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(54) Benævnelse: **TERAHERTZ-MÅLEANORDNING TIL BESTEMMELSE AF EN LAGTYKKELSE HOS ET TESTOBJEKT OG TILSVARENDE MÅLEMETODE**

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Terahertz measuring device

The invention relates to a trahertz measuring device for measuring test objects as well as a corresponding method.

Terahertz measuring devices emit terahertz radiation within a frequency band between 10 GHz and 10 THz towards test objects. The terahertz radiation is partially reflected on boundary surfaces of materials having different refraction indices so that distances between boundary surfaces and, therewith, layer thicknesses can be measured using the run-time of the THz radiation emitted and reflected and received.

Hereby, THz measuring devices are used e.g. immediately following the production of plastics extrusion products like pipes, sheets etc. in order to test these test objects for consistent layer thicknesses. Hereby, they allow contactless measuring of the layer thicknesses, as opposed e.g. to ultrasound devices requiring coupling means for bodily contact with test objects to be measured.

For a THz run-time measurement the THz measuring device must be positioned with its optical axis perpendicular to the surface of the test object so that the reflected radiation is reflected back exactly along the optical axis. Thus, THz measuring devices are generally mounted on exterior frames spaced and angular adjusted exactly in relation to the test objects and e.g. pivoted on a curvilinear rail around the test object so as to allow contactless measurements of the test object over the entire circumference.

Further, optical THz measuring systems are known, for example, for measuring varnish layers, in which a measuring head manipulated by a user is connected to a fixed optical THz detector system via a fiber optical cable connection so that the measuring head can be positioned in a suitable manner.

The video entitled “Single Point Gauge” which can be retrieved via the internet portal YouTube describes a THz measuring device which can be manually grabbed by a user and positioned at objects to be tested in order to measure a layer thickness. Hereby, different extensions can be placed onto the testing device serving to position at the measurement objects.

The dpcument “Terahertz pulsed Inagming in vivo” by E. Pickwell-Macpherson, 2011, Proc. Of SPIE, Vol. 7897, describes a system for *in vivo* sking imaging, wherein a user places a measuring head onto the skin in order to examine the outer skin layer.

The citation US 6,873,931 B1 describes a measuring device for measuring the angular alignment of a rotatable or rotating object in relation to one point utilizing an acceleration sensor in order to detect the alignment of a rotatable object in space.

The invention is based on the object of creating a THz measuring device and a THz measuring method allowing secure layer thickness masurements of test objects, in particular spherical or cylindrical test objects with little expenditure.

This task is solved by means of a THz measuring device as well as a method according to the independent claims. Preferred further developments are described in the sub-claims. Hereby, further, a measuring array is provided consisting of the THz measuring device and the test object to be measured.

The method according to the invention may be carried out, in particular, using a THz measuring device according to the invention and/or using a measuring array according to the invention. The THz measuring device according to the invention may, in particular, be used for carrying out a method according to the invention.

Thus, the THz measuring device is designed to include a contact contour for contact with the surface of the test object and a grip region. Preferably, it is portable, i.e. the entire measuring apparatus can be carried by the user, whereby it may be grabbed and positioned e.g. using one or two hands by its grip region. Thus the user can grab the THz measuring device and position it by pressing it against the test object. Hereby, in contrast to measuring systems having merely a portable measuring head, the entire THz measuring device is portable so that the user can cover even larger distances, e.g. in the case of an inspection in a warehouse, unimpaired local restraints by being connected to a stationary detector system via a connecting cord or fiber optical cable.

Preferably, the THz measuring device is independent as regards energy using an energy storage device, preferably, it is battery powered, i.e. supplied with energy by a battery or an accumulator. In the case of a fully electronic system e.g. a transceiver chip having a voltage supply in the microvolt range can be used.

The contact contour serves for exact positioning, i.e. for perpendicular positioning of the optical axis of the THz measuring device in relation to the surface. Hereby, preferably, the contact contour comprises exactly four alignment points that come into contact on the surface of a defined body, in particular, a cylindrical tube having a defined diameter. To that end the contact contour is preferably designed to include a pair of contour lines spaced apart in a direction perpendicular to the optical axis and forming four alignment points when brought into contact with the cylindrical - or even spherical - body.

Thus, the four alignment points are, in particular equidistant to the optical axis and are preferably arranged in symmetry with each other, whereby, in particular, the two contour lines, on which two alignment points each are formed, can be designed in parallel or mirror symmetry to each other.

In particular, the contact contour with its contour lines can also contact with pipes or spherical bodies having differing diameters. Thus, a contact contour having two concave contour lines, i.e. lines extending towards the center and backwards, may serve to contact e.g. a first tube having a first, smaller diameter and a second tube havin a larger second diameter, each of which forming alignment points on defined, differing spots of the contour lines.

Thus, the contour lines is preferably designed not spherical form form-fit contact with a cylindrical or spherical surface but, rather, in such a way that merely the defined four alignment points are formed. Hereby, the invention recognizes the fact that, in particular, such a formation of defined exclusive alignment points, in particular, of four alignment points, allows for advantages compared to contact contours having a shape complementary to the test surface of the test object including, in particular, the option of measuring test objects having varying diameters.

Thus, the user is able to conduct sample tests e.g. at different spots with little effort during production. He/she can grab the THz measuring device, place it against the tubular or spherical test object in a first measuring abgle position, and carry out a layer thickness measurement which is e.g. displayed directly on a display device of the measuring apparatus, e.g. as a numerical value indicating a layer thickness determined, or on an external display – e.g. using wireless data transmission. Moreover, e.g. the measured value can be compared and a signal can be output indicating whether or not the layer thickness determined is correct or faulty.

This alone allows for a quick and secure test with exact perpendicular alignment to the test object. Thus, such measurements deliberately do not avail themselves of the advantage of contactless measurement made possible by a THz measurement as oppose to e.g. an ultra-sonic measurement; however, it is recognized that in the case of a manual measurement using the THz measuring device such a contact can be made quickly and securely and causes no damage to the test object.

According to a preferred embodiment several pairs of contact lines, e.g. two pairs of contact lines offset against each other by 90°, may be formed so that a larger number of different diameters can be measured. The contact contour may comprise e.g. front corners and contour lines extending concavely away from the corners towards the center for contacting different pipe diameters or spherical diameters. Thus, a user can apply the measuring device to the surface of the test object in a first alignment with the first pair of contour lines or, pivoted 90° about the optical axis hereto, with another pair of contour lines.

Hereby, in particular, operating errors can be avoided to a large extent because the user will notice, when applying the device, whether a stabile position with extactly four alignment points has been reached or the measuring device tends to tilt or slip.

The contact contour is preferably designed on a replaceable extension which is rigid and can be attached at a defined angular position. Thus, different extensions can be attached depending on the test object allowing for a high flexibility at low cost and quick conversion. The connection of the extension on the measuring head or on the basic housing may be e.g. a bayonet connection or another latching connection. The extension may be, in particular, a preferably metallic moulded screen serving, at the same time, also as a shield against scattered radiation. Thus, the extension serves, on the one hand, as a defined contact alignment via the contour or contour lines and, on the other, as as a shield against scattered radiation.

Preferably, the e extension is made to be rigid, i.e. not flexible, so as to enable the defined contact.

The THz measuring device is designed to include, in particular, an elongated housing which also forms the grip region and, preferably, operating units like switches, buttons or similar, e.g. having a length of 25 to 50 cm. Hereby, in particular, fully electronic THz transmitter and receiver units are suitably lightweight so that the THz measuring device is portable and can be handled by the user e.g. manually using one or two hands. The terahertz radiation lies in a frequency range between 0.01 and 10 THz, in particular, 100 GHz to 3 THz, and is emitted, in particular, fully electronically by means of a transmitter and receiver dipole, in particular, using frequency modulation or pulsed radiation. Thus, run-time measurements can be carried out directly in the time domain or correspondingly in the frequency domain, whereby, in principle, an optical system with run-time measurement is possible.

