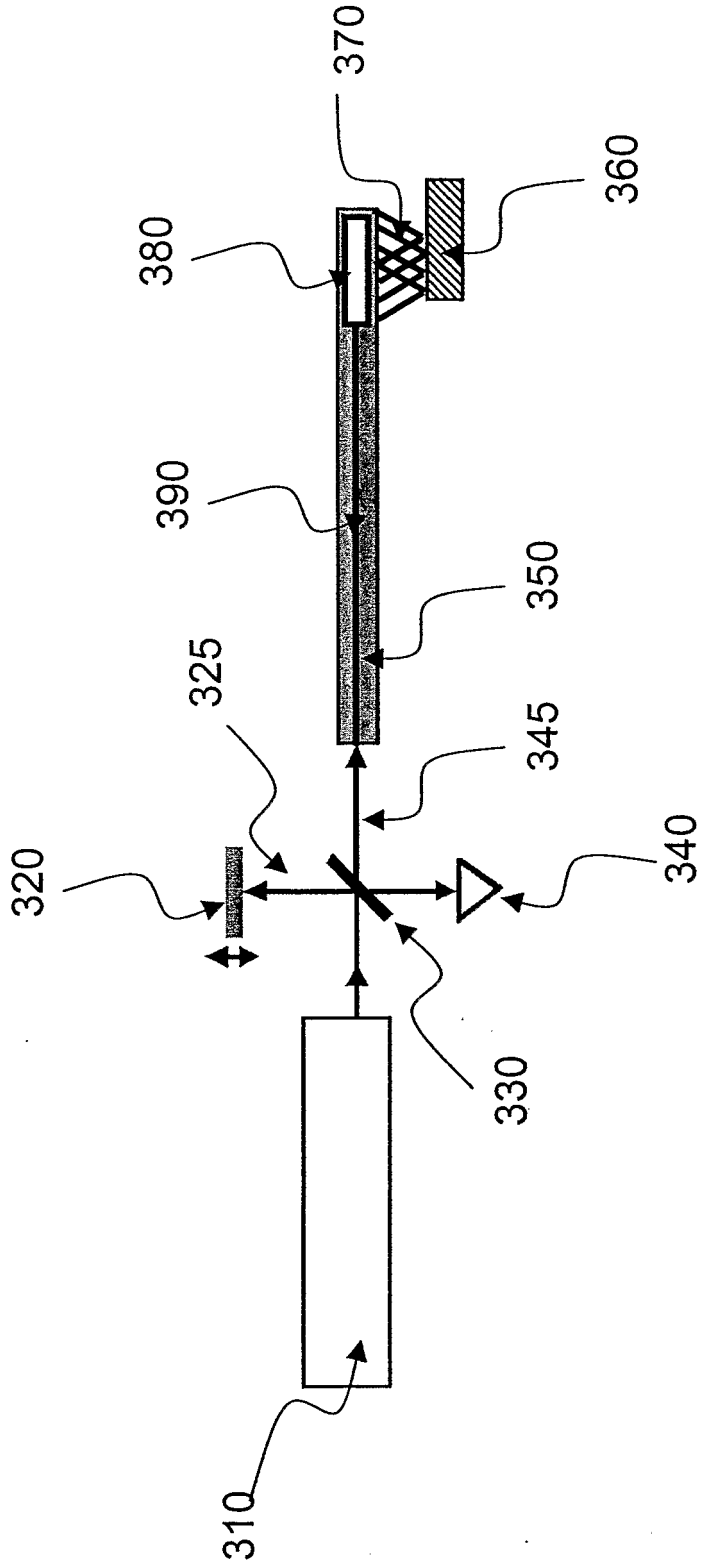

FIGURE 3

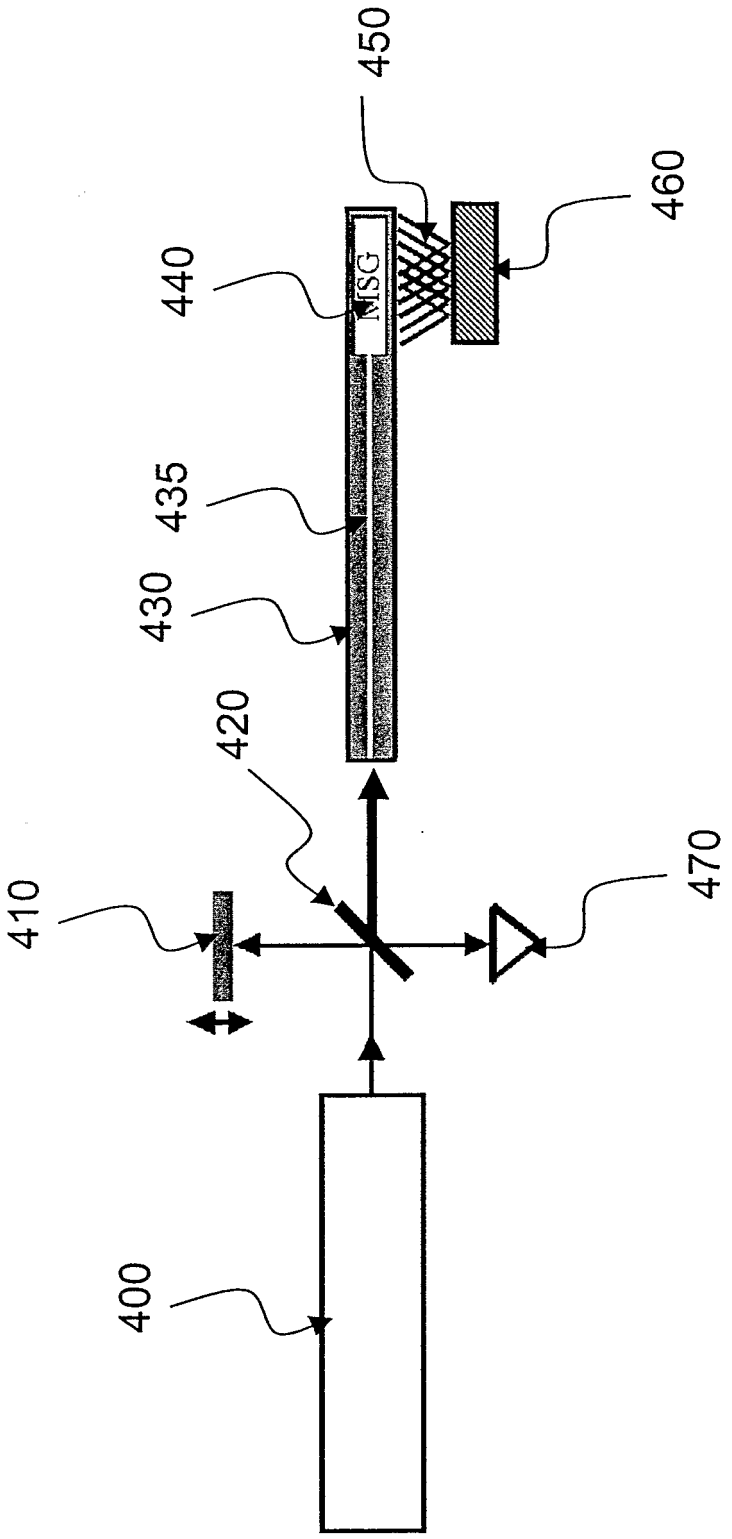

FIGURE 4

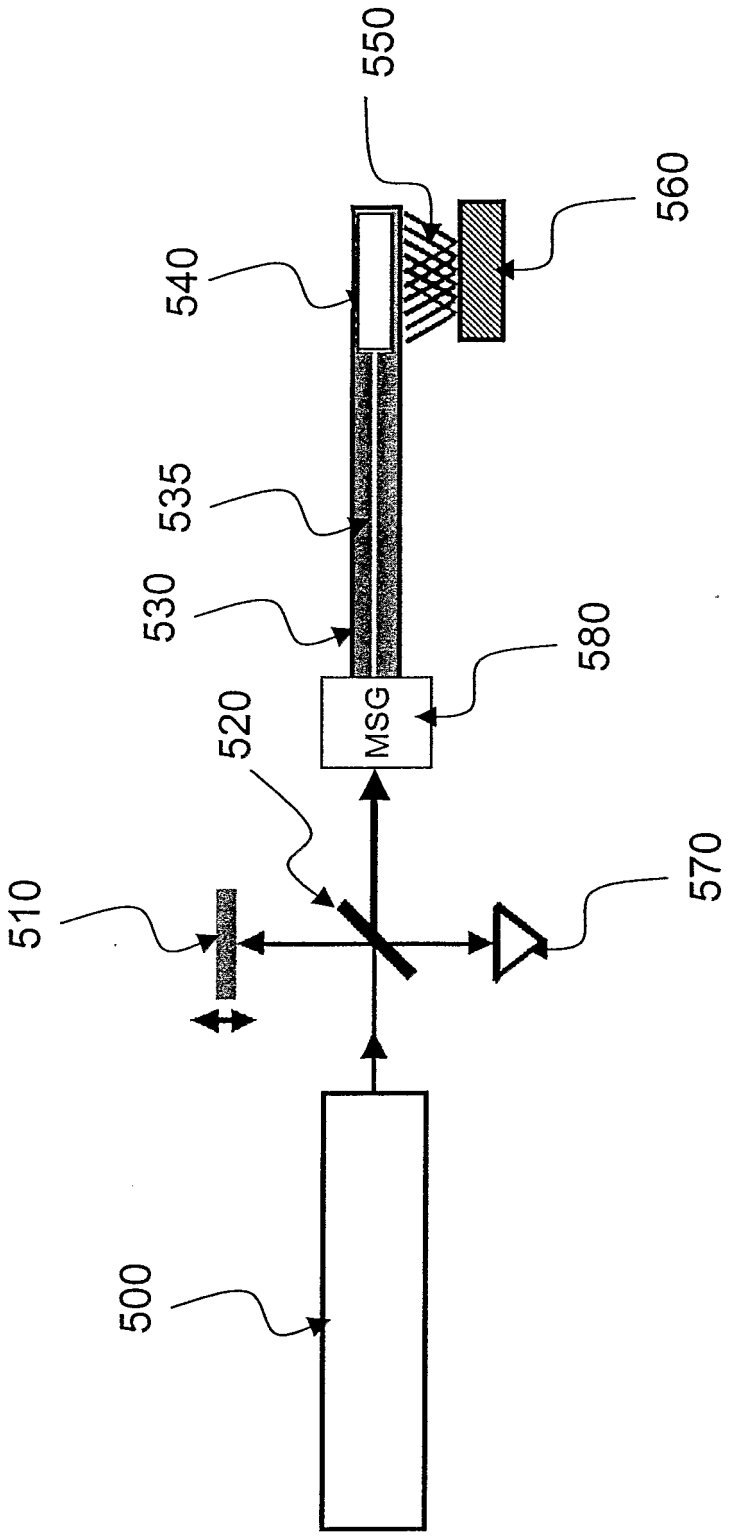

FIGURE 5

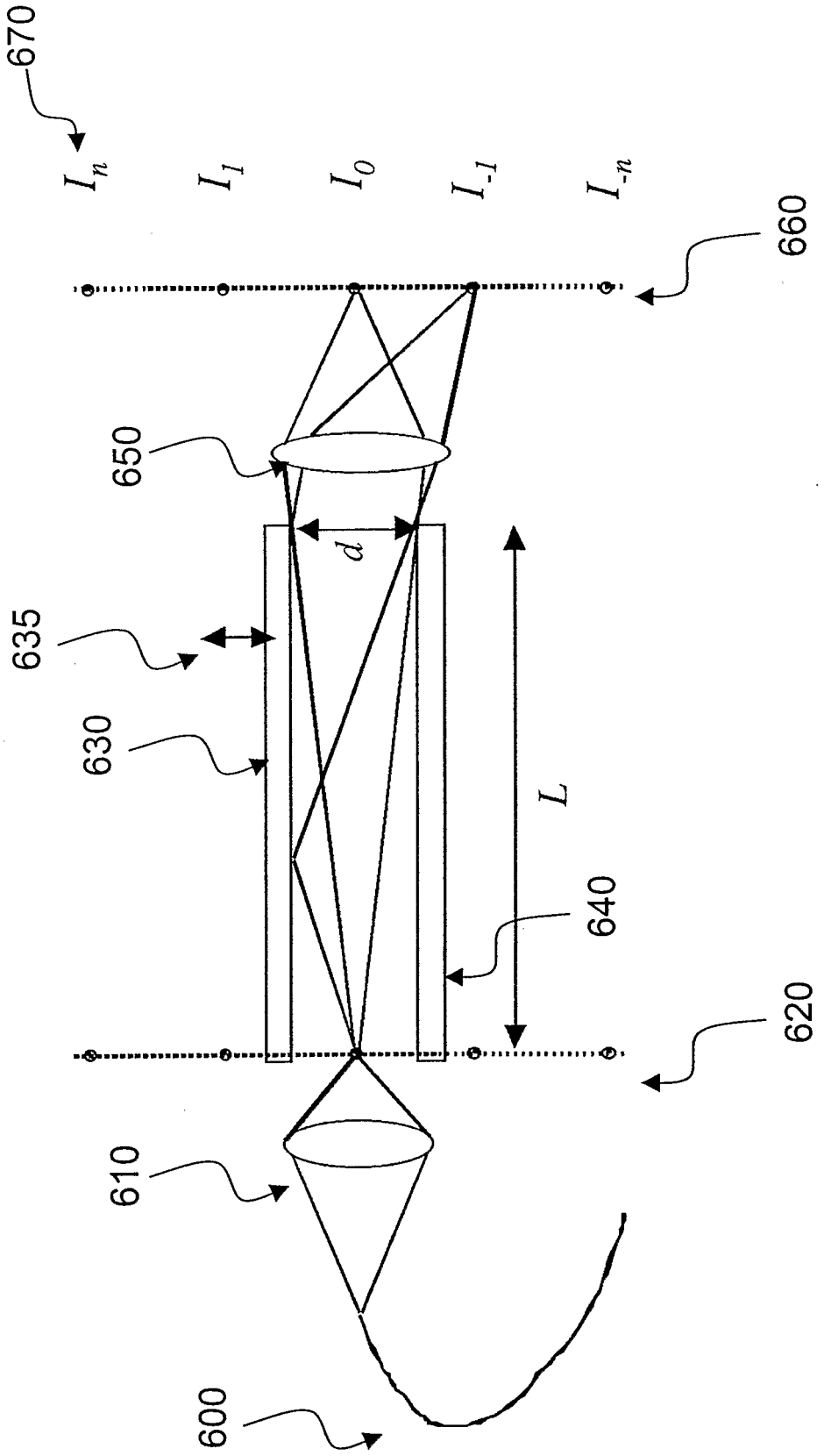

FIGURE 6

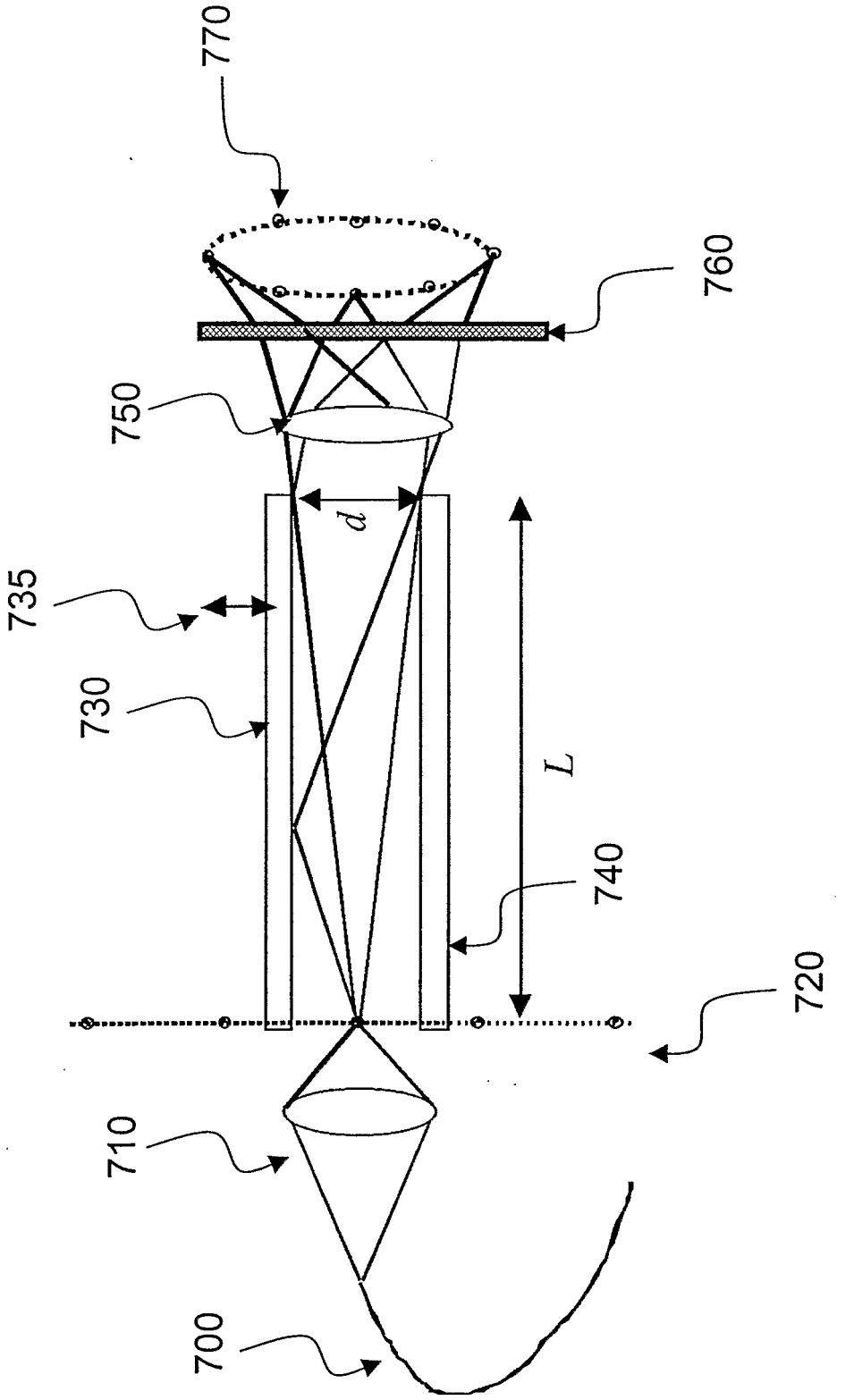

FIGURE 7

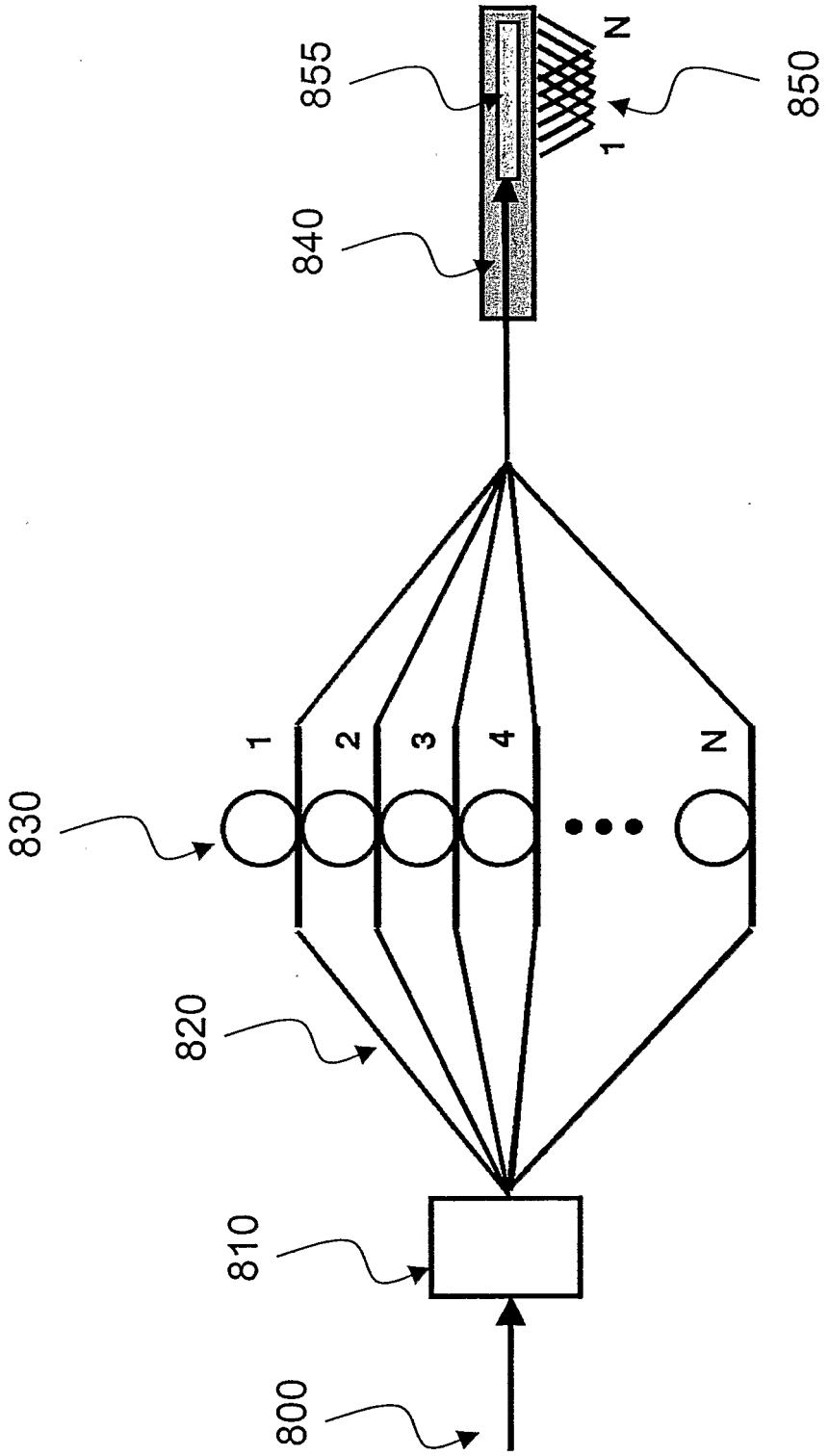

FIGURE 8

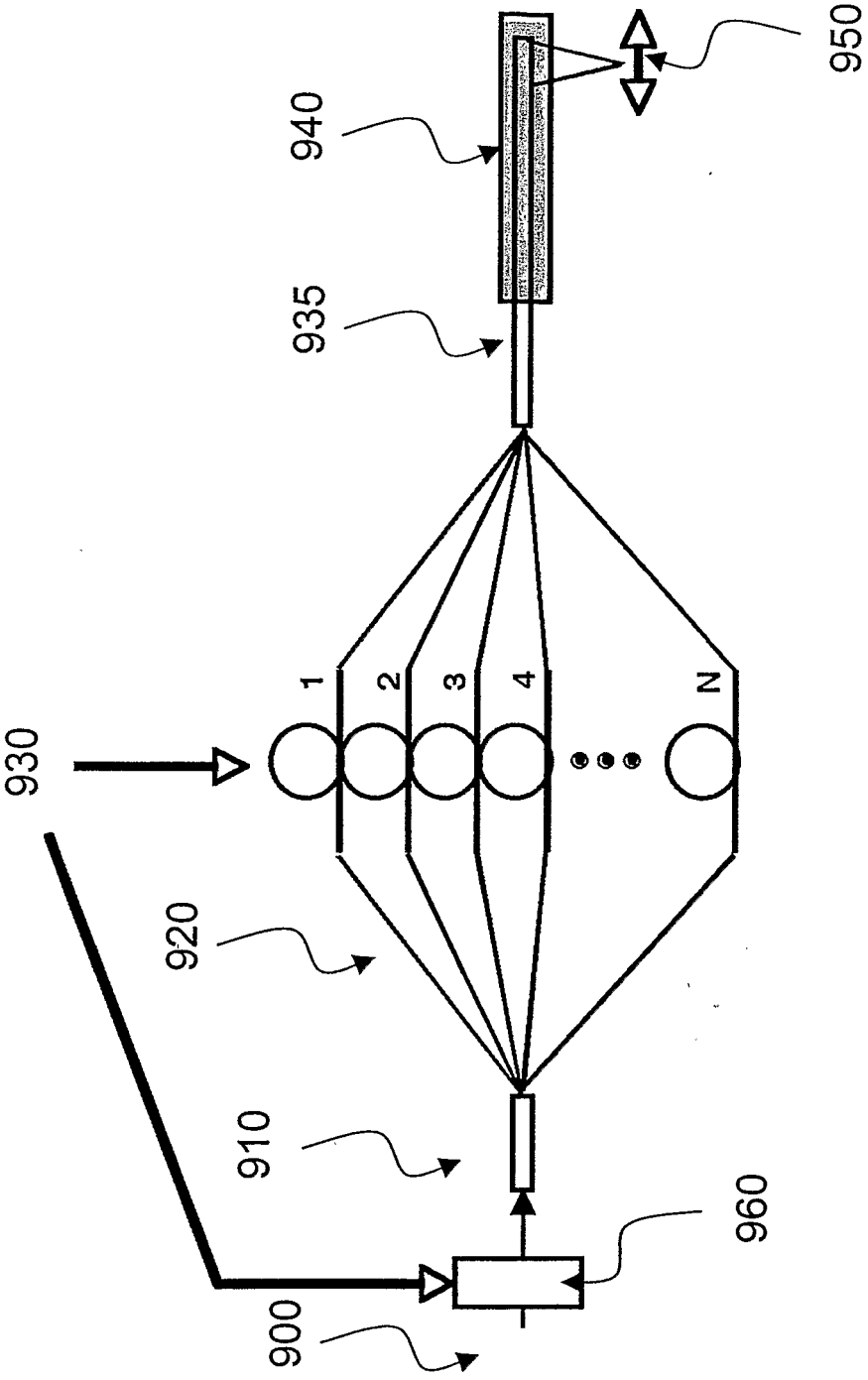

FIGURE 9

INTERNATIONAL SEARCH REPORT

