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(54) **METHODS, ARRANGEMENTS AND SYSTEMS FOR OBTAINING INFORMATION ASSOCIATED WITH AN ANATOMICAL SAMPLE USING OPTICAL MICROSCOPY**

VERFAHREN, ANORDNUNGEN UND SYSTEME ZUM ABRUFEN VON INFORMATIONEN IM ZUSAMMENHANG MIT EINER ANATOMISCHEN PROBE MITHILFE EINES OPTISCHEN MIKROSKOPS

PROCÉDÉS, AGENCEMENTS ET SYSTÈMES POUR OBTENIR DES INFORMATIONS ASSOCIÉES À UN PRÉLÈVEMENT ANATOMIQUE UTILISANT LA MICROSCOPIE OPTIQUE

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Description**FIELD OF THE INVENTION**

[0001] The present invention relates to methods, arrangements and systems which obtain information associated with an anatomical sample using optical microscopy, and more particularly to such methods, systems and arrangements that obtain the information based on light scattering in an anatomical structure via acoustic phonons optically generated in the anatomical structure.

BACKGROUND INFORMATION

[0002] When an optical wave is propagated in a medium, a portion of its energy can be converted to the kinetic energy of the medium by exciting acoustic phonons. This process can be facilitated by various mechanisms such as thermal or electrostriction effect. The excited acoustic phonons in turn generate inelastic scattering of the optical wave, known as Brillouin scattering. The magnitude and frequency (e.g., spectrum) of the Brillouin scattered light can be determined using the acoustic phonons generated therein. Such generated photons are likely closely related to mechanical properties of the medium, such as modulus, density, and structural shape. These mechanical properties therefore can be measured by examining the Brillouin scattered light. This technique is known as Brillouin spectroscopy. Various conventional techniques to detect the Brillouin signal have been applied in physics, material science, and mechanical engineering area. In addition, the Brillouin process can be enhanced via the use of multiple optical pump waves with frequencies separated by those of the acoustic phonons in the medium.

[0003] The Brillouin microscopy generally differs from the Raman microscopy or spectroscopy in that the Brillouin microscopy involves acoustic phonons instead of vibrational phonons Raman scattering is generally based upon. Since the Brillouin shift ranges typically from 10 MHz to 10 GHz, the direct electrical detection of the acoustic wave may also be possible.

[0004] Accordingly, there is a need to overcome the deficiencies described herein above.

OBJECTS AND SUMMARY OF THE DISCLOSURE

[0005] To address and/or overcome the above-described problems and/or deficiencies, exemplary embodiments of microscopy systems, arrangements and processes can be provided that are capable of combining the Brillouin effects with high-resolution microscopy to probe mechanical properties of an anatomical sample, such as human tissue in vivo or artificially engineered tissue. When applied to the biological tissue, these exemplary embodiments of the microscopy systems, arrangements and processes allow the biomechanical properties to be characterized at the tissue or possibly cellular level. The invention/s is/are defined in the claims.

[0006] In one exemplary embodiment of the present disclosure, a pump beam can be scanned over the biological sample through an objective lens, and the beating signal between the pump and Brillouin-shifted optical waves may be detected to characterize the Brillouin spectrum. The measured spectral features of the Brillouin signal can be converted to an image, e.g., by use of a proper lookup table or computer software which associates the spectral features to data associated with images. For example, thin cross-sectional images of a thick biological sample can be obtained by using a high numerical-aperture objective lens and confocal detection.

[0007] According to another exemplary embodiment of the present disclosure, a secondary pump beam with a different optical frequency can be used to facilitate a generation of acoustic phonons through stimulated or forced Brillouin scattering. In an exemplary variant of the present invention, anti-stokes Brillouin scattering technique(s) can be implemented using multiple pump beams. Various pump and probe techniques, and/or heterodyne or spectrometer-based detection techniques can be used.

[0008] Tissue biomechanical properties can be altered in a variety of disease states, and therefore may be appropriate targets for non-invasive diagnosis. A further exemplary embodiment of the systems, arrangements and processes of the present disclosure can make it possible to obtain the information about intrinsic tissue biomechanical properties that are not readily available by other ways, and therefore determine a wide range of applications in biology and medicine. For example, the Brillouin microscopy can become a clinical tool for the detection of early-stage cancers or intra-operative determination of tumor margins. Considering that tumors are generally stiffer than surrounding healthy tissue, the Brillouin spectrum of a tumor can possibly exhibit a stronger magnitude at high frequencies than that of normal tissues. Atherosclerosis is another medical area the Brillouin microscopy may be useful for characterizing stress and tissue compliance to identify plaques at risk for causing an acute coronary event. For example, it is disclosed, but not part of the claimed inventive methods, that a scanning catheter or hand-held endoscope may be used to perform the Brillouin measurement in living patients.

[0009] Thus, in accordance with one exemplary embodiment of the present disclosure, arrangements and methods

are provided for obtaining information associated with an anatomical sample. For example, at least one first electro-magnetic radiation can be provided to the anatomical sample so as to generate at least one acoustic wave in the anatomical sample. At least one second electro-magnetic radiation can be produced based on the acoustic wave. At least one portion of at least one second electro-magnetic radiation can be provided so as to determine information associated with at least one portion of the anatomical sample.

[0010] According to another exemplary embodiment of the present disclosure, the information based on data associated with the second electro-magnetic radiation can be analyzed. The first electro-magnetic radiation may include at least one first magnitude and at least one first frequency. The second electro-magnetic radiation can include at least one second magnitude and at least one second frequency. The data may relate to a first difference between the first and second magnitudes and/or a second difference between the first and second frequencies. The second difference may be approximately between -100 GHz and 100 GHz, excluding zero.

[0011] In another exemplary embodiment of the present disclosure, at least one fourth arrangement configured to image the portion of the anatomical sample based on data associated with the second electro-magnetic radiation can be provided. Further, at least one fifth arrangement configured may be provided to translate the at least one electro-magnetic radiation across the anatomical sample. The fifth arrangement may include at least one lens, and the lens can focus the first electro-magnetic radiation and can collect the second electro-magnetic radiation. The second arrangement can include a spectral filter which may facilitate a determination of a spectrum of the second electro-magnetic radiation. The information can be associated with a biomechanical property of the anatomical sample. The anatomical sample may be a living subject.

[0012] According to still another exemplary embodiment of the present disclosure, the first electromagnetic radiation may have a center wavelength which is approximately between 0.5 - 1.8 μm . The first electromagnetic radiation can have a line width which is smaller than approximately 100 MHz. The first electromagnetic radiation can have a form of a plurality of pulses, and the duration of each of the pulses may be longer than approximately 10 ns. The first electro-magnetic radiation includes at least two first electro-magnetic radiations, a first one of the first electro-magnetic radiations having a first frequency, and a second one of the first electro-magnetic radiations having a second frequency. A difference between the first and second frequencies is between approximately zero and 100 GHz. It is possible to receive at least one third electro-magnetic radiation which has at least one third magnitude and at least one third frequency. The second frequency may be determined as a function of the first and third frequencies. The third electro-magnetic radiation can be forwarded from an electromagnetic radiation source.

[0013] These and other objects, features and advantages of the present disclosure will become apparent upon reading the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Further objects, features and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying figures showing illustrative embodiments in accordance with the present invention, in which:

Fig. 1A is a first illustration of an exemplary example and a Brillouin effect of a method in accordance with the present invention;

Fig. 1B is a second illustration of an exemplary example and a Brillouin effect of the method according to the present invention;

Fig. 2 is an illustration of a Brillouin scattering procedure in tissue using the exemplary embodiment of a method in accordance with the present invention;

Fig. 3A is a first illustration of a further application of the exemplary embodiment of a method in accordance with the present invention which produces a beam scanning Brillouin imaging;

Fig. 3B is a second enlarged illustration of the application of the exemplary embodiment of the method shown in Fig. 3A;

Fig. 4A is a first illustration of a beam focusing procedure implemented by the exemplary embodiment of the method in accordance with the present invention in an exemplary embodiment of an arrangement according to the present invention;

Fig. 4B is a second illustration of a beam focusing procedure implemented by the exemplary embodiment of the method as shown in Fig. 4A

Fig. 4C is a third illustration of a beam focusing procedure implemented by the exemplary embodiment of the method as shown in Figs. 4A and 4B;

Fig. 5 is a block diagram of an exemplary embodiment of a scanning-beam Brillouin spectroscopy arrangement in accordance with the present invention;

Fig. 6A is a block diagram of a first exemplary embodiment of a Brillouin microscopy arrangement that can use

interferometry in accordance with the present invention;

Fig. 6B is a block diagram of a second exemplary embodiment of the Brillouin microscopy arrangement that can use interferometry in accordance with the present invention;

Fig. 6C is a block diagram of a third exemplary embodiment of the Brillouin microscopy arrangement that can use interferometry in accordance with the present invention;

Fig. 7A is an illustration of a first stage in generating an exemplary two-frequency pump wave using an exemplary embodiment of a method and arrangement in accordance with the present invention;

Fig. 7B is an illustration of a second stage in generating the exemplary two-frequency pump wave in conjunction with the generation shown in Fig. 7A;

Fig. 7C is an illustration of a third stage in generating the exemplary two-frequency pump wave in conjunction with the generation shown in Figs. 7A and 7B;

Fig. 7D an illustration of is a fourth stage in generating the exemplary two-frequency pump wave in conjunction with the generation shown in Figs. 7A-7C;

Fig. 8A is a first exemplary illustration of a Brillouin signal generation using the exemplary embodiment of the method and arrangement in accordance with the present invention;

Fig. 8B is a second exemplary illustration of the Brillouin signal generation using the exemplary embodiment of the method and arrangement in accordance with the present invention;

Fig. 8C is a illustration of an image produced by the signals shown in Figs. 8A and 8B using the exemplary embodiment of the method and arrangement in accordance with the present invention;

Fig. 9A is an illustration of a medical application using an exemplary embodiment of a catheter in accordance with the present invention; and

Fig. 9B is an illustration of a medical application using an exemplary embodiment of an endoscope in accordance with the present invention.