Hereby, in particular, a portable fully electronic THz measuring device with a battery or accumulator is of advantage since the fully electronic design comprising a THz transceiver chip requires no optical power components such as a laser and has a very low power consumption thereby allowing for a compact, portable design.

According to a preferred embodiment measurements can be carried out in several measuring angle positions or measuring positions respectively to achieve a thorough, in particular, even fully circumferential measurement of the test object, in that with the individual layer thicknesses measurements the measuring angle position of the THz measuring devices is measured also. To that end, preferably, an internal (longitudinal) acceleration sensor is used which measures an acceleration formed as a component of the gravitational acceleration. Thus, in the case of vertical positioning of the THz measuring device, the full gravitational acceleration is measured as – positive or negative – longitudinal acceleration and, consequently, in the case of e.g.

horizontal arrangement of the longitudinal acceleration sensor no acceleration component; in-between there will be components of gravitational acceleration corresponding to the cosine of the ratio of the angle of incidence to the vertical.

Thus, it is possible to attain a precise survey of the measuring angle position with little effort, whereby readily available longitudinal acceleration sensors allow for sufficient accuracy of the measurement.

Hereby, e.g. even two longitudinal acceleration sensors may be arranged in directions offset against each other, e.g. by 90° or 45°, so as to distinguish symmetrical positions – left and right – from each other.

Thus, the user is able to carry out a measurement at several successive measuring angle positions, or even in the course of a sliding movement around the test object in a practically continuous manner as a sequence of successive, quick measurements.

Hereby, each run-time measurement allows, first of all, the measurement of the distance between the surface and the transmistter and receiver unit, as the terahertz radiation upon htting the surface is subjected to a difference in refraction index – in the case of plastics e.g. a refraction index of n = 1.5 –, and subsequently a layer thickness measurement of the front wall thickness and, if applicable, in the case of tubes comprising several layers, of the several layers. Further, e.g. an interior diameter can be measured as a subsequent air gap, and, even further, also a layer thickness of the back tube wall can be measured.

Togetherh with the test object to be measured the THz measuring device forms a THz measuring array. This shows a high efficiency since the contact contour of the measuring device is adapted to the external shape, in particular, the cylindrical external shape, of the test object.

An embodiment of the invention is subsequently further illustrated by means of the attached drawings. These show in:

Fig. 1	the front area of a portable terahertz measuring device with the moulded screen removed;
Fig. 2	the terahertz measuring device when applied to a first tube with a definined smaller first diameter, in various views;
Fig. 3	a view corresponding to Fig. 2c) of the appliance of the measuring device to the first tube;
Fig. 4	the terahertz measuring device when applied to a second tube with a larger second diameter;
Fig. 5	a perspective view of the arrangement according to Fig.4;
Fig. 6	the terahertz measuring device being applied to a third tube with a larger third diameter in a position offset by 90° against Fig. 5;
Fig. 7	a lateral view of the arrangement according to Fig. 6;
Fig. 8	several measuring angle positions of terahertz measuring device according to a further embodiment for measuring the entire circumference of the tube;

Fig. 9	terahertz measuring devices having two acceleration sensors according to various embodiments in the partial images a), b), c);
Fig. 10	the measurement of a test object at various measuring angle positions by means of the terahertz measuring device according to Fig. 9a;
Fig. 11	the alignments and angles of the acceleration sensors according to Fig. 9 relative to the optical axis.

A terahertz measuring device 1 according to e.g. Figs. 1 and Fig. 2 comprises ein basic housing 2, a measuring head 3 with radially projecting guide bolts 4, as well as a moulded screen 5 serving as extension, which is, according to this embodiment, provided with bayonet slots 6 by means of which it is affixed to the guide bolts 4 of the measuring head 3. Thus, the guide bolts 4 and the bayonet slots 6 together form a bayonet connection allowing for a defined alignment along the optical axis A which also represents the symmetry axis of the terahertz measuring device 1. At its end opposite the bayonet slots 6 the moulded screen 5 is provided with a contact contour 7 for being applied to test objects which shall be described in more detail below.

The terahertz measuring device 1 is portable by a user; it is designed e.g. to have a length L of 25 to 50 cm and includes in the basic housing 2 einen energy storage 11, e.g. a galvanic cell (battery, accumulator), as well as a controller device 10, user controls 35, preferably a display device 12, and further a terahertz measuring electronics including a terahertz transmitter and receiver chip 14 that emits terahertz (THz) radiation within a frequency band between 10 GHz and 10 THz. Hereby, the terahertz measuring device or, respectively, its terahertz measuring electronics 14 is designed to be fully electronic (without optical elements such as e.g. femtosecond laser) and can thus be dimentioned in such a compact manner. Thus, the transmitter and receiver chip 14 emits terahertz radiation 15 along the der optical axis A and detects reflected terahertz radiation 16. Hereby, the emitted terahertz radiation is partially reflected, in particular, upon transition between layers having different refraction indices n for the terahertz radiation 15. Therefore, if the boundary surfaces, e.g. the surface 18 of a test object 20, are positioned vertical (perpendicular) to the terahertz radiation 15 transmitted along the optical axis A, the reflected terahertz radiation 16 will again be reflected back along the optical axis A and received by the transmitter and receiver chip 14.

Hereby, the terahertz measuring device 1 allows distance measurement of distances to boundary surfaces of the test object 20, and following, in particular by means of superimposing the transmitted terahertz radiation 15 and the received terahertz radiation 16. Hereby, in particular, a frequency modulation or pulsed radiation may be provided.

Thus, when measuring a cylindrical plastic pipe as test object 20, with a perpendicular alignment of the optical axis A of the terahertz measuring device 1 in relation to the pipe axis B, layer thicknesses of the tube 20 can be determined from the measured signal, i.e. the distance a1 of the front surface or, respectively, the front side of the tested pipe 20 to the transmitter and receiver chip 14, also the layer thickness a2 of the pipe wall of the tube 20, thereafter the inner diameter of the pipe a3 as the thickness of the air gap to the opposite wall, and subsequently the wall thickness a4 as the thickness of the plastic layer of the opposite wall.

The axact vertical alignment of the optical axis A in relation to the pipe axis B is ensured by the moulded screen 5 with its contact contour 7. Die contact contour 7 is designed in such a way that it, when applied to the surface 18 of the test object 20, is in contact with the surface 18 at exactly four contact points P, i.e. P1, P2, P3, P4. To that end, the contact contour 7 is designed, on the one hand, symmetrical in such a way that is exhibits two contour lines 7-1 and 7-2 that are displaced in perpendicular direction – i.e. perpendicular to the optical axis A –, e.g. curved, which are e.g. identical or mirror symmetrical to each other. Thus, the contact points P1, P2, P3, P4 are designed in such a way that upon application of the contact contour 7 onto the cylindrical surface 18 at a defined first diameter D1, e.g. 40 mm, a perpendicular alignment of the optical axis A in relation to the pipe axis B is attained. To that end, the contact points P1, P2, P3, P4 preferably lie in a plane perpendicular to the optical axis A. Thus, the contour lines 7-1, 7-2 are shaped not spherical for large-area conact, but for a defined contact at two contact points P1, P2.

