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(54) Title: DEVICE FOR OPTICALLY SCANNING AND MEASURING AN ENVIRONMENT

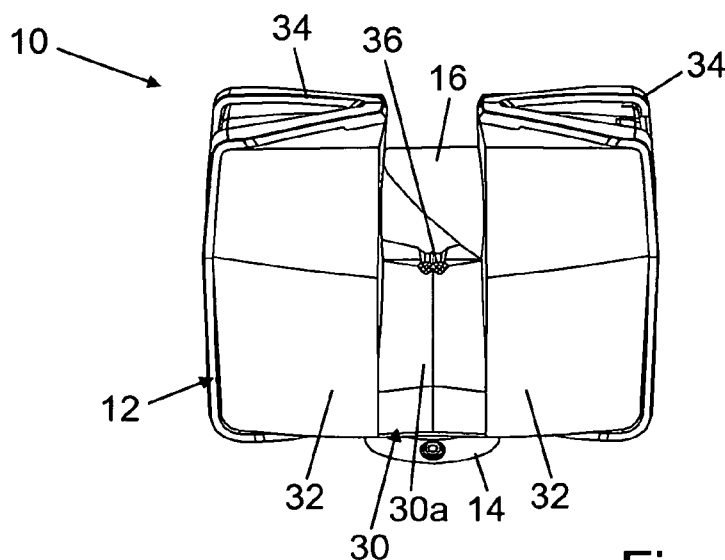


Fig. 2

(57) Abstract: With a device for optically scanning and measuring an environment, which is designed as a laser scanner (10), with a light emitter (17), which emits an emission light beam (18), with a light receiver (21) which receives a reception light beam (20) which is reflected from an object (O) in the environment of the laser scanner (10) or scattered otherwise, and with a control and evaluation unit (22) which, for a multitude of measuring points (X), determines at least the distance to the object (O), the spot of the emission light beam (18) temporarily moves along a prism (36) of the laser scanner (10), said prism having at least two different brightness levels and/ or colors.

5

Device for optically scanning and measuring an environment

The invention relates to a device having the features of the generic term of Claim 1.

10 By means of a device such as is known for example from DE 20 2006 005 643 U1, and which is designed as a laser scanner, the environment of the laser scanner can be optically scanned and measured.

The invention is based on the object of improving a device of the type mentioned in
15 the introduction. This object is achieved according to the invention by means of a device comprising the features of Claim 1. The dependent claims relate to advantageous configurations.

The components of the laser scanner are arranged in two parts of the measuring
20 head and in a traverse of the carrying structure which connects said parts. In order to reduce weight of the laser scanner, a shell is provided as part of the housing, preferably one shell for each of the two parts of the measuring head, wherein said shell can be made of a light material, for example plastic material, and covers the corresponding components of the laser scanner in order to protect them. To protect
25 the shell in turn, a yoke is provided, preferably one yoke for each of the shells, which partially covers the outside of the shell and which can be made of a light material, for example aluminum, as well.

The carrying structure, which, for weight purposes, preferably is made of aluminum
30 as well, preferably has walls which serve for fixing the components with the optics and the rotating mirror. The walls can also close the semi-open shells. The yoke preferably extends along the outer edges and/or diagonally over the outer surfaces

of the shell and is fixed to the carrying structure, preferably at its ends, if and when necessary also in its center, at one of the two walls. In addition to the protective function, also further functions can be integrated into the yoke.

- 5 The parameters of the laser scanner, particularly temperature, can change during operation. Comparative measuring is necessary for a correction. It is suggested to move the spot of the emission light beam temporarily along a prism which has a known geometry and a known distance to the center of the laser scanner. The prism additionally has at least two different brightness levels and/or colors, in order to
10 generate different signal levels of the reception light beam. The different brightness levels and/or colors alternate preferably along the direction of motion of the spot of the emission light beam.

During the rotation of the mirror, the emission light beam is projected onto the tra-
15 verse of the carrying structure once during every turn, without the environment below being able to be measured. The prism therefore is preferably configured at the traverse. A particular geometrical shape, perpendicular to the direction of motion of the spot of the emission light beam (or in direction of motion), can take account of the imaging properties of the receiving optics and thus control the resulting signal
20 quality. By means of the different brightness levels and/or colors and the known distance of the prism, the control and evaluation unit carries out a (correction of the) distance correction.