[0015] 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.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0016] Figs. 1A and 1B illustrate exemplary application of an exemplary embodiment of a method which implement a principle of Brillouin scattering in accordance with the present invention. For example, a monochromatic pump light with a frequency $\nu = \omega/2\pi$ can be provided incident on a medium under test. An exemplary generation of an acoustic wave can be initiated by seed photons which may quantum-mechanically originate from a vacuum fluctuation. There may be one seed photon per unit frequency bandwidth.

[0017] The pump and seed photons may interfere with one another, and generate a mechanical stress modulation in the medium via thermal or electrostriction effects. When the stress modulation is phase-matched to one of the characteristic acoustic phonon modes in the medium, the corresponding acoustic phonons can develop efficiently through a coherent process. The excited acoustic phonons in turn may create a refractive-index modulation in the medium, and generate inelastic scattering of photons. The energy and momentum of the photons can be modified by an inelastic scattering procedure. The magnitude of a frequency shift in the scattered photons can be substantially or approximately equal to that of the acoustic phonons. This exemplary procedure is called "Brillouin phenomenon" or "Brillouin scattering." Although both Stokes and anti-Stokes components can be generated, typically Stokes Brillouin component (e.g., frequency down shifted) would likely be predominantly generated.

[0018] Exemplary phase matching conditions between the pump scattering light and the acoustic wave can be expressed as:

$$\omega_A = \omega_p - \omega_s \quad (1)$$

$$\vec{k}_A = \vec{k}_p - \vec{k}_s \quad (2)$$

where ω and k are angular frequency and wave number, respectively, and the subscript A, p, and s represent acoustic phonons, pump and scattering (or signal) photons, respectively. The frequency of the phase matched phonons, e.g., the difference between the pump and scattering photons, can be given by

$$\omega_A = |\vec{k}_A| V_A = 2V_A |\vec{k}_p| \sin(\theta/2) \quad (3)$$

[0019] Where V_A denotes the speed of the acoustic phonon mode (e.g., an acoustic wave) in the medium and θ is an angle between the pump and scattering photons (e.g., optical waves). The Brillouin shift, as expressed in Eq. (3), can increase with the acoustic speed. In a solid state medium, the acoustic speed is proportional to the square root of the modulus. When the two waves propagate at the opposite direction, $\theta = 180^\circ$, the magnitude of Brillouin shift can become maximum.

[0020] For example, Fig. 1A illustrates a backward Brillouin scattering effect in an exemplary implementation of an exemplary embodiment of the present invention. The pump wave 12 with frequency ν is incident on a medium 10, and generates an acoustic wave represented by the wave fronts 13 and its wave vector 14 corresponding to an acoustic frequency ν_B . The Brillouin scattered light 16 satisfying the phase matching condition may have a frequency $\nu - \nu_B$. For example, if there are a large number of acoustic modes present in a sample; then the spectrum of the Brillouin scattered light may consist of multiple lines characterized by their frequencies, magnitudes, and spectral widths, all of which may be related to the mechanical properties of the sample. If the medium 10 is optically transparent, no Anti-stokes Brillouin light 18 with a frequency higher than that of the pump wave would likely be produced. In a turbid medium such as biological tissue, and the light can experience a strong elastic Mie or Rayleigh scattering, in addition to much weaker inelastic Brillouin or Raman scattering. The elastically scattered light, diffused in random directions, may interfere with each other, and can result in a detectable Anti-stokes Brillouin light.

[0021] When the acoustic wave is initially provided, the Brillouin phenomenon can be accelerated because of the presence of the scattered light. The scattered light, coherent with the pump light, may amplify the resonant acoustic wave, which in turn may enhance the Brillouin scattering. This positive feedback can result in a strong Brillouin shifted scattered light, e.g., a procedure called "stimulated Brillouin scattering." In a long optical fiber, this exemplary procedure can arise at a very low pump power of several tens of mW, and may be characterized by the Brillouin gain provided by

$$g_B(\nu_B) = \frac{2\pi n^7 p_{12}^2}{c \lambda_p^2 \rho_0 V_A \Delta \nu_B} \omega_p - \omega_s \quad (4)$$

where n is the refractive index, p_{12} is the elasto-optic coefficient, and ρ is the density.

[0022] Fig. 1B shows another application of a Brillouin interaction according to the exemplary embodiment of the present invention in a turbid medium 22 initiated by two pump waves 20, 21 with a frequency difference of $\Delta\nu$. The exemplary elastic scattering of the pump waves can stimulate the excitation of acoustic waves (phonons) propagating multiple directions. In the exemplary illustration of Fig. 1B, only two waves propagating along the forward and backward directions 23, 24. The resulting Brillouin scattered light has multiple spectral lines including the Stokes 26 and anti-Stokes 28 components. This exemplary application according to the present invention may be used to enhance the generation of the anti-Stokes line. For example, the maximum Brillouin efficiency can be achieved when the frequency difference substantially matches the frequency of at least one of the acoustic waves (phonons) generated in this manner.

[0023] Because the efficiency of Brillouin scattering is likely proportional to an optical intensity, a higher efficiency can be obtained by focusing the pump light to the sample. By focusing, higher spatial discrimination or resolution can be obtained. Figure 2 illustrates an exemplary use of objective lens 30 in accordance with an exemplary embodiment of the present invention for both focusing a pump beam 32 to a sample 34, and collecting a backward propagating Brillouin scattered light 36. Such exemplary detection scheme can be called the "epi configuration." For example, Fig. 2 shows an associated acoustic wave 38 propagating forward, as well as elastically scattered, diffused waves 40. A portion of the elastically scattered light within the numerical aperture of the lens may be also collected. Because the Brillouin process can produce a phase conjugation, the backward Brillouin scattering may be efficiently collected, even with a low numerical-aperture objective lens.

[0024] Brillouin spectroscopy is a technique that can measure the spectrum of the Brillouin scattered light, thereby allowing the properties of inherent acoustic phonons of a medium. The Brillouin spectrum may be closely related to the mechanical properties of the medium through the phase matching conditions represented in Equations (1) and (2) (e.g., in their simplest forms).

[0025] One of the important features of an exemplary embodiment of the present invention is an image generation feature. Using a predetermined or calculated conversion table, the spatial variation of the Brillouin spectra may be presented as an image. To generate images, the pump or probe beam can be scanned laterally across the sample, and/or the sample can itself be translated. Figs 3A and 3B illustrate two respective beam scanning applications in accordance with an exemplary embodiment of the present invention which can use a galvanometer and rotational catheter. As shown in Fig. 3A, the pump wave 60 may be reflected by a galvanometer-mounted mirror 62, and focused

by an objective lens 64 to a medium 68. Light collected by the objective lens 64 in the epi mode can consist of a backscattered component 70 and a Brillouin shifted component 72. Other conventional scanners can be used, including but not limited to polygonal mirror scanners and MEMS mirrors. Fig. 3B depicts an exemplary beam-scanning application that uses an exemplary embodiment of an arrangement according to the present invention based on a fiber-optic catheter or endoscope for an application to, for example, luminal organ imaging. For example, a catheter can include a single mode fiber 80, a focusing lens 82, a prism 84, a drive shaft 86, and a protective sheath 88. A catheter core, rotated inside the stationary sheath 88, can scan across the tissue 92 using an optical beam 90 in a helical manner.

[0026] The beam size of the pump beam at the sample can determine the spatial resolution. When a coarse spatial resolution is sufficient, it is possible to use a collimated beam. As shown in Fig. 4A, an exemplary implementation of an objective lens 100 with a low numerical aperture ("NA") can result in a low transverse resolution. With the longitudinal interaction length likely being long and well defined (Fig. 4A); an objective lens 102 with a high NA may provide better transverse and axial resolution, as shown in Fig. 4B. With the high NA, the Brillouin interaction length is likely to be short, and the phase matching can be met over a large solid angle. In both cases, the backward-propagating Brillouin light may be detected in the epi configuration, Fig. 4C depicts another exemplary implementation an use of the exemplary embodiments of the method and arrangement according to the present disclosure using at least two objective lenses 104, 106. This scheme, however, may not be appropriate for thick tissue or *in vivo* applications.

[0027] Fig. 5 depicts a block diagram of an exemplary embodiment of an arrangement according to the present invention. For example, the arrangement of Fig. 5 includes a light source 110, preferably a monochromatic laser emitting visible or infrared light source, and a pump beam/wave 111 that can be illuminated to a sample 112 through a beam splitter 114, a beam scanner 116, and an objective lens 118. The light source 110 can be, but not limited to, a cw single frequency laser with a center wavelength between 0.5 and 1.8 microns and a narrow line width, typically less than 100 MHz, providing temporal coherence longer than the lifetime of phonons. Another preferred type of light source is a Q-switched single frequency laser. The pulse repetition rate may range from 1 to 100 kHz, and the pulse duration from 10 ns to 1 μ s. The Q-switched pump light can result in higher Brillouin generation efficiency because the intensity is higher than that of cw light at the same average power level. The light source 110 may utilize or include an optical arrangement to deliver more than one frequency components (illustrated in Figs. 8A and 8B). The lateral step size of the beam scan can be approximately equal to the focal spot size of the pump beam/wave 111 in the sample 112.

