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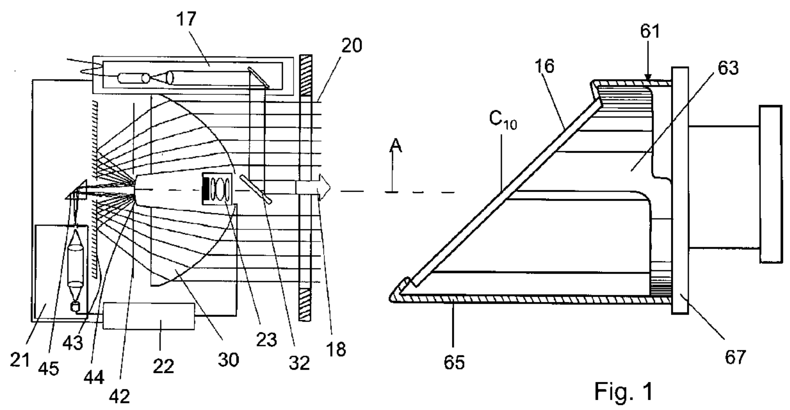

Fig. 1

(57) Abstract: In a device for optically scanning and measuring an environment, which device is designed as a laser scanner (10), with a light emitter (17), which, by means of a rotary mirror (16), emits an emission light beam (18), with a light receiver (21) which receives a reception light beam (20) which, after passing the rotary mirror (16) and a receiver lens (30) which has an optical axis (A), is reflected from an object (O) in the environment of the laser scanner (10) or scattered otherwise, and a control and evaluation unit (22) which, for a multitude of measuring points (X), determines the distance to the object (O), a rear mirror (43) is provided on the optical axis (A) behind the receiver lens (30), which rear mirror reflects towards the receiver lens (30) the reception light beam (20) which is refracted by the receiver lens (30).

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Device for optically scanning and measuring an environment

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

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 rotary mirror which is rotating and which is designed as a polished plate of a metallic rotor, deflects both, emission light beam and reception light beam. The collimator of the light emitter is seated in the center of the receiver lens. The receiver lens reproduces the reception light beam on the light receiver which is arranged on the optical axis behind the receiver lens. For gaining additional information, a line scan camera, which takes RGB signals, is mounted on the laser scanner, so that the measuring points of the scan can be completed by a color information.

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

Due to the fact that a rear mirror, which reflects the reception light beam that has been refracted by the receiver lens towards the receiver lens, is provided on the optical axis behind the receiver lens, the available space can be better utilized. To complete the „folded optics", preferably a central mirror is provided between receiver lens and rear mirror, which central mirror reflects the reception light beam towards the rear mirror. A suitable form of the mirrors supports focusing, wherein the focusing length with respect to the unfolded optics can still be increased. The central mirror can be used for near-field correction, just like an additional mask, by reducing the intensity from the near field compared to the far field. Further savings in space result from an arrangement of the light receiver radial to the optical axis of the receiver lens (in a cylinder-coordinate system which is defined by the optical axis).

The arrangement of a color camera on the optical axis of the receiver lens, with respect to the rotary mirror on the same side, has the advantage of avoiding parallax errors almost completely, since light receiver and color camera take the environment from the same angle of view and with the same side of the rotary mirror. Besides, the same mechanism can be used for the rotary mirror. The used side of the rotary mirror is the same, too. The reception light beam being reflected by the rotary mirror is running in parallel to the optical axis of the receiver lens and continously hitting on said receiver lens. The receiver lens preferably takes the place of the light receiver, so that there is no change of the shadowing effects. In order to be able to feed the emission light beam again, an emission mirror in front of the color camera is preferably provided, which emission mirror is reflecting for the emission light beam and transparent for the color camera.

The design of the rotor as a hybrid structure, i.e. as a multi-element structure from different materials, permits a short design which, despite the inclination of the rotary mirror remains balanced. A combination of a metallic holder, a rotary mirror of coated glass and a plastic housing is preferable, another combination is, however, possible as well. The holder which is dominating with respect to the mass makes balancing possible, while the housing serves as accidental-contact protection. Glue between the rotor components makes balancing of the different temperature coefficients of expansion possible without impairing the dynamic behavior.