For assembling the laser scanner the components have mechanical and electrical in-
25 terfaces. Particularly between the parts which are rotatable relative to one another, a high precision is required then. The laser scanner therefore is provided with a swivel-axis module which, as a pre-assembled assembly, on the one hand is provided with the base resting in the stationary reference system of the laser scanner and, on the other hand, with parts which can be fixed to the carrying structure of the meas-
30 uring head which is rotatable relative to the base. The interfaces which are rotatable relative to one another are then displaced into the interior of the interface module. The interfaces between the swivel-axis module and the further parts of the measur-

ing head can be configured (more) simply, so that, when inserting the swivel-axis module, for example into a receiving slot of the carrying structure, they are closed in the direction of insertion.

- 5 In the laser scanner, the motors for rotating the measuring head and the mirror, as well as the control and evaluation unit and the further electronic components generate heat which must be removed. For this purpose, the laser scanner is provided with an integrated cooling device, based on a ventilation. Hereby, the air is led by an air inlet into a space between the carrying structure and the shell, serving as a
- 10 housing, from where it gets through a suction duct, which is sealed with respect to the interior of the carrying structure, into the interior of the cooling device. From there, a fan blows the heated-up air through a further outlet duct, which is sealed with respect to the interior of the carrying structure, and through an air outlet to the outside. The heat can thus preferably be removed without impairing the tightness of
- 15 central components. One filter at air inlet and air outlet each, avoids intrusion of dust and coarse dust particles into the spaces and ducts of the cooling device. The air inlet and the air outlet are orientated, for example by means of ribs, in that the air streams point away from each other, i.e. unintersectedly into directions which are spread apart as possibly. The suction duct and the outlet duct, having for ex-
- 20 ample a rectangular profile, are connected to the housing of the fan in a sealed manner. Additionally, if required, the ducts can be completely sealed by means of suitable plugs. Each of the preferably two shells is semi-open and closed by a wall of the carrying structure, the air inlet and the air outlet meeting preferably exactly one of the two shells, sealed with respect to one another and with respect to the space. A
- 25 sealing of the shells, which are arranged outside, against the carrying structure thus guarantees a complete sealing of the laser scanner. In addition to this ventilation, the cooling device preferably is provided with passive cooling elements, for example cooling fins and/or heat pipes, in order to transfer heat (from sections of the interior of the carrying structure) to the active cooling elements. This can be the
- 30 heat from the electronics or, if the carrying structure is subdivided into two halves which are sealed with respect to one another, the heat from the other half (without active cooling elements) of the carrying structure.

The invention is explained in more detail below on the basis of an exemplary embodiment illustrated in the drawing, in which

5 Fig. 1 shows a perspective illustration of the laser scanner,

Fig. 2 shows a slightly perspective lateral view of the laser scanner,

Fig. 3 shows the bottom view of the laser scanner,

10

Fig. 4 shows a section of the laser scanner in the zone of the swivel-axis module,

Fig. 5 shows a perspective partial view of the laser scanner without shell,

15 Fig. 6 shows a partial view of the cooling device with the perspective of Fig. 5, and

Fig. 7 shows a schematic illustration of the laser scanner during operation.

A laser scanner 10 is provided as a device for optically scanning and measuring the
20 environment of the laser scanner 10. The laser scanner 10 has a measuring head 12
and a base 14. The measuring head 12 is mounted on the base 14 as a unit that can
be rotated about a vertical axis. The measuring head 12 has a rotary mirror 16,
which can be rotated about a horizontal axis. The intersection point of the two rota-
tional axes is designated center C_{10} of the laser scanner 10.