[0028] The scattered light 120 provided from the sample 112 and collected by the objective lens 118 may originate from both elastic and inelastic scattering. The spectrum of the scattered light may be measured using a spectrally-selective arrangement 120, such as scanning filters, etalons, virtual interferometer phase arrays, or spectrometers. Various scanning filters are known in the art, including but not limited to a Fabry-Perot interferometer. For example, the Brillouin shift can be as high as several tens of GHz. The exemplary Fabry-Perot scanning interferometer may have a free spectral range of 50 GHz, and finesse of 1000. The spectrally selected optical photons may then be converted to electrical signals at a detector 122 (e.g., a photo-multiplier tube, avalanche photodiode, or charge-coupled-device array).

[0029] Other exemplary embodiments of the present invention that use fiber-optic heterodyne interferometers are shown in the block diagrams of Figs. 6A and 6B. In Fig. 6A, a single-frequency laser 150 is shown to be coupled to a fiber-optic beam splitter 152 with an exemplary splitting ratio of approximately 90:10. One optical path, termed a sample arm 154, can be connected to a beam scanner 156 via a circulator 158, and the other path, termed a reference arm 170, may contain a frequency shifter 172 such as an acousto-optic or electro-optic modulator. Both the sample and reference arms 154, 170 may be combined at another fiber-optic beam splitter 180, with, e.g., equal splitting ratios. The interference signal between the backscattered light in the sample arm 154 and the frequency-shifted reference light in the reference arm 170 can be measured by a dual balanced receiver 182, and processed using a computer 184. The frequency shifter 172 can be used to decrease the beat frequency between scattered and reference light, and a polarization controller 174 may also be utilized, as shown in Fig. 6A. According to another exemplary embodiment of the present invention, an electrical spectrum analyzer may replace or complement the computer 184. Alternatively, the Brillouin spectra may be determined by tuning the magnitude of frequency shift by the shifter 172 and measuring the beat signal with a low-bandwidth detector 182.

[0030] Fig. 6B depicts a block diagram of another exemplary configuration according to a further exemplary embodiment of the present invention that uses two monochromatic lasers 200, 202, with a tunable frequency difference. One laser 200 is coupled to a sample arm 210 for delivering the pump wave. The second laser 202 can serve as a local oscillator to provide the reference light with a frequency detuned from that of the pump source by a predetermined amount. The frequency of the local oscillator can be close to that of one of Brillouin signal light, and the beat frequency may be measured by a detector 220. For example, the line widths of the pump source 200 and the local oscillator 202 should be significantly narrow, and typically less than 100 kHz, to effect a temporal coherency between the scattered and reference light.

[0031] Fig. 6C illustrates a block diagram of yet another exemplary embodiment of the arrangement according to the present invention based on a frequency-swept laser 230 that can be preferably either one of a mode-hop-free extended-cavity semiconductor laser, temperature-tuned distributed feedback laser, and cavity-modulated solid-state laser. The

reference arm 232 may contain a delay line 234 providing an optical delay by a fixed amount and/or a variable amount controlled by the length difference between the reference and sample arms 232, 240. The length mismatch between the two arms can be selected as follows:

$$\Delta L \approx \frac{c}{n \alpha} v_B, \quad (5)$$

where c is the speed of light, n is the refractive index of medium, α is the tuning speed, and v_B is the frequency of acoustic phonons of interest. Pursuant to such selection, the electrical beat frequency measured by a detector 244 can be significantly smaller than the acoustic frequency. On the other hand, when the path lengths of the two arms 232, 240 are substantially matched, such exemplary measurement technique may be similar to the optical frequency domain reflectometry. The interference signal measured as a function of wavelength can be processed via a Fourier transform to produce an axial profile of elastic backscattering coefficients. Similarly, with appropriate length mismatch, similar signal processing may yield an axial profile of Brillouin scattering coefficients.

[0032] Figs. 7A-7D depict various stages of two different exemplary source arrangements according to an exemplary embodiment of the present invention which are capable of producing the pump wave consisting of two different frequency components. The Brillouin spectroscopy based on such two-frequency pump wave is illustrated in Fig. 1B and described herein above. For example, in Fig. 7A, an electro-optic modulator with a proper DC bias can produce two sidebands from a monochromatic laser input. In Fig. 7B, two low-drift monochromatic lasers may be combined with a beam combiner 270. In the epi configuration, the combined pump waves may be delivered to a sample 280 through an objective lens 282, as shown in Fig. 7C. In a transmission configuration, a secondary objective lens 284 may be used to launch one of the two frequency components in the opposite direction, as shown in Fig. 7D.

[0033] Figs. 8A and 8B illustrate exemplary Brillouin spectra obtained from two different locations in a sample according to the exemplary embodiment of the present invention. For example, the difference between the two spectra, represented in these figures by the magnitude of v_B , may indicate a difference in stiffness between the two locations. An image 300 (shown in Fig. 8C) can be formed based on the measured Brillouin signal and by using a grayscale look up table 310 and/or a false color lookup table 320. The lookup table(s) 310, 320 may be based on the magnitude and/or the frequency of one or more specific Brillouin peaks.

[0034] Figs. 9A and 9B illustrates possible exemplary clinical applications of Brillouin microscopy 400 in human 410 by use of a fiber-optic catheter 420 or endoscope 430 in accordance with an exemplary embodiment of the present inventive arrangement. The catheter 420 may have a similar configuration as shown in Fig. 3B. and described above. The endoscope 430 may employ a two-axis XY beam scanning actuator, such as MEMS scanners. Potential applications of Brillouin microscopy can include tissue characterization based on biomechanical properties, cancer diagnosis, tumor margin determination, wound healing monitoring, tissue ablation monitoring, and tissue engineering among many.

[0035] 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, spectral domain OCT (SD-OCT) system or other 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 referenced 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.

Claims

1. An arrangement comprising:

at least one first arrangement configured to provide at least one first electromagnetic radiation to an anatomical sample which is a living subject so as to be able to generate at least one acoustic wave in the anatomical sample, wherein at least one second electro-magnetic radiation is producible in the living subject based on the at least one acoustic wave; and

at least one second arrangement configured to receive at least one portion of the at least one second electro-magnetic radiation so as to determine information associated with at least one portion of the anatomical sample; and

wherein the at least one first electromagnetic radiation includes at least two different frequency components,

wherein a first one of the at least two components has a first frequency, and a second one of the at least two components has a second frequency, and wherein a difference between the first and second frequencies is between approximately 0 and 100 GHz;

at least one third arrangement configured to image the at least one portion of the anatomical sample based on data associated with the at least one second electro-magnetic radiation;

at least one fourth arrangement configured to translate the at least one electro-magnetic radiation across the anatomical sample, or configured to scan or configured to scan the at least one electro-magnetic radiation across or over the anatomical sample; and wherein the at least one fourth arrangement is at least one of a catheter, an endoscope, a laparoscope, or an ophthalmic visualization device;

and wherein the fourth arrangement comprises an objective lens adapted to deliver the first electromagnetic radiation to the anatomical sample and adapted for collecting said second radiation, said second radiation being a Brillouin backscattered light component from the anatomical sample due to said at least one acoustic wave.

2. The arrangement according to claim 1, wherein the anatomical sample is at least one of an organ, a tissue or cell.

3. The arrangement according to claim 1, wherein the first component of the at least one first electro-magnetic radiation has a first magnitude, wherein the at least one second electro-magnetic radiation includes at least one component having a second magnitude and at least one second frequency, and wherein the data relates to at least one of a first difference between the first and second magnitudes or a second difference between the first frequency of the first component of the at least one first electro-magnetic radiation and the second frequency of the at least one second electro-magnetic radiation .

4. The arrangement according to claim 3, wherein the second frequency is different to the first frequency and wherein the second difference is approximately between - 100 GHz and 100 GHz.

5. The arrangement according to claim 1, wherein the at least one second arrangement includes a spectral filter which facilitates a determination of a spectrum of the at least one second electro-magnetic radiation.

6. The arrangement according to claim 1, wherein the information is associated with a biomechanical property of the anatomical sample.

7. The arrangement according to claim 1, wherein the at least one first electromagnetic radiation has at least one component having a center wavelength which is approximately between 0.5 - 1.8 μm .

8. The arrangement according to claim 7, wherein the at least one first electromagnetic radiation has at least one component having a line width which is smaller than approximately 100 MHz.

9. The arrangement according to claim 7, wherein the at least one first electromagnetic radiation has a form of a plurality of pulses, and wherein the duration of each of the pulses is longer than approximately 10 ns.

10. The arrangement according to claim 1, wherein the at least one third electromagnetic radiation is forwarded from an electromagnetic radiation source.

11. The arrangement according to claim 1, wherein, the at least one third arrangement is configured to analyze the data associated with the at least one second electro-magnetic radiation, wherein the first component of the at least one first electro-magnetic radiation has a first magnitude, wherein the at least one second electro-magnetic radiation includes at least one component having a second magnitude and at least one second frequency, and wherein the data relates to at least one of a first difference between the first and second magnitudes or a second difference between the first frequency of the first component of the at least one first electro-magnetic radiation and the frequency of the at least one second electro-magnetic radiation, and wherein the second difference is approximately between - 100 GHz and 100 GHz, excluding zero.

12. The arrangement according to claim 11, wherein the at least one first electromagnetic radiation has a center wavelength which is approximately between 0.5 - 1.8 μm .

13. The arrangement according to claim 12, wherein the at least one first electromagnetic radiation has a line width which is smaller than approximately 100 MHz.

