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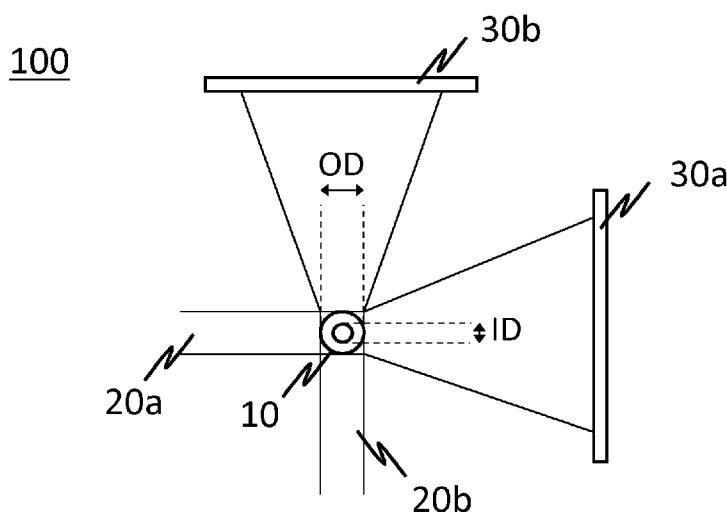


Fig. 1

(57) Abstract: A method (100) for optical measurement of a transparent tube (10), comprising directing a first collimated light beam (20a) from a first direction at the tube (10); directing a second collimated light beam (20b) from a second direction at the tube (10), wherein the first and second direction are at an angle to each other; receiving with a first detector element (30a) the light of the first light beam (20a) having passed through or about the tube (10); receiving with a second detector element (30b) the light of the second light beam (20b) having passed through or about the tube (10); and calculating an inner diameter (ID) of the tube (10) by detecting a shadow caused by the core of the tube (10) from a pattern received at the first and/or second detector element (30a,30b), respectively. Also an apparatus and a system for optical measurement as well as a method of manufacturing a transparent tube.

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OPTICAL MEASUREMENT OF INNER DIAMETER

TECHNICAL FIELD

5

[0001] The present application generally relates to optical measurement. In particular, but not exclusively, the present application relates to optical measurement of a diameter. In particular, but not exclusively, the present application relates to optical measurement of an inner diameter of a capillary tube.

10

BACKGROUND

[0002] This section illustrates useful background information without admission of any technique described herein being representative of the state of the art.

[0003] Thin, transparent tubes, such as capillary tubes, are used in large quantities in various applications, for example in healthcare and bioanalytics. As such tubes are typically disposable, large amounts thereof need to be manufactured constantly.

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[0004] Capillary tubes need to be manufactured precisely in order to fulfill the requirements of various applications thereof. Previously, the control of manufacturing, especially control of the dimensions of the tube in manufacturing has been difficult and imprecise, resulting in large spoilage.

25

[0005] Previous patent publication US2008/0198389 A1 discloses a system for measuring the inner and outer diameter of a transparent tube. However, the system disclosed is neither suitable for measurements of very thin capillary tubes, due to effects of laser interference, nor capable of detecting asymmetry along the measurement axis.

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[0006] It is the object of the current invention to provide an optical measurement mitigating the problems of the prior art.

SUMMARY

[0007] Various aspects of examples of the invention are set out in the claims.

5 [0008] According to a first example aspect of the present invention, there is provided a method for optical measurement of a transparent tube, comprising

directing a first collimated light beam from a first direction at the tube;

directing a second collimated light beam from a second direction at the tube, wherein the first and second direction are at an angle to each other;

10 receiving with a first detector element the light of the first light beam having passed through or about the tube;

receiving with a second detector element the light of the second light beam having passed through or about the tube; and

15 calculating an inner diameter of the tube by detecting a shadow caused by the core of the tube from a pattern received at the first and/or second detector element, respectively.

[0009] The method may further comprise calculating the distance from the tube to the first or second detector element from a pattern received at the other detector element.

20 [0010] The may further comprise calculating an outer diameter of the tube from a pattern received at the first and/or second detector element.

[0011] The method may further comprise calculating an inner diameter of the tube from a pattern received at the first and second detector element and comparing them for determining the ovality of the core of the tube.

25 [0012] According to a second example aspect of the present invention, there is provided an apparatus for optical measurement of a transparent tube, comprising

means for directing a first collimated light beam from a first direction at the tube; and

30 a first detector element configured to receive the light of the first light beam having passed through or about the tube; wherein the apparatus further comprises

means for directing a second collimated light beam from a second direction at the tube, wherein the first and second direction are at an angle to each other; and

a second detector element configured to receive the light of the second light beam having passed through or about the tube.

[0013] The means for directing the first and the second light beam may comprise a first and a second optical source element.

5 [0014] The means for directing the first and the second light beam may comprise a first optical source element and a beam control element and a first and second beam guide element.

[0015] The first and/or second detector element may comprise an imaging sensor configured to image a pattern formed thereon.

[0016] The first and/or second detector element may comprise a surface and a camera for imaging the pattern formed thereon from a distance.

10 [0017] According to a third example aspect of the present invention, there is provided a system for optical measurement of a transparent tube, comprising;
the apparatus of the second example aspect of the present invention; and
a processor configured to cause carrying out the method of the first example aspect of the invention.

15 [0018] According to a fourth example aspect of the present invention, there is provided a method of manufacturing a transparent tube, comprising measuring and/or controlling an inner diameter of the tube according to the method of the first example aspect of the present invention.

