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(54) **Title:** METHOD AND DEVICE FOR THE CONFOCAL MEASUREMENT OF THE DISPLACEMENT, VELOCITY OR FLOW AT A GIVEN POINT OF A SAMPLE AND USES THEREOF

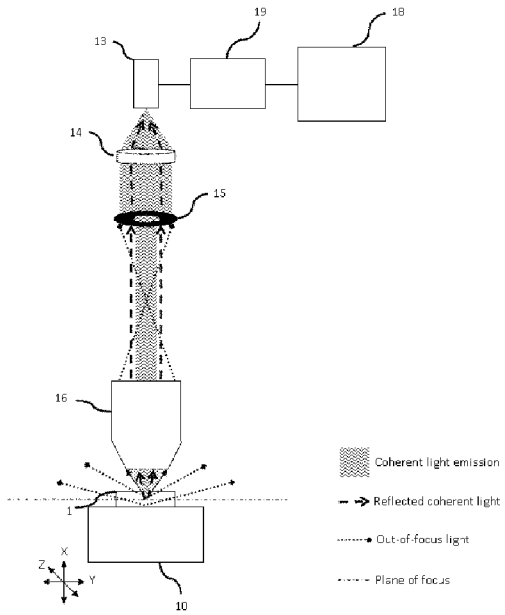

Fig. 1

(57) **Abstract:** The invention relates to a method and device for the confocal measurement of the millimetric or micrometric displacement, velocity or flow at a given point of a sample and uses thereof. The method comprises emitting, by a first source (13), a first coherent or quasi coherent light beam, and modifying, by a diaphragm (15), the first light beam, providing a beam with a circular shape approximation which is guided over a sample (1) via a microscope objective (16). The first source (13) receives a part of the signal reflected by the sample (1), and a computer system (18) measures the displacement, velocity or flow on a vertical, horizontal or arbitrary plane of the sample (1) using said part. The spatial resolution of the measurement is adjusted by modifying the diameter of the diaphragm (15) and a numerical aperture of the microscope objective (16), depending on the sample (1) to be measured.

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Method and device for the confocal measurement of the displacement, velocity or flow at a given point of a sample and uses thereof

Technical Field

Present invention, in general, relates to optical measurement methods and devices. In particular, the invention relates to a method and device for the real-time confocal measurement of the millimetric or micrometric displacement, velocity or flow on a vertical plane (i.e., perpendicular to or outside the plane of focus of the objective), horizontal plane (i.e., contained in the plane of focus of the objective); or arbitrary plane (i.e., oriented in any direction) of a sample, for example a millimetric or micrometric sample. For example, the proposed device can be used to simultaneously measure the vertical and/or horizontal millimetric or micrometric displacement of the sample, or to take measurements of the maximum velocity of a flow within a capillary in the vertical, horizontal or arbitrary direction, or of the velocity profile of a flow within a capillary, or of the velocity of displacement of the sample in the vertical and/or horizontal planes, etc.

Background of the Invention

An apparatus for measuring the speed of blood in blood vessels in biological samples, for example, in retinal blood vessels, is known through patent document EP-B1-0707823. The mentioned apparatus comprises a short coherence light source (i.e. a superluminiscent light emitting diode) having a principal wavelength, which radiation is substantially spatially coherent and has a temporal coherence length less than 1 picosecond; a beam splitter for splitting the beam into a sample beam and reference beam; an optical apparatus for directing the sample beam to an area within the biological sample; a reflector for reflecting the reference beam; a detector for detecting an interference between the sample beam reflected from the area and the reflected reference beam and for generating an interference signal; an apparatus for altering an optical path length of the reference beam from the beam splitter to the detector at an alteration velocity; and an analyzer for analyzing the interference signal to determine the speed of blood in the area from a shift of a central frequency of a frequency spectrum of the interference signal from a frequency determined from the alteration velocity and principal wavelength. The accuracy of the referred apparatus is given by the balance between the reference and sample paths, which requires a precise location of the reflector in order to provide an accurate measurement of the position of the sample beam.

An adaptive optics scanning system is known through patent document US-B2-9200887, said system comprising a beam projection module with four or more axes of motion that can project and control the position and angle of a light beam to or from an adaptive optics element. The adaptive optics scanning system is compact in size, overcoming the challenges of a traditional lens and mirror pupil relay design. The adaptive optics scanning system has little to no dispersion, chromatic aberration, and off-axis aberration for improved optical performance.

Document WO 98/04924 A1 provides an apparatus based in the well-known reference arm method for laser Doppler velocimetry for measuring the speed of particles moving in the same direction (i.e. blood flowing within a blood vessel of an eye). The apparatus includes a light source for producing a source beam of light and an optical element for applying the source beam of light to the blood vessel to scatter a portion of the source beam of light and produce bidirectional scattered beams. A detector system for detecting the bidirectional scattered beams provides signals representative of the scattered beams. The light source and the detector system are disposed in a confocal relationship. An output representative of the velocity of the blood flow is produced in accordance with the signals. The light source and the detector system include respective pinholes wherein the respective pinholes are disposed in a confocal relationship. The blood vessel is conjugate with the respective pinholes of the light source and the detector system. The angle between the bidirectional scattered beams is determined and a measurement of blood flow velocity is determined according to the angle.

Document CN 102564909 B discloses a laser self-mixing multi-physical parameter measurement method and device. The laser self-mixing multi-physical parameter measurement device comprises a microchip laser, a collimating lens, a beam splitter, converging lenses, a photodetector, an amplifier, a data acquisition card and a spectrum analyzer. Laser emitted by the microchip laser is randomly focused onto an atmospheric particulate to be measured through the collimating lens and the converging lens, and part of generated backwards-scattered light is fed back to the laser due to the reversibility principle of an optical path, so that parameters such as power and wavelength of the laser are changed, namely a laser self-mixing effect is achieved.