Moreover, the contour lines 7-1 and 7-2 may have a path such that they can receive different surface curvatures, i.e. different pipe diameters, as shown in Figs. 3 and 4: According to Fig. 3 a tube having a small first kleinem diameter D1 as test object 20 is received at contact points P1 and P2 in a central area of the contour line 7-1 (and, displaced against the drawing plane, also according to the contour line 7-2), while, according to Fig. 4 a second pipe having a larger second diameter D2, e.g. D2= 125 mm, as test object 120 which is in contact with contact points P1 and P2 at the contour line 7-1 which is offset towards the outside in relation to the center or optical axis. Thus, by means of a suitable contour line 7-1 – and the contour line 7-2 displaced in relation thereto but identical or, respectively, symmetrical – several test pipes 20, 120 with different diameters can be captured in a defined manner or, respectively, the THz measuring device 1 can always be positioned in a defined manner and perpendicular to the pipe axis D.

The basic housing 2 is equipped with a grip region 34 so that a user can grab the terahertz measuring device 1 – e.g. using only one hand – and press it at the moulded screen 5 towards the front (in the direction of the optical axis A) against the test object 20, 120, i.e. against the surface 18,

118. This automatically creates a stabile contact of the moulded screen 5 at the four contact points P1, P2, P3, P4, whereby, owing to the sufficient lateral distance – between P1, P2 on the one hand, and P3, P4 on the other – applying contact pressure at minimal force safely preventy wobbling thereby attaining exact positioning.

Hereby, the moulded screen 5 can be made of metal thereby, preferably, also shield against scattered radiation, i.e. serve as a moulded screen and for creating the contour.

Thus, by virtue of the two contour lines 7-1 and 7-2 spacewd apart in perpendicular direction alone, precise measurements of tubes 20, 120 with different diameters D1, D2 can be carried out.

Moreover, using the same moulded screen 5, also a measurement of larger pipes can be carried out, e.g. according to Figs. 6 and 7 of the third tube 220 with a diameter D3, e.g. D3= 315 mm. To that end the THz measuring device 1 is merely pivoted about um 90° and, consequently, by means of the further contour lines 7-3 and 7-4, applied to the surface 218 of the test object 220 which is designed to have a correspondingly larger curvature. The further contour lines 7-1 and 7-2 do not impede this measurement because, again, contact points P1, P2, P3, P4 are created only at the contour lines 7-3 and 7-4. Hereby, too, using the contour lines 7-3 and 7-4 pipes with several diameters can be measured in that a suitable concave curvature of the contour lines 7-3 and 7-4 is created allowing for the capturing of pipes with different diameters at different contact points P.

In principle, a moulded screen 5 can be designed as having more than two pairs of contour lines. However, in principle, it is of advantage, when measuring a larger number of different tubes, to exchange the moulded screens by means of the afore-mentioned bayonet connector made of guide bolts 4 and bayonet slots 6.

Using the portable THz measuring device 1 preferably allows even measuring a test object 20 120, 220 across its entire circumference in that the THz measuring device 1 includes a sensor system for determining einer position or inclination:

According to the embodiment of Fig. 8 a THz measuring device 1 comprises an acceleration sensor 30 which is sensitive enough to measure the gravitational acceleration g or, respectively, shares of g. The acceleration sensor 30 comprises a sensing direction or, respectively, longitudinal direction which may be, in particular, the optical axis A. This longitudinal direction, in each position or location, exhibits a definede measuring angle position α in relation to the vertical, i.e. the direction of gravitational acceleration g. Thus, the THz- Messvorrichtung 1 can be positioned successively in several measuring angle positions α along the circumference of the test object 20. Thus, when applied vertically, i.e. on the top side (uppermost position), α = 0, when applied on exactly the bottom side, consequently, α = 180° or, respectively, π. Thus, the result for the horizontal position shown in Fig. 8 in the left upper corner gezeigten is α = 270°.

Thus, the acceleration sensor 30 in each case measures an acceleration ac, which results from

$$ac = g * \text{arc} \cos \alpha.$$

In addition, e.g. a second acceleration sensor 30-2 may be provided which is aligned in a second sensing direction C2 offset in relation, not parallel, to the first sensing direction C1 of the first acceleration sensor 30-1 so that symmetrical angles of inclination (left and right) having identical values can be distinguished also. Fig. 9 shows in the partial Figures a), b), c) variuous such embodiments having two acceleration sensors 30-1, 30-2, the sensing directions C1, C2 of which are each offset against each other.

According to Fig. 9a) a first sensing direction C1 of the first acceleration sensor 30-1 and a second sensing direction C2 of the second acceleration sensor 30-2 are offset by an angular displacement β, wobei, according to Fig. 9a) β = 90°. Fig. 11 shows this arrangement in more detail: According to this embodiment, the sensing directions C1 and C2 lie symmetrical to the optical axis A, i.e. the first angular distance γ1 of the first sensing direction C1 to the optical axis A is – as far as the value is concerned – equal to the second angular distance γ2 of the second sensing direction C2 to the optical axis A; thus, the acceleration sensors 30-1 and 30-2 are titled or mirrowred respectively about the optical axis. Hereby, embodiments with γ1 and γ2 < 90° so that both sensing directions C1 and C2 face the test object 20 are especially preferred.

Fig. 9b) shows an embodiment alternative hereto in which the sensing directions C1 and C2 have unequal angular distances γ1, γ2 to the optical axis A, whereby they are offset relative to the optical axis preferably in different directions. According to the embodiment of Fig. 9c) the first sensing direction C1 lies in the direction of the optical axis A and the second sensing direction C2 in a direction not parallel hereto, e.g. orthogonally, so that the sensing directions C1, C2 span the angular offset of β = 90°.

Thus, it is an advantage according to the representation of Fig. 10, in particular, that the sensing directions C1, C2 span the plane in which the optical axis A also lies. Thus, the various measurement shown in Fig. 10 result in pairs of measured values of the measured accelarations ac1, ac2 of the two accelaration sensors 30-1 and 30-2 which allow, when combined, an unambiguous determination of the measuring angle position. Thus, the two horizontal positions I and II shown in Fig. 10 are distinguishable from each other because the first acceleration sensor 30-1 measures in the left position I an upwards, i.e. negative, first acceleration ac1 while it measures in the right position II a downwards, i.e. positive, first acceleration ac1, and correspondingly, *vice versa*, the second acceleration sensor 30-2 measures in the right position I a downwards, i.e. positive, second acceleration ac2 and in the right position II an upwards, i.e. negative, second acceleration ac2.

This can be illustrated by an example: when measuring the angle of inclination α in the Figures clockwise in relation to the vertical downwards (direction of gravitational acceleration g), therefore, in the embodiment of Fig. 9a) the result is γ1 = γ2 = 45° preferably in the left horizontal position I a first acceleration ac1 = g * cos(135°) = - g * cos(45°) and
a second acceleration ac2 = g * cos(315°) = g * cos(45°).
and *vice versa* in the right horizontal position.

These measurements can also be carried out using the terahertz measuring devices according to Figs. 9b) and Fig. 9c).

Thus, the two acceleration sensors 30-1 and 30-2 in a non-parallel alignment in this plane are sufficient, whereby the acceleration sensors 30-1 and 30-2 each supply as measured value a value and a sign, for unambiguous definition of the measuring angle position on the test object 20.