20 [0019] According to a fifth example aspect of the present invention, there is provided a computer program comprising computer code for causing performing the method of the first example aspect of the present invention, when executed by an apparatus.

25 [0020] According to a sixth example aspect of the present invention, there is provided a non-transitory memory medium comprising the computer program of the fifth example aspect of the present invention.

30 [0021] Different non-binding example aspects and embodiments of the present invention have been illustrated in the foregoing. The embodiments in the foregoing are used merely to explain selected aspects or steps that may be utilized in implementations of the present invention. Some embodiments may be presented only with reference to certain example aspects of the invention. It should be appreciated that corresponding embodiments may apply to other example aspects as well.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] For a more complete understanding of example embodiments of the present invention, reference is now made to the following descriptions taken in connection with the accompanying drawings in which:

[0023] Fig. 1 shows a schematic principle view of an optical measurement system according to an embodiment of the invention;

[0024] Fig. 2 shows a schematic block view of an optical measurement apparatus according to an embodiment of the invention;

[0025] Fig. 3 shows a schematic block view of an optical measurement apparatus according to an embodiment of the invention;

[0026] Fig. 4 shows a principle view of light ray propagation in an optical apparatus according to an embodiment of the invention;

[0027] Fig. 5A shows an example of resulting intensity image of an optical measurement according to an embodiment of the invention;

[0028] Fig. 5B shows a schematic view of the principle of optical measurement according to an embodiment of the invention;

[0029] Fig. 6 shows a flow chart of an optical measurement method according to an embodiment of the invention; and

[0030] Fig. 7 shows a block view of an optical measurement system according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0031] The present invention and its potential advantages are understood by referring to Figs. 1 through 7 of the drawings. In this document, like reference signs denote like parts or steps.

[0032] Fig. 1 shows a schematic principle view of an optical measurement apparatus 100 according to an embodiment of the invention. The system 100 is configured to measure at least one dimension of a transparent tube 10, for example a capillary tube, having an inner diameter ID and an outer diameter OD. Fig. 1 shows the electromagnetic radiation 20a, 20b directed at the tube 10 from at least two directions, i.e. a first direction and a second direction. In an embodiment, the

electromagnetic radiation 20a comprises visible, infrared or ultraviolet light, and will be referred to as light hereinafter. In an embodiment, the first light beam 20a and the second light beam 20b comprise light of low coherence. In an embodiment, the coherence length of the first and second light beam 20a,20b is shorter than the smallest dimensions of the tube 10, either its wall thickness or the inner diameter.

[0033] Fig. 1 shows the principle of light propagation in the system, i.e. part of the light is refracted and/or reflected by the material, such as glass, of the tube and the light forms a pattern thereafter. The pattern is received on a first detector element 30a and a second detector element 30b, respectively. In an embodiment, the detector element comprises a linear camera sensor having a predetermined number of sensor elements, i.e. pixels, for a desired resolution. In an embodiment, the number of pixels is for example 8192. In a further embodiment, the detector element comprises a charge-coupled device (CCD) imaging sensor or a complementary metal oxide semiconductor (CMOS) imaging sensor, for example comprised in a digital camera apparatus. In still further embodiment, the detector element comprises a screen, i.e. a surface on which the light pattern is received and imaged with imaging means positioned at a distance from the surface.

[0034] Fig. 2 shows a schematic block view of an optical measurement apparatus 100 according to an embodiment of the invention. Fig. 2 shows the tube 10 to be measured, the first and second light beam 20a,20b directed thereat and the first and the second detector element 30a,30b. Fig. 2 further shows a first optical source element 40a and a second optical source element 40b. In an embodiment, the first and second optical source element 40a,40b comprise a light source and optical elements configured to form a collimated light beam and to direct said beam on the tube 10 the dimensions of which are to be measured. In an embodiment, the optical source element comprises a narrowband light emitting diode, LED, or a superluminescent diode, SLD. In a further embodiment, the optical source comprises a wideband light emitting diode, such as a white light emitting diode. In an embodiment, the optical elements comprise suitable optics, such as a microscope objective. In an embodiment, the light source is coupled to the optical elements with an optical fibre, i.e. the light source is in an embodiment positioned distant from the optical elements.

[0035] Fig. 3 shows a schematic block view of an optical measurement apparatus 100 according to an embodiment of the invention. Fig. 3 shows the tube

10 to be measured, the first and second light beam 20a,20b directed thereat and the first and the second detector element 30a,30b. Fig. 2 further shows a first optical source element 40. The first optical source element 40 comprises elements as hereinbefore described with reference to the first and second optical source element 40a,40b of Fig. 2. Fig. 3 further shows a beam control element 50, such as a beam splitter, configured to split the beam from the first optical source element 40 and direct it to a first beam guide element 60a and a second beam guide element 60b configured to direct the beam at the tube 10 the dimensions of which are to be measured. In an embodiment, the first and second beam guide element 60a,60b comprise mirrors. It is to be noted that the apparatus of Figs. 2 and 3 in an embodiment comprises further optical elements known in the art, which are not shown, related to forming the beam and controlling the propagation light.

[0036] In the schematic view of Figs. 2 and 3 the first and second light beam 20a,20b have been depicted as being directed at the tube 10 from a first direction and a second direction perpendicular to each other. In an embodiment, however, the first and second light beam 20a,20b are directed at the tube 10 from a first direction and a second direction at an angle to each other, wherein the angle is not a right angle. In such a situation the first and second detector element 30a,30b are also accordingly positioned, in an embodiment on the opposite side of the tube to the corresponding beam 20a,20b. Furthermore, in an embodiment, the apparatus comprises optical arrangements in such a way that the first and second detector element 30a,30b are not positioned on the opposite side of the tube to the direction of the corresponding beam 20a,20b, but rather the light having passed through or around the tube 10 is guided with optical elements known in the art to the first or second detector element 30a,30b.