Document CN 201397302 Y relates to a measurement system for three-dimensional imaging of biological tissue structures. A part of a laser emission permeate through a spectroscope, the direction of the beam is changed through a reflecting mirror, then the beams convergent through a micro objective and irradiating on a measured object

placed on a slide are scattered by the measured object, and part of the scattered lights are returned to a laser, thereby reducing the emissive power of the laser. A three-dimensional scanning platform drives the measured object placed on the slide to move under the control of a computer, and the rest part of the lasers are received by a photodetector and converted into voltage signals for output, and the voltage signals are collected through a data acquisition card to input into a computer in order to obtain confocal three-dimensional images.

Document US 6233045 B1 relates to a self-mixing sensor usable for remotely measuring speed, vibrations, range, and length in a manner making the device practical for economic implementation while retaining accuracy. The device is configured to avoid mode hopping, such as by providing for relatively high loss for all modes other than the desired mode. Preferably this is accomplished by utilizing laser types that have a high degree of side mode suppression, such as DFB lasers or through active or passive control of the amount of light permitted to reenter the laser.

In light of the foregoing, there is a need in the art for new methods and devices that allow taking a confocal measurement and performing confocal characterization of the millimetric or micrometric displacement (i.e. vibration), velocity or flow in millimetric or micrometric biological or artificial samples (or particles).

Description of the Invention

To that end, embodiments of the present invention provide, according to a first aspect, a method for the confocal measurement of the millimetric or micrometric displacement, velocity or flow of a given point of a sample (for example, a micrometric or millimetric sample). The mentioned confocal measurement can be taken on a vertical, horizontal and/or arbitrary plane of the sample.

In a first embodiment, the proposed method comprises emitting, by a first light-emitting source, a coherent or quasi coherent light beam at a certain wavelength to illuminate said sample, wherein the coherent or quasi coherent light beam is collimated by a collimating lens, and wherein the sample is positioned on a supporting structure; modifying, by a diaphragm of a certain diameter, positioned in front of the collimating lens, said first light beam, providing a beam with a circular shape approximation which is guided over the sample via a microscope objective having a certain numerical aperture; receiving, by said first light-emitting source, a part of the signal reflected by said sample; and measuring, by a computer system, the displacement, velocity or flow on said plane

of the sample using said part of the signal reflected.

In a second embodiment, the method comprises emitting, by a second light-emitting source, in particular a white light, a second light beam at a certain power to illuminate the mentioned sample and make it visible to acquisition means, for example a camera, wherein the sample is positioned on a supporting structure; emitting, by a first light-emitting source, a first coherent or quasi-coherent light beam at a certain wavelength which is collimated by a collimating lens; modifying, by a diaphragm of a certain diameter, positioned in front of the collimating lens, the mentioned first light beam providing a beam with a circular shape approximation; redirecting, by an optical unit, such as a polarized or non-polarized beam splitter, or a dichroic mirror, the beam with a circular shape approximation to a microscope objective, the beam with a circular shape approximation being guided over the sample, wherein said microscope objective has a certain numerical aperture; capturing, by the acquisition means, a second part of the signal reflected by said sample and receiving, by the first light-emitting source, a first part of the signal reflected by the sample; and measuring, using the self-mixing interference of said signal within the first source, by using a computer system, the displacement, velocity or flow on said plane of the sample using the first part of the signal reflected by the sample.

According to the proposed method, in any of the above-described embodiments, the spatial resolution of the measurement in the direction of the beam of the first light source is adjusted by modifying the diameter of the diaphragm and the numerical aperture of the microscope objective, as a function of the sample to be measured. Such dimension will be normally depth in the sample, and its spatial resolution is thus adjustable by the mentioned means.

In an embodiment, the method further comprises adjusting by means of displacement, via a control unit included or integrated in, or in the area close to, the supporting structure, the measuring point by displacing the sample on the vertical or horizontal plane in at least a certain direction, taking advantage of the capacity of locating the suitable point of the sample by means of the combination of the two light sources and of the acquisition means for taking the desired measurement. Likewise, and by means of taking successive or parallel measurements of said displacement, the computer system further allows generating two-dimensional or three-dimensional profiles of the displacement, velocity of flow (i.e. velocity profiles) within the sample, storing the measurements taken and the position of such measurements in the sample in a recording/storage means arranged for such purpose.

In an embodiment, the method further comprises implementing, preferably via the computer system, a digital processing on the displacement, velocity or flow measurement.

In an embodiment, the emission of the second light beam is performed continuously and the emission of the first light beam is performed at different configurable moments in time. Alternatively, in another embodiment, the emissions of the two light beams are performed simultaneously. In yet another embodiment, both of them are performed in a configurable moment in time.

In an embodiment, the emission of the second light beam is used to select an optimal measuring point in which the measurement corresponding to the first light beam is taken.

Preferably, the first light-emitting source is a single-mode, monochromatic and coherent laser light source. Nevertheless, according to the present invention, a multimode laser light source, or even a high-coherence LED, could also be used as a first light-emitting source.

Other embodiments of the invention that are described herein also include a device for the confocal measurement of the millimetric or micrometric displacement, velocity or flow at a given point of a sample, wherein the confocal measurement can be taken on a vertical, horizontal and/or arbitrary plane of the sample.

In a first embodiment, the proposed device particularly comprises:

- a supporting structure configured for housing the sample the displacement, velocity or flow of which are to be measured and characterized;

- a first light-emitting source configured to emit a first light beam at a certain wavelength which is collimated by a collimating lens, said first light beam being a coherent or quasi coherent light beam;

- a diaphragm, of a certain diameter, positioned in front of the collimating lens and configured to modify the first light beam, providing a beam with a circular shape approximation which is redirected to a microscope objective having a certain numerical aperture; and

- a computer system operatively connected to the first light-emitting source.

Thus, in the proposed system the same light-emitting source is used as both, emission and detection element due to a Self-Mixing confocal approach; so the confocal behavior occurs in the same diaphragm used in front of the first light-emitting source.

According to this first embodiment, the first light-emitting source is further configured to receive a first part of the signal reflected by the sample, such that the received signal is used by the computer system to measure the displacement, velocity or flow on the mentioned plane(s) of the sample. Likewise, the spatial resolution of the measurement is adjusted by modifying the diameter of the diaphragm and the numerical aperture of the microscope objective, as a function of the sample to be measured.