Thus, layer thickness measurements can be combined with measurements of the measuring angle position α. Thus, for a measurement according to Fig. 8 for measuring the entire circumference of a test object 20 the following steps are being carried out:

providing the THz measuring device 1 having a suitable moulded screen 5 (Schritt St1),

applying the THz measuring device 1 by means of the moulded screen 5 in such a way that two spaced-apart contour lines 7-1 and 7-2 each having two contact points, i.e. P1, P2, P3, P4, come into defined contact. To thate end, a user presses the THz-Messvorrichtung 1 at its moulded screen 5 with light force against the surface 18 of the test object 20; this is executed by the user by hand or manually without any further means (step St2), commencing a measurement, e.g. by pushing a user control 35 at the basic housing 2, causing THz radiation 15 to be emitted and reflected THz radiation 16 to be measured, whereby, further, the measuring angle position α of the acceleration sensor 30 is captured and accociated with THz-measuring signals, (step St3)

evaluating the measuring signal, i.e. the received THz radiation 16 for determining run-times and, theredby, layer thicknesses a1, a2, a3, a4 and the measuring angle position α (step St4),

returning to step St2, while re-adjusting the measuring angle position α by re-aplying or sliding along on the surface 18,

until the test object 20 has been measured across its entire circumference.

List of reference numerals

1	terahertz measuring device
2	basic housing
4	guide bolt
3	measuring head
5	moulded screen
6	bayonet slots
7	contact contour
7-1, 7-2, 7-3, 7-4	contour lines
10	controller device
11	energy storage, preferably battery or accumulator
12	display device
14	terahertz transmitter and receiver device
15	terahertz radiation
16	reflected terahertz radiation
18	surface
20	first test object
30	acceleration sensor
30-1	first acceleration sensor
30-2	second acceleration sensor
34	grip region
35	user controls
40	THz measuring array
118	surface
218	surface
120	second test object
220	third test object
ac,	longitudinal accelaration
ac1, ac2	first, second longitudinal accelaration
g	gravitational accelaration

A	optical axis
B	tube axis
C1	first sensing direction
C2	second sensing direction
P, P1, P2, P3, P4	contact points
a1	distance between surface 18 and transmitter, receiver device
a2	layer thickness of the tube wall 21
a3	interior diameter of tube
a4	wall thiockness of opposite wall
D1	first diameter
D2	second diameter
D3	third diameter
I	left position
II	right position
L	length
α	measuring angle position
β	angular offset
γ1, γ2	first angular distance, second angular distance

Patentkrav

1. THz-måleanordning (1) til bestemmelse af mindst én lagtykkelse (a1, a2, a3, a4) på et testobjekt (20, 120, 220), hvor måleanordningen (1) har:

en THz-sende/modtage-enhed (14) til udsendelse af THz-stråling (15) langs en optisk akse (A) og til modtagelse af reflekteret THz-stråling (16) langs den optiske akse (A),
en styreenhed (10) til aktivering af sende/modtage-enheden (14),
et gribeområde (34), som brugeren kan holde og placere, hvor det, i et forendeområde (5), har en kontaktkontur (7), der har en flerhed af kontaktpunkter (P, P1, P2, P3, P4) til placering på en kurvet overflade (18) på testobjektet (20, 120, 220), til vinkelret positionering af den optiske akse (A) på overfladen (18, 118, 218), **kendetegnet ved, at**
kontaktkonturen (7) er designet på en sådan måde, at når kontaktkonturen (7) placeres på den cylindriske overflade (18) på testobjektet (20, 120, 220), der har en defineret diameter (D1, D2, D3), kommer nøjagtigt fire kontaktpunkter (P1, P2, P3, P4) i kontakt,
hvor de fire kontaktpunkter (P1, P2, P3, P4) ligger i et plan vinkelret på den optiske akse (A),
hvor kontaktkonturen (7) har to konturlinjer (7-1, 7-2; 7-3, 7-4), der er placeret adskilt fra hinanden i en krydsende retning vinkelret på den optiske akse (A) på en overflade (18), der skal måles,
hvor ved hver konturlinje (7-1, 7-2; 7-3, 7-4) henholdsvis to kontaktpunkter (P1, P2; P3, P4) for den definerede overflade, der skal måles, dannes, og hvor konturlinjerne er designet parallelt eller spejlsymmetrisk med hinanden.

2. THz-måleanordningen (1) ifølge krav 1,
kendetegnet ved, at THz-måleanordningen (1) er bærbar, f.eks. med en længde (L) på 25 cm til 50 cm.

3. THz-måleanordningen (1) ifølge krav 1 eller 2,
kendetegnet ved, at
kontaktkonturen (7) er dannet på en udskiftelig forlængelse (5), der kan monteres stift ved en defineret vinklet position.

4. THz-måleanordningen (1) ifølge krav 3,
kendetegnet ved, at forlængelsen (5) er formstøbt skærm (5), der er fremstillet af metal, og som er tilvejebragt til afskærmning mod spredt stråling, fortrinsvis til fastgørelse på et målehoved (3) på THz-måleanordningen (1).

5. THz-måleanordningen (1) ifølge krav 3 eller 4,
kendetegnet ved, at forlængelsen (5), i dens bagende, har en konnektoranordning, f.eks. bajonetporte (6), til defineret fastgørelse til styrebolte (4) på målehovedet (3) eller et grunddelshus (2) og har kontaktkonturen (7) i dens forende.

6. THz-måleanordningen (1) ifølge ethvert af de foregående krav,
kendetegnet ved, at med henholdsvis et par konturlinjer (7-1, 7-2) kan mindst to forskellige overflader (18, 118) måles gennem kontakt,
hvor kontaktpunkterne (P1, P2) på de forskellige overflader (18, 118) er dannet ved forskellige positioner på konturlinjerne (7-1, 7-2), specielt med en forskellig afstand mellem hinanden, hvor konturlinjerne (7-1, 7-2; 7-3, 7-4) er designet til at være hovedsageligt konkave og strække sig bagud mod deres midte.

7. THz-måleanordningen (1) ifølge ethvert af de foregående krav,
kendetegnet ved, at den har to par konturlinjer (7-1, 7-2; 7-3, 7-4), der er forskudt i forhold til hinanden, specielt med 90°, ved kontaktkonturen (7) i en drejeretning (s) omkring den optiske akse (A) til måling af cylindriske eller sfæriske overflader (18, 118, 218), der har forskellige diametre (D1, D2, D3).

8. THz-måleanordningen (1) ifølge ethvert af de foregående krav,
kendetegnet ved, at den desuden har én eller en flerhed af elementer fra følgende gruppe:

– et energilager (11), specielt et batteri eller en akkumulator, til uafhængig forsyning af elektricitet til THz-sende/modtage-anordningen (14) og styreanordningen (10), fortrinsvis til komplet uafhængig forsyning af energi til THz-måleanordningen (1),

– operatørstyreanordning (35), f.eks. en kontakt, til start af en lagtykkelsesmåling,

– et forlænget grunddelshus (2),

– en visningsanordning (12).

9. THz-måleanordningen (1) ifølge ethvert af de foregående krav, **kendetegnet ved, at** den har en vinkelpositionsmåleanordning (30, 30-1, 30-2) til måling af en målevinkelposition (α), når den anvendes på testobjektet (20, 120, 220), til måling af hele omkredsen af testobjektet (20, 120, 220), når der måles i en flerhed af målevinkelpositioner (α) over omkredsen.

10. THz-måleanordningen (1) ifølge krav 9, **kendetegnet ved, at** vinkelpositionsmåleanordningen har mindst én accelerationssensor (30, 30-1, 30-2) til måling af en langsgående acceleration (ac, ac1, ac2), f.eks. langs den optiske akse (A), som en komponent af tyngdeacceleration (g), og styreenheden (10) er designet til at bestemme målevinkelpositionen (α) ud fra forholdet mellem den målte langsgående acceleration (ac) og tyngdeaccelerationen (g), specielt under hensyntagen til et tegn på den målte langsgående tyngdeacceleration (ac, ac1, ac2).