14. The arrangement according to claim 12, wherein the at least one first electromagnetic radiation has a form of a plurality of pulses, and wherein the duration of each of the pulses is longer than approximately 10 ns.
15. The arrangement according to claim 11, wherein the at least one second arrangement is configured to receive at least one third electro-magnetic radiation which has at least one component having a third magnitude and at least one third frequency, and wherein the second frequency is determined as a function of the first and third frequencies.
16. The arrangement according to claim 1, wherein the at least one acoustic wave is generated through stimulated or forced Brillouin scattering.
17. The arrangement according to claim 16, wherein the second one of the at least two first electromagnetic radiations is provided from a pump beam that is different to that used to provide the first one of the at least two first electro-magnetic radiations.
18. The arrangement according to claim 1, wherein the difference between the first and second frequencies is configured to substantially match a frequency of at least one of the at least one acoustic wave.
19. The arrangement according to claim 1, wherein a line width of each of the at least two first electro-magnetic radiations is less than 100kHz.
20. A method comprising:
 - providing by at least one first arrangement at least one first electromagnetic radiation to an anatomical sample which is a living subject and generating at least one acoustic wave in the anatomical sample, wherein at least one second electro-magnetic radiation is produced in the living subject based on the at least one acoustic wave; and
 - receiving by at least one second arrangement at least one portion of the at least one second electro-magnetic radiation so as to determine information associated with at least one portion of the anatomical sample; and
 - wherein the at least one first electromagnetic radiation includes at least two different frequency components, wherein a first one of the at least two components has a first frequency, and a second one of the at least two components has a second frequency, and wherein a difference between the first and second frequencies is between approximately 0 and 100 GHz;
 - imaging by at least one third arrangement the at least one portion of the anatomical sample based on data associated with the at least one second electro-magnetic radiation;
 - translating the at least one electro-magnetic radiation across the anatomical sample, or scanning the at least one electro-magnetic radiation across or over the anatomical sample by an ophthalmic visualization device; and
 - wherein the ophthalmic visualization device comprises an objective lens adapted to deliver the first electromagnetic radiation to the anatomical sample and adapted for collecting said second radiation, said second radiation being a Brillouin backscattered light component from the anatomical sample due to said at least one acoustic wave.
21. The method according to claim 20, wherein the anatomical sample is at least one of an organ, a tissue or cell.
22. The method according to claim 20, wherein the first component of the at least one first electro-magnetic radiation has a first magnitude, wherein the at least one second electro-magnetic radiation includes at least one component having a second magnitude and at least one second frequency, and wherein the data relates to at least one of a first difference between the first and second magnitudes or a second difference between the first frequency of the first component of the at least one first electro-magnetic radiation and the second frequency of the at least one second electro-magnetic radiation .
23. The method according to claim 22, wherein the second frequency is different to the first frequency and wherein the second difference is approximately between -100 GHz and 100 GHz.
24. The method according to claim 20, wherein the at least one second arrangement includes a spectral filter and wherein the method comprises determining a spectrum of the at least one second electro-magnetic radiation.
25. The method according to claim 20, wherein the information is associated with a biomechanical property of the anatomical sample.

26. The method according to claim 20, wherein the at least one first electromagnetic radiation has at least one component having a center wavelength which is approximately between 0.5 - 1.8 μm .
27. The method according to claim 26, wherein the at least one first electromagnetic radiation has at least one component having a line width which is smaller than approximately 100 MHz.
28. The method according to claim 26, wherein the at least one first electromagnetic radiation has a form of a plurality of pulses, and wherein the duration of each of the pulses is longer than approximately 10 ns.
29. The method according to claim 20, wherein method comprises forwarding the at least one third electromagnetic radiation from an electromagnetic radiation source.
30. The method according to claim 20, wherein, the at least one third arrangement analyzes the data associated with the at least one second electromagnetic radiation, wherein the first component of the at least one first electro-magnetic radiation has a first magnitude, wherein the at least one second electro-magnetic radiation includes at least one component having a second magnitude and at least one second frequency, and wherein the data relates to at least one of a first difference between the first and second magnitudes or a second difference between the first frequency of the first component of the at least one first electro-magnetic radiation and the frequency of the at least one second electro-magnetic radiation, and wherein the second difference is approximately between -100 GHz and 100 GHz, excluding zero.
31. The method according to claim 30, wherein the at least one first electromagnetic radiation has a center wavelength which is approximately between 0.5 - 1.8 μm .
32. The method according to claim 33, wherein the at least one first electromagnetic radiation has a line width which is smaller than approximately 100 MHz.
33. The method according to claim 331, wherein the at least one first electromagnetic radiation has a form of a plurality of pulses, and wherein the duration of each of the pulses is longer than approximately 10 ns.
34. The method according to claim 30, wherein the method comprises receiving by the at least one second arrangement at least one third electro-magnetic radiation which has at least one component having a third magnitude and at least one third frequency, and wherein the second frequency is determined as a function of the first and third frequencies.
35. The method according to claim 20, wherein the at least one acoustic wave is generated through stimulated or forced Brillouin scattering.
36. The method according to claim 35, wherein the second one of the at least two first electromagnetic radiations is provided from a pump beam that is different to that used to provide the first one of the at least two first electromagnetic radiations.
37. The arrangement according to claim 20, wherein the difference between the first and second frequencies substantially matches a frequency of at least one of the at least one acoustic wave.
38. The arrangement according to claim 20, wherein a line width of each of the at least two first electro-magnetic radiations is less than 100kHz.

Patentansprüche

1. Anordnung umfassend:

mindestens eine erste Anordnung, die eingerichtet ist, eine anatomische Probe, die ein lebendes Subjekt ist, mit mindestens einer ersten elektromagnetischen Strahlung zu versorgen, um in der Lage zu sein, mindestens eine akustische Welle in der anatomischen Probe zu erzeugen, wobei mindestens eine zweite elektromagnetische Strahlung in dem lebenden Subjekt auf Basis der mindestens einen akustischen Welle erzeugbar ist; und mindestens eine zweite Anordnung, die eingerichtet ist, mindestens einen Bereich der mindestens einen zweiten elektromagnetischen Strahlung zu empfangen, um Informationen zu bestimmen, die mindestens einem Bereich

der anatomischen Probe zugeordnet sind; und

wobei die mindestens eine erste elektromagnetische Strahlung mindestens zwei verschiedene Frequenzkomponenten umfasst, wobei eine erste der mindestens zwei Komponenten eine erste Frequenz aufweist und eine zweite der mindestens zwei Komponenten eine zweite Frequenz aufweist, und wobei eine Differenz zwischen der ersten und der zweiten Frequenz zwischen ungefähr 0 und 100 GHz liegt;

mindestens eine dritte Anordnung, die eingerichtet ist, den mindestens einen Bereich der anatomischen Probe basierend auf Daten abzubilden, die der mindestens einen zweiten elektromagnetischen Strahlung zugeordnet sind;

mindestens eine vierte Anordnung, die eingerichtet ist, die mindestens eine elektromagnetische Strahlung durch die anatomische Probe zu übertragen, oder eingerichtet ist, die mindestens eine elektromagnetische Strahlung durch oder über die anatomische Probe zu scannen; und wobei die mindestens eine vierte Anordnung mindestens eines von einem Katheter, einem Endoskop, einem Laparoskop oder einer ophthalmischen Visualisierungs-
vorrichtung ist;

und wobei die vierte Anordnung eine Objektivlinse umfasst, die eingerichtet ist, die erste elektromagnetische Strahlung an die anatomische Probe abzugeben, und eingerichtet ist, die zweite Strahlung zu sammeln, wobei die zweite Strahlung eine von der anatomischen Probe aufgrund der mindestens einen akustischen Welle Brillouin-rückgestreute Lichtkomponente ist.

2. Anordnung nach Anspruch 1, wobei die anatomische Probe mindestens eines von einem Organ, einem Gewebe oder einer Zelle ist.

3. Anordnung nach Anspruch 1, wobei die erste Komponente der mindestens einen ersten elektromagnetischen Strahlung eine erste Größe aufweist, wobei die mindestens eine zweite elektromagnetische Strahlung mindestens eine Komponente eine zweite Größe und mindestens eine zweite Frequenz aufweist, und wobei sich die Daten auf mindestens eine erste Differenz zwischen der ersten und der zweiten Größe oder eine zweite Differenz zwischen der ersten Frequenz der ersten Komponente der mindestens einen ersten elektromagnetischen Strahlung und der zweiten Frequenz der mindestens einen zweiten elektromagnetischen Strahlung beziehen.

4. Anordnung nach Anspruch 3, wobei die zweite Frequenz sich von der ersten Frequenz unterscheidet und wobei die zweite Differenz ungefähr zwischen -100 GHz und 100 GHz liegt.

5. Anordnung nach Anspruch 1, wobei die mindestens eine zweite Anordnung einen Spektralfilter umfasst, der eine Bestimmung eines Spektrums der mindestens einen zweiten elektromagnetischen Strahlung erleichtert.

6. Anordnung nach Anspruch 1, wobei die Information einer biomechanischen Eigenschaft der anatomischen Probe zugeordnet ist.

7. Anordnung nach Anspruch 1, wobei die mindestens eine erste elektromagnetische Strahlung mindestens eine Komponente mit einer Zentralwellenlänge aufweist, die ungefähr zwischen 0,5 - 1,8 μm liegt.

8. Anordnung nach Anspruch 7, wobei die mindestens eine erste elektromagnetische Strahlung mindestens eine Komponente mit einer Linienbreite aufweist, die kleiner als etwa 100 MHz ist.

9. Anordnung nach Anspruch 7, wobei die mindestens eine erste elektromagnetische Strahlung eine Form einer Vielzahl von Pulsen aufweist und wobei die Dauer jedes der Pulse länger als etwa 10 ns ist.

10. Anordnung nach Anspruch 1, wobei die mindestens eine dritte elektromagnetische Strahlung von einer elektromagnetischen Strahlungsquelle gesendet ist.