In a second embodiment, the proposed device further comprises a second light-emitting source, preferably a white light, configured to emit a second light beam at a certain power to illuminate said sample and make it visible to acquisition means; and an optical unit configured to redirect the first light beam from the diaphragm to the microscope objective. According to this second embodiment, the acquisition means are further configured to capture a second part of the signal reflected by the sample.

The sample to be measured, or its characteristics of interest in the measurement, can typically be of micrometric or millimetric dimensions.

In one embodiment, the proposed device further includes a control unit, included or integrated in the supporting structure, and configured to automatically adjust the measuring point by displacing the sample in one or more directions (x, y, and/or z).

The wavelength of the first and the second light-emitting sources can be variable and belong to any band in the spectrum, depending on the characteristics or needs that are required (medical interval, type of tissue, etc.). Nevertheless, in a particular embodiment of the present invention, the mentioned wavelength at which the first light beam is emitted is comprised in a range of 800 to 900 nanometers.

Other embodiments of the invention also include different uses of the proposed device for: taking a real-time measurement of the maximum velocity of a flow within an artificial or biological capillary; reconstructing a velocity profile of a flow within an artificial or biological capillary; performing real-time vertical sectioning of a flow with micrometric resolution; taking a viscosity measurement at different depths in a homogeneous or heterogeneous liquid; taking an amplitude and frequency measurement of a micrometric sample under vibration; measuring the velocity of solid or gas flows; and/or performing reconstruction of a vertical displacement pattern of different micrometric samples for the

identification and/or classification thereof.

Therefore, the present invention combines two known functions for performing a new type of displacement, velocity or flow measurement in micrometric or millimetric particles. On one hand, it presents an optical microscope working like a real-time viewfinder, which allows selecting the measuring point and that is further (optionally) used for recording static or video images of the sample(s) to be measured. On the other hand, it presents a laser interferometer based feedback interferometry (OFI or SMI), capable of measuring changes in the optical path with a resolution less than the wavelength of the laser light, typically between λ/2 and λ/50 and then inferring with it the displacement of the sample(s) to be measured. Besides, in a different contribution made by the present invention, a confocal function is added to the measuring part (by means of the mentioned diaphragm) which had not previously been present in similar devices.

Furthermore, the present invention can be comprised only of the laser interferometer based on OFI of a first light source in a confocal arrangement, without the need of the optical microscope arm used as viewfinder.

Brief Description of the Drawings

The foregoing and other features and advantages will be more fully understood based on the following detailed description of several merely illustrative and non-limiting embodiments in reference to the attached drawings, in which:

Fig. 1 schematically illustrates a diagram of the proposed device according to a first embodiment.

Fig. 2 schematically illustrates a diagram of the proposed device according to a second embodiment.

Fig. 3 schematically illustrates an enlargement of the first arm of the proposed device of Fig. 2.

Fig. 4 is a flow chart showing a method for the confocal measurement of the millimetric or micrometric displacement, velocity or flow of a given point of a sample on a vertical, horizontal and/or arbitrary plane of the sample according to an embodiment of the present invention.

Fig. 5 is a flow chart showing another embodiment of the proposed method.

Detailed Description of Several Embodiments

With reference to Fig. 1 therein it is shown a first embodiment of the proposed device for the confocal measurement of the millimetric or micrometric displacement, velocity or flow of a sample on a vertical, horizontal or arbitrarily oriented plane. According to this first embodiment, the device includes a supporting structure 10, such as a three-dimensional base, for housing the sample 1 to be measured/analyzed. Likewise, as can be seen in the figure, the device has a single light source 13 (or first light-emitting source as termed in the claims), in this case a single-mode, monochromatic and coherent light-emitting source, which emits, for example, at 830 nanometers, a first divergent light beam which is collimated by a collimating lens 14. The device also includes a microscope objective 16 having a certain numerical aperture; a diaphragm 15 positioned in front of the collimating lens 14; and a computer system 18 operatively connected to the first light-emitting source 13 to perform the measurement.

The cited diaphragm 15 (or pinhole), of a certain diameter, depending on the characteristics of the measurement, receives the first light beam and an approximately circular beam is obtained at its outlet, which approximately circular beam is then (partially) redirected over the entrance pupil of the microscope objective 16. The size of the point of focus at the outlet of the microscope objective 16 is determined by the numerical aperture thereof and the diameter of the diaphragm 15. Said size of the point of focus will be a critical parameter for defining the measurement volume of the proposed device, and will therefore determine the spatial resolution of the measurements. Therefore, the resolution of the device can be adjusted, depending on the need of the user, as a function of the size of the sample 1 to be measured.

Once the first light beam is focused on the sample 1, the measuring point can be adjusted by means of the mentioned supporting structure 10 displacing the sample 1 in direction x, y, and/or z. To that end, the supporting structure 10 particularly integrates a control unit, or is operatively connected to a control unit, for example via a cable or wirelessly.

When the first light beam interacts with the sample 1 (which can be displaced in any point in space) a part of the incident monochromatic radiation returns to the cavity of the first light-emitting source 13, where the interference including the information relating to the displacement and/or to the flowmetry or velocity of the sample originates. In the case of displacement measurements, the number of displacement bands appearing in the signal will be considered. In the case of flowmetry and/or velocity measurements, the

information relating to the change in Doppler frequency caused by the motion of the sample 1 will be considered. Likewise, the returning radiation experiences a phase change due to the distance at which the sample 1 is located at the time of the interaction. By means of the interference between the original radiation emitted and the returning radiation with changes due to sample 1 the velocity, frequency and amplitude of the motion of the sample 1 in the vertical, horizontal or arbitrary directions can be induced. Due to the scattering of the first light beam within the sample 1, part of the light returning to the cavity comes from an undesired region within the near and far fields, inducing the out-of-focus effect which must sometimes be corrected with an additional digital processing 19 to obtain a clear measurement of the desired phenomenon. In this case, in the optical return path to the cavity of the first light-emitting source 13, the diaphragm 15 serves as a spatial filter to limit light coming from out-of-focus regions reaching the cavity and inducing noise in the measurement due to light returned from outside the measurement volume.