[0037] Furthermore, in the schematic view of Figs 2 and 3, the first and second optical source element 40a,40b and/or the first and second beam guide element 60a,60b as well as the first and second detector element 30a,30b have been depicted as being equidistant, respectively, from the tube 10. However, in an embodiment, the first and second optical source element 40a,40b and/or the first and second beam guide element 60a,60b and/or the first and second detector element 30a,30b are not equidistant from the tube 10, respectively, i.e. the distance of any of the two similar elements differ from one another.

[0038] The schematic view of Figs. 2 and 3 is a two dimensional view on a

plane perpendicular to the tube 10. However, in an embodiment, the first and second beam 20a,20b do not propagate in the same plane, i.e. they are at a distance from each other in the direction parallel to the tube 10. Correspondingly, in an embodiment, the first and second detector element 30a,30b are at a distance from each other in the direction parallel to the tube 10 in order to minimize stray light from interfering with the measurement. In a further embodiment, the apparatus comprises a shield element (not shown) for preventing stray light from reaching the first and second detector element 30a,30b.

[0039] The schematic view of Figs. 2 and 3 shows a first and second optical source element 30a,40b or a first optical source element 40 and a beam control element 50 with a first and second beam guide element 60a,60b. In an embodiment, however, the apparatus comprises means for, or an arrangement for, illuminating the tube 10 with two light beams 20a,20b at an angle, for example a right angle, to each other different from that depicted. In an embodiment, the apparatus comprises a first optical source arranged to be movable in such a way as to direct a first light beam 20a and a second light beam 20b at the tube 10 from different directions. In such a case the two light beams are not directed simultaneously at the tube but one after another. Furthermore, in such case, the apparatus comprises the first and the second detector element 30a,30b as hereinbefore described, or a single detector element arranged to be movable to the position of and to function as the first and the second detector element 30a,30b.

[0040] Fig. 4 shows a principle view of light ray propagation in an optical apparatus according to an embodiment of the invention. The light rays of a collimated beam 20a,20b propagate from left to right in the figure around and through the tube 10 having an outer diameter OD and an inner diameter ID. Rays 410, propagate past the tube unobstructed and directly to the detector element 30a,30b. Rays 420 are refracted in the material of the tube wall and rays 430 are refracted and/or reflected in the material of the tube wall and in the tube core. It is to be noted that while the propagation has been described with reference to the rays on the upper side of the figure, propagation takes place in an analogue manner on the lower side of the figure. The rays 410,420,430 form a pattern, or profile on the detector element 30a,30b with an unmagnified shadow of the outer diameter OD and a magnified shadow of the inner diameter ID. Said pattern is then detected and dimensions of the tube, for example the inner diameter ID of the tube, are calculated

therefrom.

[0041] Fig. 5A shows an example of resulting intensity image of an optical measurement according to an embodiment of the invention. Fig. 5A shows an example of a pattern 500a formed on the detector element 30a,30b and detected or imaged and the resulting intensity profile 500b calculated from the detected pattern 500a. The edges of the shadow cast by the core of the tube 10, i.e. the hollow having an inner diameter ID, are shown as slopes 510a,510b in the intensity profile.

[0042] Fig. 5B shows a schematic view of the principle of optical measurement according to an embodiment of the invention. Fig. 5B shows some of the important dimensions and angles in determining the inner diameter ID. The shadow cast by the core having an inner diameter ID is magnified on the detector element 30a,30b and has a half length H. The half length H, i.e. the half width of the shadow on the detector element 30a,30b, is realized by the ray path shown in Fig. 5B of the ray that is closest to the centre of the tube 10 and unobstructed by the core 10 of the tube. The size of the shadow, i.e. the half length H, depends on the distance D from the tube centre to the detector element 30a,30b, on the ratio of the inner diameter ID and outer diameter OD.

[0043] The distance D has an almost linear effect on the half length H and accordingly the distance D is either controlled or measured. During manufacturing, for example due to vibration and tolerances, the distance D does not remain constant. In accordance with embodiments of the invention, the two light beams 20a and 20b provide for two measurement channels, one of which provides information on the distance D as the pattern formed on the second detector element 30b shifts as the distance from the tube centre to the first detector element 30a changes and vice versa.

[0044] The ratio of the inner diameter ID to the outer diameter OD affects the pattern formed and accordingly, if the inner diameter is to be determined, the outer diameter is measured or known. In an embodiment, the outer diameter is determined from the pattern on the second detector element 30b, and the inner diameter from the pattern on the first detector element 30a or vice versa. In an embodiment, the outer diameter is known with enough precision beforehand.

[0045] In manufacturing transparent tubes, such as capillary tubes, it is foreseeable that the core of the tube might not be exactly round, i.e. the inner diameter might be depend on the direction of the measurement due to ovality of the

core of the tube. In an embodiment, as the inner diameter is measured from two directions, the ovality of the tube core can be determined. It is also foreseeable that the core of the tube might not be exactly in the middle of the tube, i.e. the tube might be eccentric. In an embodiment, the concentricity of the tube is measured in addition to or instead of other measurements. In an embodiment, an inner diameter ID of the tube is calculated from the left and right halves of the shadow separately, and on each detector separately, and the result of said calculations is compared for determining the concentricity of the core of the tube with respect to the outer shape of the tube.