11. Anordnung nach Anspruch 1, wobei die mindestens eine dritte Anordnung eingerichtet ist, die Daten zu analysieren, die der mindestens einen zweiten elektromagnetischen Strahlung zugeordnet sind, wobei die erste Komponente der mindestens einen ersten elektromagnetischen Strahlung eine erste Größe aufweist, wobei die mindestens eine zweite elektromagnetische Strahlung mindestens eine Komponente mit einer zweiten Größe und mindestens einer zweiten Frequenz aufweist, und wobei sich die Daten auf mindestens eine einer ersten Differenz zwischen den ersten und zweiten Größen oder einer zweiten Differenz zwischen der ersten Frequenz der ersten Komponente der mindestens einen ersten elektromagnetischen Strahlung und der Frequenz der mindestens einen zweiten elektromagnetischen Strahlung beziehen, und wobei die zweite Differenz ungefähr zwischen -100 GHz und 100 GHz, ausgenommen Null, liegt.

12. Anordnung nach Anspruch 11, wobei die mindestens eine erste elektromagnetische Strahlung eine Zentralwellenlänge aufweist, die ungefähr zwischen 0,5 - 1,8 μm liegt.
13. Anordnung nach Anspruch 12, wobei die mindestens eine erste elektromagnetische Strahlung eine Linienbreite aufweist, die kleiner als etwa 100 MHz ist.
14. Anordnung nach Anspruch 12, wobei die mindestens eine erste elektromagnetische Strahlung eine Form einer Vielzahl von Pulsen aufweist und wobei die Dauer jedes der Pulse länger als etwa 10 ns ist.
15. Anordnung nach Anspruch 11, wobei die mindestens eine zweite Anordnung eingerichtet ist, mindestens eine dritte elektromagnetische Strahlung zu empfangen, die mindestens eine Komponente mit einer dritten Größe und mindestens einer dritten Frequenz aufweist, und wobei die zweite Frequenz als eine Funktion der ersten und dritten Frequenz bestimmt ist.
16. Anordnung nach Anspruch 1, wobei die mindestens eine akustische Welle durch stimulierte oder erzwungene Brillouin-Streuung erzeugt ist.
17. Anordnung nach Anspruch 16, wobei die zweite der mindestens zwei ersten elektromagnetischen Strahlungen aus einem Pumpstrahl zur Verfügung gestellt ist, der sich von dem unterscheidet, der zur Erzeugung der ersten der mindestens zwei ersten elektromagnetischen Strahlungen verwendet wird.
18. Anordnung nach Anspruch 1, wobei die Differenz zwischen der ersten und der zweiten Frequenz eingerichtet ist, im Wesentlichen mit einer Frequenz von mindestens einer der mindestens einen akustischen Welle übereinzustimmen.
19. Anordnung nach Anspruch 1, wobei die Linienbreite jeder der mindestens zwei ersten elektromagnetischen Strahlungen kleiner als 100 kHz ist.
20. Verfahren, umfassend:
 - Versorgen, durch mindestens eine erste Anordnung, einer anatomischen Probe, die ein lebendes Subjekt ist, mit mindestens einer ersten elektromagnetischen Strahlung und Erzeugen mindestens einer akustischen Welle in der anatomischen Probe, wobei mindestens eine zweite elektromagnetische Strahlung in dem lebenden Subjekt basierend auf der mindestens einen akustischen Welle erzeugt wird; und
 - Empfangen durch mindestens eine zweite Anordnung mindestens eines Bereichs der mindestens einen zweiten elektromagnetischen Strahlung, um Informationen zu bestimmen, die mindestens einem Bereich der anatomischen Probe zugeordnet sind; und
 - wobei die mindestens eine erste elektromagnetische Strahlung mindestens zwei verschiedene Frequenzkomponenten umfasst, wobei eine erste der mindestens zwei Komponenten eine erste Frequenz aufweist und eine zweite der mindestens zwei Komponenten eine zweite Frequenz aufweist, und wobei eine Differenz zwischen der ersten und der zweiten Frequenz zwischen ungefähr 0 und 100 GHz liegt;
 - Abbilden des mindestens einen Bereichs der anatomischen Probe durch mindestens eine dritte Anordnung basierend auf Daten, die der mindestens einen zweiten elektromagnetischen Strahlung zugeordnet sind;
 - Übertragen der mindestens einen elektromagnetischen Strahlung durch die anatomische Probe, oder Abtasten der mindestens einen elektromagnetischen Strahlung durch oder über die anatomische Probe durch eine ophthalmische Visualisierungsvorrichtung;
 - und wobei die ophthalmische Visualisierungsvorrichtung eine Objektivlinse umfasst, die eingerichtet ist, die erste elektromagnetische Strahlung an die anatomische Probe abzugeben und eingerichtet ist, die zweite Strahlung zu sammeln, wobei die zweite Strahlung eine von der anatomischen Probe aufgrund der mindestens einen akustischen Welle Brillouin-rückgestreute Lichtkomponente ist.
21. Verfahren nach Anspruch 20, wobei die anatomische Probe mindestens eines von einem Organ, einem Gewebe oder einer Zelle ist.
22. Verfahren nach Anspruch 20, wobei die erste Komponente der mindestens einen ersten elektromagnetischen Strahlung eine erste Größe aufweist, wobei die mindestens eine zweite elektromagnetische Strahlung mindestens eine Komponente mit einer zweiten Größe und mindestens einer zweiten Frequenz umfasst, und wobei sich die Daten auf mindestens eine erste Differenz zwischen der ersten und der zweiten Größe oder eine zweite Differenz zwischen

der ersten Frequenz der ersten Komponente der mindestens einen ersten elektromagnetischen Strahlung und der zweiten Frequenz der mindestens einen zweiten elektromagnetischen Strahlung beziehen.

23. Verfahren nach Anspruch 22, wobei sich die zweite Frequenz von der ersten Frequenz unterscheidet und wobei die zweite Differenz ungefähr zwischen -100 GHz und 100 GHz liegt.

24. Verfahren nach Anspruch 20, wobei die mindestens eine zweite Anordnung einen Spektralfilter umfasst und wobei das Verfahren die Bestimmung eines Spektrums der mindestens einen zweiten elektromagnetischen Strahlung umfasst.

25. Verfahren nach Anspruch 20, wobei die Information einer biomechanischen Eigenschaft der anatomischen Probe zugeordnet ist.

26. Verfahren nach Anspruch 20, wobei die mindestens eine erste elektromagnetische Strahlung mindestens eine Komponente mit einer Zentralwellenlänge aufweist, die ungefähr zwischen 0,5 - 1,8 liegt μm .

27. Verfahren nach Anspruch 26, wobei die mindestens eine erste elektromagnetische Strahlung mindestens eine Komponente mit einer Linienbreite aufweist, die kleiner als etwa 100 MHz ist.

28. Verfahren nach Anspruch 26, wobei die mindestens eine erste elektromagnetische Strahlung eine Form einer Vielzahl von Pulsen aufweist und wobei die Dauer jedes der Pulse länger als etwa 10 ns ist.

29. Verfahren nach Anspruch 20, wobei das Verfahren ein Senden der mindestens einen dritten elektromagnetischen Strahlung von einer elektromagnetischen Strahlungsquelle umfasst.

30. Verfahren nach Anspruch 20, wobei die mindestens eine dritte Anordnung die Daten analysiert, die der mindestens einen zweiten elektromagnetischen Strahlung zugeordnet sind, wobei die erste Komponente der mindestens einen ersten elektromagnetischen Strahlung eine erste Größe aufweist, wobei die mindestens eine zweite elektromagnetische Strahlung mindestens eine Komponente mit einer zweiten Größe und mindestens einer zweiten Frequenz umfasst, und wobei sich die Daten auf mindestens eine einer ersten Differenz zwischen den ersten und zweiten Größen oder eine zweite Differenz zwischen der ersten Frequenz der ersten Komponente der mindestens einen ersten elektromagnetischen Strahlung und der Frequenz der mindestens einen zweiten elektromagnetischen Strahlung beziehen, und wobei die zweite Differenz ungefähr zwischen -100 GHz und 100 GHz, ausgenommen Null, liegt.

31. Verfahren nach Anspruch 30, wobei die mindestens eine erste elektromagnetische Strahlung eine Zentralwellenlänge hat, die ungefähr zwischen 0,5 - 1,8 μm liegt.

32. Verfahren nach Anspruch 33, wobei die mindestens eine erste elektromagnetische Strahlung eine Linienbreite aufweist, die kleiner als etwa 100 MHz ist.

33. Verfahren nach Anspruch 331, wobei die mindestens eine erste elektromagnetische Strahlung eine Form einer Vielzahl von Pulsen aufweist und wobei die Dauer jedes der Pulse länger als etwa 10 ns ist.

34. Verfahren nach Anspruch 30, wobei das Verfahren ein Empfangen mindestens einer dritten elektromagnetischen Strahlung durch die mindestens eine zweite Anordnung umfasst, die mindestens eine Komponente mit einer dritten Größe und mindestens einer dritten Frequenz aufweist, und wobei die zweite Frequenz als eine Funktion der ersten und dritten Frequenz bestimmt wird.

35. Verfahren nach Anspruch 20, wobei die mindestens eine akustische Welle durch stimulierte oder erzwungene Brillouin-Streuung erzeugt wird.

36. Verfahren nach Anspruch 35, wobei die zweite der mindestens zwei ersten elektromagnetischen Strahlungen aus einem Pumpstrahl erzeugt wird, der sich von dem unterscheidet, der zur Erzeugung der ersten der mindestens zwei ersten elektromagnetischen Strahlungen verwendet wird.

37. Anordnung nach Anspruch 20, wobei die Differenz zwischen der ersten und der zweiten Frequenz im Wesentlichen mit einer Frequenz mindestens einer der mindestens einen akustischen Welle übereinstimmt.