25

The measuring head 12 is further provided with a light emitter 17 for emitting an
emission light beam 18. The emission light beam 18 is preferably a laser beam in
the range of approx. 300 to 1600 nm wave length, for example 790 nm, 905 nm or
less than 400 nm, on principle, also other electro-magnetic waves having, for ex-
30 ample, a greater wave length can be used, however. The emission light beam 18 is
amplitude-modulated, for example with a sinusoidal or with a rectangular-wave-
form modulation signal. The emission light beam 18 is emitted by the light emitter

17 onto the rotary mirror 16, where it is deflected and emitted to the environment. A reception light beam 20 which is reflected in the environment by an object O or scattered otherwise, is captured again by the rotary mirror 16, deflected and directed onto a light receiver 21. The direction of the emission light beam 18 and of the reception light beam 20 results from the angular positions of the rotary mirror 16 and the measuring head 12, which depend on the positions of their corresponding rotary drives which, in turn, are registered by one encoder each.

A control and evaluation unit 22 has a data connection to the light emitter 17 and to the light receiver 21 in measuring head 12, whereby parts of it can be arranged also outside the measuring head 12, for example a computer connected to the base 14. The control and evaluation unit 22 determines, for a multitude of measuring points X, the distance d between the laser scanner 10 and the (illuminated point at) object O, from the propagation time of emission light beam 18 and reception light beam 20. For this purpose, the phase shift between the two light beams 18 and 20 can, for example, be determined and evaluated.

Scanning takes place along a circle by means of the (quick) rotation of the rotary mirror 16. By virtue of the (slow) rotation of the measuring head 12 relative to the base 14, the whole space is scanned step by step, by means of the circles. The entity of measuring points X of such a measurement is designated scan. For such a scan, the center C_{10} of the laser scanner 10 defines the origin of the local stationary reference system. The base 14 rests in this local stationary reference system.

In addition to the distance d to the center C_{10} of the laser scanner 10, each measuring point X comprises a brightness information which is determined by the control and evaluation unit 22 as well. The brightness value is a gray-tone value which is determined, for example, by integration of the bandpass-filtered and amplified signal of the light receiver 21 over a measuring period which is attributed to the measuring point X. A color camera can optionally generate pictures, by means of which colors (R,G,B) can be assigned to the measuring points as values.

A display device 24 is connected to the control and evaluation unit 22. The display device 24 is integrated into the laser scanner 10, in the present case into the measuring head 12. The display device 24 shows a preview of the scan.

5 The laser scanner 10 has a carrying structure 30 which serves as „skeleton“ of the measuring head 12 and at which different components of the laser scanner 10 are fixed. In the present case, the metal carrying structure 30 is made of aluminum and in one piece. Above the base 14, the carrying structure 30 has a traverse 30a which is visible from outside and which, at both ends, carries two walls 30b, which are
10 parallel to one another and project upwards from the traverse 30a. Two shells 32 are configured as a housing which is open to one side, preferably made of plastic. Each of the two shells 32 covers part of the components of the laser scanner 10 which are fixed to the carrying structure 30 and is assigned to one of the two walls 30b, to which it is fixed (sealed with a sealing). The walls 30b and the shells 32 thus serve
15 as housing of the laser scanner 10.

On the outer side of each of the two shells 32 a – preferably metal – yoke 34 is arranged, which partially covers and thus protects the assigned shell 32. Each yoke 34 is fixed to the carrying structure 30, and more precisely on the bottom of the tra-
20 verse 30a. In the present case, each yoke 34 is made of aluminum and screwed to the traverse 30a at the side of the base 14. Each yoke 34 extends from its fixing point at the bottom of the traverse 30a obliquely to the next outer corner of the assigned shell 32, from where it extends along the outer edge of shell 32 to the outer corner of shell 32 which is above, on the upper side of shell 32 obliquely up to the
25 wall 30b, a short distance along it (may be with an additional fixing point), and then mirror-symmetrically to the described course on the upper side of shell 32, obliquely to the other outer corner, along the outer edge of shell 32 to the outer corner of shell 32 which is below and obliquely to the other fastening point at the bottom side of traverse 30a.

30

The two yokes 34 together circumscribe a (convex) space, within which the two shells 32 are completely arranged, i.e. the two yokes 34 together project over all

outer edges and outer surfaces of the shells 32. On top and on the bottom the oblique sections of the yokes 34 project over the top and/or bottom of the shells 32, on the four other sides, two sections each extending along an outer edge of the shells 32. The shells 32 are thus protected extensively. Although each of the yokes 34

5 primarily has a protective function, particularly with respect to impacts which might damage the shells 32 and the components of the laser scanner 10 which are arranged below, further functions can be integrated in one or both of the yokes 34, for example a gripping possibility for carrying the laser scanner 10 and/or an illumination.