[0046] Fig. 6 shows a flow chart of an optical measurement method according to an embodiment of the invention. At 610 the tube 10 is illuminated with the first light beam 20a and the second light beam 20b, either simultaneously or concurrently depending on the setup of the measurement apparatus. At 620, the pattern formed on the first and second detector element 30a,30b is detected, or imaged, again simultaneously or concurrently depending on the setup of the measurement apparatus.

[0047] At 630 the distance, or the position of the tube 10, i.e. the distance from the tube 10 to the detector element 30a,30b is calculated from the detected pattern, or e.g. from an intensity profile calculated from the detected pattern. The distance is calculated from the shift of the shadow image, i.e. the magnified shadow of the core of the tube 10. As the tube 10 is illuminated from two directions at an angle to each other, there is provided a first measurement and a second measurement, wherein the first or second measurement is used to determine the distance for the second or first measurement respectively. The measurement of distance allows the inner diameter ID measurement with high precision, also in circumstances, typical in manufacturing, with vibrations and the like that may cause the distance from the tube 10 to the detector element 30a,30b to vary.

[0048] At 640 the outer diameter OD is calculated from the detected pattern, or e.g. from an intensity profile calculated from the detected pattern. In an embodiment, the step 640 is carried out concurrently or prior to the step 630. In a further embodiment, the outer diameter OD of the tube 10 is previously known, for example due to a calibration measurement, with enough precision, and step 640 involves retrieving the previously known value.

[0049] At 650, the inner diameter ID of the tube 10 is calculated from the

detected pattern, or e.g. from an intensity profile calculated from the detected pattern, i.e. the edges of the magnified shadow of the core are detected and the inner diameter of the core is calculated therefrom. The calculation is in an embodiment carried out using trigonometry and operations known to a skilled person. In an example embodiment, the calculation is carried out using the following operation, wherein n and n_0 are the refractive indexes of the tube and of the surrounding medium.

$$H = \tan(2\alpha) \cdot \left[D - \sin \alpha \cdot \frac{ID}{2} - \cos \alpha \cdot \frac{\sqrt{OD^2 - ID^2}}{2} \right] - \cos \alpha \cdot \frac{ID}{2} + \sin \alpha \cdot \frac{\sqrt{OD^2 - ID^2}}{2}$$

$$\alpha = \sin^{-1} \left(\frac{n}{n_0} \cdot \frac{ID}{OD} \right) - \sin^{-1} \left(\frac{ID}{OD} \right)$$

In a further embodiment, the calculation is carried out using a further operation based on calibration or on optical modeling.

[0050] As an example, referring to Fig. 5B, in a situation in which the refractive index of the material of the tube is 1,54, the outer diameter OD is 2mm, the distance D is 50mm and the half length H is 10mm, the angle α is found to be 5,81° resulting in an inner diameter ID of 0,37 mm. In an embodiment, the measurement of the inner diameter is used to monitor and/or control the manufacturing of transparent tubes, i.e. used in a manufacturing method.

[0051] It should be noted that the optical measurement of inner diameter hereinbefore described is in an embodiment applied in detecting whether the core of a tube is hollow or contains a substance other than air, as this would change the light propagation and accordingly the resulting pattern on the detector element 30a,30b. The material of the tube, and the refractive index thereof and of the core substance, affects the propagation, and accordingly the optical measurement according to embodiments of the invention is used to determine the refractive index of the material of the core and accordingly the material, provided that the refractive index of the material of/or in the core is smaller than that of the material of the tube wall.

[0052] Fig. 7 shows a schematic block view of an optical measurement system 700 according to an embodiment of the invention. The system 700 comprises an optical measurement apparatus 100 according to an embodiment of the invention as hereinbefore described. In an embodiment, the system 700 comprises more than

one apparatus 100 according to an embodiment of the invention, for example in a manufacturing facility with several measurement locations.

[0053] The system 700 further comprises electronics configured to control the operations of the system and apparatus, to carry out calculations and to cause carrying out the steps of the method according to the invention. The system 700, in an embodiment, comprises a memory 740 and a processor 720. The processor 720 is, in an embodiment, configured to control the apparatus 100 and to cause storing the data into the memory 740. The processor 720 is further configured to cause controlling of the operation of the system 700 and the apparatus 100 using a non-transitory computer program code stored in the memory 740.

[0054] In a further embodiment, the system 700 comprises a communication unit 710 comprising, for example, a local area network (LAN) port; a wireless local area network (WLAN) unit; Bluetooth unit; cellular data communication unit; near field communication unit or satellite data communication unit. The system 700 further comprises a power source, such as a battery 750 or a connection to external power.

[0055] In a further embodiment the system 700 comprises a user interface unit 730 comprising for example a display or a touch display for showing the measurement result. In a still further embodiment, the system 700 comprises, or is comprised in, a personal electronic device such as a laptop computer, a tablet computer or a personal computer and configured to co-operate with the optical measurement apparatus. In an embodiment, the system 700 is comprised in a larger entity, such as a control system of a manufacturing plant.

[0056] Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein is the provision of a precise and reliable measurement of an inner diameter of a tube, such as a capillary tube. Another technical effect of one or more of the example embodiments disclosed herein is a robust and cost effective measurement of inner diameter for inline use in manufacturing. Another technical effect of one or more of the example embodiments disclosed herein is the provision of a measurement not requiring overly taxing calculations. A still further technical effect of one or more of the example embodiments disclosed herein is minimizing spoilage in manufacturing through precise and robust measurement.

[0057] Although various aspects of the invention are set out in the

independent claims, other aspects of the invention comprise other combinations of features from the described embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims.

