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(54) Title: OPTICAL PARTICLE DETECTOR

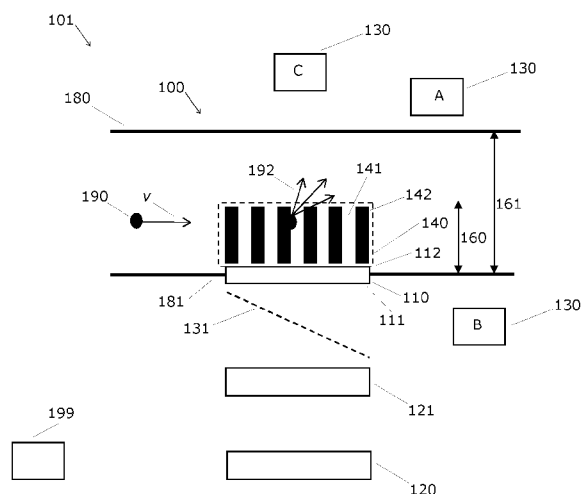


Fig. 1

(57) Abstract: The invention relates to an optical particle detector. A light beam is transmitted through a spatial filter which includes a spatially distributed pattern of varying transmittances. On the back side of the filter the shadow of the low transmittances of the varying transmittances forms a spatially distributed pattern of varying light intensities in the. A particle which passes the spatially distributed pattern of varying light intensities generates a variation in light intensity of scattered or transmitted light. The scattered or transmitted light is measured and analyzed in order to determine properties particles in a fluid.



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OPTICAL PARTICLE DETECTOR

FILED OF THE INVENTION

The invention relates to optical particle detectors.

5

BACKGROUND OF THE INVENTION

Commercial equipment for measurement of velocity, size and concentration of particles is often complex and expensive.

- 10 Laser Doppler Velocimeters (LDV), Particle Imaging Velocimeters and Laser Flow Cytometers are high-end and expensive equipment which specifications that prohibits use within many applications. Laser Particle Counters are less expensive and are limited by technology since a constant flow may be needed across the sensor which for practical purposes means that extensive and space-consuming
- 15 tubing is needed which is prohibitive for many applications.

Accordingly there is a need for a particle detector which is not expensive. There is also a need for a particle detector which does not require extensive rearrangement of fluid guides which guides the fluid to be analyzed.

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- EP1308732 discloses a device for measuring the velocity of objects, particles or a fluid flow. The device comprises transmitter means comprising at least one linear array of surface emitting light sources, said light sources being arranged in a linear configuration spaced apart by a predetermined separation distance, an
- 25 optical system including at least one imaging lens directing the substantially coherent electromagnetic radiation emitted from the light sources into a measurement region in a predetermined manner producing an array of fringes or spots, receiver means comprising light manipulating means for directing the electromagnetic radiation scattered from the measurement region to detection
- 30 means including at least one detector detecting the scattered electromagnetic radiation from the measurement region as an object passes through the measurement region, detector processing means processing the detected signals from the detector means corresponding to the particle(s) and surface passing the fringes in the measurement region.

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Whereas EP1308732 discloses a particle detector the inventor of the present invention has appreciated that an improved particle detector is of benefit, and has in consequence devised the present invention.

5 SUMMARY OF THE INVENTION

It would be advantageous to achieve improvements within particle detection. In general, the invention preferably seeks to mitigate, alleviate or eliminate one or more of the above mentioned disadvantages of particle detectors singly or in any combination. In particular, it may be seen as an object of the present invention to
10 provide a method that solves the above mentioned problems relating to the complexity, cost and complicated use of particle detectors, or other problems, of the prior art.

To better address one or more of these concerns, in a first aspect of the invention
15 an optical measurement device for analysing particles in a fluid is presented that comprises:

- an optical transmission filter configured with a spatially distributed pattern of alternating transmittances,
- a light source arranged in front of the filter so as to enable transmission of light
20 through the filter,
- a measurement zone arranged behind and adjacent the filter so that the measurement zone can be illuminated by the light transmitted through the filter and so that the transmitted light creates a spatially distributed pattern of alternating light intensities corresponding to the alternating transmittances of the
25 filter,
- a light sensor configured to receive light from the measuring zone.

The alternating transmittances, i.e. alternating high and low transmittances, are
30 provided over at least a part of the filter. The alternating transmittances may be achieved by making holes in an opaque plate, e.g. a thin metal plate, or the alternating transmittances may be achieved by other methods wherein the transmittance is varied spatially, e.g. by printing opaque dots on a glass plate where the density of the dots are varied spatially. Accordingly, the transmittances
35 may vary between 100% transmittance and 0% transmittance, between 80% and

20 % transmittance, or other varying transmission values. Accordingly, the filter may be configured with zones having a given spatial extension (measured perpendicular to propagation direction of light from the light source) where neighbor zones have different transmittances. The zones, e.g. a hole, may be
5 shaped as circular zones, elongate zones or may have other shapes.

The filter may be shaped as a plane plate or a curved plate, e.g. the filter may have a cylindrical or spherical shape.

10 The light source may be a laser light source or a light emitting diode (LED). The light source may be provided with an optical unit such as an optical homogenizer in order to create a uniform intensity across the spatial filter. The light source may also be a light guide, e.g. an optical fiber, which transmits light over a distance from a light source (the light source may be fixedly connected with the light guide
15 or connectable with the light guide) to the transmission filter.

The optical measurement device is configured so that the particles to be analysed are present in a volume adjacent to a face of the transmission filter.

20 The light sensor may be configured to receive scattered light from the measurement zone, e.g. light which is scattered in a forward, backward or sideways directions relative to the propagation direction of light from the light source.

25 Alternatively, the light sensor may be arranged opposite to the measurement zone so as to measure light propagating along the propagation direction of light from the light source and through the measurement zone. Accordingly, when no particles are present in the measurement zone, the light sensor substantially measures the amount of light transmitted through the light sensor. When one or
30 more particles are present in the measurement zone, the amount of light (i.e. the power or energy of received light) which is not absorbed or scattered away in other directions is measured.

Accordingly, depending on the configuration and arrangement of the light detector, the light detector will measure an increase or decrease in light intensity when a particle passes a high light intensity fringe in the measurement zone.

- 5 Advantageously, the light source may be a type such as a LED which generates incoherent light since such a light type may be less expensive, stable and durable than other types of light sources such as laser light sources.

Applications of the optical measurement device include measurement of particles
10 in waste water, clean water or process fluids by integrating at least the transmission filter or the entire optical measurement device in a pipe suited for guiding a particular fluid. Other applications comprise measurement of particles in air or other gasses. The gas may be guided in a closed fluid guide suited for guiding a gas. The optical measurement device may also be configured to
15 measure particles in a gas (e.g. air-borne particles) without guiding the gas in a fluid guide. For example, the optical transmission filter may be arranged as a window in an apparatus containing the other components of the optical measurement device so that the apparatus may be placed at an arbitrary location for measurement of particles. By measuring particles in a gas, the velocity of the
20 particles and, thereby, the velocity of the gas can be determined. Accordingly, an application of the optical measurement device is for wind speed measurement. Other applications include particle measurement in micro-fluid systems, e.g. determination of size, velocity and/or concentration of biological objects, e.g. cells, in a fluid. Particularly, applications could comprise determination of bacterial
25 concentration in urine and sperm cell counting.