10

On top of the traverse 30a a prism 36 is provided, which extends parallel to the walls 30b. In the present case, the prism 36 is an integrally formed (i.e. designed in one piece) component of the carrying structure 30, but a separate formation and fastening to the traverse 30a is conceivable as well. When the mirror 16 rotates, it

15 directs the emission light beam 18 onto the traverse, and more precisely onto the prism 36, once during each rotation, and moves the spot which is generated by the emission light beam 18, along the prism 36. Perpendicularly to the sense of movement of the spot of emission light beam 18, the profile of the prism 36 is designed in such a way that, from the top of the traverse 30a, two trapezoids pointing downwards are designed, from which an isosceles triangle pointing upwards projects.

20

Usually, the spot of the emission light beam 18 is so small that it hits the top of the triangle, but illuminates the sides only partially. The surface of the prism 36 is designed in such a way that at least two different brightness levels and/or colors are provided along the direction of motion of the spot of emission light beam 18. For

25 example, the half which is illuminated first can have a high brightness level („light grey“, „white“), and the half which is illuminated next a low brightness level („dark grey“, „black“). A reverse order or a striped pattern with several changes of the brightness level is possible as well.

30

Due to non-linearities in the electronic components, for example in the light receiver 21, the measured distances d depend on signal intensity, i.e. brightness, temperature and further parameters. A distance correction, which is stored as a function of

brightness and is non linear, is therefore necessary. Since the prism 36 has a known distance d and known brightness levels, a correction of the distance correction can be performed by means of the prism 36, namely online, i.e. during operation the influence of temperature and other parameters can be compensated. At the points corresponding to the brightness levels of the prism 36, the difference between the known distance and measured distance is determined. The correction of the distance correction is performed by adapting the curve of distance correction to said determined difference. This correction of distance correction preferably takes place in the control and evaluation unit 22.

The traverse 30a has a receiving slot which is open at the bottom, and into which a swivel-axis module 40 is introduced. The swivel-axis module 40 is a pre-assembled assembly which comprises, on the one hand, parts which are to be fixed at the carrying structure 30 and, on the other hand, the base 14 – which is rotatable in relation to said parts - and parts which are fixed to it. The base 14 is provided with a dome 14a which protrudes upward. A sealing 41 is interposed between the dome 14a and the carrying structure 30. A swivel axis 42 which protrudes vertically upward is fixed to the dome 14a, in the present case screwed. A horizontally arranged worm gearing 44 is fixed to the swivel axis 42. The swivel axis 42 has an inner head 46 which, by means of a crossed roller bearing 47, bears an outer head 48. A horizontally arranged encoder disk 50 is fixed to the upper end of the inner head 46, above which the outer head 48 has encoder read heads 52. Besides, slip rings 54 for the internal (i.e. which takes place within the swivel-axis module 40) transmission of data and energy of power supply are provided between the inner head 46 and the outer head 48. At the upper end of the outer head 48 and at the lower end of the base 14, electric plug connectors 55 for the transmission of data and energy from and to the measuring head 12 are provided.

For interaction with the worm gearing 44 a motor 56 with a planetary gear 57 is provided, which is borne in the carrying structure 30 and which drives a worm 58 which meshes with the worm gearing 44. The described swivel-axis module 40 is introduced into the traverse 30a, so that the plug connectors 55 at the outer head 48

are plugged together with suitable counter-contacts, the worm 58 meshes with the worm gearing 44, the outer head 48 can be fixed to the carrying structure 30 and a sealing 59 comes to lie between the base 14 and the carrying structure 30. In the swivel-axis module 40, the swivel axis 42, the worm gearing 44, the inner head 46 and the encoder disk 50 are fixed to the base 14, while, rotatably relative to this, the outer head 48 and the encoder read heads 52 are fixed to the carrying structure 30, and the motor 56 with the planetary gear 57 and the worm 58 are borne. The measuring head 12 is thus rotatable about a vertical axis, relative to the base 14.