Figs. 2 and 3 show a second embodiment of the proposed device for the confocal measurement of the millimetric or micrometric displacement, velocity or flow of a sample on a vertical, horizontal or arbitrarily oriented plane. Unlike the first embodiment, in this second embodiment the proposed device has two light sources, the mentioned single-mode, monochromatic and coherent light-emitting source 13 and a second light-emitting source 11 (in this particular case a white light, not limitative as other type of light sources could be equally used such as a LED or a laser, among others). Thus, the proposed device of this second embodiment includes the supporting structure 10 for housing the sample 1 to be measured/analyzed, the light-emitting source 11 to provide the radiation required to illuminate the sample 1 and make it visible to acquisition means 12, such as a camera or a similar device, the first light-emitting source 13 to emit the first divergent light beam which is collimated by the collimating lens 14, the diaphragm 15, the microscope objective 16 and the computer system 18. It should be noted that the optical path of the first light-emitting source 13 is depicted in Fig. 1 in a lighter color than the beam going to the sample 1 is, and in a darker color than the portion of the beam that will go through the diaphragm 15 and return to the first light-emitting source 13 is. As it comes from a source that emits a non-Gaussian beam with two different divergence angles, the collimated beam has an elliptical shape with an astigmatism effect, where said effect may not be produced depending on the type of light source used.

It should be noted that the first light-emitting source 13, in other embodiments, may not be a single-mode, coherent light source, but rather it may be a multimode laser or even

a LED. Likewise, a group of lasers or a group of LEDs could also be used. Likewise, the wavelength of this first light-emitting source 13 is variable, where it could cover any range of the spectrum, depending on the characteristics or needs of the sample 1 to be measured/analyzed.

Now in reference to Fig. 4, therein it is shown an embodiment of the proposed method. According to this embodiment, a first light-emitting source 13, at step 401, emits a first light coherent or quasi coherent light beam at a certain wavelength to illuminate a sample 1 (positioned on a supporting structure 10). Next, at step 402, the coherent or quasi coherent light beam is collimated by a collimating lens 14. At step 403, a diaphragm having a certain diameter modifies the collimated coherent or quasi coherent light beam providing a beam with a circular shape approximation, which is guided over the sample 1 (step 404) via a microscope objective 16 having a certain numerical aperture. At step 405, a part of the signal reflected by the sample 1 is received by the first light-emitting source 13. Finally, the received part is used by the computer system 18, such as a computer, a laptop, a server, among others, to measure the displacement, velocity or flow on the vertical or horizontal planes or on an arbitrary plane of the sample 1.

Now in reference to Fig. 5, therein it is shown another embodiment of the proposed method. According to this alternative embodiment, a second white light source 11, step 501, emits a second light beam at a certain power to illuminate a sample 1 (positioned on a supporting structure 10). Next, or at the same time, a first light source 13, in this case a laser, step 502, emits a first light beam at a certain wavelength which is collimated by a collimating lens 14. Then, step 503, a diaphragm 15 of a certain diameter modifies the first light beam, providing a beam with a circular shape approximation, which is redirected (step 504) to a microscope objective 16 of a certain numerical aperture, said beam being guided over the sample 1. A part (or second part as termed in the claims) of the signal reflected by the sample 1 is captured by acquisition means 12 (step 505), whereas a first part of the signal reflected by the sample 1 is received by the laser light source 13 (step 506). Finally, the mentioned first part is used, by a computer system 18, such as a computer, among other similar devices, which is operatively connected to the second laser light source 13, to measure (step 507) the displacement, velocity or flow on the vertical or horizontal planes or on an arbitrary plane of the sample 1.

The spatial resolution of the mentioned measurement can be adjusted as a function of the needs and characteristics of the sample 1 by modifying the mentioned diameter of

the diaphragm 15 and the numerical aperture of the microscope objective 16.

In one embodiment, the computer system 18 further generates, by means of successive or parallel measurements, two-dimensional or three-dimensional profiles of the displacement, velocity or flow measured by means of a scan of the sample 1.

The possible potential applications or uses of the present invention include, among others: taking real-time measurement of the maximum velocity of a flow within a (artificial or biological) capillary, reconstructing the velocity profile of a flow within a (artificial or biological) capillary, performing real-time vertical sectioning of a flow with micrometric resolution, taking a viscosity measurement at different depths in a homogeneous or heterogeneous liquid, taking an amplitude and frequency measurement of a micrometric particle under vibration, or reconstructing the vertical displacement pattern of different micrometric particles for the identification and/or classification thereof, among other functions. In all these cases, the second light source 11 can be used as means to select the optimal measuring point, or the measuring point of greatest interest, in each case.

The scope of the present invention is defined in the attached claims.

CLAIMS

1. A method for the confocal measurement of the millimetric or micrometric displacement, velocity or flow at a given point of a sample, wherein said confocal measurement is performed on a vertical, horizontal or arbitrary plane of said sample, the method comprising:

emitting, by a first light-emitting source (13), a first light beam at a certain wavelength to illuminate a sample (1), said first light beam being a coherent or quasi coherent light beam which is collimated by a collimating lens (14), and said sample (1) being positioned on a supporting structure (10);

modifying, by a diaphragm (15), of a certain diameter, positioned in front of the collimating lens (14), said first light beam, providing a beam with a circular shape approximation which is guided over the sample (1) via a microscope objective (16) having a certain numerical aperture;

receiving, by said first light-emitting source (13), a first part of the signal reflected by said sample (1); and

measuring, by a computer system (18), the displacement, velocity or flow on said plane of the sample (1) using said first part of the signal reflected by the sample (1) received in the first light-emitting source (13),

wherein the spatial resolution of the measurement is adjusted by modifying the diameter of the diaphragm (15) and the numerical aperture of the microscope objective (16), as a function of the sample (1) to be measured.

2. The method according to claim 1, further comprising:

emitting, by a second light-emitting source (11), a second light beam at a certain power to illuminate the sample (1) and make the sample (1) visible to acquisition means (12), said second light emitting source (11) comprising a white light;

redirecting, by an optical unit (17), the beam with a circular shape approximation to the microscope objective (16); and

capturing, by the acquisition means (12), a second part of the signal reflected by the sample (1).