11. THz-måleanordningen (1) ifølge krav 10, **kendetegnet ved, at** vinkelpositionsmåleanordningen har to accelerationssensorer (30-1, 30-2), hvis registreringsanordninger (C1, C2) er justeret ikke-parallelt, f.eks. med en vinkelforskydning (β) på 45° eller 90° i forhold til hinanden, til utvetydig bestemmelse af målevinkelpositionen (α) fra de to langsgående accelerationer (ac1, ac2) af de to accelerationssensorer (30-1, 30-2).

12. THz-måleanordningen (1) ifølge ethvert af de foregående krav, **kendetegnet ved, at** styreanordningen (10) er designet til at bestemme kørselstiderne for de afgivne og reflekterede THz-stråling (15, 16), fortrinsvis i periode- eller frekvensområde og, på grundlag af disse, mindst én lagtykkelse (a1, a2, a3, a4), fortrinsvis en frontvægstykkelse (a2), en indvendig diameter (a3) og en bagvægstykkelse (a4) på et rør som testobjekt (20, 120, 220).

13. THz-måleanordningen (1) ifølge ethvert af de foregående krav, **kendetegnet ved, at** terahertz-sende/modtage-enheden (3) udsender terahertz-stråling (15) inden for frekvensområdet mellem 0,01 og 10 THz, specielt 100 GHz til 3 THz, specielt helt elektrisk ved hjælp af en dipol, f.eks. med frekvensmodulationer eller pulseret.

14. THz-målearrangementet (40), der har en THz-måleanordning (1) ifølge ethvert af de foregående krav og det testobjekt (20, 120, 220), der skal måles, hvor kontaktkonturen (7) er designet til at have en flerhed af kontaktpunkter (P, P1, P2, P3, P4) til placering på den kurvede overfladen (18, 118, 218) på testobjektet (20, 120, 220), til vinkelret positionering af den optiske akse (A) på overfladen (18, 118, 218).

15. Metode til måling af mindst én lagtykkelse (a1, a2, a3, a4) på et testobjekt (20, 120, 220) med en THz-måleanordning (1), som har mindst følgende trin:

– tilvejebringelse af en bærbar THz-måleanordning (1) ifølge ethvert af kravene 1 til 13, som har THz-sende/modtage-enheden (14), et grunddelshus (2) og kontaktkonturen (7), der er dannet på en forende (St1),
– anvendelse af THz-måleanordningen (1) med kontaktkonturen (7) på overfladen (18) af testobjektet (20, 120, 220) ved hjælp af tryk på en sådan måde, at kontaktkonturen (7) er i kontakt med overfladen (18) ved nøjagtigt fire kontaktpunkter (P1, P2, P3, P4), og en optisk akse (A) på sende/modtage-enheden (14) er justeret vinkelret på overfladen (18) (St2),

– udførelse af mindst én afstandsmåling gennem udsendelse af THz-stråling (15) mod testobjektet (20, 120, 220) med delvis refleksion på mindst to grænseoverflader på testobjektet (20, 120, 220) og detektion af reflekteret THz-stråling (16) (St3),

– bestemmelse af mindst én lagtykkelse (a2, a3, a4) på testobjektet (20, 120, 220) ud fra en kørselsmåling af den udsendte og reflekterede THz-stråling (15, 16) (St4).

16. Metoden ifølge krav 15,
kendetegnet ved, at testobjektet (20, 120, 220) er et rør, f.eks. et plastikrør, og trinnene til anvendelse (St2) og gennemførelse af afstandsmålingen (St2) udføres efterfølgende i en flerhed af målevinkelpositioner (α) på tværs af omkredsen af testobjektet (20, 120, 220), f.eks. i diskrete trin eller kontinuerligt,
hvor, i trinnet til gennemførelse af afstandsmålingen (St2), en målevinkelposition (α) af THz-måleanordningen (1) desuden bestemmes, specielt gennem måling af en langsgående acceleration (ac) som en komponent af tyngdeaccelerationen (g).