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

Fig. 1 shows a partially sectional view of the laser scanner,

Fig. 2 shows a schematic illustration of the laser scanner, and

Fig. 3 shows a perspective illustration of the rotor holder.

A laser scanner 10 is provided as a device for optically scanning and measuring the 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 rotational axes is designated center C_{10} of the laser scanner 10.

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. 340 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 example, 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-waveform 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 is determined and evaluated.

Scanning takes place along a circle by means of the (quick) rotation of the 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. For certain applications it is desirable to have a color information in addition to the gray-tone value. The laser scanner 10 is therefore also provided with a color camera 23 which is connected to the control and evaluation unit 22 as well. The color camera 23 is, for example, designed as a CCD camera or a CMOS camera and provides a signal which is three-dimensional in the color space, preferably an RGB signal, for a two-dimensional picture in the real space. The control and evaluation unit 22 links the scan (which is three-dimensional in real space) of the laser scanner 10 with the colored pictures of the color camera 23 (which are two-dimensional in real space), such process being designated “mapping”. Linking takes place picture by picture for any of the colored pictures which has been taken, in order to give, as a final result, a color (in RGB shares) to each of the measuring points X of the scan, i.e. to color the scan.

In the following, the measuring head 12 is described in details.

The reception light beam 16 which is reflected by the rotary mirror 16 hits on a preferably plano-convex, spherical receiver lens 30 which, in the present invention, has an almost semi-spherical shape. The optical axis A of the receiver lens 30 is orientated towards the center C_{10} of the laser scanner. The convex side of the highly-refractive receiver lens 30 is orientated towards the rotary mirror 16. The color camera 23 is arranged on the same side of the rotary mirror 16 as the receiver lens 30 and on its optical axis A; in the present invention it is arranged on the point of the receiver lens 30 which is closest to the rotary mirror 16. It can be fixed on the (untreated) surface of the receiver lens 30, for example, be glued on it, or be placed in an appropriate recess of the receiver lens 30.

In front of the color camera 23, i.e. closer to the rotary mirror 16, an emission mirror 32 is arranged, which is dichroic, i.e. in the present invention it transmits visible light and reflects (red) laser light. The emission mirror 32 is consequently transparent for the color camera 23, i.e. it offers clear view onto the rotary mirror 16. The emission mirror 32 is at an angle with the optical axis A of the receiver lens 30, so that the light emitter 17 can be arranged at the side of the receiver lens 30. The light emitter 17, comprising a laser diode and a collimator, emits the emission light beam 18 onto the emission mirror 32, from where the emission light beam 18 is then projected onto the rotary mirror 16. For taking the colored pictures, the rotary mirror 16 rotates slowly and step by step, for taking the scan, it rotates quickly (100 cps) and continuously. The mechanism of the rotary mirror 16 remains the same.

Due to the arrangement of the color camera 23 on the optical axis A of the receiver lens 30. there is virtually no parallax between the scan and the colored pictures. Since, in known laser scanners, the light emitter 17 (and its connection) is arranged instead of the color camera 23 (and its connection, for example a flexible printed circuit board), the shadowing effects of the receiver lens 30, due to the color camera 23 (and to the emission mirror 32) do not change or change only insignificantly.

In order to register also remote measuring points X with a big focal length on the one hand and, on the other hand, to require little space, the laser scanner 10 has „folded optics“. For this purpose, a mask 42 is arranged on the optical axis A behind the receiver lens 30, which mask is orientated coaxially to the optical axis A. The mask 42 radially inward (referred to the optical axis A) has a (big) free area, in order to let the reception light beam 20, which is reflected by the remote objects O, pass unimpeded, while the mask 42, radially outward, has (smaller) shaded regions in order to reduce intensity of the reception light beam 20 which is reflected by nearby objects O, so that comparable intensities are available.