In an embodiment the spatially distributed pattern of alternating light intensities is formed by shadows behind and adjacent to the low transmittance parts of the transmission filter. Accordingly, in a distance from the transmission filter (along
30 the propagation direction) the difference in intensities of the alternating light intensities will vanish, e.g. due to diffraction from the filter and non-perfect collimated light from the light source. Therefore, the depth of the measurement zone, i.e. a range in a direction perpendicular to the transmission filter wherein the difference in intensities of the alternating light intensities varies sufficiently, is
35 determined by the properties of the filter and the transmitted light.

Advantageously, the depth (and thereby volume) of the measurement zone may be made small so that typically only one particle is present in the measurement zone at a time. The depth of the measurement zone may be determined by the dimensions (in a plane of the filter) of the zones of alternating transmittances.

In an embodiment the optical measurement device is configured so that a medium containing the particles is in contact with the transmission filter. Since the measurement zone is located adjacent to the filter the fluid medium (liquid or gas) is in contact with the filter. Since the filter may be formed e.g. by printing opaque zones (or semi-transparent zones having a transmittance coefficient below one) on a glass plate (or other transparent media) and the printing may be arranged adjacent to the light source, it is understood that the filter may comprise both the opaque parts and a support such as a glass plate. Accordingly, the medium containing the particles may not be directly in contact with the opaque parts but may contact a possibly support structure of the opaque parts or medium (e.g. a glass plate or an optical fiber) wherein the opaque parts are formed.

In an embodiment the optical measurement device is configured without any optical components between the transmission filter and the measurement zone. Accordingly, since the measurement zone is located adjacent to the transmission filter no optical components for focusing, spreading or imaging of light from the light source or of light scattered by the particles in the measurement zone are required. For example, no optical components are required for imaging spatially alternating light intensities onto a measurement zone.

In an embodiment the light sensor is configured to receive scattered light from the measurement zone. Accordingly, when a particle passes the measurement zone the light sensor will detect increased light intensity – at least when the particle is located in the high intensity regions.

In a related embodiment the light sensor is arranged to receive the scattered light from the measurement zone via the transmission filter. Accordingly, the scattered light from a particle which is transmitted back through the filter will be detected by the light sensor.

In an embodiment the depth of the measurement zone extending from a back face of the transmission filter is less than 100 mm. The measurement zone extends through the entire depth from the filter to the depth of the measurement zone. Accordingly, the depth of the measurement zone - measured along the propagation direction of light transmitted by the light source - from a back face of the transmission filter which is in contact with the measurement zone to a depth of the measurement zone wherein the alternating light intensities varies e.g. less than 50 % (relative to the variation at the back face of the filter) is less than 100 mm.

A second aspect of the invention relates to a measurement system, comprising

- an optical measurement device according to the first aspect, and
- a fluid guide component for a fluid guide wherein the fluid guide is for guiding a fluid containing the particles, wherein the fluid guide component comprises the transmission filter.

The measurement system may be a pipe, e.g. a pipe for water, waste water or process fluids, wherein the optical transmission filter is integrated in the shell or a shell component of the pipe. By detecting particles the purity of the water or process fluid can be measured.

The measurement system could also be a system for continuous measurement of particle size and concentration in processes, e.g. a system for online monitoring of industrial crystallization processes or yeast development during fermentation.

The measurement system could also be a micro-flow system for measurement of volume flow, flow velocity or flow profiles.

The micro-flow system may be integrated on a single platform where the fluid guide is formed as cut out or slot in given material and where the cut out may be closed with a lid, i.e. a fluid guide component, wherein the transmission filter is integrated in the lid.

The measurement system could also be configured for analysing air or other gasses, e.g. by measuring concentration of particles or velocity of particles in air.

The optical transmission filter may be integrated in a structure, generally a
5 structure which makes part of the fluid guide such as a wall or shell of the fluid guide.

The transmission filter may be integrated in the fluid guide so that a back face (i.e. a face which faces the measurement zone) of the transmission filter is in
10 contact with the measurement zone.

Advantageously, the back of the transmission filter may be flush with an inner surface of the fluid guide in order to avoid that the filter affects the flow in the fluid guide.

15

Alternatively, the measurement system may be configured so that an output part of the transmission filter is located a distance away from the inner surface of the fluid guide in order to measure particle properties at locations other than near the inner surface.

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According to an embodiment of the measurement system an extension 160 of the measurement zone 140 is equal to, substantially equal to or greater than a cross-sectional dimension 161 of the fluid guide 180.

25 A third aspect of the invention relates to method for analysing particles in a fluid comprising:

- providing an optical transmission filter configured with a spatially distributed pattern of alternating transmittances,
- illuminating a front face of the filter so as to form a spatially distributed pattern
30 of alternating light intensities behind and adjacent to a back face of the filter,
- measuring light from the spatially distributed pattern of alternating light intensities.
- analysing the measured light so as to determine one or more characteristics of the particles.

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In summary the invention relates to an optical particle detector. A light beam is transmitted through a spatial filter which includes a spatially distributed pattern of varying transmittances. On the back side of the filter the shadow of the low transmittances of the varying transmittances forms a spatially distributed pattern of varying light intensities in the. A particle which passes the spatially distributed pattern of varying light intensities generates a variation in light intensity of scattered or transmitted light. The scattered or transmitted light is measured and analyzed in order to determine properties particles in a fluid.

10 In general the various aspects of the invention may be combined and coupled in any way possible within the scope of the invention. These and other aspects, features and/or advantages of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

15 BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be described, by way of example only, with reference to the drawings, in which

Fig. 1 shows an optical measurement device 100,

20 Fig. 2 shows a spatial filter 110 combined with a fluid guide component 181,

Fig. 3 shows how the contrast between zones of relatively high light intensity and neighbor zones of relatively low light intensity reduces as a function of the distance from the filter,

Fig. 4A shows an example of the optical measurement device configured as a

25 micro-flow particle sensor 401,

Fig. 4B shows an example of the optical measurement device configured as a fibre optic particle sensor 402,

Fig. 5 shows an example of the output signal 501 from an optical measurement device,

30 Fig. 6 shows measurements of particle size,

Fig. 7 shows measurements of particle velocity, and

Fig. 8 shows measurement of particle concentration.

DETAILED DESCRIPTION OF AN EMBODIMENT

Fig. 1 shows an optical measurement device 100 for analysing particles 190 in a fluid flowing in a fluid guide 180, e.g. a pipe. The optical measurement device 100 comprises an optical transmission filter 110 configured with a spatially distributed pattern of alternating transmittances, i.e. high and low transmittances. A light source 120 is arranged in front of the filter, i.e. the light source faces a front side 111 of the filter. Light from the light source is transmitted towards a front side of the filter and through the filter.

On the back side 112 of the filter a spatially distributed pattern of alternating, i.e. high and low, light intensities are created in response to the light transmitted through the filter. Thus, the alternating light intensities are formed by shadows appearing behind and adjacent to parts of the transmission filter having low transmittances or parts which are opaque. The spatially distributed pattern of alternating light intensities comprises zones of relatively high light intensity 141 and neighbor zones of relatively low light intensity 142.

The spatially distributed pattern of alternating light intensities formed behind the transmission filter 110 by shadows of light transmitted through the alternating transmittances constitutes a measurement zone 140. The measurement zone 140 has an extension, i.e. depth, 160 in a direction along the propagation direction of light transmitted by the light source 120. The measurement zone 140 has other extensions perpendicular to the light propagation direction, i.e. in the plane of the back face 112 of the transmission filter 110, which are determined by the dimensions of the transmission filter 110.