3. The method according to claim 1 or 2, further comprising adjusting, by a control unit of the supporting structure (10), the measuring point by displacing the sample (1) in at least a certain direction based on information provided by the device.

4. The method according to previous claims, further comprising generating, by the computer system (18), by means of successive or parallel measurements, two-

dimensional or three-dimensional images of said displacement, velocity or flow measured by means of a scan of the sample (1).

5. The method according to claim 1 or 2, further comprising applying a digital processing to said displacement, velocity or flow measurement.

6. The method according to claim 2, wherein said emission of the second light beam is continuous and the emission of the first light beam is performed at different configurable moments in time.

7. The method according to claim 2, wherein the emission of the second light beam and the emission of the first light beam are performed simultaneously.

8. The method according to claim 2, wherein the emission of the second light beam is used to select an optimal measuring point in which the measurement corresponding to the first light beam is taken.

9. The method according to previous claims, wherein the sample (1) comprises a micrometric or millimetric sample.

10. A device for the confocal measurement of the millimetric or micrometric displacement, velocity or flow at a given point of a sample, wherein the confocal measurement is taken on a vertical, horizontal or arbitrary plane of said sample, the device comprising:

a supporting structure (10) configured to house a sample (1) the displacement, velocity or flow of which are to be measured and characterized;

a first light-emitting source (13) configured to emit a first light beam at a certain wavelength which is collimated by a collimating lens (14), said first light beam being a coherent or quasi coherent light beam;

a microscope objective (16) having a certain numerical aperture;

a diaphragm (15), of a certain diameter, positioned in front of the collimating lens (14) and configured to modify said first light beam providing a beam with a circular shape approximation which is redirected to said microscope objective (16); and

a computer system (18) operatively connected to the first light-emitting source (13),

wherein the first light-emitting source (13) is further configured to receive a first part of the signal reflected by the sample (1), such that the received signal is used by said computer system (18) to measure the displacement, velocity or flow on said plane of the sample (1), and

wherein the spatial resolution of the measurement is adjusted by modifying the diameter of the diaphragm (15) and the numerical aperture of the microscope objective (16), as a function of the sample (1) to be measured.

11. The device according to claim 10, further comprising:

a second light-emitting source (11) configured to emit a second light beam at a certain power to illuminate said sample (1) and make it visible to acquisition means (12), said second light emitting source (11) comprising a white light; and

an optical unit (17) configured to redirect the first light beam from the diaphragm (15) to the microscope objective (16),

wherein the acquisition means (12) are further configured to capture a second part of the signal reflected by the sample (1).

12. The device according to claim 10 or 11, wherein said device further comprises a control unit included in said supporting structure (10) configured to automatically adjust the measuring point by displacing the sample (1) in at least a certain direction based on information provided by the device.

13. The device according to claim 10, wherein the first light-emitting source (13) comprises a single-mode, monochromatic and coherent light source, a multimode laser light source or a high-coherence light-emitting diode, LED.

14. The device according to claim 10, wherein said wavelength at which the first light beam is emitted is comprised in a range between 800 and 900 nanometers.

15. Use of the device of previous claims 10 to 14 for: taking a real-time measurement of the maximum velocity of a flow within an artificial or biological capillary; reconstructing a velocity profile of a flow within an artificial or biological capillary; performing real-time vertical sectioning of a flow with micrometric resolution; taking a viscosity measurement at different depths in a homogeneous or heterogeneous liquid; taking an amplitude and frequency measurement of a micrometric sample under vibration; and/or performing reconstruction of a vertical displacement pattern of different micrometric samples for the identification and/or classification thereof.

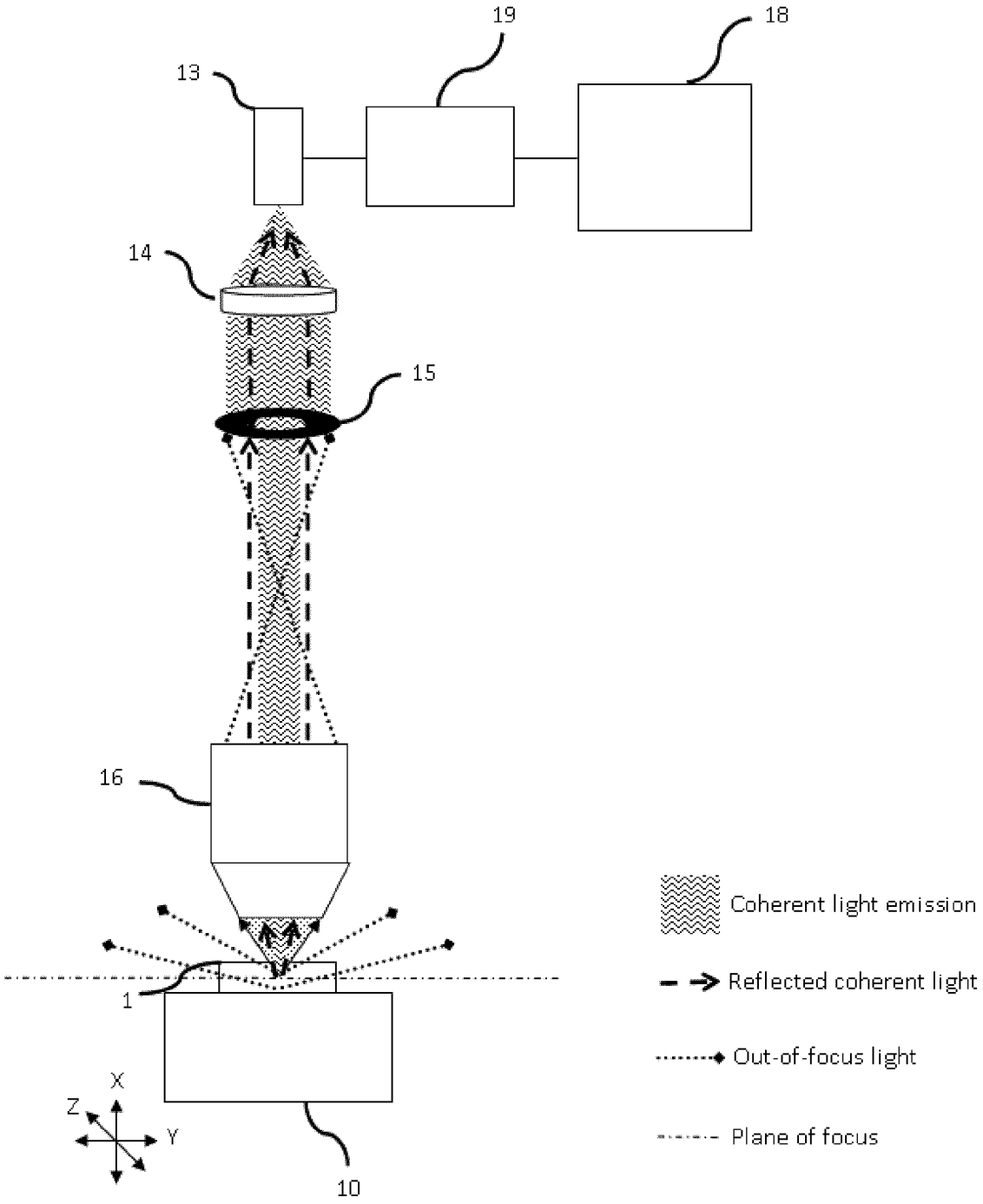
19
18
13
14
15
16
1
X
Z
Y
10
Coherent light emission
Reflected coherent light
Out-of-focus light
Plane of focus