A rear mirror 43 is arranged on the optical axis A behind the mask 42, which mirror is plane and perpendicular to the optical axis A. This rear mirror 43 reflects the reception light beam 20 which is refracted by the receiver lens 30 and which hits on the central mirror 44. The central mirror 44 is arranged in the center of the mask 42 on the optical axis A, which is shadowed by the color camera 23 (and the emission mirror 32). The central mirror 44 is an aspherical mirror which acts as both, negative lens, i.e. increases the focal length, and as a near-field-correction lens, i.e. shifts the focus of the reception light beam 20 which is reflected by the nearby objects O. Additionally, a reflection is provided only by such part of the reception light beam 20, which passes the mask 42 which is arranged on the central mirror 44. The central mirror 44 reflects the reception light beam 20 which hits through a central orifice at the rear of the rear mirror 43.

The light receiver 21, comprising an entrance diaphragm, a collimator with filter, a collecting lens and a detector, is arranged at the rear of the rear mirror 43. To save space, preferably a reception mirror 45 is provided, which deflects the reception light beam 20 by 90°, so that the light receiver 21 can be arranged radial to the optical axis A. With the folded optics, the focal length can be approximately doubled with respect to known laser scanners.

The rotary mirror 16 as a two-dimensional structure is part of a rotor 61 which can be turned as a three-dimensional structure by the corresponding rotary drive, and the angle position of which is measured by the assigned encoder. In order to save space also with respect to the rotary mirror 16 due to a short design of the rotor 61 and to keep the rotor 61 balanced, the rotor 61 is designed as hybrid structure, comprising a holder 63, the rotary mirror 16 which is mounted at the holder 63 and a housing 65 made of plastic material, which housing additionally holds the rotary mirror 16.

The metallic holder 63 has a cylindrical basic shape with a 45°-surface and various recesses. Portions of material, for example blades, shoulders and projections, each of which serves for balancing the rotor 61, remain between theses recesses. A central bore serves for mounting the motor shaft of the assigned rotary drive. The rotary mirror 16 is made of glass, which is coated and reflects within the relevant wavelength range. The rotary mirror 16 is fixed at the 45°-surface of the holder 63 by means of glue, for which purpose preferably special attachment surfaces 63b are provided at the holder 63.

The housing 65 made of plastic material has the shape of a hollow cylinder which has been cut below 45° and encloses at least the holder 63. The housing 65 can be glued to the rotary mirror 16 or be fixed otherwise. The housing 65 can clasp the rotary mirror 16 at its periphery - preferably in a form-locking way -, if necessary with the interposition of a rubber sealing or the like. The housing 65 can also be glued to the holder 63 or be otherwise fixed to it directly, or, by the mounting of the rotor 61, it can be connected to the holder 63, for example screwed to it, preferably by means of an end plate 67. The glue used on the one hand must offset the different temperature coefficients of expansion of the materials used and, on the other hand, leave the dynamic behavior unaffected, for example show an elasticity which is not too big, in order to avoid speed-dependent unbalances.

The rotor 61 rotates about the optical axis A. The rotary mirror 16 covers the holder 63 on one of its faces (namely on the 45°-surface). The housing 65 covers the holder 63 radially outside (with respect to the optical axis A). Thus, sharp edges of the holders 63 are covered in order to prevent injuries. The holder 63 is balancing the rotor 61. Instead of metal, the holder 63 may be made of an other heavy material, dominating the moment of inertia. .Instead of plastic, the housing 65 may be made of an other light material, having few influence on the moment of inertia. Instead of coated glass, the rotary mirror 16 may be reflective (and transparent) otherwise. Designed as a hybrid structure, the rotary mirror 16, the holder 63, and the housing 65 are separately formed parts fixed together.

List of Reference Symbols

10	laser scanner
12	measuring head
14	base
16	rotary mirror
17	light emitter
18	emission light beam
20	reception light beam
21	light receiver
22	control and evaluation unit
23	color camera
30	receiver lens
32	emission mirror
42	mask
43	rear mirror
44	central mirror
45	reception mirror
61	rotor
63	holder
63b	attachment surface
65	housing
67	end plate
A	optical axis (of the receiver lens)
C_{10}	center of the laser scanner
d	distance
O	object
X	measuring point

Patent Claims

1. Device for optically scanning and measuring an environment, which device is designed as a laser scanner (10), with a light emitter (17), which, by means of a rotary mirror (16), emits an emission light beam (18), with a light receiver (21) which receives a reception light beam (20), which, after passing the rotary mirror (16) and a receiver lens (30) which has an optical axis (A), 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 a rear mirror (43 is provided on the optical axis (A) behind the receiver lens (30), which rear mirror reflects the reception light beam (20), which has been refracted by the receiver lens (30), towards the receiver lens (30).