- 5 **[0058]** It is also noted herein that while the foregoing describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications which may be made without departing from the scope of the present invention as defined in the appended claims.

CLAIMS

1. A method (100) for optical measurement of a transparent tube (10), comprising
directing a first collimated light beam (20a) from a first direction at the
5 tube (10);
directing a second collimated light beam (20b) from a second direction at
the tube (10), wherein the first and second direction are at an angle to each
other;
receiving with a first detector element (30a) the light of the first light
10 beam (20a) having passed through or about the tube (10);
receiving with a second detector element (30b) the light of the second
light beam (20b) having passed through or about the tube (10); and
calculating an inner diameter (ID) of the tube (10) by detecting a shadow
caused by the core of the tube (10) from a pattern received at the first and/or
15 second detector element (30a,30b), respectively.
2. The method of claim 1, further comprising calculating the distance from the tube
to the first or second detector element (30a,30b) from a pattern received at the
other detector element (30a,30b).
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3. The method of claim 1 or 2, further comprising calculating an outer diameter (OD)
of the tube (10) from a pattern received at the first and/or second detector
element (30a,30b).
- 25 4. The method of any of the claims 1-3, further comprising calculating an inner
diameter (ID) of the tube (10) from a pattern received at the first and second
detector element (30a,30b) and comparing them for determining the ovality of the
core of the tube (10).
- 30 5. An apparatus (100) for optical measurement of a transparent tube (10),
comprising
means for directing a first collimated light beam (20a) from a first
direction at the tube (10); and

a first detector element (30a) configured to receive the light of the first light beam (20a) having passed through or about the tube (10); **characterized** in that the apparatus further comprises

means for directing a second collimated light beam (20b) from a second direction at the tube (10), wherein the first and second direction are at an angle to each other; and

a second detector element (30b) configured to receive the light of the second light beam (20b) having passed through or about the tube (10).

6. The apparatus of claim 5, wherein the means for directing the first and the second light beam (20a,20b) comprise a first and a second optical source element (40a,40b).

7. The apparatus of claim 5, wherein the means for directing the first and the second light beam (20a,20b) comprise a first optical source element (40) and a beam control element (50) and a first and second beam guide element (60a,60b).

8. The apparatus of any of the claims 5-7, wherein the first (30a) and/or second (30b) detector element comprise an imaging sensor configured to image a pattern formed thereon.

9. The apparatus any of the claims 5-8, wherein the first (30a) and/or second (30b) detector element comprise a surface and a camera for imaging the pattern formed thereon from a distance.

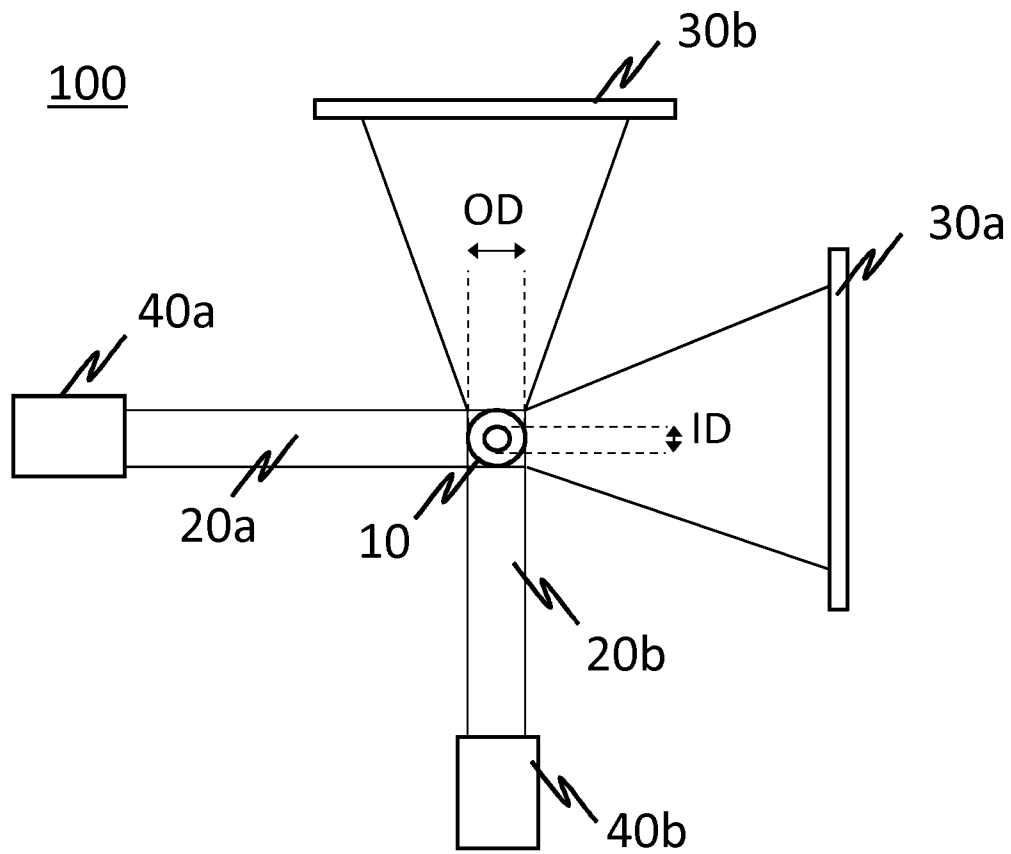
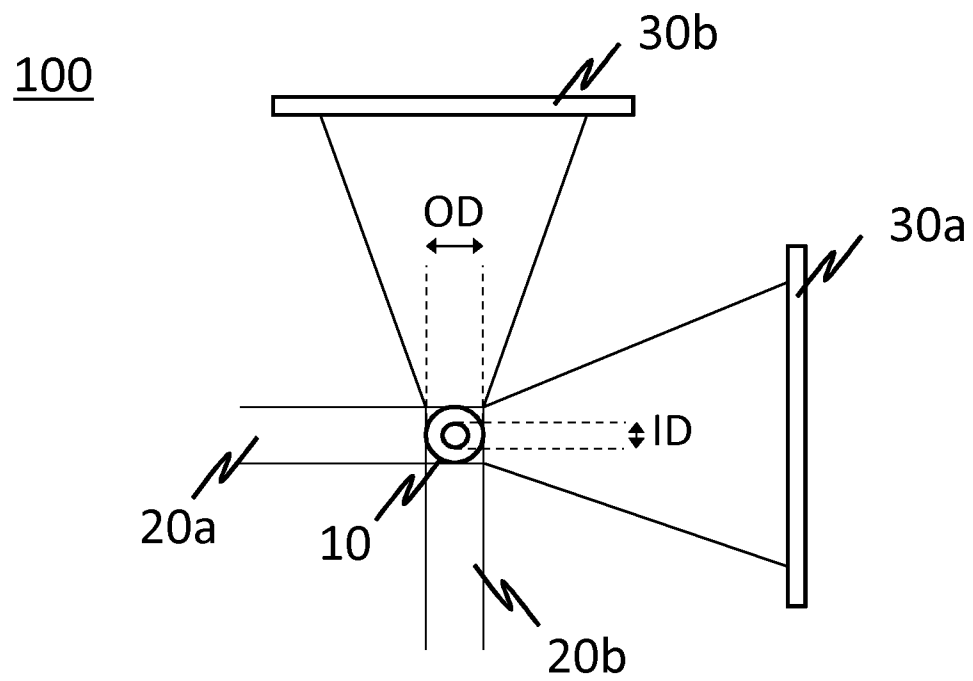
10. A system (700) for optical measurement of a transparent tube, comprising;
the apparatus of any of the claims 5-9; and
a processor configured to cause carrying out the method of any of the claims 1-4.