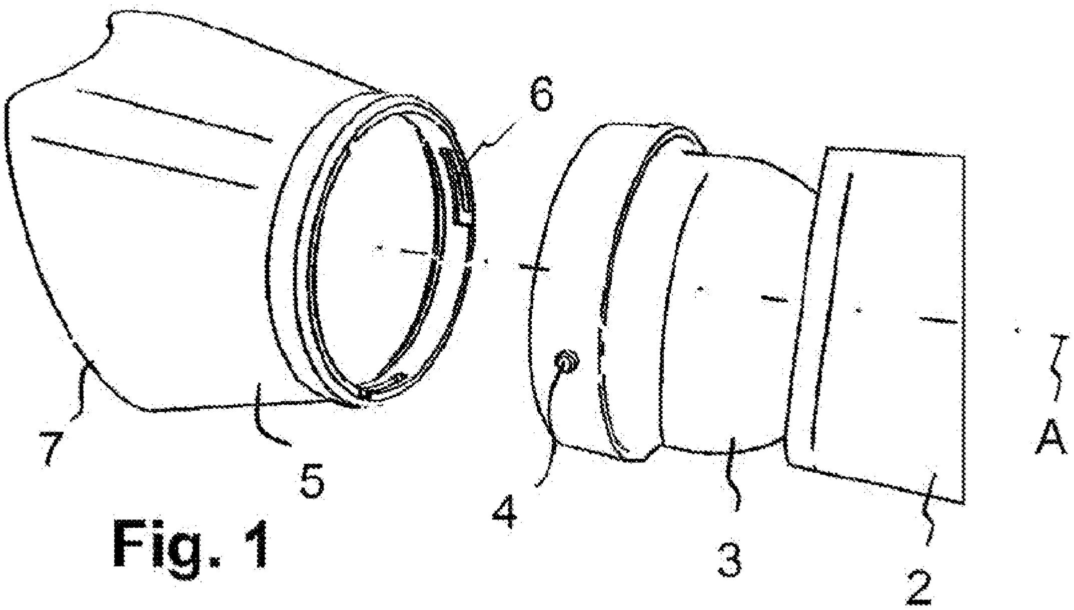
6
7
5
4
3
2
A

Fig. 1

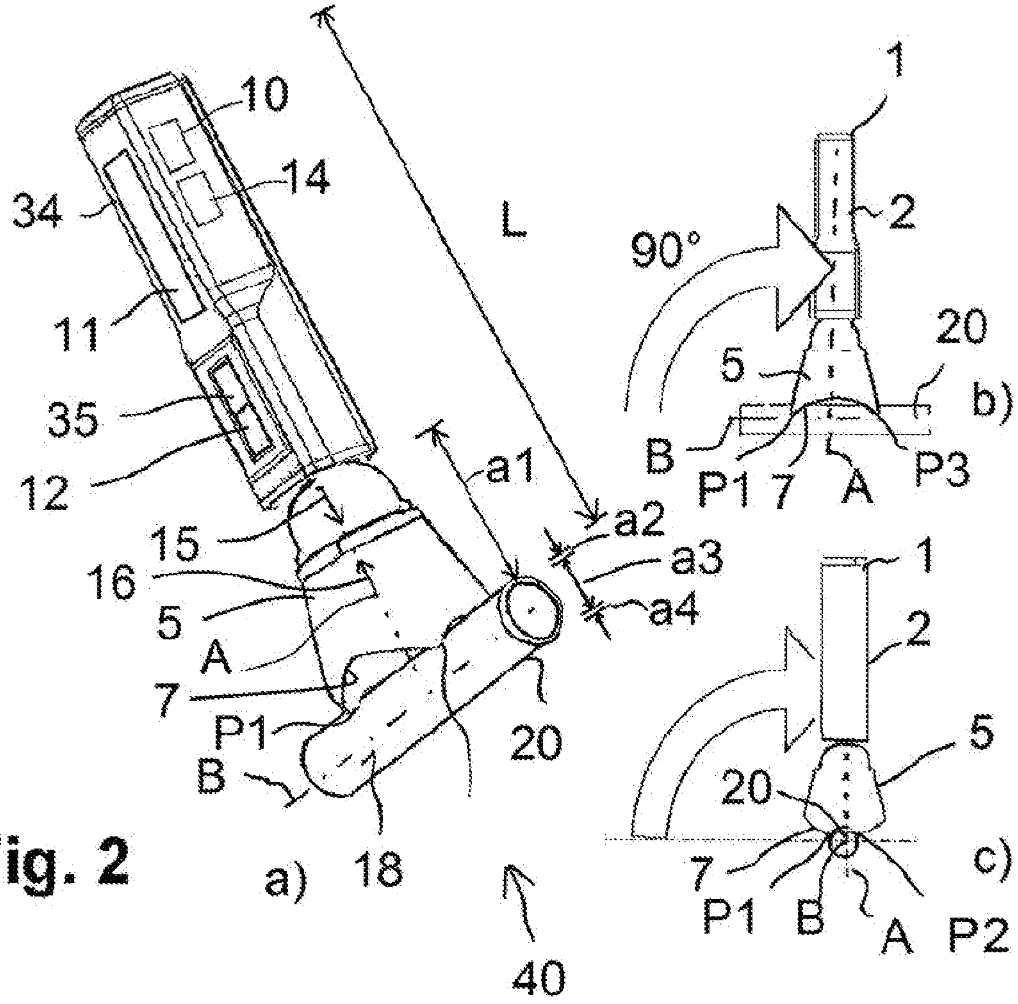
10
14
34
L
11
35
12
15
16
5
A
7
P1
B
18
20
a1
a2
a3
a4
40
a)
1
2
90°
20
5
b)
B
P1 7 A P3
1
2
5
20
c)
7
P1 B A P2