The fluid guide 180 (or fluid guide component 181) has an extension 161 between the back face 112 of the transmission filter 110 and the opposite wall (e.g. the most distant point of the opposite wall in case of non-planar wall, e.g. when the fluid guide 180 is a cylinder) in the same direction as the extension 160. Thus, the lumen of fluid guide 180 has a cross-sectional dimension 161 transversal to the flow direction and in the propagation direction of light from the light source 120.

Besides that the measurement zone 140 may be defined in that the alternating light intensities of the measurement zone is formed directly by shadows of the

spatial filter 110, the measurement zone may further be defined in that no optical components such as lenses are located between the back 112 of the transmission filter 110 and the measurement zone 140.

- 5 When a particle 190 passes the spatially distributed pattern of alternating light intensities, the particle will scatter light 192 in various directions. The scattered light is detected by a light sensor 130. Since the light is scattered in different directions, the light sensor may be located at different locations, e.g. at the opposite site of the fluid guide compared to the location of the light source 120
10 such as location A.

The light sensor may also be located and arranged to receive the scattered light via the transmission filter, i.e. so that that the light sensor 130 receives the light which is transmitted back though the transmission filter. In that case a beam
15 splitter 131 may be used for redirecting the scattered towards the light sensor. Alternatively, the light from the light source could be redirected by a beam splitter. Accordingly, the light sensor 130 could be located at the same site of the fluid guide as the light source such as location B.

- 20 Alternatively, the light sensor 130 may be located at a location C opposite to the filter 110 and in line with the propagation direction of light from the light source 120 in order to enable detection of light transmitted through the filter 110. When a particle 190 is located in a high intensity light zone in the spatially distributed pattern of alternating light intensities, the light intensity detected by a light sensor
25 130 at location C is reduced as compared to the situation where no particles are located in the spatially distributed pattern of alternating light intensities.

Accordingly, a particle may be detected by measuring variations in scattered light intensity or variations in the light intensity of light transmitted through a volume
30 in the fluid guide, i.e. variations in non-scattered light transmitted directly from the light source 120. Therefore, the light sensor is generally configured to receive light from the measurement zone which can be direct light from the light sensor or scattered light from particles located.

The optical measurement device 100 may further comprise an optical component 121 such as a collimator or homogenizer for collimating light from the light source 120 and/or for making the light intensity of the beam from the light source 120 more uniform.

5

The optical measurement device 100 may be configured so that the transmission filter 110 constitutes a window in the device 100 so that the filter 110 enables measurement of particles in the surroundings of the optical measurement device 100. Alternatively, the optical measurement device 100 may be configured so that
10 the transmission filter 110 is configured to be combined with a fluid guide 180 or a fluid guide component 181.

FIG. 1 further illustrates a measurement system 101 which includes the optical measurement device 100 and a fluid guide component 181. The fluid guide
15 component 181 is a component of a fluid guide for guiding a fluid containing the particles. For example, the fluid guide may be a pipe and the fluid guide component may be a part of the pipe, for example a pipe-ring which is connectable with the main pipe. As another example, the fluid guide may be a fluid guide of a micro-flow system and the fluid guide component may be a
20 window or a lid for the micro-flow system.

The fluid guide component may comprise the transmission filter. For example, a through hole may be made in the shell of a pipe or pipe-ring and the transmission filter may be fitted and attached to the hole in a fluid-proof way so that the
25 transmission filter forms a window into the interior of the of the pipe-ring. Similarly, a lid or other closure for a micro-flow system may be configured so that the transmission filter forms a window in the closure.

Generally, the transmission filter may be integrated in the fluid guide component
30 so that a back of the transmission filter is in contact with the measurement zone. That is, the back face of the transmission filter (opposite to the front face which faces the light source 120) faces the interior of the fluid guide.

The back of the transmission filter may be flush with an inner surface of the fluid
35 guide to enable detection of particles near the inner surface of the fluid guide.

Alternatively, the back of the transmission filter may protrude into the interior of the fluid guide to enable detection of particles, e.g. in the center of the fluid guide.

- 5 The light sensor 130 may be a photodiode or other detector capable of measuring light intensity. The electrical output from the light sensor may be connected to an electronic circuit 199, e.g. for amplifying the output signal from the light sensor 130. The electronic circuit 199 may further comprise a data processor or may be connectable to a data processor for analysing the output signal in order to
- 10 determine particle velocity, particle size, particle concentration or other particle characteristics.

Fig. 2 shows an example of the optical transmission filter 110 integrated in a fluid guide component 181. The spatially distributed pattern of alternating

15 transmittances is achieved by means of a part 201 which is opaque or has a relatively low transmission coefficient, e.g. close to zero, and a part 202 which is transparent or has a relatively high transmission coefficient, e.g. close to one.

The parts 201, 202 of relative high and low transmittances may be elongate in

20 shape or may have other shapes.

The parts 201, 202 of relative high and low transmittances have widths 211 and 212, respectively. The period 213 of the alternating transmittances is given by the sum of widths 211 and 212. The widths 211, 212 of the high and low

25 transmittances parts may be equal or different.

The period 213 of the alternating transmittances may be in the range from 2 to 1000 micrometers. Currently investigated periods 213 have widths of 10, 40 and 120 micrometers.

30

Fig. 3 shows an example of how the contrast between zones of relatively high light intensity 141 and neighbor zones of relatively low light intensity 142 reduces as a function of the distance from the back surface 112 of the filter in a direction perpendicular to the filter back 112 or equivalently in a direction parallel with the

35 propagation direction of light from the light source 120. Fig. 3 shows intensity

values I at distances: 0, 260, 500, 760 and 1000 micrometers. In Fig. 3 the period 213 of the alternating transmittances is 80 μm . The contrast is defined in terms of the light intensities of the high and low intensity zones 141, 142, e.g. as:

$(I_{\text{max}} - I_{\text{min}}) / (I_{\text{max}} + I_{\text{min}})$ where I_{max} and I_{min} are the intensities of the

5 respective high intensity and low intensity zones 141, 142.

The distance 160 from the filter back 112 to a depth defined by a given contrast, variation in intensity I or other measure defines the depth of the measurement zone.

10

The depth of the measurement zone depends on the widths 211, 212 of the high and low transmittances parts so that the larger the widths are the larger the depth of the measurement zone is. This dependency is due to diffraction effects of light diffracted by the filter parts or zones 201, 202.

15

For example, the depth of the measurement zone may be given by the length scale $z \sim 0.25 \cdot f \cdot \pi \cdot w^2 / \lambda$, where z is the length scale, w is the width of the period 213 of the alternating transmittances, λ is the wavelength of the light source and f is a number that depends on the exact definition of the measurement zone and exact
20 physical conditions. The value of f is of the order 0.05-1. Using $f=0.1$, for a typical wave length 0.5 μm , the depth of the measuring zone is approximately 63 μm if a period 213 of 20 μm is used. Alternatively the depth of the measuring zone is approximately 1.6 mm if a period 213 of 100 μm is used.

25 As another example, when using a period 213 of 360 μm and a collimated light source the divergence of the light after the optical transmission filter 110 is mostly determined by diffraction and $f=0.5$ is an appropriate value. Using $\lambda = 0.5 \mu\text{m}$ results in a depth of the measuring zone which is approximately 102 mm.

30 In another example, the depth of the measurement zone may be defined from the criteria that the contrast of the variations of the intensity I is larger than 0.25, meaning that the difference between I_{max} and I_{min} is larger than 50 percent of

the mean intensity value. In Fig. 3, the difference between $I_{\max}$ and $I_{\min}$ is close to 50 percent of the mean intensity implying that the depth is 760 micrometer.