2. Device according to Claim 1, characterized in that the rear mirror (43) has a plane design.

3. Device according to Claim 1 or 2, characterized in that a mask (42) is provided on the optical axis (A) between receiver lens (30) and the rear mirror (43), which mask shadows the part of the reception light beam (20) which - relative to the optical axis (A) - is radially outward.

4. Device according to any of the preceding claims, characterized in that a central mirror (44) is provided on the optical axis (A) between receiver lens (30 and rear mirror (43), which central mirror reflects towards the rear mirror (43) the reception light beam (20), which is reflected by the rear mirror (43).

5. Device according to Claims 3 and 4, characterized in that the central mirror (44) is arranged in the center of the mask (42), which is shadowed particularly

by a color camera (23) and/or an emission mirror (32) and/or the light emitter (17) in front of or in the receiver lens (30).

6. Device according to Claims 4 or 5, characterized in that the central mirror (44) is designed aspherically.

7. Device according to any of Claims 4 to 6, characterized in that the reception light beam (20) which is reflected by the central mirror (44) hits though a central orifice of the rear mirror (43).

8. Device according to any of the preceding claims, characterized in that a reception mirror (45) is provided on the optical axis (A) behind the rear mirror (44), which reception mirror (45) deflects the reception light beam (20) and emits?? it onto the light receiver (21).

9. Device according to Claim 8, characterized in that the light receiver (21) is arranged radially to the optical axis (A).

10. Device according to any of the preceding claims, characterized in that a measuring head (12) is provided, which rotates about a vertical axis, and which bears the light emitter (17), the receiver lens (30), the rear mirror (43), the light receiver (21) and the rotary mirror (16), wherein the rotary mirror (16) rotates about the horizontally arranged, optical axis (A).