Fig. 1

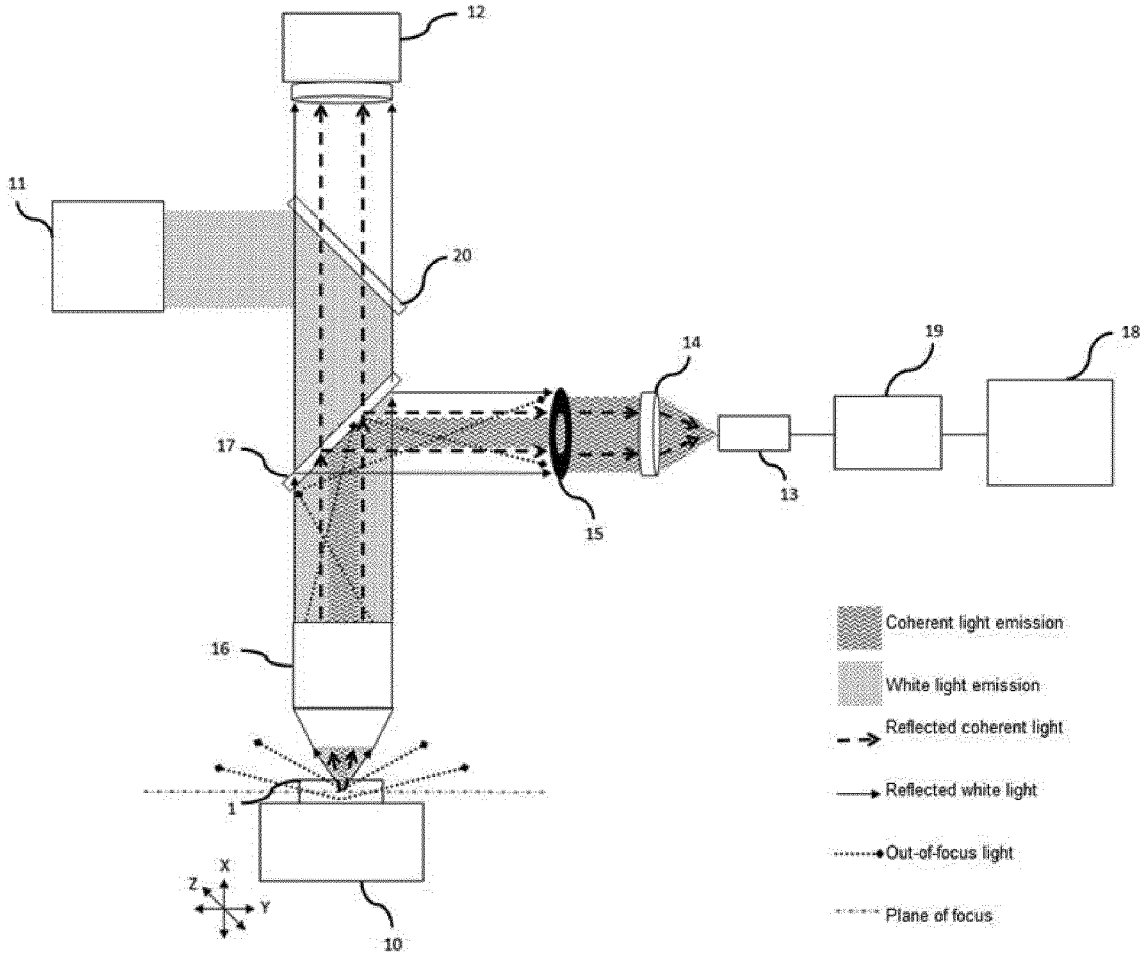
12
11
20
14
19
18
17
13
15
16
1
X
Z
Y
10
Coherent light emission
White light emission
Reflected coherent light
Reflected white light
Out-of-focus light
Plane of focus