Typical values of the depth of the measurement zone are below approximately
5 100 millimeter, e.g. in a range from 5 micrometer to 100 millimeter, such as 63 micrometer, 760 micrometer or 1.6 millimeter as explained above.

In an embodiment the fluid guide 180 or fluid guide component 181 has an extension or depth 161 which is equal to or smaller than the extension 160 of the
10 measurement zone 140. Thereby, the measurement system 101 may be configured so that the measurement zone 140 fills a section of the fluid guide 180 or fluid guide component 181, i.e. so that a volume of the fluid guide extending along the longitudinal direction of the fluid guide 181 and extending over the entire transversal cross section of the fluid guide is filled with a pattern of
15 alternating light intensities. Thereby, any particle moving through a transversal cross section of the lumen of the fluid guide where the measurement zone 140 is located will move through the pattern of alternating light intensities and will therefore be detectable by the light sensor 130.

20 A configuration of the measurement system 101 where the measurement zone 140 fills a section of the fluid guide component 181 may be particularly useful for detection of fluids containing a low concentration of particles since all particles or substantially all particles passing through a transversal cross section of the fluid guide will be detected.

25

A configuration of the measurement system 101 where the measurement zone 140 only extends a fraction of the distance 161 between the back face 112 of the transmission filter 110 and the opposite wall, i.e. where the measurement zone 140 only fills a fraction of the volume of section of the fluid guide component
30 181 may be particularly useful for detection of fluids containing a high concentration of particles since a high concentration may be difficult to detect if a high number of particles passes a measurement zone 140.

Fig. 4A shows an example of the optical measurement device 101,401 configured as a micro-flow system where the fluid guide 413 is formed in a part 412 of the micro-flow system and where a closure 181 for the fluid guide 413 contains the optical transmission filter 110. The light source 120 and the light sensor 130 may both be contained in an optical unit 411 which may be fixedly connected or
5 removably connected to the filter 110.

Fig. 4B shows an example of the optical measurement device 101,402 configured as an optical fibre system. The optical transmission filter 110 may be formed on
10 the end of the optical fibre 422 or the optical transmission filter 110 may be formed within the fibre near the end of the fibre 422. For example, the pattern of alternating transmittances may be written on the outside of the fiber by modifying the optical properties of the fiber material using micro-machining or by direct photo lithographic techniques on the fiber end or by mounting a pre-manufactured
15 optical component with alternating transmittances onto the fiber end.

The light source 120 and the light sensor 130 may both be contained in an optical unit 421 which may be fixedly connected or removably connected to the fibre 422. The fibre 422 may be inserted in a fluid guide 423 and possibly the position of the filter 110 inside the fluid guide may be adjustable by displacing the fibre 422.

20

Fig. 5 shows the output signal 501, e.g. a voltage signal, from the light sensor 130 or an electronic circuit 199 connected to the light sensor 130 as a function of time t in milliseconds (along the abscissa). In Fig. 5, the output signal is obtained by measuring scattered light from particles passing the measurement zone.

25 However, an output signal could also have been determined by measuring light from the light source which is transmitted through the measurement zone. The output signal 501 in graph A shows two peaks where the first peak is generated in response to passage of a single first particle and the second peak is generated in response to passage of a single second particle. The output signal 501 in graph B
30 shows the first peak of graph B in detail where the peaks 502 correspond to scattered light from high intensity zones 141 generated as a particle passes the high intensity zones 141, i.e. a single high intensity zone 141 generates a single peak in the output signal 501. The output signal 501 in graph B is characterized by the amplitude S_{pp} and the period T of the signal oscillations.

35

Fig. 6 shows measurement of particle size obtained by the optical measurement device 100. Known particle sizes (PS) are given along the abscissa (0.1-100 micrometer) and the amplitudes S_{pp} (see Fig. 5) of the output signal oscillations are given along the ordinate (arbitrary scale). At least for a certain range of particle sizes, there exists an approximately linear relationship between particle size and the amplitude S_{pp} as seen from the amplitude measurements.

Accordingly, the size of a particle which generates an output signal 501 can be determined from the amplitude S_{pp} of the signal oscillations of the output signal 501, e.g. by multiplying an average of several amplitudes S_{pp} by a given factor which is dependent on the configuration of the optical measurement device 100.

Fig. 7 shows measurement of particle velocity v (mm/s) (see Fig. 1) obtained by the optical measurement device 100. Known particle velocities v_{vol} (mm/s) are given along the abscissa (0 -12 mm/s) and the determined particle velocities v are given along the ordinate. The particle velocity v from a particle passing the measurement zone 140 can be determined from the equation $v=a/T$ where a is the period 213 of the alternating transmittances corresponding to the period of the alternating light intensities in the measurement zone 140, and T is the period of output signal oscillations (see Fig. 1).

20

Fig. 8 shows measurement of particle concentration C (particles per volume) obtained by the optical measurement device 100. Known particle concentrations C_m are given along the abscissa and the determined particle concentrations C are given along the ordinate. Concentrations C are determined for different known concentrations C_m and different particles sizes (1.5 and 2 micrometer). The concentration C from particles passing the measurement zone 140 can be determined from the equation $C = N/V$, where N is the number of particles detected within a certain time period (t) and V is the volume of gas or liquid passed through the measurement zone in the same time period. V can be obtained from the measurement of the particle velocities (v), the depth of the measuring zone and the height 214 (h) of the pattern of the alternating transmittances through $V = w \cdot h \cdot v \cdot t$. The height 214 is defined in Fig. 2.

30

Advantageously, since the determined volume V is independent of flow velocity of the fluid carrying the particles to be detected, the measurement device 100 can be used in various fluid guides 180 and independent of flow velocity.

- 5 An aspect of the invention relates to an optical measurement device 100 for analysing particles 190 in the form of bacteria in urine, e.g. for determining concentration of bacteria.

It is important that the device 100 configured for detecting bacterial in urine is
10 capable of detecting low concentrations of bacteria in order to detect a possible bacterial infection. Therefore, the fluid guide 180 or fluid guide component 181 and the optical components, particularly the transmission filter 110, may be configured so that the measurement zone 140 fills as section of the fluid guide 180 or fluid guide component 181 so that each bacteria transported past the filter
15 110 (via a flow of the urine) will generate a detectable optical change, e.g. a pulse of scattered light. For example, the device 100 should be capable of detecting a concentration of at least 50-100 bacteria per millilitre.

Another aspect of the invention relates to an optical measurement device 100 for
20 analysing particles 190 in the form of sperm cells in a fluid, e.g. for counting sperm cells, for determining concentration of sperm cells and/or for determining velocities/speeds of individual sperm cells or a velocity/speed distribution of sperm cells. In order to measure speeds of sperm cells, the fluid containing the sperm cells may be driven past the filter 110 with a constant or substantially
25 constant flow velocity. Thus, even though sperm cells moves in different directions the flow velocity of the fluid containing the sperms cells ensures that correct speeds of individual sperm cells can be determined.

Another aspect of the invention relates to an optical measurement device 100 for
30 analysing particles 190 in the form of particles in waste water, e.g. waste water from an industrial process, for determining a concentration of such particles. The concentration of such particles may be high, e.g. about one million particles per millilitre. Therefore, the fluid guide 180 or fluid guide component 181 and the transmission filter 110 may be configured so that the measurement zone 140 only

extends a fraction of fluid guide dimension 161 into the fluid so that only a fraction of the particles in the fluid moves through the measurement zone 140.