10 The laser scanner 10 has an integrated cooling device 70 which cools by means of air flowing through sealed ducts. The cooling device 70 comprises a suction duct 72 which preferably is designed with a rectangular profile, a fan 74 and an outlet duct 76 which preferably is designed with a rectangular profile as well. The fan 74 with its housing is connected to the suction duct 72 and to the outlet duct 76 in a sealed manner. The suction duct 72 is arranged between the motor 56 for the swiveling movement of the measuring head 12 and a motor for the rotation of the mirror 16 which is arranged above. The outlet duct 76 is arranged between the motor 56 and the electronics.

20 The suction duct 72 opens to a (largely) sealed space Z between the carrying structure 30 and the shell 32. The sealing of the space Z (with respect to the interior of the carrying structure 30) prevents intrusion of dirt and dust into the interior of the carrying structure. The carrying structure 30 has cooling fins 78 next to the motor 56, which transfer the heat from the interior of the carrying structure 30 into the space Z. From outside, the air gets over an air inlet 80, preferably a ventilation grille with ribs, into the space Z. A filter (for example a filter mat) at the air inlet 80 prevents intrusion of coarse dust particles and dust into the space Z.

The outlet duct 76 terminates - sealed with respect to the space Z - at an air outlet 30 82, preferably a ventilation grille with ribs. The air inlet 80 and the air outlet 82 are spaced apart from each other and, in the present case, are separated by the yoke 34 and configured on the bottom of the shell 32. The ribs of the ventilation grilles are

preferably aligned in such a way that the air flow to the air inlet 80 and from the air outlet 82 point away from one another, i.e. no heated-up air is sucked in. Additionally, a heat pipe extends between the area of the measuring head 12 with the control and evaluation unit 22 and the suction duct 72, said heat pipe transferring heat to the cooling device 70 as well. The fan 74 sucks in air via the air inlet 80, the space Z and the suction duct 72 and blows the air again out of the laser scanner 10, via the outlet duct 76 and the air outlet 82. Cooling thus takes place.

The laser scanner 10 preferably has different sensors, for example thermometer, inclinometer, altimeter, compass, gyroscopic compass, GPS, etc. which are preferably connected to the control and evaluation unit 22. By means of said sensors the operating conditions of the laser scanner 10 are monitored, which are defined by certain parameters, for example geometric orientation or temperature. If one or several parameters have a drift, this is recognized by the corresponding sensors and can be compensated by the control and evaluation unit 22. By means of said sensors, also a sudden change of operating conditions can be recognized, for example an impact on the laser scanner 10 which changes its orientation, or a displacement of the laser scanner 10. If the extent of said changes cannot be registered with sufficient precision, the scanning process must be interrupted or aborted. If the extent of said changes of operating conditions can be roughly estimated, the measuring head 12 can be turned back by some angular degrees (until there is an overlapping with the area which has been scanned before the sudden change), and the scanning process continues. The two different parts of the scan can be assembled by an evaluation of the overlapping area.

List of Reference Symbols

	10	laser scanner
5	12	measuring head
	14	base
	14a	dome
	16	mirror
	17	light emitter
10	18	emission light beam
	20	reception light beam
	21	light receiver
	22	control and evaluation unit
	24	display device
15	30	carrying structure
	30a	traverse
	30b	wall
	32	shell
	34	yoke
20	36	prism
	40	swivel-axis module
	41	sealing
	42	swivel axis
	44	worm gearing
25	46	inner head
	47	crossed roller bearing
	48	outer heat
	50	encoder disk
	52	encoder read head
30	54	slip ring
	55	plug connectors
	56	motor

	57	planetary gear
	58	worm
	70	cooling device
	72	suction duct
5	74	fan
	76	outlet duct
	78	cooling fin
	80	air inlet
	82	air outlet
10	C ₁₀	center of the laser scanner
	d	distance
	O	object
	X	measuring point
	Z	space