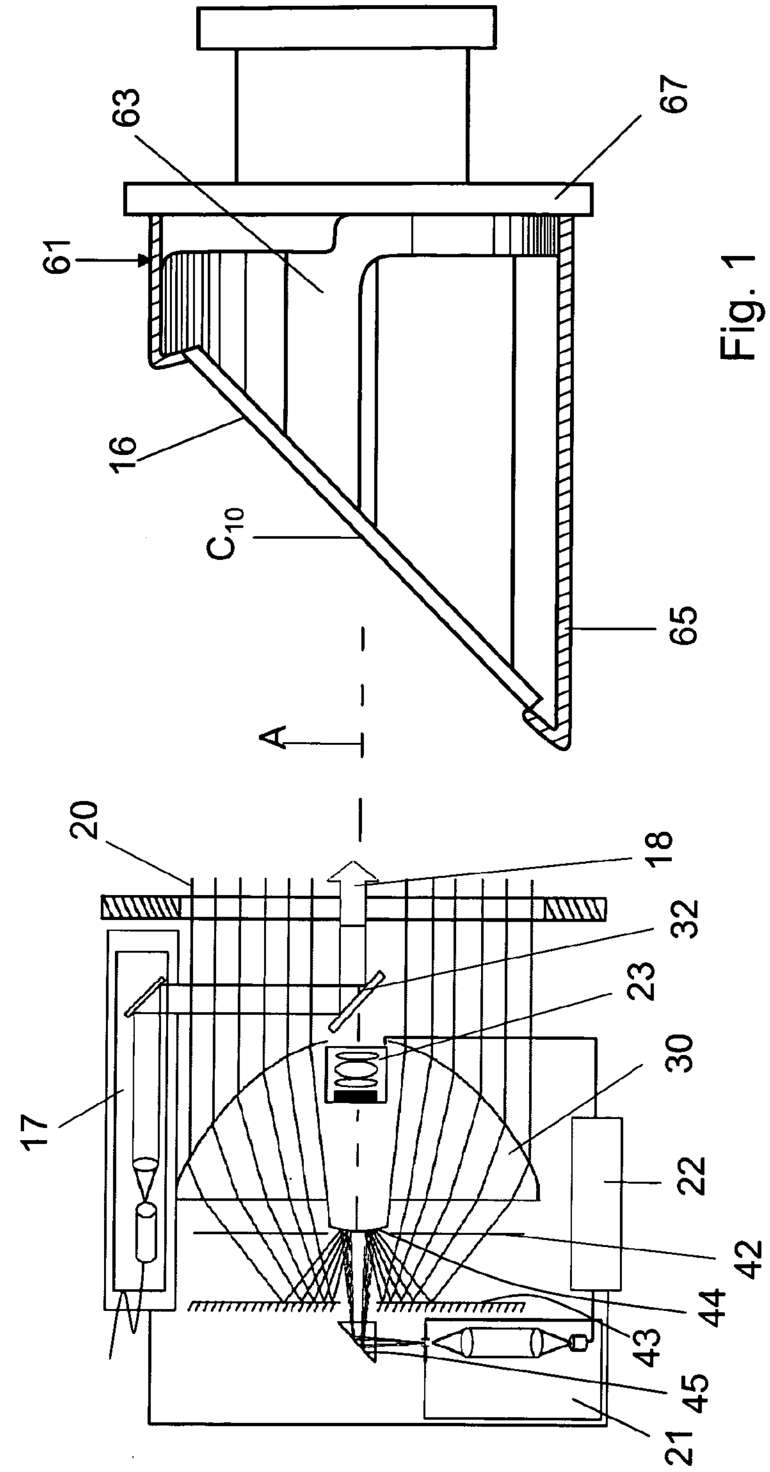

Fig. 1

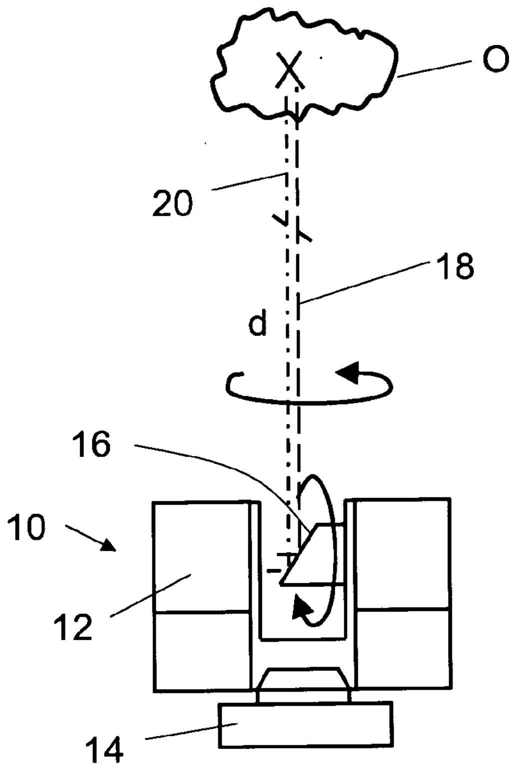

Fig. 2

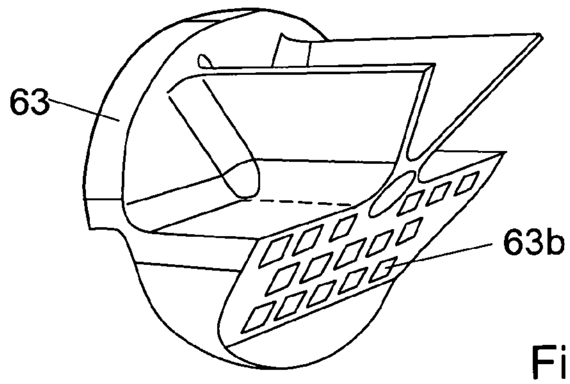

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/006866

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S17/89 G01S7/481
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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 5 329 347 A (WALLACE ROBERT E [US] ET AL) 12 July 1994 (1994-07-12) * abstract; figures 1,2 columns 1-4	1,2,4, 6-10
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
7 March 2011	14/03/2011

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/006866

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 517 297 A (STENTON CONRAD [CA]) 14 May 1996 (1996-05-14) * abstract; figure 1 columns 1-3 -----	1
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2

INTERNATIONAL SEARCH REPORT

Information on patent family members

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