Advantageously, since the device 100 is capable of measuring the velocity of the particles moving through the measurement zone 140, the speed of the fluid carrying the particles can be determined from the particle velocities. Accordingly, the device 100 does not require a particular or known flow velocity of the fluid carrying the particles in order to analyse the particles, e.g. determine a concentration.

10

Since the device 100 does not require a particular or known flow velocity of the fluid carrying the particles the device may be used e.g. to determine particle concentrations in clean-rooms where the flow velocity of the air varies. Further, the optical measurement device 100 may be configured, e.g. as a probe, so that the measurement device 100 can be inserted directly into an existing fluid guide 180 without a need to take a fluid sample from the existing fluid guide 180 for creating a known flow velocity of the fluid sample.

In an aspect the optical measurement device 100 is configured for analysing particles 190 in the form of particles in clean water, e.g. for determining a concentration of E-coli bacteria in clean water. By determining the velocities particles in clean water the flow velocity and, thereby, water flow can be determined in order to determine a water consumption. Thus, in an aspect the optical measurement device 100 may be configured to determine velocity of a fluid by analysing particles in the fluid.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS

1. An optical measurement device (100) for analysing particles (190) in a fluid comprising:
- 5 - an optical transmission filter (110) configured with a spatially distributed pattern of alternating transmittances,
- a light source (120) arranged in front of the filter so as to enable transmission of light through the filter,
- a measurement zone (140) arranged behind and adjacent the filter so that the
- 10 measurement zone can be illuminated by the light transmitted through the filter and so that the transmitted light creates a spatially distributed pattern of alternating light intensities corresponding to the alternating transmittances of the filter,
- a light sensor (130) configured to receive light from the measurement zone.
- 15
2. An optical measurement device according to claim 1, wherein the spatially distributed pattern of alternating light intensities is formed by shadows behind and adjacent the low transmittance parts (201) of the transmission filter.
- 20
3. An optical measurement device according to any of claims 1-2, wherein the optical measurement device is configured so that a medium containing the particles is in contact with the transmission filter.
4. An optical measurement device according to any of claims 1-3, wherein the
- 25 optical measurement device is configured without any optical components between the transmission filter and the measurement zone.
5. An optical measurement device according to any of claims 1-4, wherein the
- 30 light sensor is configured to receive scattered light from the measurement zone.
6. An optical measurement device according to claim 5, wherein the light sensor is arranged to receive the scattered light from the measurement zone via the transmission filter.

7. An optical measurement device according to any of claims 1-2, wherein a depth of the measurement zone extending from a back face (112) of the transmission filter is less than 100 mm.

- 5 8. A measurement system (101), comprising
- an optical measurement device (100) according to claim 1,
 - a fluid guide component (181) for a fluid guide (180) wherein the fluid guide is for guiding a fluid containing the particles, wherein the fluid guide component comprises the transmission filter.

10

9. A measurement system according to claim 8, wherein the transmission filter is integrated in the fluid guide component so that a back of the transmission filter is in contact with the measurement zone.

- 15 10. A measurement system according to any of claims 8-9, wherein the back of the transmission filter is flush with an inner surface of the fluid guide component.

11. A measurement system according to claim any of claims 8-10, wherein the system is a micro-flow system.

20

12. A measurement system according to claim any of claims 8-11, wherein an extension (160) of the measurement zone (140) is equal to, substantially equal to or greater than a cross-sectional dimension (161) of the fluid guide (180).

- 25 13. A method for analysing particles in a fluid comprising:
- providing an optical transmission filter (110) configured with a spatially distributed pattern of alternating transmittances,
 - illuminating a front face of the filter so as to form a spatially distributed pattern of alternating light intensities behind and adjacent to a back face of the filter,
 - 30 - measuring light from the spatially distributed pattern of alternating light intensities, and
 - analysing the measured light so as to determine one or more characteristics of the particles.

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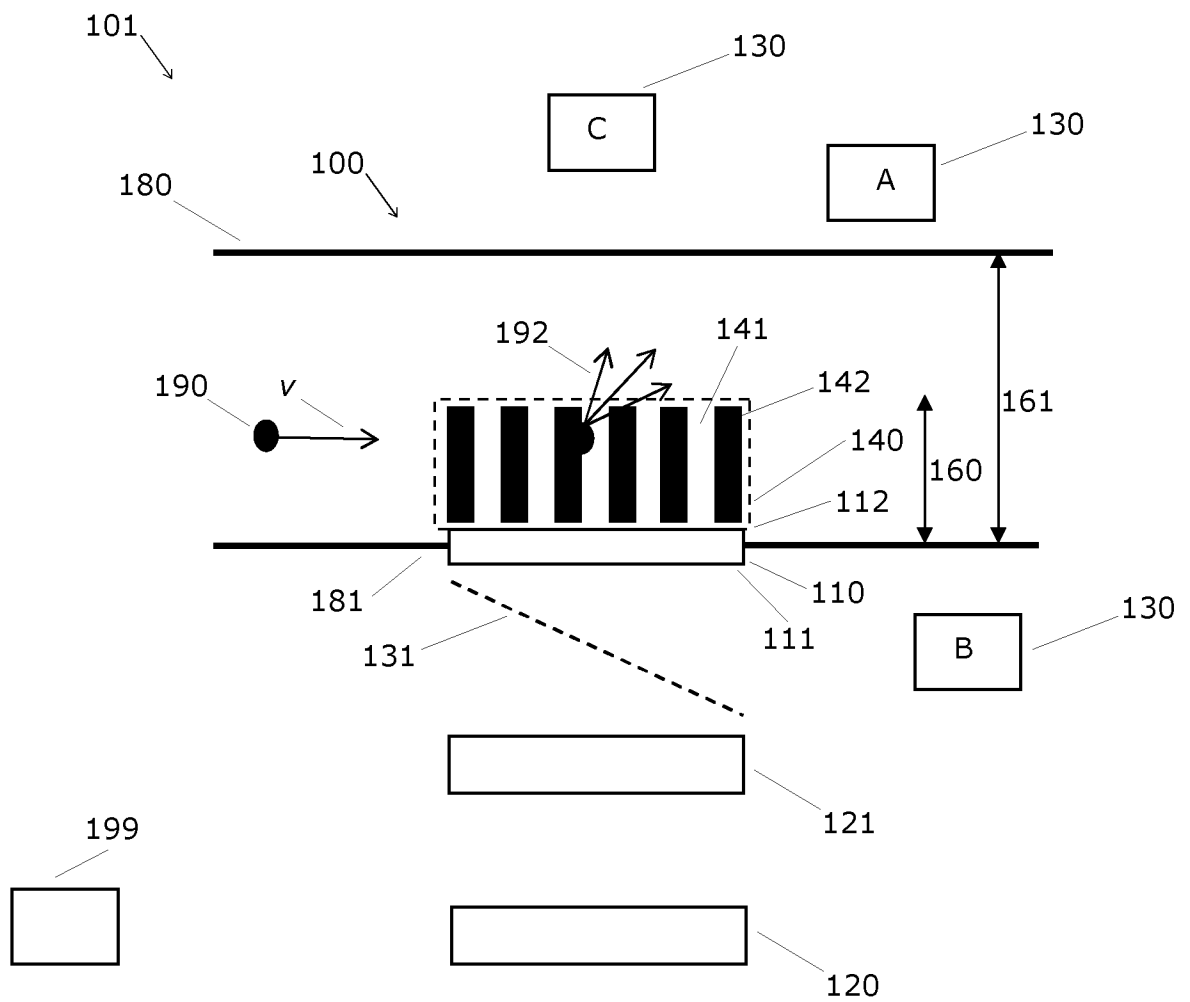