Fig. 2

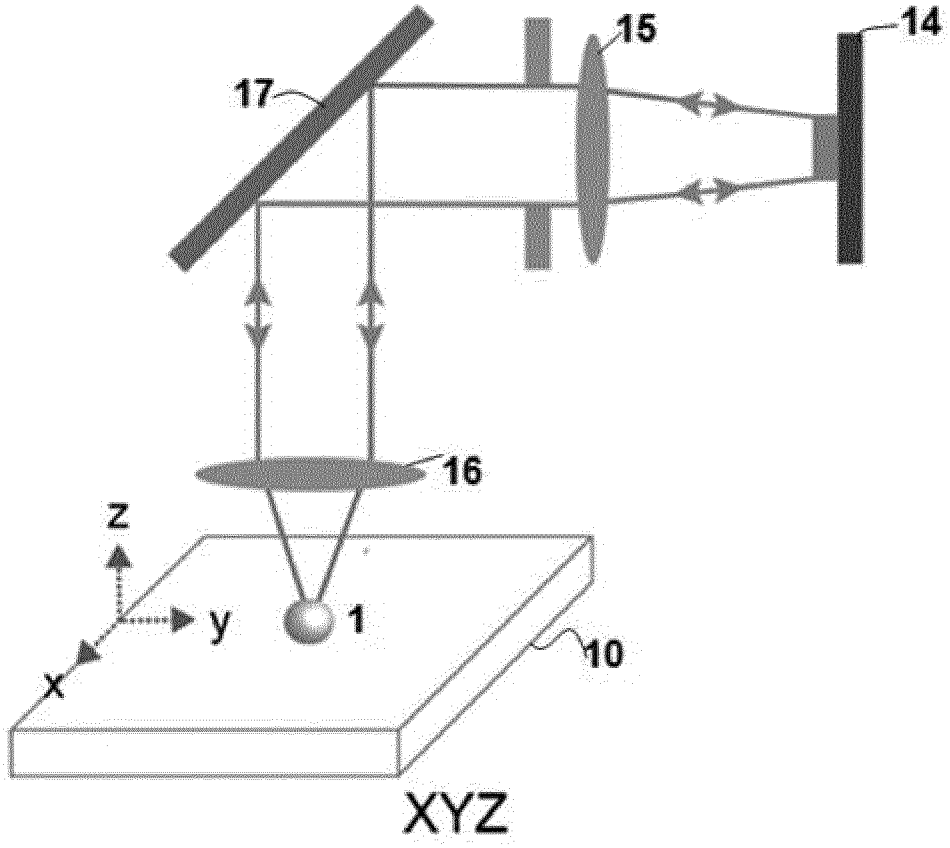

Fig. 3

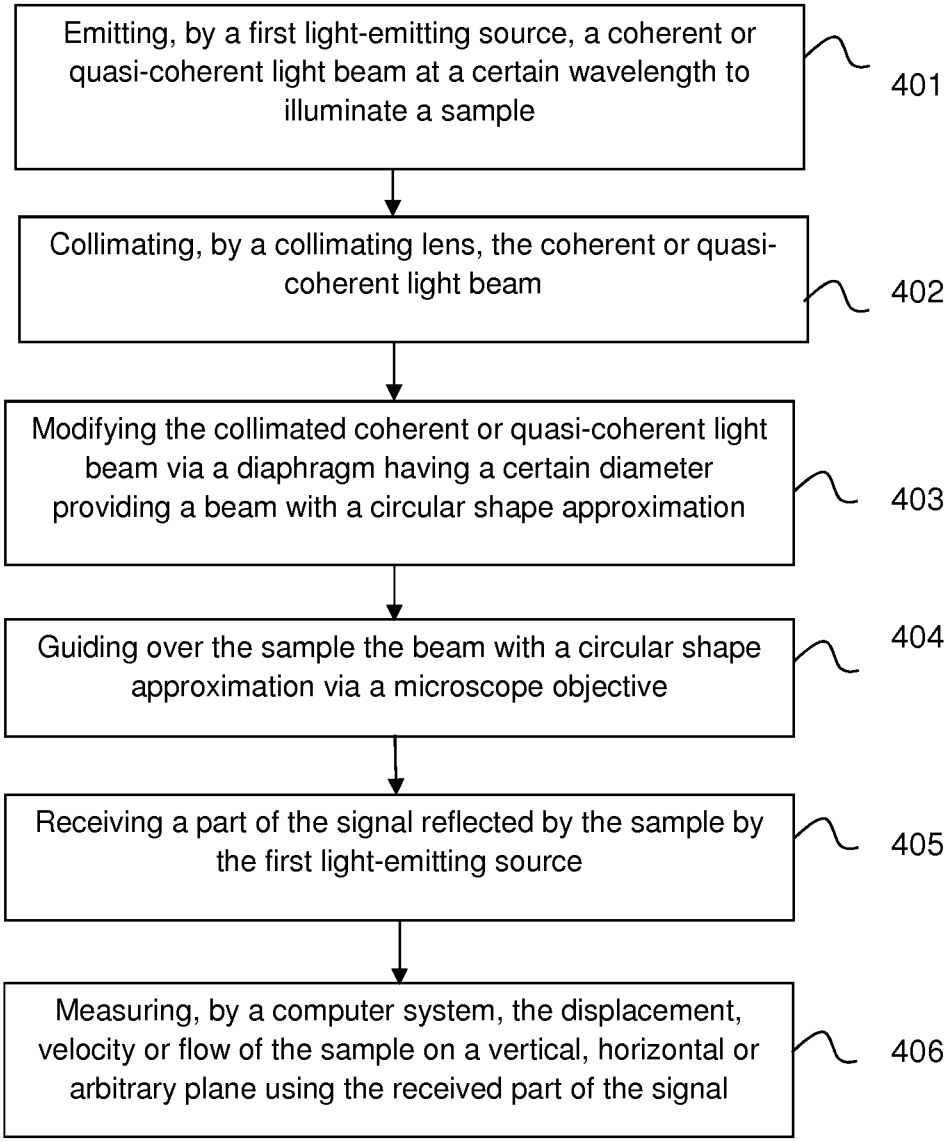
Emitting, by a first light-emitting source, a coherent or quasi-coherent light beam at a certain wavelength to illuminate a sample
401
Collimating, by a collimating lens, the coherent or quasi-coherent light beam
402
Modifying the collimated coherent or quasi-coherent light beam via a diaphragm having a certain diameter providing a beam with a circular shape approximation
403
Guiding over the sample the beam with a circular shape approximation via a microscope objective
404
Receiving a part of the signal reflected by the sample by the first light-emitting source
405
Measuring, by a computer system, the displacement, velocity or flow of the sample on a vertical, horizontal or arbitrary plane using the received part of the signal
406