Patent Claims

1. Device for optically scanning and measuring an environment, said device being designed as a laser scanner (10), with a light emitter (17), which emits an emission light beam (18), with a light receiver (21) which receives a reception light beam (20) which is reflected from an object (O) in the environment of the laser scanner (10) or scattered otherwise, and with a control and evaluation unit (22) which, for a multitude of measuring points (X), determines the distance to the object (O), characterized in that the spot of the emission light beam (18) temporarily moves along a prism (36) of the laser scanner (10), said prism having at least two different brightness levels and/or colors.
5
2. Device according to Claim 1, characterized in that the prism (36) is configured at a traverse (30a) of a carrying structure (30) of the laser scanner (10).
10
3. Device according to Claim 1 or 2, characterized in that the prism (36), perpendicular to the direction of motion of the spot of the emission light beam (18), has a profile with two trapezoids between which a triangle projects.
15
4. Device according to Claim 3, characterized in that the spot of the emission light beam (18) illuminates the top of the triangle and part of the sides.
20
5. Device according to any of the preceding claims, characterized in that the different brightness levels and/or colors alternate along the direction of motion of the spot of the emission light beam (18).
25

6. Device according to any of the preceding claims, characterized in that the control and evaluation unit (22) carries out a distance correction by means of the different brightness levels and/or colors and the known distance of the prism (36).
5
7. Device according to Claim 6, characterized in that the control and evaluation unit (22) corrects a distance correction which depends on the brightness.
- 10 8. Device according to any of the preceding claims characterized in that, as part of the housing of the laser scanner (10), at least one shell (32) is provided, which partially is covered at its outer side by at least one yoke (34) serving as protection.
- 15 9. Device according to any of the preceding claims, characterized in that the laser scanner (10) has a swivel-axis module (40), which, as a pre-assembled assembly is provided, on the one hand, with a base (14) which rests in the stationary reference system of the laser scanner (10) and, on the other hand, with parts which are to be fixed to a carrying structure (30) of a measuring head
20 (12) which is rotatable relative to the base (14).
10. Device according to any of the preceding claims, characterized in that the laser scanner (10) is provided with a cooling device (70) with a space (Z) between a carrying structure (30) and a shell (32) which serves as a housing, said space
25 (Z) opening to the outside by means of an air inlet (80) and, for the rest, is sealed with respect to the interior of the carrying structure (30) and with respect to the shell (32).