Fig. 1

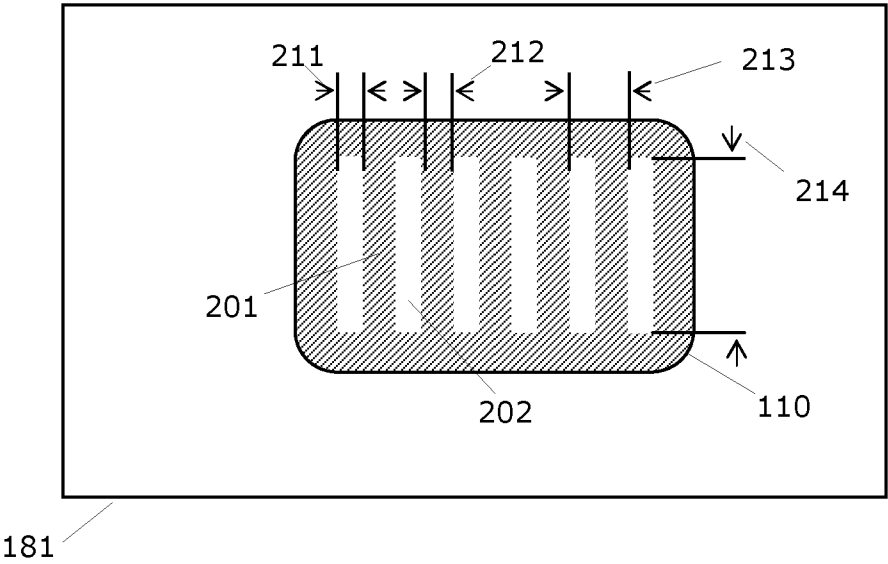


Fig. 2

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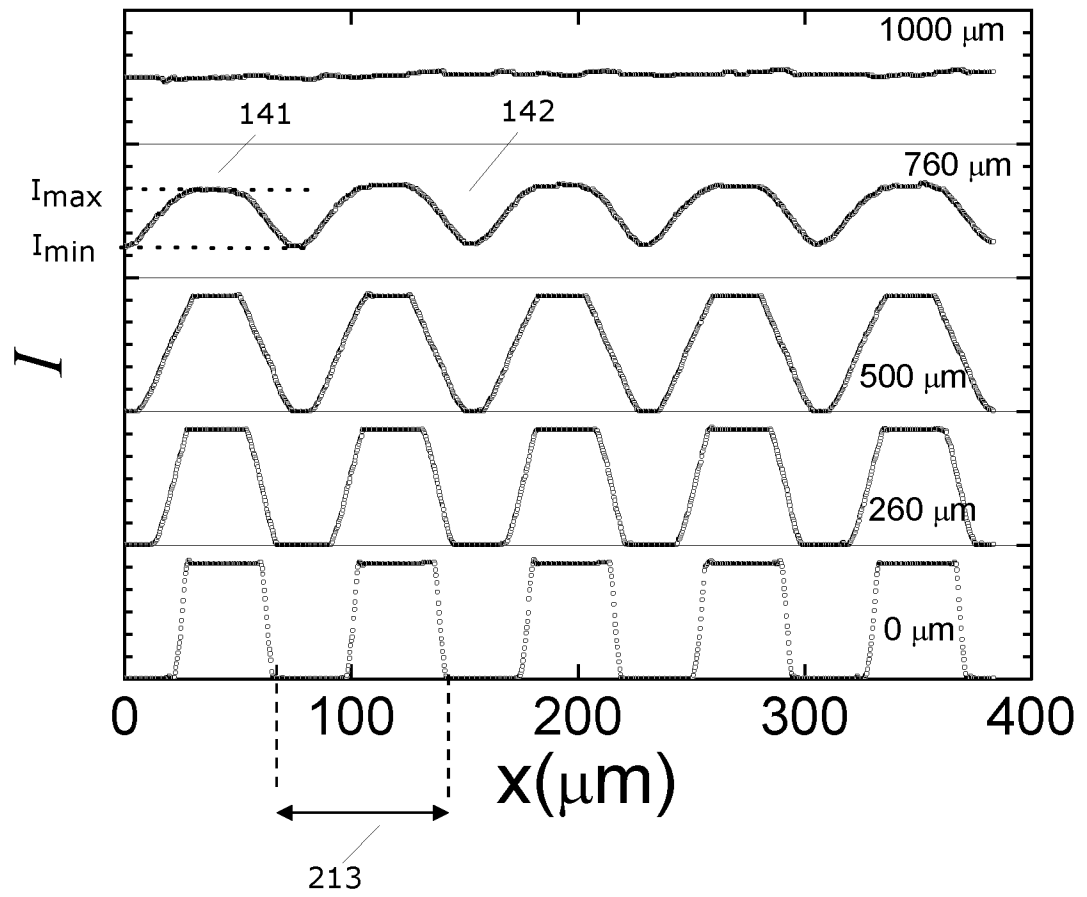


Fig. 3

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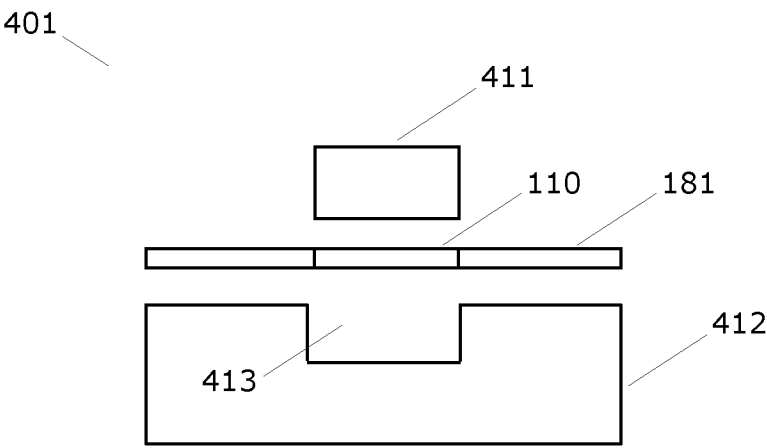