Fig. 4

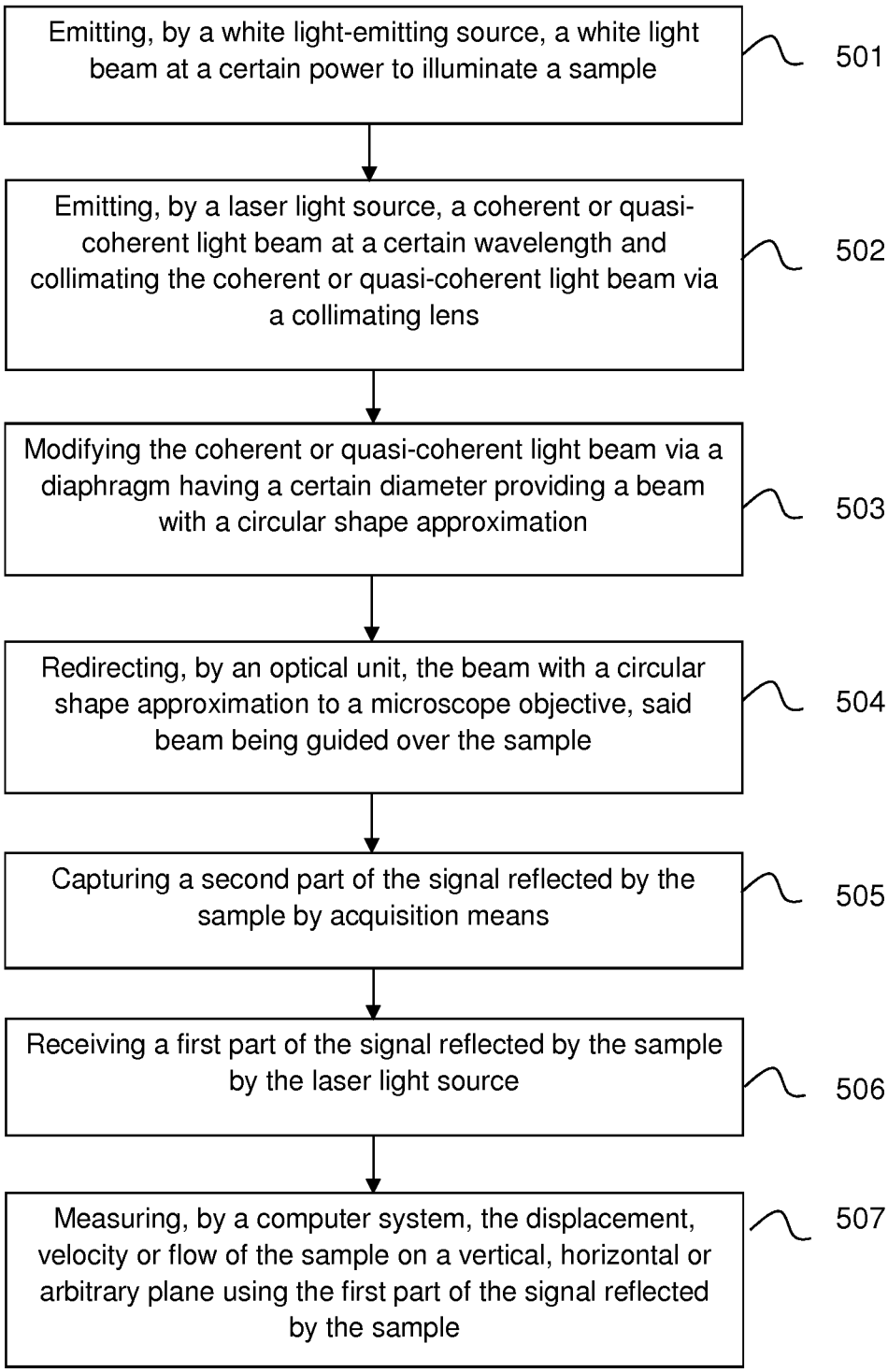
Emitting, by a white light-emitting source, a white light beam at a certain power to illuminate a sample
501
Emitting, by a laser light source, a coherent or quasi-coherent light beam at a certain wavelength and collimating the coherent or quasi-coherent light beam via a collimating lens
502
Modifying the coherent or quasi-coherent light beam via a diaphragm having a certain diameter providing a beam with a circular shape approximation
503
Redirecting, by an optical unit, the beam with a circular shape approximation to a microscope objective, said beam being guided over the sample
504
Capturing a second part of the signal reflected by the sample by acquisition means
505
Receiving a first part of the signal reflected by the sample by the laser light source
506
Measuring, by a computer system, the displacement, velocity or flow of the sample on a vertical, horizontal or arbitrary plane using the first part of the signal reflected by the sample
507

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/05 1588

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01P5/26 G01S17/58
ADD.

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)
G01P G01S G01F G01B

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 practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 98/04924 A1 (RIVA CHARLES E [CH]; PETRIG BENNO L [CH]; GEISER MARTIAL [CH]) 5 February 1998 (1998-02-05) page 8, line 3 - page 9, line 11 page 10, line 4 - page 24 figures 2,3	1-15
X	CN 102 564 909 B (ANHUI INST OPTICS & FINE MECH) 7 May 2014 (2014-05-07)	1,10,15
Y	abstract paragraph [0009] - paragraph [0011] figures 1,2	2-9, 11-14
A	CN 201 397 302 Y (UNIV SHANGHAI SCIENCE & TECH) 3 February 2010 (2010-02-03) figure 1	1-15

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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 application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) orwhich 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
14 March 2019	03/04/2019

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, Fax: (+31-70) 340-3016	Rabenstein, **wi nfri ed**

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 233 045 B1 (SUNI PAUL J M [US] ET AL) 15 May 2001 (2001-05-15) column 6, line 24 - line 31 column 15, line 1 - line 25 figures 9, 21	1-15
Y	US 5 501 226 A (PETERSEN CHRISTOPHER L [US] ET AL) 26 March 1996 (1996-03-26) cited in the application column 6, line 19 - line 63 column 9, line 4 - line 7 column 10, line 39 - column 11, line 54 figures 3,5,6	1-14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/05 1588

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