38. Anordnung nach Anspruch 20, wobei eine Linienbreite jeder der mindestens zwei ersten elektromagnetischen Strahlungen weniger als 100 kHz beträgt.

5 Revendications

1. Agencement comprenant :

- 10 au moins un premier agencement configuré pour fournir au moins un premier rayonnement électromagnétique à un prélèvement anatomique qui est un sujet vivant de manière à être capable de produire au moins une onde acoustique dans le prélèvement anatomique, au moins un second rayonnement électromagnétique étant pro-
- 15 ductible dans le sujet vivant sur la base d'au moins une onde acoustique ; et
au moins un second agencement configuré pour recevoir au moins une partie de l'au moins un second rayonnement électromagnétique de manière à déterminer les informations associées avec au moins une partie du
- 20 prélèvement anatomique ; et
l'au moins un premier rayonnement électromagnétique comprenant au moins deux composants de fréquence différents, un premier un des au moins deux composants ayant une première fréquence et un second un des au moins deux composants ayant une seconde fréquence, et une différence entre les première et seconde fréquences étant comprise entre environ 0 et 100 GHz ;
- 25 au moins un troisième agencement configuré pour imager l'au moins une partie du prélèvement anatomique sur la base des données associées avec l'au moins un second rayonnement électro-magnétique ;
au moins un quatrième agencement configuré pour convertir l'au moins un rayonnement électro-magnétique à travers le prélèvement anatomique, ou configuré pour scanner ou configuré pour scanner l'au moins un rayonnement électro-magnétique à travers ou sur le prélèvement anatomique ; et
- 30 l'au moins un quatrième agencement étant au moins un d'un cathéter, d'un endoscope, d'un laparoscope ou d'un dispositif de visualisation ophtalmique ;
et le quatrième agencement comprenant une lentille d'objectif adaptée pour délivrer le premier rayonnement électromagnétique au prélèvement anatomique et adaptée pour collecter ledit second rayonnement, ledit second rayonnement étant un composant de lumière rétrodiffusée de Brillouin du prélèvement anatomique dû à ladite
- 35 au moins une onde acoustique.
2. Agencement selon la revendication 1, dans lequel le prélèvement anatomique est au moins un d'un organe, d'un tissu ou d'une cellule.
3. Agencement selon la revendication 1, dans lequel le premier composant de l'au moins un premier rayonnement électromagnétique a une première grandeur, l'au moins un second rayonnement électromagnétique comprenant au moins un second composant ayant une seconde grandeur et au moins une seconde fréquence, et les données concernant au moins une d'une première différence entre les première et seconde grandeurs ou une seconde différence entre la première fréquence du premier composant de l'au moins un premier rayonnement électro-magnétique et la seconde fréquence de l'au moins un second rayonnement électro-magnétique.
4. Agencement selon la revendication 3, dans lequel la seconde fréquence est différente de la première fréquence et la seconde fréquence étant environ comprise entre -100 GHz et 100 GHz.
- 45 5. Agencement selon la revendication 1, dans lequel l'au moins un second agencement comprend un filtre spectral qui facilite une détermination d'un spectre de l'au moins un second rayonnement électro-magnétique.
6. Agencement selon la revendication 1, dans lequel les informations sont associées avec une propriété biomécanique du prélèvement anatomique.
- 50 7. Agencement selon la revendication 1, dans lequel l'au moins un premier rayonnement électro-magnétique a au moins un composant ayant une longueur d'onde centrale qui est environ comprise entre 0,5 et 1,8 μm .
8. Agencement selon la revendication 7, dans lequel l'au moins un premier rayonnement électromagnétique a au moins un composant ayant une largeur de ligne qui est plus petite qu'environ 100 MHz.
- 55 9. Agencement selon la revendication 7, dans lequel l'au moins un premier rayonnement électromagnétique a une forme d'une pluralité d'impulsions, et la durée de chacune des impulsions étant plus longue qu'environ 10 ns.

10. Agencement selon la revendication 1, dans lequel l'au moins un troisième rayonnement électromagnétique est transmis d'une source de rayonnement électromagnétique.

11. Agencement selon la revendication 1, dans lequel, l'au moins un troisième agencement est configuré pour analyser les données associées avec l'au moins un second rayonnement électromagnétique, le premier composant de l'au moins un premier rayonnement électro-magnétique ayant une première grandeur, l'au moins un second rayonnement électro-magnétique comprenant au moins un composant ayant une seconde grandeur et au moins une seconde fréquence, et les données concernant au moins une d'une première différence entre les première et seconde grandeurs ou une seconde différence entre la première fréquence du premier composant d'au moins un premier rayonnement électro-magnétique et la fréquence de l'au moins un second rayonnement électromagnétique, et la seconde différence étant comprise environ entre -100 GHz et 100 GHz, en excluant zéro.

12. Agencement selon la revendication 11, dans lequel l'au moins un premier rayonnement électro-magnétique a une longueur d'onde centrale qui est environ comprise entre 0,5 et 1,8 μm .

13. Agencement selon la revendication 12, dans lequel l'au moins un premier rayonnement électromagnétique a une largeur de ligne qui est plus petite qu'environ 100 MHz.

14. Agencement selon la revendication 12, dans lequel l'au moins un premier rayonnement électromagnétique a une forme de pluralité d'impulsions et la durée de chacune des impulsions étant plus longue qu'environ 10 ns.

15. Agencement selon la revendication 11, dans lequel l'au moins un second agencement est configuré pour recevoir au moins un troisième rayonnement électro-magnétique qui a au moins un composant ayant une troisième grandeur et au moins une troisième fréquence, et la deuxième fréquence étant déterminée comme une fonction de la première et de la troisième fréquences.

16. Agencement selon la revendication 1, dans lequel l'au moins une onde acoustique est produite par diffusion de Brillouin stimulée ou forcée.

17. Agencement selon la revendication 16, dans lequel le second un des au moins deux premiers rayonnements électromagnétiques est fourni à partir d'un faisceau de pompe qui est différent de celui utilisé pour fournir le premier un des au moins deux premiers rayonnements électromagnétiques.

18. Agencement selon la revendication 1, dans lequel la différence entre la première et la seconde fréquences est configurée pour essentiellement correspondre à une fréquence d'au moins une de l'au moins une onde acoustique.

19. Agencement selon la revendication 1, dans lequel une largeur de ligne de chacun des au moins deux premiers rayonnements électro-magnétiques est de moins de 100 kHz.

20. Procédé comprenant :

la fourniture par au moins un premier agencement d'au moins un premier rayonnement électro-magnétique à un prélèvement anatomique qui est un sujet vivant et produisant au moins une onde acoustique dans le prélèvement anatomique, au moins un second rayonnement électro-magnétique étant produit dans le sujet vivant sur la base de l'au moins une onde acoustique ; et

la réception par au moins un second agencement d'au moins une partie de l'au moins un second rayonnement électromagnétique de manière à déterminer les informations associées avec au moins une partie du prélèvement anatomique ; et

l'au moins un premier rayonnement électromagnétique comprenant au moins deux composants de fréquence différents, un premier un des au moins deux composants ayant une première fréquence, et un second un des au moins deux composants ayant une seconde fréquence, et une différence entre les première et seconde fréquences étant comprise entre environ 0 et 100 GHz ;

l'imagerie par au moins un troisième agencement de l'au moins une partie du prélèvement anatomique sur la base des données associées avec l'au moins un second rayonnement électro-magnétique ;

la conversion de l'au moins un rayonnement électro-magnétique à travers le prélèvement anatomique, ou le scannage de l'au moins un rayonnement électro-magnétique à travers ou sur le prélèvement anatomique par un dispositif de visualisation ophtalmique ;

et le dispositif de visualisation ophtalmique comprenant une lentille d'objectif adaptée pour délivrer le premier

rayonnement électromagnétique au prélèvement anatomique et adaptée pour prélever ledit second rayonnement, ledit second rayonnement étant un composant de lumière rétrodiffusée de Brillouin du prélèvement anatomique dû à ladite au moins une onde acoustique.

- 5 21. Procédé selon la revendication 20, dans lequel le prélèvement anatomique est au moins un d'un organe, d'un tissu ou d'une cellule.
- 10 22. Procédé selon la revendication 20, dans lequel le premier composant de l'au moins un premier rayonnement électromagnétique a une première grandeur, l'au moins un second rayonnement électromagnétique comprenant au moins un composant ayant une seconde grandeur et au moins une seconde fréquence, et les données concernant au moins une d'une première différence entre les première et seconde grandeurs ou une seconde différence entre la première fréquence du premier composant de l'au moins un premier rayonnement électromagnétique et la seconde fréquence de l'au moins un second rayonnement électromagnétique.
- 15 23. Procédé selon la revendication 22, dans lequel la seconde fréquence est différente de la première fréquence et la seconde différence étant environ comprise entre -100 GHz et 100 GHz.
- 20 24. Procédé selon la revendication 20, dans lequel l'au moins un second agencement comprend un filtre spectral et le procédé comprenant la détermination d'un spectre de l'au moins un second rayonnement électromagnétique.
- 25 25. Procédé selon la revendication 20, dans lequel les informations sont associées avec une propriété biomécanique du prélèvement anatomique.
26. Procédé selon la revendication 20, dans lequel l'au moins un premier rayonnement électromagnétique a au moins un composant ayant une longueur d'onde centrale qui est environ comprise entre 0,5 et 1,8 μm .
27. Procédé selon la revendication 26, dans lequel l'au moins un premier rayonnement électromagnétique a au moins un composant ayant une largeur de ligne qui est plus petite qu'environ 100 MHz.
- 30 28. Procédé selon la revendication 26, dans lequel l'au moins un premier rayonnement électromagnétique a une forme d'une pluralité d'impulsions, et la durée de chacune des impulsions étant plus longue qu'environ 10 ns.
- 35 29. Procédé selon la revendication 20, dans lequel le procédé comprend le renvoi de l'au moins un troisième rayonnement électromagnétique d'une source de rayonnement électromagnétique.
- 40 30. Procédé selon la revendication 20, dans lequel, l'au moins un troisième agencement analyse les données associées avec l'au moins un second rayonnement électromagnétique, le premier composant de l'au moins un premier rayonnement électromagnétique ayant une première grandeur, l'au moins un second rayonnement électromagnétique comprenant au moins un composant ayant une seconde grandeur et au moins une seconde fréquence, et les données concernant au moins une d'une première différence entre les première et seconde grandeurs ou une seconde différence entre la première fréquence du premier composant de l'au moins un premier rayonnement électromagnétique et la fréquence de l'au moins un second rayonnement électromagnétique, et la seconde différence étant environ comprise entre -100 GHz et 100 GHz, en excluant zéro.
- 45 31. Procédé selon la revendication 30, dans lequel l'au moins un premier rayonnement électromagnétique a une longueur d'onde centrale qui est environ comprise entre 0,5 et 1,8 μm .
- 50 32. Procédé selon la revendication 33, dans lequel l'au moins un premier rayonnement électromagnétique a une largeur de ligne qui est plus petite qu'environ 100 MHz.
33. Procédé selon la revendication 331, dans lequel l'au moins un premier rayonnement électromagnétique a une forme d'une pluralité d'impulsions, et la durée de chacune des impulsions étant plus grande qu'environ 10 ns.
- 55 34. Procédé selon la revendication 30, dans lequel le procédé comprend la réception par l'au moins un second agencement d'au moins un troisième rayonnement électromagnétique qui a au moins un composant ayant une troisième grandeur et au moins une troisième fréquence, et la deuxième fréquence étant déterminée comme une fonction des première et troisième fréquences.