1/4

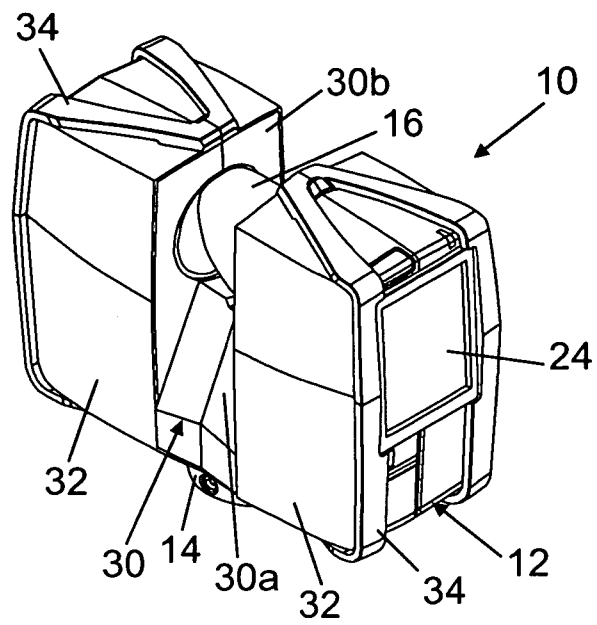


Fig. 1

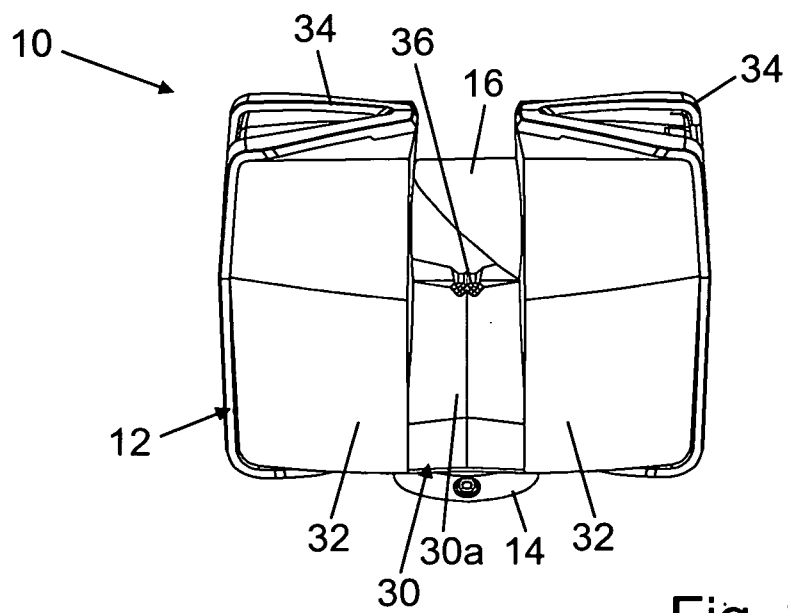


Fig. 2

2/4

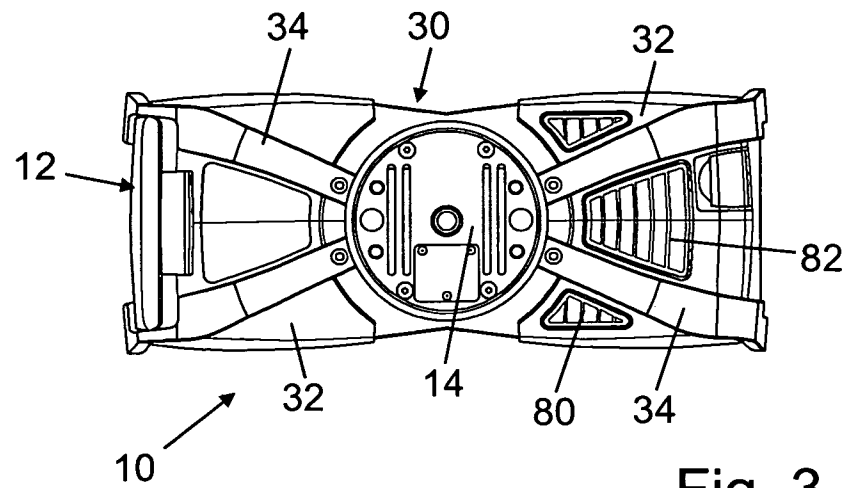


Fig. 3

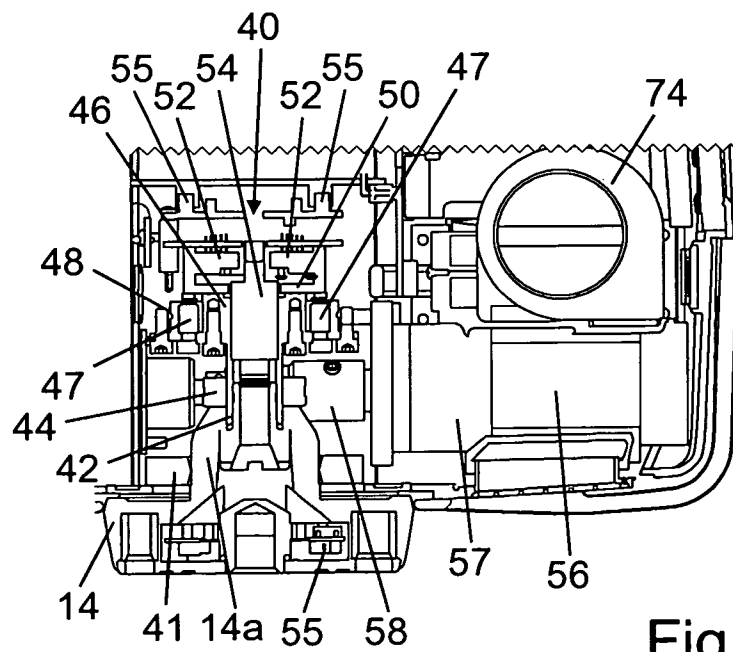


Fig. 4

3/4

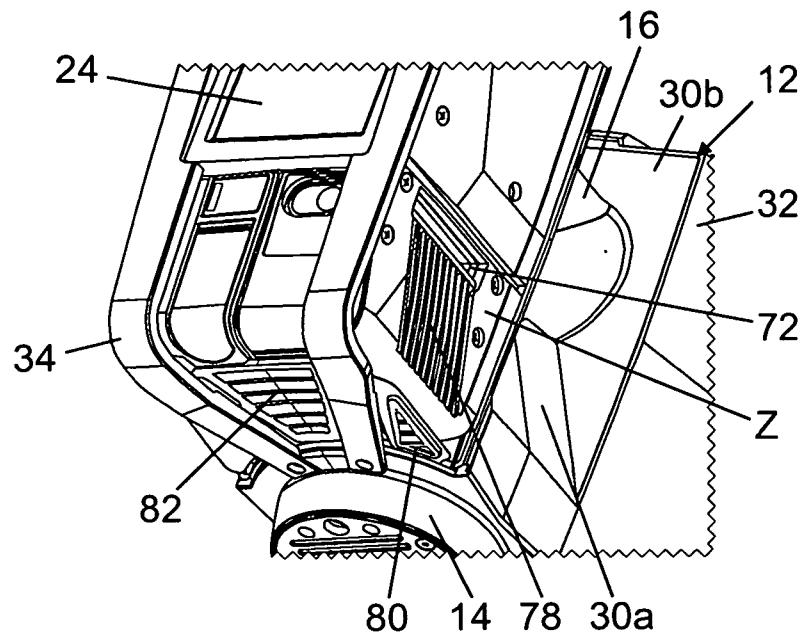


Fig. 5

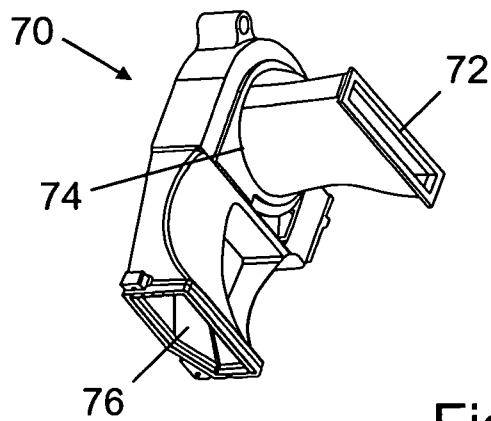


Fig. 6

4/4

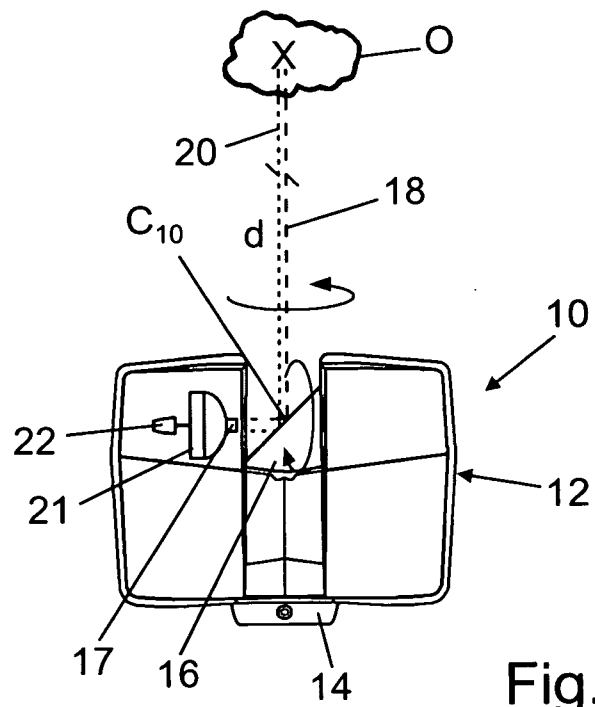


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/003262

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01S7/497 G01S17/89 G02B26/10
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)

G01S G02B

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/141052 A1 (BECKER REINHARD [DE] ET AL) 30 June 2005 (2005-06-30) figure 1 abstract paragraph [0026]	1-10
Y	EP 0 838 696 A1 (PORT CONSTR BUREAU MINI TRANSPORT [JP]; PORT & HARBOUR RES INST MINI T) 29 April 1998 (1998-04-29) abstract column 2, line 20 - line 30	1-10
A	WO 02/084327 A2 (FARO TECH INC [US]) 24 October 2002 (2002-10-24) abstract page 5, line 7 - line 12	1



Further documents are listed in the continuation of Box C.



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