Fig. 4A

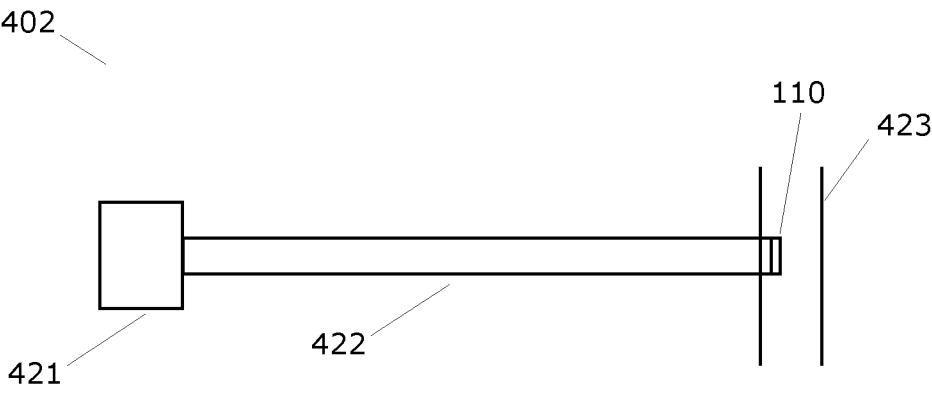


Fig. 4B

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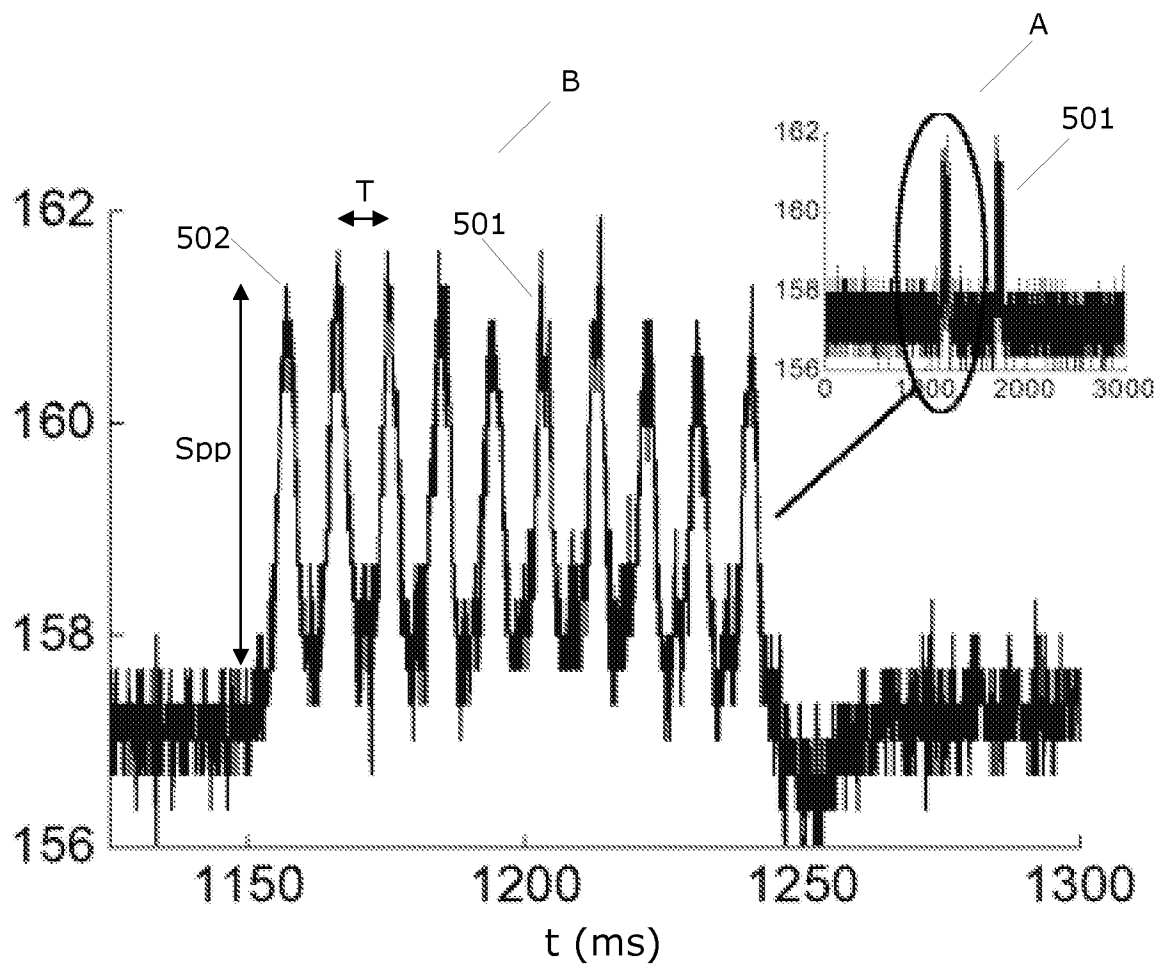


Fig. 5

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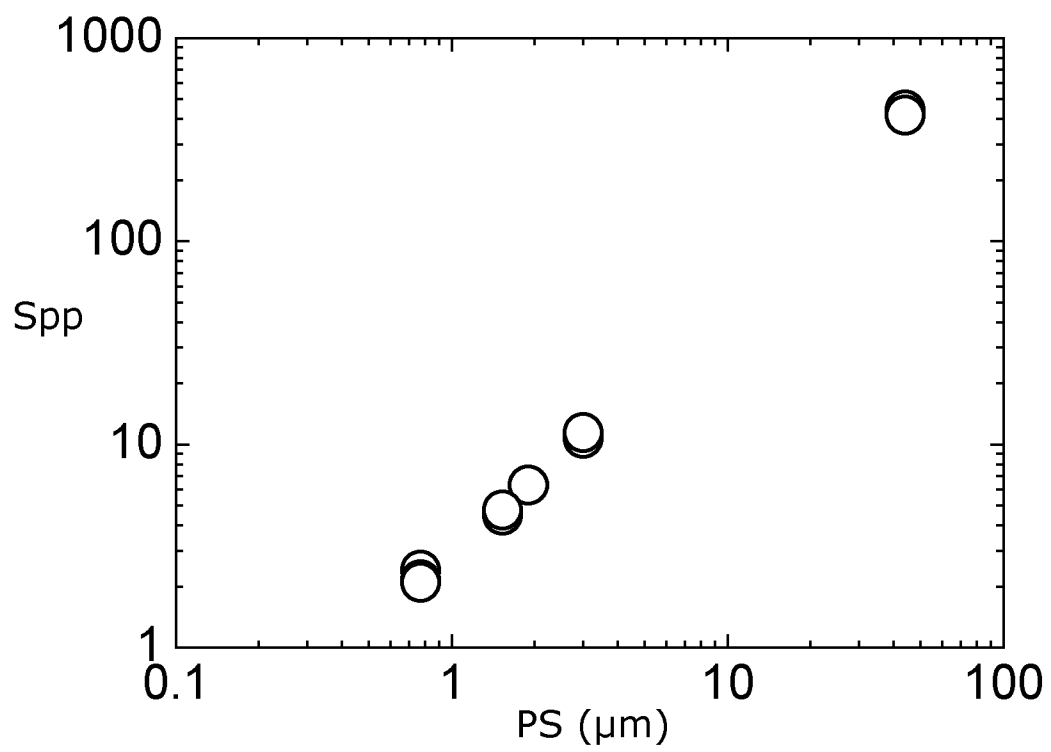