International application No
IS2005/043951

A. CLASSIFICATION OF SUBJECT MATTER
A61B5/00 G02B21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B G01N G01B G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/122246 A1 (TEARNEY GUILLERMO J ET AL) 5 September 2002 (2002-09-05) paragraph [0004] - paragraph [0014]; figures 1-20 paragraph [0036] - paragraph [0061]	1-30
X	WO 02/38040 A (THE GENERAL HOSPITAL CORPORATION; TEARNEY, GUILLERMO, J; BOUMA, BRETT,) 16 May 2002 (2002-05-16) page 4, line 2 - page 11, line 25; figures 1-7 page 13, line 5 - page 14, line 18 page 15, line 22 - page 19, line 26 page 21, line 13 - page 22, line 13	1-9, 16-20, 22-30

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex

* Special categories of cited documents :

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"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 March 2006	06/04/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Neef, T

INTERNATIONAL SEARCH REPORT

International application No
US2005/043951

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
A	EP 1 426 799 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD) 9 June 2004 (2004-06-09) paragraph [0016] - paragraph [0081]; figures 1-27	

INTERNATIONAL SEARCH REPORT

International application No
/US2005/043951

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002122246 A1	05-09-2002	US 6341036 B1	22-01-2002
WO 0238040 A	16-05-2002	AU 3119802 A	21-05-2002
		EP 1343411 A2	17-09-2003
EP 1426799 A	09-06-2004	CN 1504781 A	16-06-2004