11. A method of manufacturing a transparent tube, comprising measuring and/or controlling an inner diameter (ID) of the tube according to the method of any of the claims 1-4.

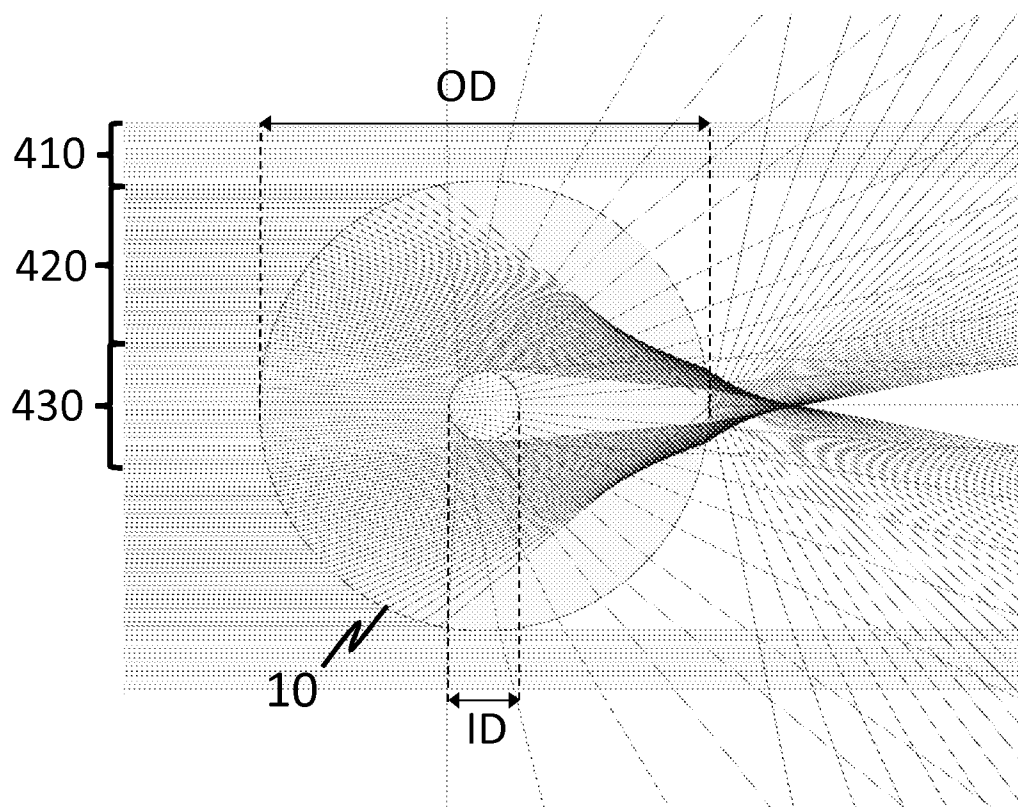
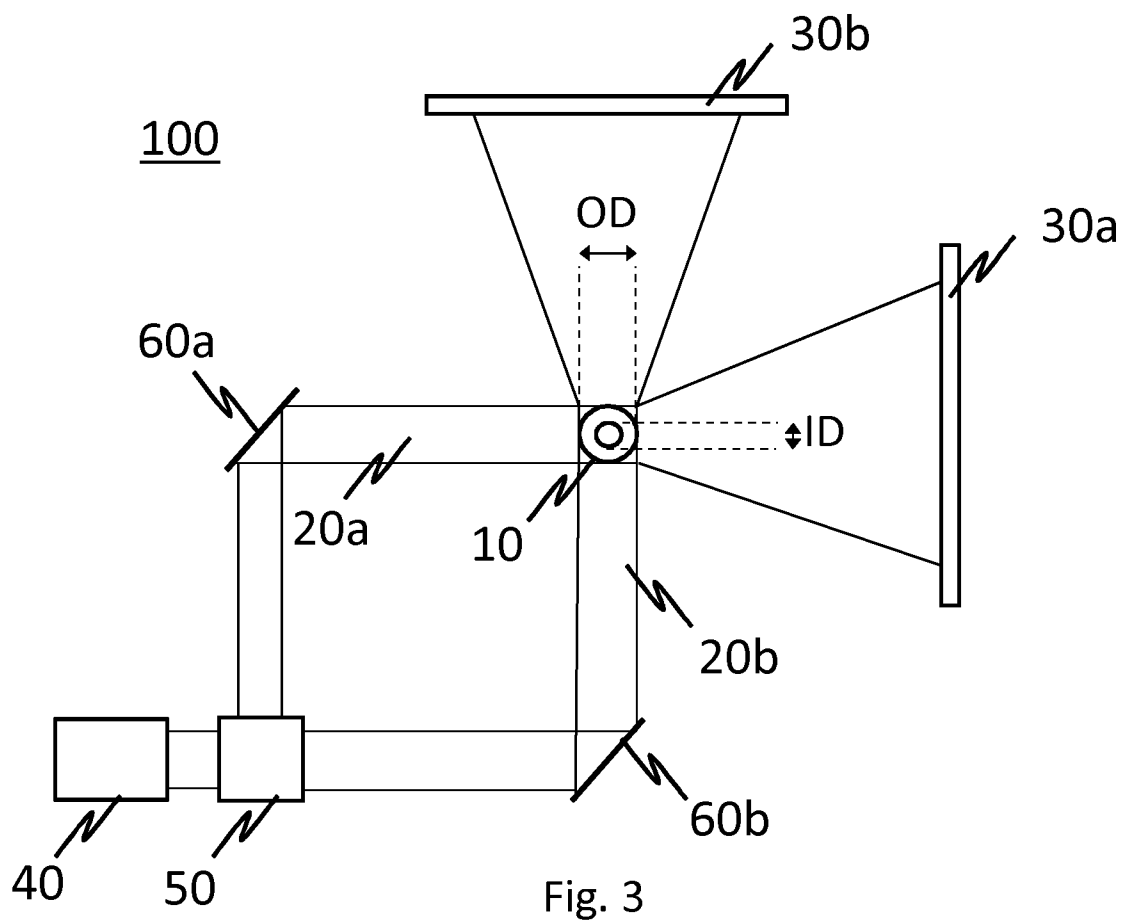
12. A computer program comprising computer code for causing performing the method of any of the claims 1-4, when executed by an apparatus.