Fig. 6

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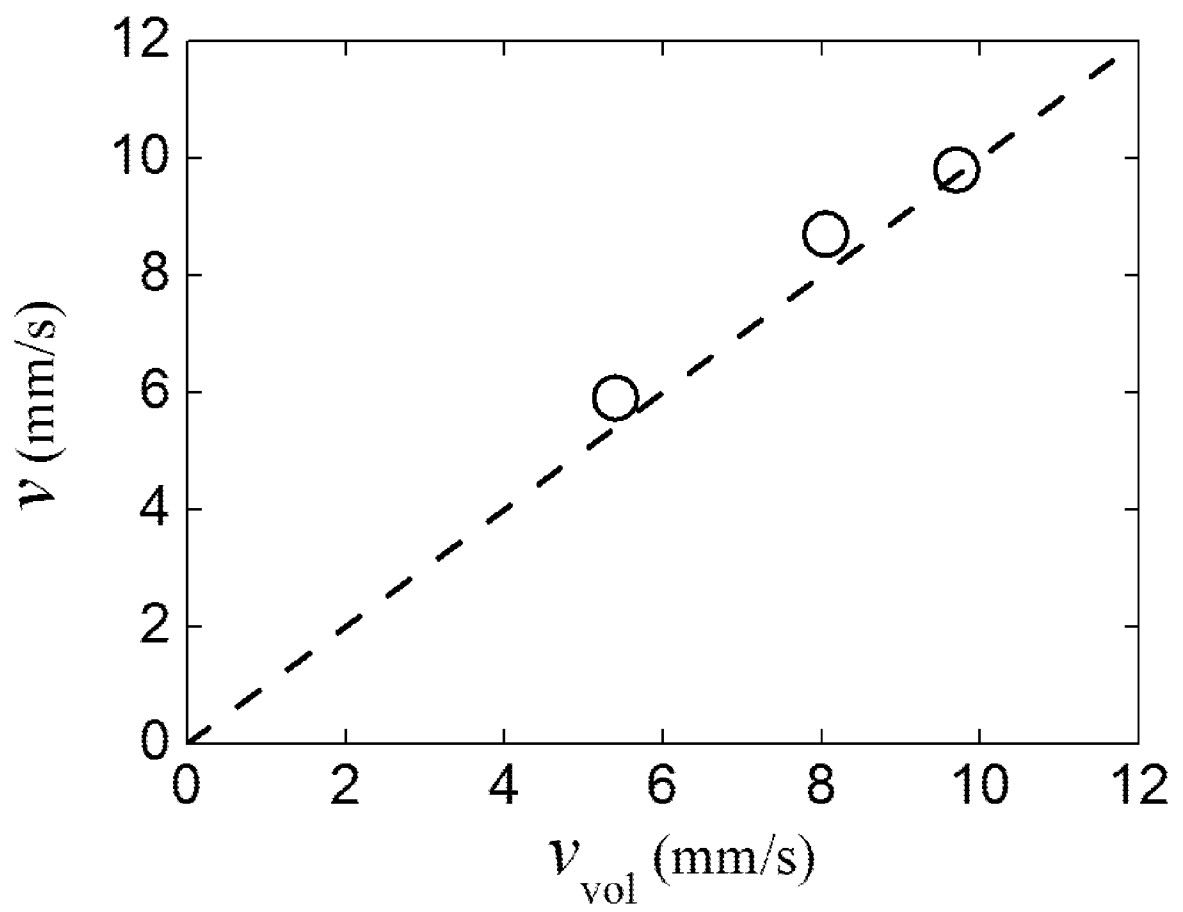


Fig. 7

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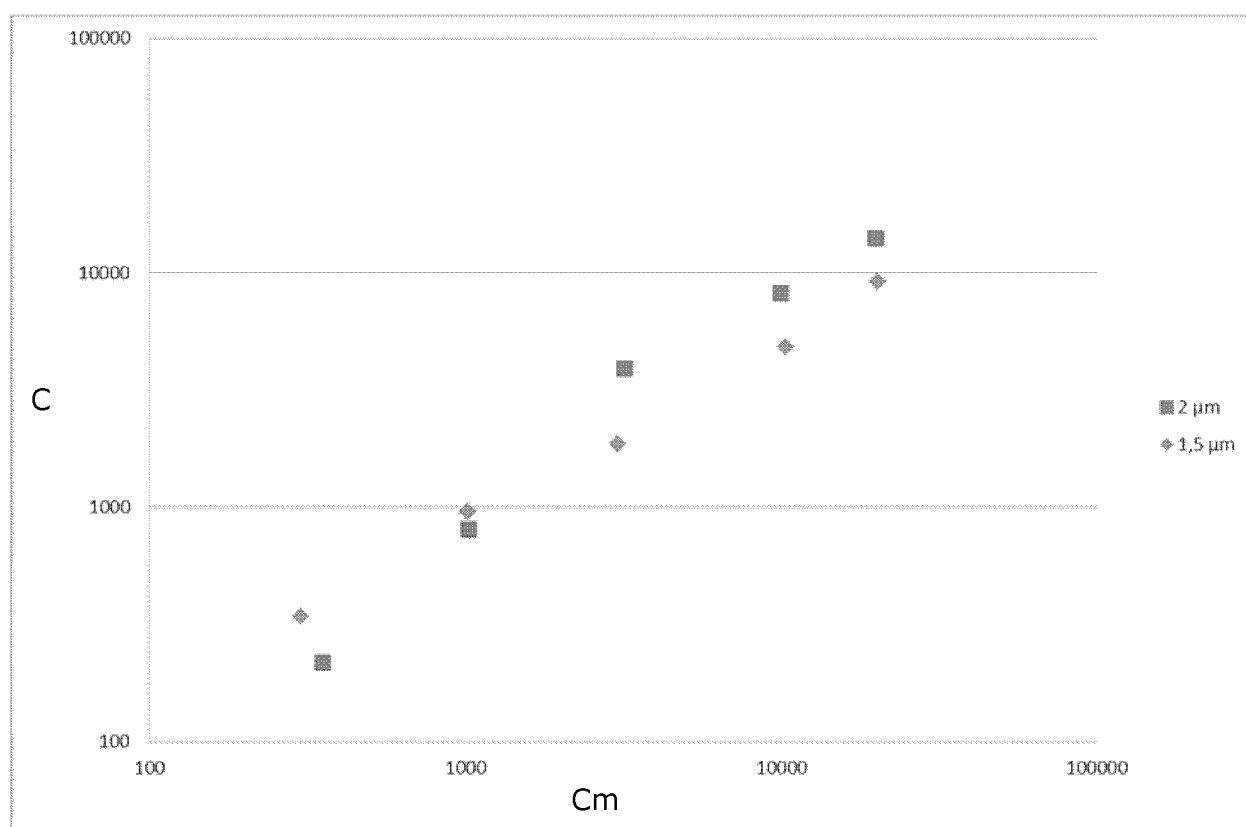


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2013/050418

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01N15/14 G01P5/20 G01F1/708 G01P5/26
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)

G01N G01P G01F

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.
X	TSUNG-FENG WU ET AL: "Optofluidic device for label-free cell classification from whole blood", LAB ON A CHIP, vol. 12, no. 19, 16 July 2012 (2012-07-16) , page 3791, XP055111603, ISSN: 1473-0197, DOI: 10.1039/c2lc40560a figure 1 page 3792, column 2 - page 3793, column 2 ----- -/-	1-13

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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"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

3 April 2014

Date of mailing of the international search report

16/04/2014

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Authorized officer

Lefortier, Stéphanie

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2013/050418

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	Zhe Mei ET AL: "Applying an optical space-time coding method to enhance light scattering signals in microfluidic devices", Biomicrofluidics, 16 August 2011 (2011-08-16), pages 034116-034116-6, XP055111609, United States DOI: 10.1063/1.3624740 Retrieved from the Internet: URL:http://dx.doi.org/10.1063/1.3624740 [retrieved on 2014-04-02] figure 1 -----	1-13
A	FR 2 330 011 A1 (SCHNERB PIERRE [FR]) 27 May 1977 (1977-05-27) figures 2,3,9,10 page 12 - page 13 page 16 -----	1-13
A	WO 2009/018597 A1 (UNIV GRAZ TECH [AT]; FORSCHUNGSHOLDING TU GRAZ GMBH [AT]; FUCHS ANTON) 12 February 2009 (2009-02-12) claim 4; figures 4-6 -----	1-13
A	WO 2007/136818 A2 (MASSACHUSETTS INST TECHNOLOGY [US]; HERZOG WILLIAM D [US]; SANCHEZ-RUB) 29 November 2007 (2007-11-29) figures 1,4 -----	1-13
A	EP 1 308 732 A1 (FORSKNINGSCT RISO [DK]) 7 May 2003 (2003-05-07) cited in the application abstract; figure 11 -----	1-13

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			WO 03038446 A1	08-05-2003