35. Procédé selon la revendication 20, dans lequel l'au moins une onde acoustique est produite par diffusion de Brillouin stimulée ou forcée.
- 5 36. Procédé selon la revendication 35, dans lequel le second un d'au moins deux premiers rayonnements électromagnétiques est fourni à partir d'un faisceau de pompe qui est différent de celui utilisé pour fournir le premier un des aux moins deux premiers rayonnements électromagnétiques.
- 10 37. Agencement selon la revendication 20, dans lequel la différence entre les première et seconde fréquences correspond essentiellement à une fréquence d'au moins une de l'au moins une onde acoustique.
- 15 38. Agencement selon la revendication 20, dans lequel une largeur de ligne de chacun des au moins deux premiers rayonnements électro-magnétiques est de moins de 100 kHz.

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Fig 1A

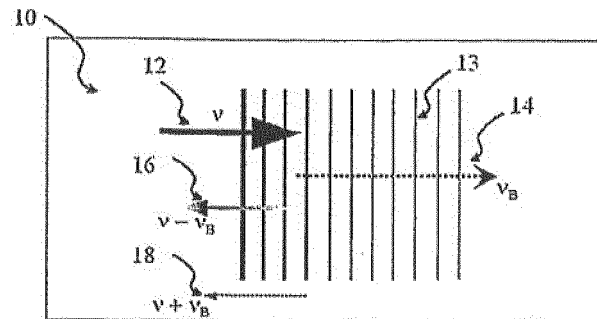


Fig 1B

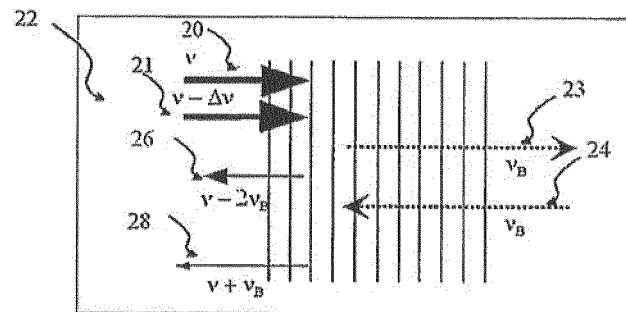


Fig 2

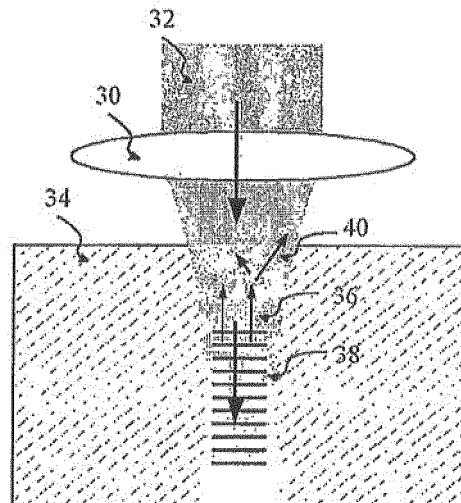


Fig 3A

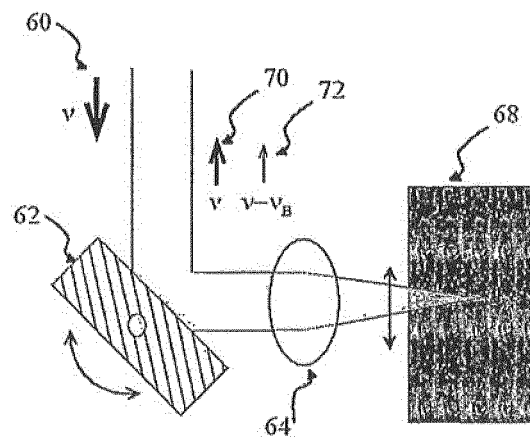
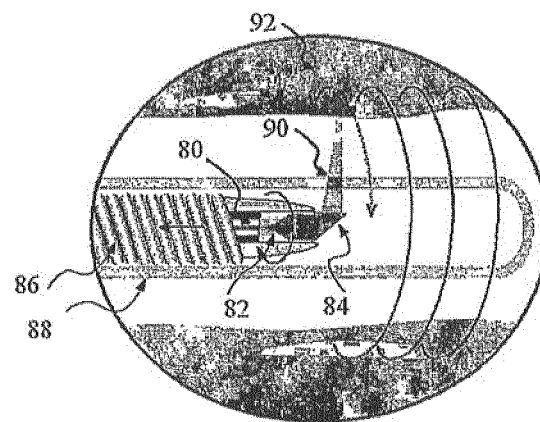


Fig 3B



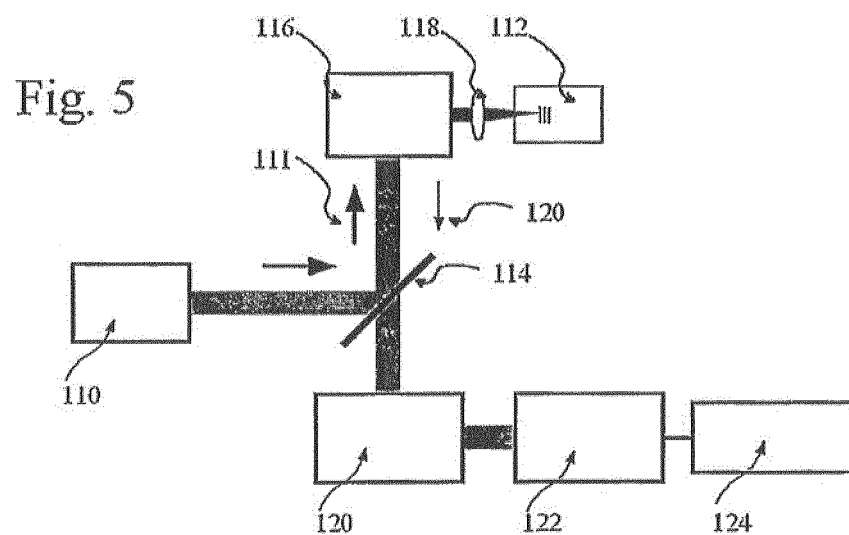
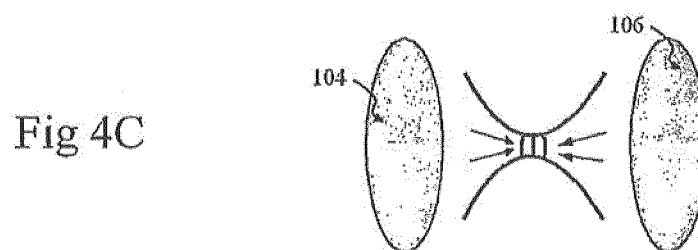
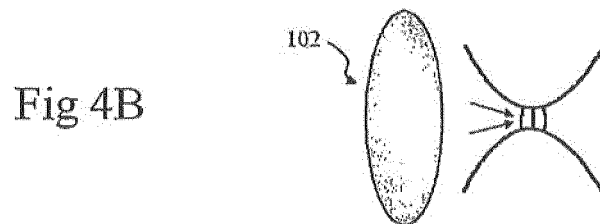
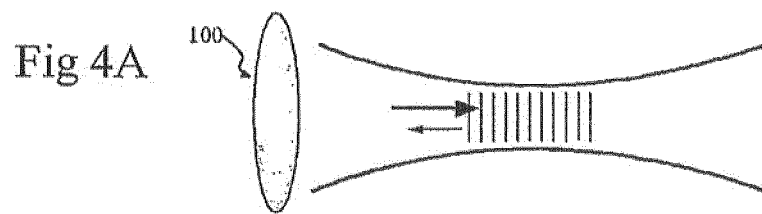