Fig. 2

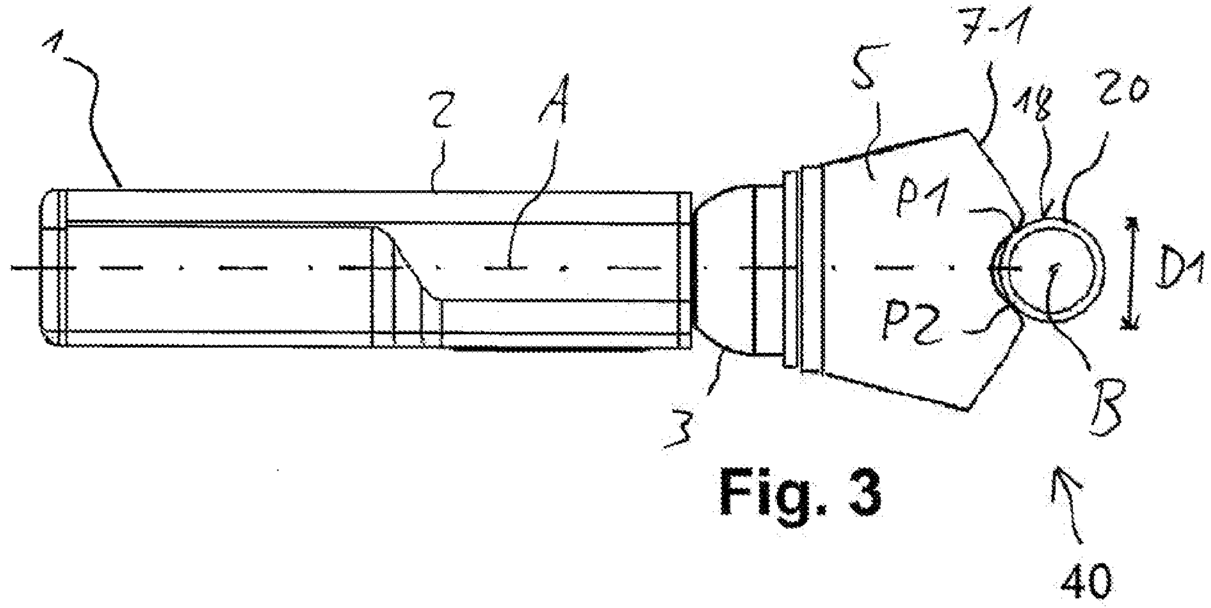

Fig. 3

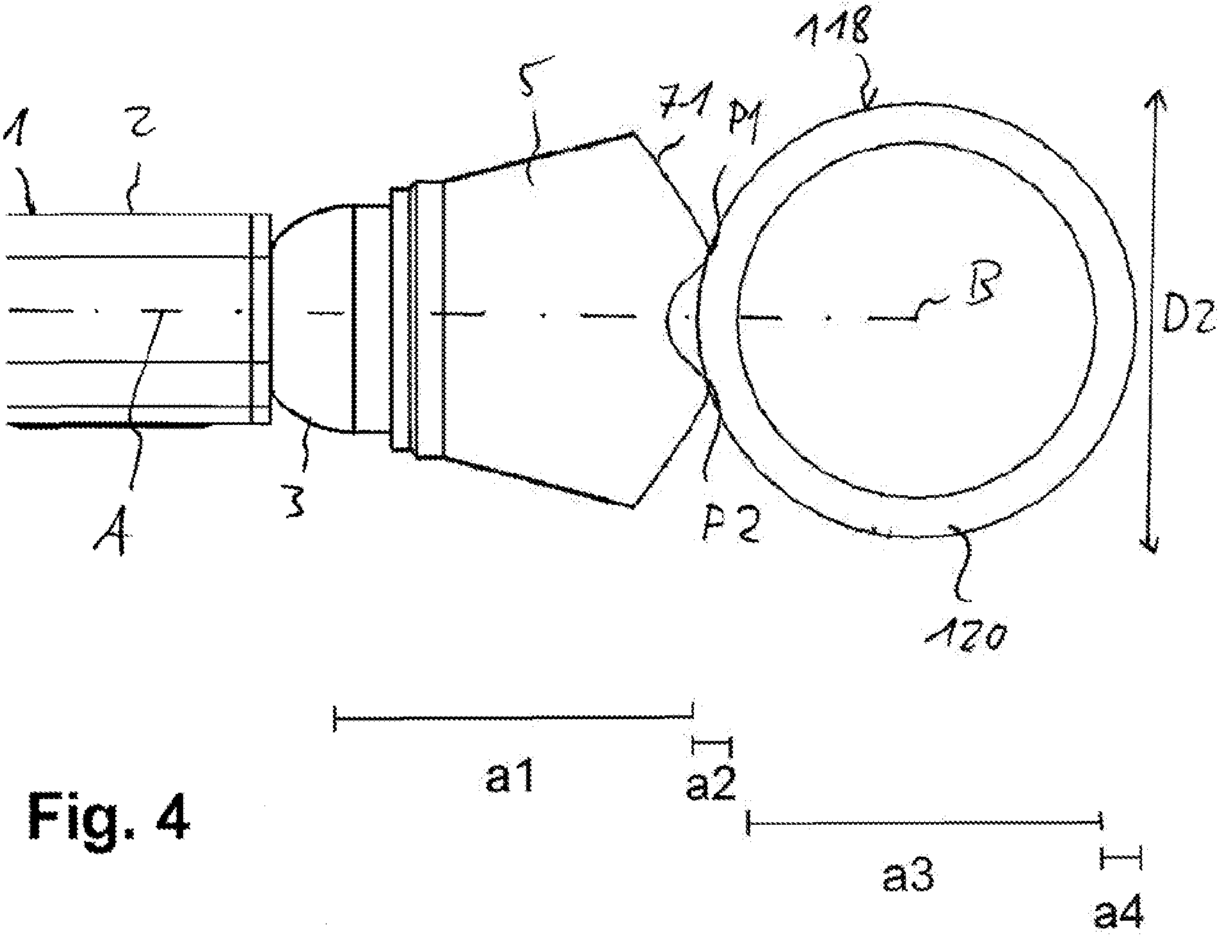

Fig. 4

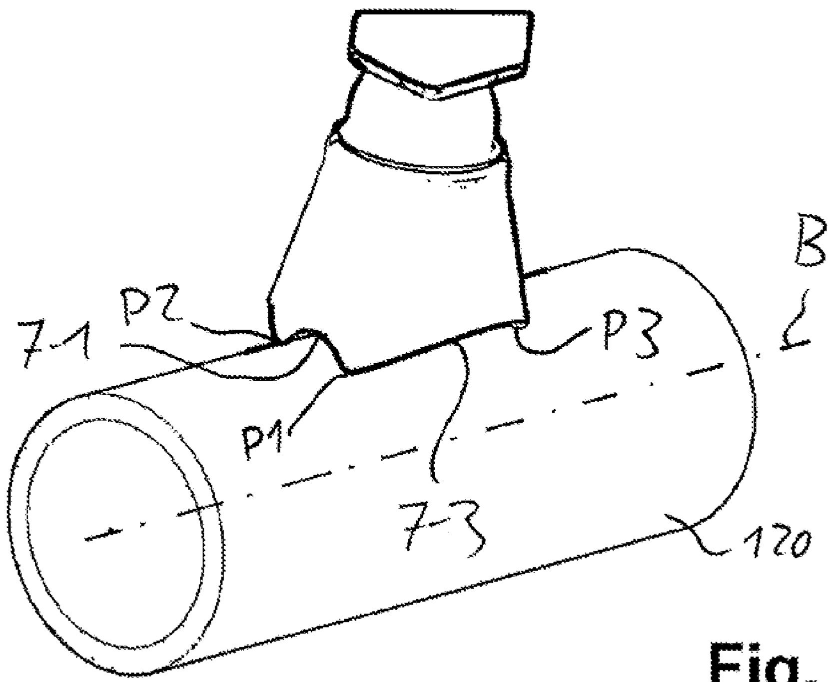

Fig. 5

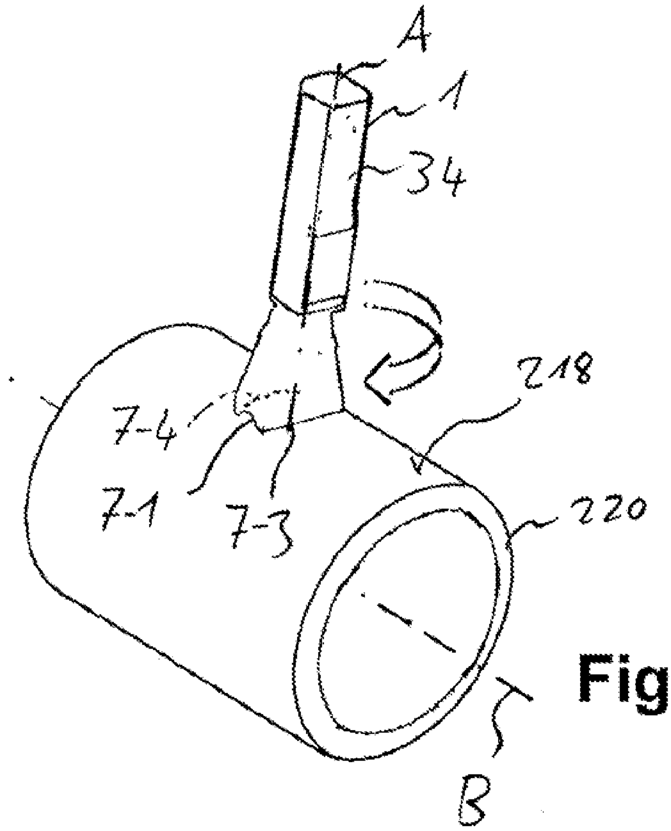

Fig. 6

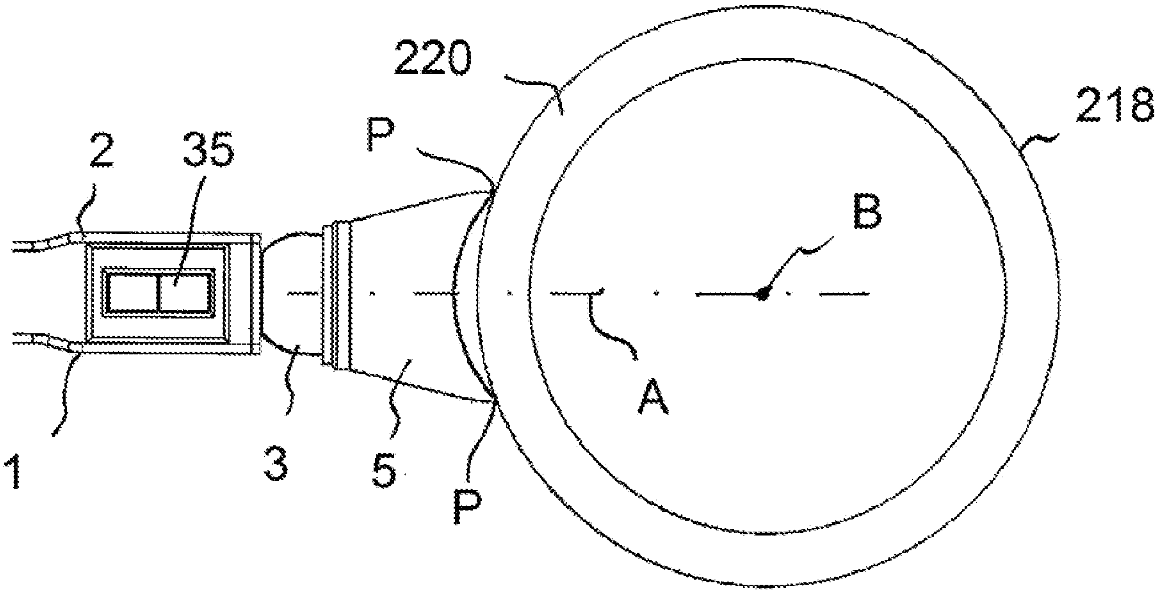
220
218
2
35
P
B
A
1
3
5
P

Fig. 7