		US 2004105677 A1	03-06-2004

专利名称(译)	通过同时照射和检测样品上的多个点来执行光学成像的装置，装置，内窥镜，导管和方法		
公开(公告)号	EP1816949A1	公开(公告)日	2007-08-15
申请号	EP2005826091	申请日	2005-11-29
[标]申请(专利权)人(译)	通用医疗公司		
申请(专利权)人(译)	总医院CORPORATION		
当前申请(专利权)人(译)	总医院CORPORATION		
[标]发明人	TEARNEY GUILLERMO J DEBOER JOHANNES F BOUMA BRETT EUGENE		
发明人	TEARNEY, GUILLERMO, J. DEBOER, JOHANNES, F. BOUMA, BRETT, EUGENE		
IPC分类号	A61B5/00 G02B21/00		
CPC分类号	G02B23/2469 A61B5/0066 A61B5/0073 A61B5/6852 G01B9/02001 G01B9/02091 G02B21/0032 G02B21/0056 G02B23/2453 G02B23/26		
优先权	60/631539 2004-11-29 US		
外部链接	Espacenet		

摘要(译)

提供了适于传播至少一个电磁辐射的装置，装置，内窥镜，导管和方法。特别地，可以利用具体配置的波导装置将电磁辐射分成多个光束，这些光束用于照射生物样品，并赋予每个光束独特的相关特性。光束可以用于在不同的位置照射生物样品，并且为每个光束赋予独特的相关特性。另外，可以提供一种控制装置，该控制装置被配置成控制至少一根光纤并且可以输入光纤，以便修改沿光纤传播的光束的独特相关特性，从而改变特性。样本上的不同位置。