Fig 6A

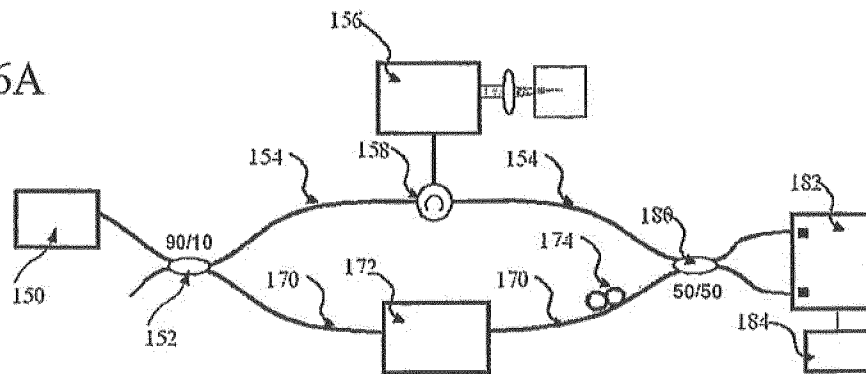


Fig 6B

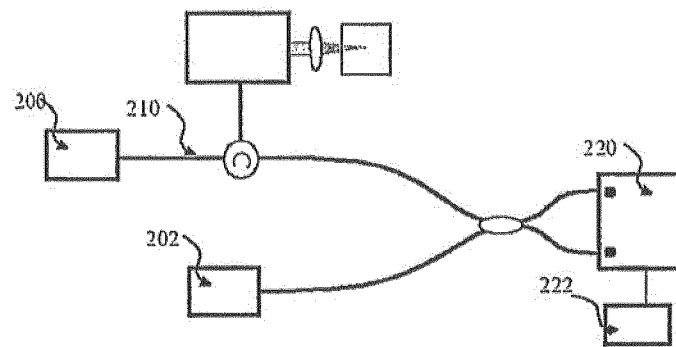


Fig. 6C

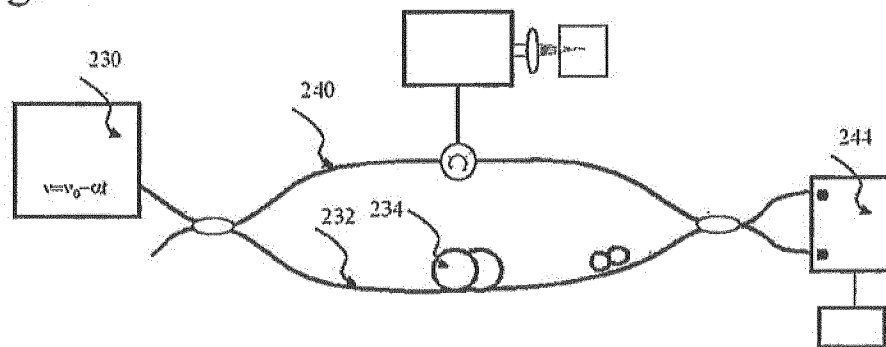


Fig 7A

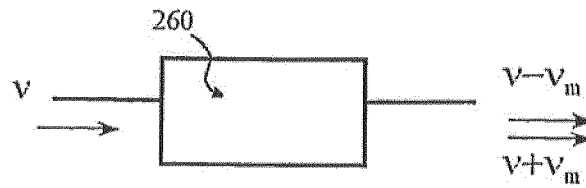


Fig 7B

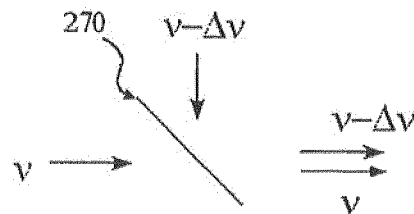


Fig 7C

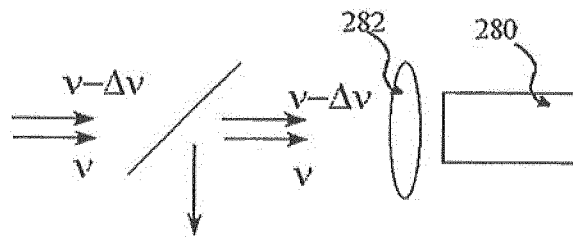


Fig 7D

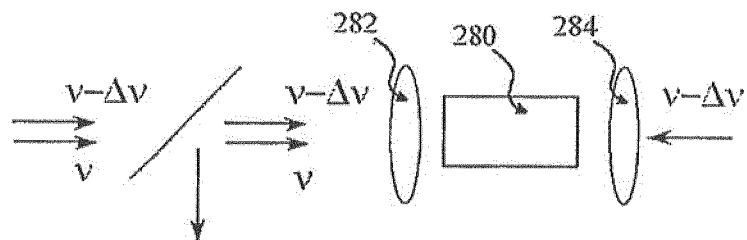


Fig 8A

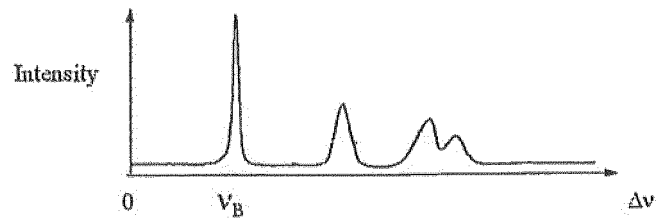


Fig 8B

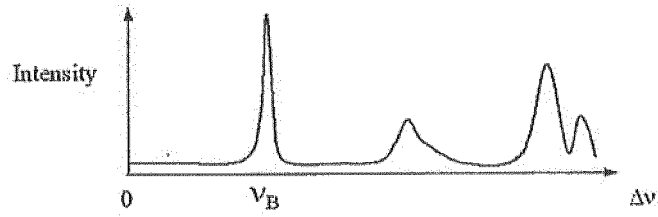


Fig 8C

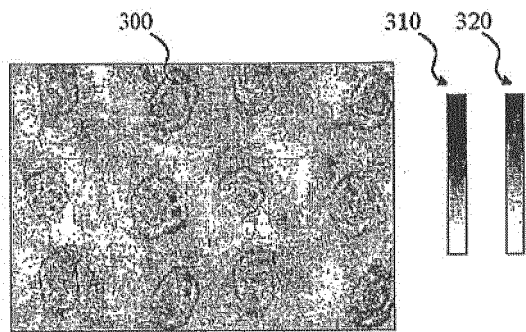


Fig 9A

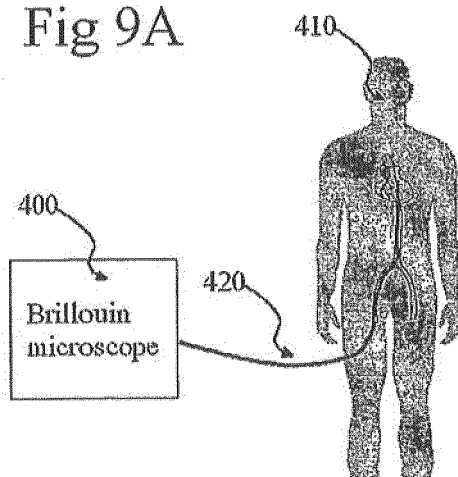
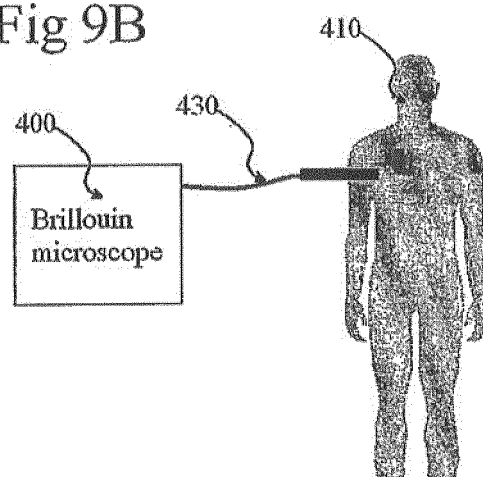


Fig 9B



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2004029148 W [0035]
- US 26677905 [0035]
- US 50127604 [0035]

专利名称(译)	利用光学显微镜获取与解剖采样有关的信息的方法,装置和系统		
公开(公告)号	EP3143926B1	公开(公告)日	2020-07-01
申请号	EP2016185740	申请日	2007-02-08
[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	YUN SEOK HYUN		
发明人	YUN, SEOK-HYUN		
IPC分类号	A61B5/00 G01N21/63 G01J3/44 G01N21/17		
CPC分类号	A61B5/0059 A61B5/0066 A61B5/0073 A61B5/0075 A61B5/0084 A61B5/0086 A61B5/0095 A61B5/0097 A61B5/4088 A61B5/412 A61B5/413 C07K14/70503 C07K2319/30 C07K2319/32 C07K2319/70 G01J3/4412 G01N21/1717 G01N21/4795 G01N21/636 G01N2021/1725 G01N2021/638 G01N2800/042 G01N2800/387 A61B3/102 A61B3/117 G01B9/02091 G01N2201/06 G01N2201/0612 G01N2800/7023 G01N2800/7028 G02B21/0052		
优先权	60/771916 2006-02-08 US PCT/US2007/061815 2007-02-08 WO		
其他公开文献	EP3143926A1		
外部链接	Espacenet		

摘要(译)

提供用于获得与解剖学样本相关的信息的装置和方法。例如,可以将至少一个第一电磁辐射提供给解剖学样本,以便在解剖学样本中产生至少一个声波。可以基于声波产生至少一个第二电磁辐射。可以提供至少一个第二电磁辐射的至少一部分,以便确定与解剖样本的至少一部分相关的信息。另外,可以分析基于与第二电磁辐射相关联的数据的信息。第一电磁辐射可以包括至少一个第一幅度和至少一个第一频率。第二电磁辐射可以包括至少一个第二幅度和至少一个第二频率。该数据可以涉及第一和第二幅度之间的第一差异和/或第一和第二频率之间的第二差异。第二个差异可能约为-100 GHz和100 GHz之间,不包括零。