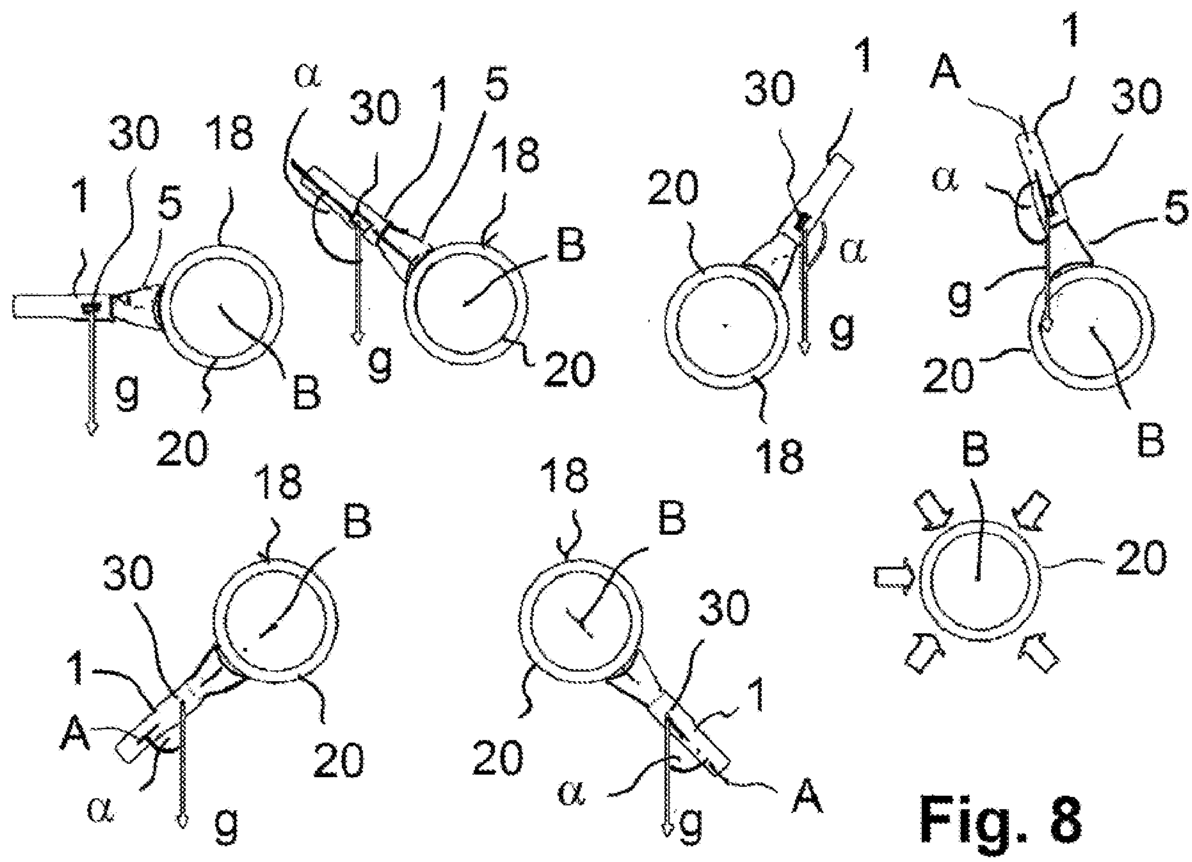
30
18
1
5
g
B
20
α
30
1
5
18
B
g
20
30
1
20
α
g
18
A
1
30
α
5
g
20
B
18
B
30
1
A
α
g
20
18
B
30
1
20
α
A
g
B
20

Fig. 8

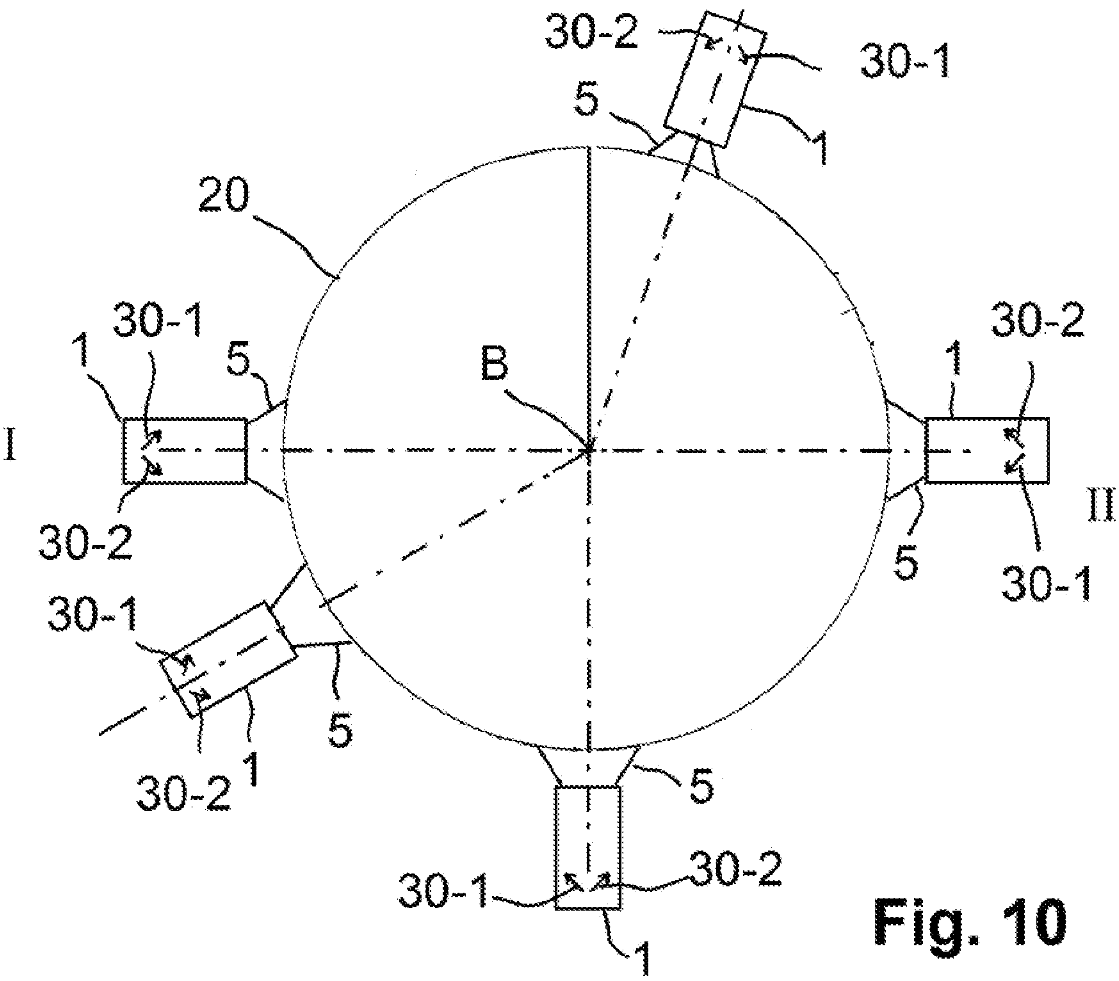

Fig. 10

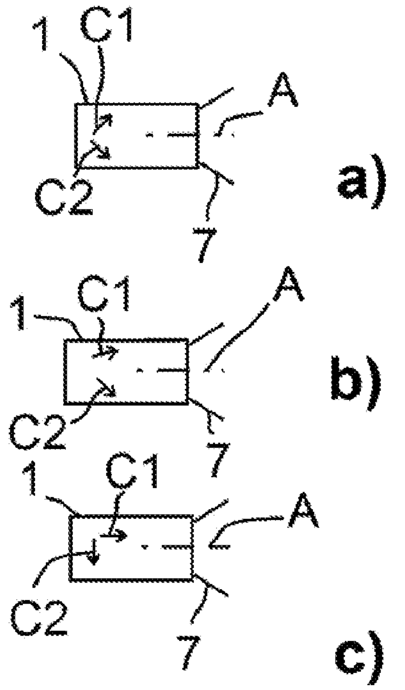

Fig. 9

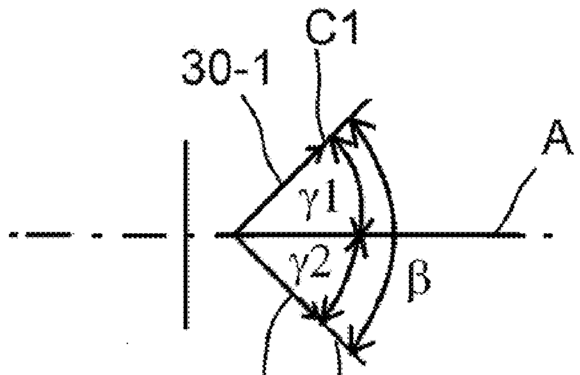

Fig. 11