13. A non-transitory memory medium comprising the computer program of claim 12.

1 / 4



2 / 4



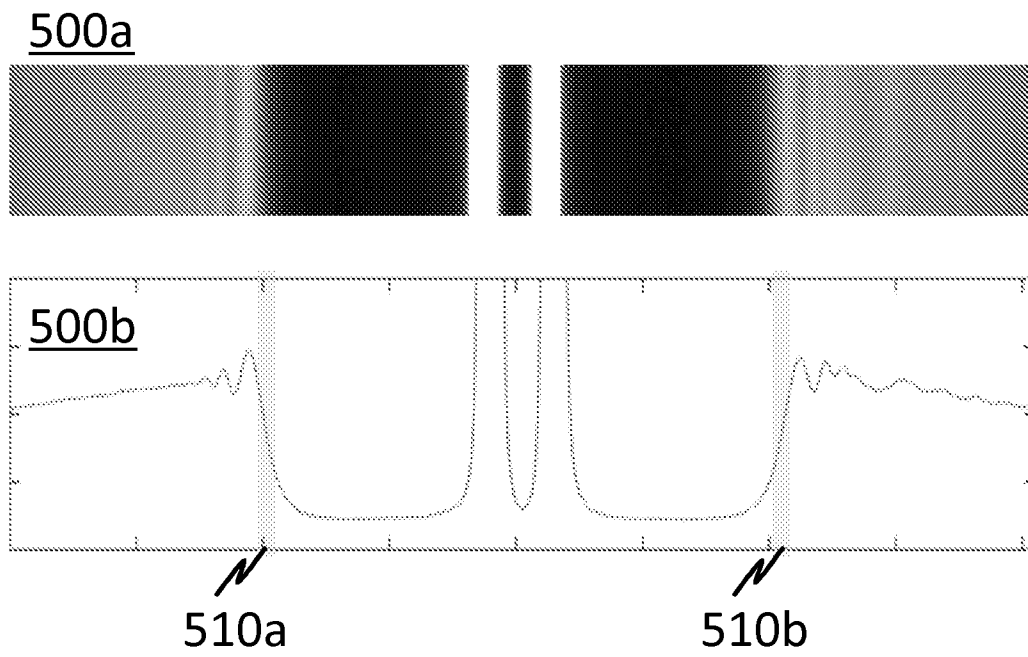


Fig. 5A

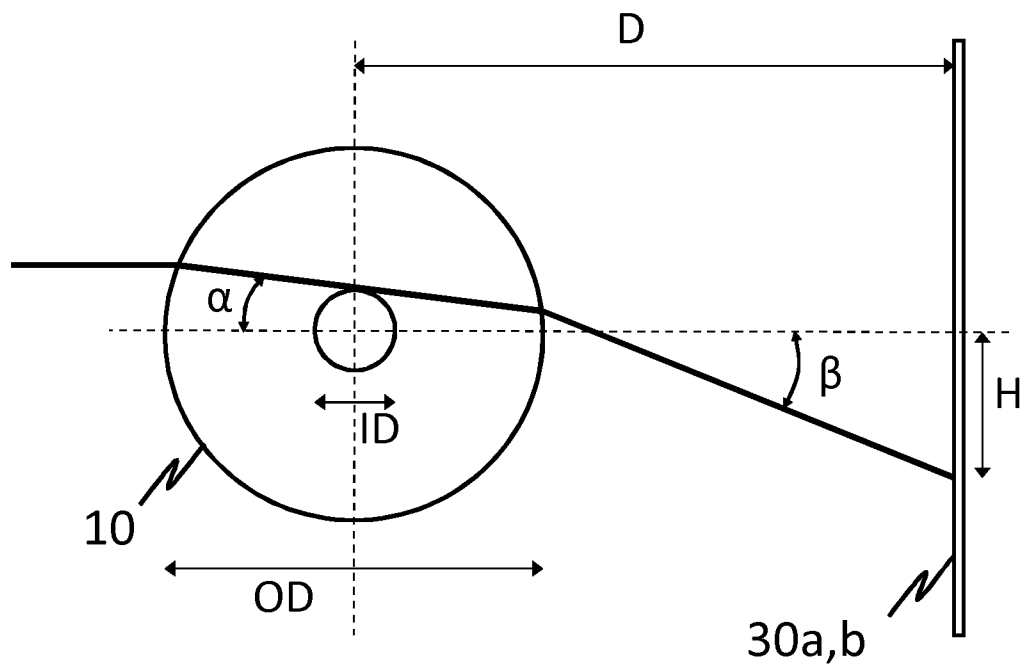


Fig. 5B

4 / 4

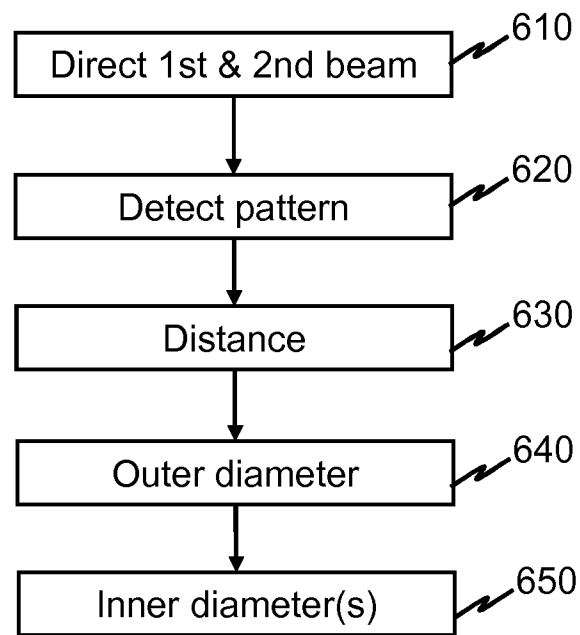


Fig. 6

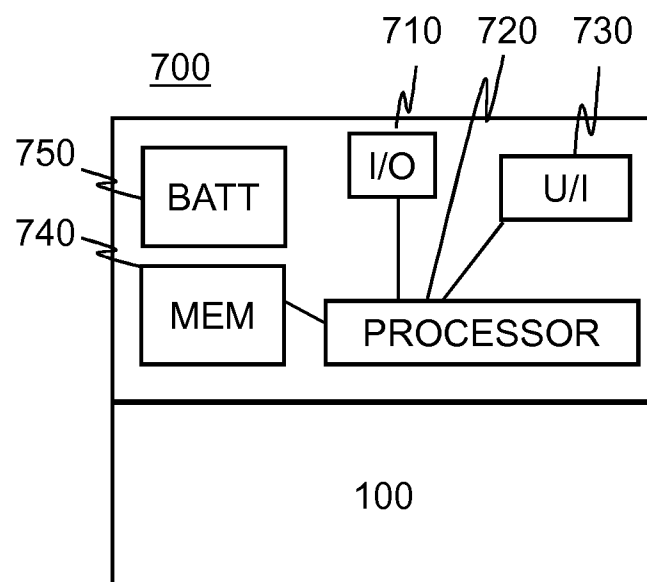


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2019/050251

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01B11/12 G01B11/24
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)
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, INSPEC, IBM-TDB, 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	US 2017/167854 A1 (IMAIZUMI RYOICHI [JP]) 15 June 2017 (2017-06-15) abstract; figures 1,2 paragraphs [0032] - [0038] -----	1-13
Y	JP S57 72003 A (NIPPON ELECTRIC CO) 6 May 1982 (1982-05-06) the whole document -----	1-13
Y	US 5 118 954 A (GROSSO PHILIPPE [FR]) 2 June 1992 (1992-06-02) abstract; figures 1-10 column 9, lines 25-38 -----	1,3-13
Y	US 2002/044289 A1 (BLOHM WERNER [DE] ET AL) 18 April 2002 (2002-04-18) abstract; figures 1-4 paragraphs [0014], [0043] ----- -/-	1-6,8-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

10 May 2019

Date of mailing of the international search report

20/05/2019

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INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2019/050251

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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