(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 April 2020 (16.04.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/073219 A1

(51) International Patent Classification:
G01C 9/06 (2006.01) *G01D 18/00* (2006.01)
G01C 9/00 (2006.01)

(21) International Application Number:
PCT/CN2018/109608

(22) International Filing Date:
10 October 2018 (10.10.2018)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **TTI (MACAO COMMERCIAL OFFSHORE) LIMITED** [CN/CN]; Units A-c, 26/F Centro Comercial Da Praia Grande No. 429 Avenida Da Praia Grande, Macao (CN).

(72) Inventors: **LOEBIG, Jeffrey Carl**; 29/F, Tower 2, Kowloon Commerce Centre, 51 Kwai Cheong Road, Kwai Chung, Hong Kong (CN). **HO, Man Kit**; 29/F, Tower 2, Kowloon Commerce Centre, 51 Kwai Cheong Road, Kwai Chung, Hong Kong (CN). **ZHANG, Shuai**; No.1, Chuang Ke Road, Houjie Town Industrial Park, Houjie Town, Dongguan City, Guangdong 523945 (CN).

(74) Agent: **RUNPING&PARTNERS**; Suite 515, Yingu Mansion, No.9 Beisihuanxilu, Haidian District, Beijing 100190 (CN).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,

(54) **Title:** Laser Level with Electronic Tilt Sensor

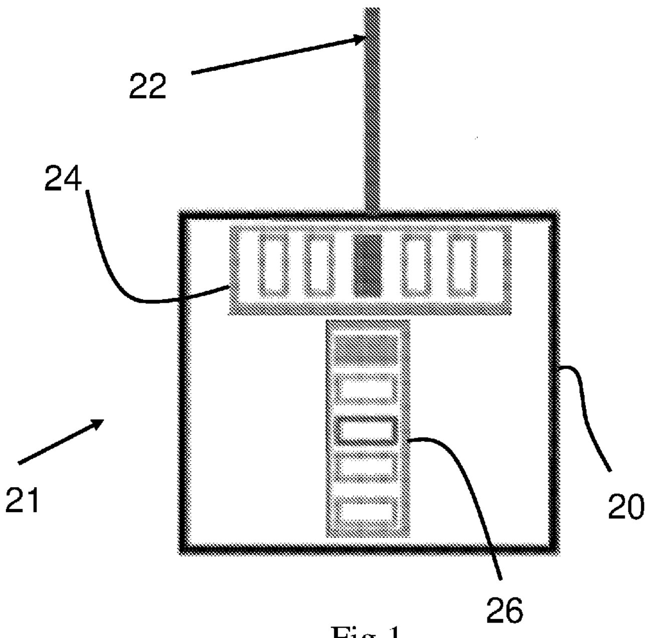

Fig.1

(57) **Abstract:** A laser level (21) containing a housing (20), an electronic tilt sensor (32) located in the housing (20); a controller (30) to which the electronic tilt sensor (32) is connected, and a laser module (36). The controller (30) is communicable with a first display device (24) and a second display device (26). The laser module (36) is adapted to project a straight ground laser line on a flat surface. The electronic tilt sensor (32) is adapted to detect a tilt of the laser level and provide a measurement signal to the controller (30). The controller (30) is adapted to provide a display signal to the first and second display devices (24, 26) to display information about the tilt. By using an electronic tilt sensor (32), the laser level (21) can provide accurate indicate of the tilt of the device and also allows such tilt information to be processed further.

WO 2020/073219 A1

[Continued on next page]

SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Laser Level with Electronic Tilt Sensor

FIELD OF INVENTION

[0001] This invention relates to portable electronic instruments, and in particular to laser-based levels.

BACKGROUND OF INVENTION

[0002] Laser line products are commonly used in construction job sites, and such a laser line product projects at least one straight laser line which is clearly visible so as to provide the user with a reference line. Conventionally, bubble vials are commonly used in laser levels which provide reference to the user visually, so that one can determine whether the laser level (and in turn the laser line emitted therefrom), when pointing upwardly, is deviated from the vertical axis which is perpendicular to the round.

[0003] However, the bubble vials create many problems when they are used in laser levels. For instance, the bubble in the vial is not easy to be inspected and whether it is leveled or not can only be judged by human eyes, which is inaccurate. In addition, during manufacturing of the laser level, one has to align the laser line with the bubble vial level through manual procedures. Such a process takes a long time and the accuracy of the product may shift due to manual assembling processes, gluing processes, etc. Thirdly, the function of the bubble vial is limited, as each bubble vial can only identify one levelness with respect to a vertical axis, not two or more levelness.

SUMMARY OF INVENTION

[0004] In the light of the foregoing background, it is an object of the present invention to provide an alternate laser level which eliminates or at least alleviates the above technical problems.

[0005] The above object is met by the combination of features of the main claim; the sub-claims disclose further advantageous embodiments of the invention.

[0006] One skilled in the art will derive from the following description other objects of the invention. Therefore, the foregoing statements of object are not exhaustive and serve merely to illustrate some of the many objects of the present invention.

[0007] Accordingly, the present invention, in one aspect, is a laser level containing a housing, an electronic tilt sensor located in the housing; a controller to which the electronic tilt sensor is connected, and a laser module. The controller is communicable with a first display device and a second display device. The laser line is adapted to project a straight ground laser line on a flat surface. The electronic tilt sensor is adapted to detect a tilt of the laser level and provide a measurement signal to the controller. The controller is adapted to provide a display signal to the first and second display devices to display information about the tilt.

[0008] Preferably, the first display device and the second display device are mounted on the housing and connected to the controller wirely.

[0009] More preferably, the first and second display devices are configured to display levelness of a tilt angle for the ground laser line with respect to a vertical axis, in two planes respectively.

[0010] Most preferably, the vertical axis is perpendicular to the earth. The two planes are perpendicular to each other, as well as being both perpendicular to the earth.

[0011] According to a variation of the preferred embodiments, the first and second display devices each further contains a plurality of lighting elements. The plurality of lighting elements are adapted to provide a varying light pattern to indicate information about the tilt angle.

[0012] Preferably, the plurality of lighting elements is aligned in a row and contains a middle lighting element and two side lighting elements.

[0013] More preferably, the middle lighting element is configured to be activated when the laser level is at substantially at a predetermined tilt angle. A side lighting element is configured to be activated when the laser level is deviated from the predetermined tilt angle.

[0014] In one particular implementation, the predetermined tilt angles are 0°, 180° or ±90° with respect to a vertical axis.

[0015] According to another variation of the preferred embodiments, the laser level further contains a user switch which is adapted to power on/off of the laser level, and a mode switch which is adapted to switch between a normal measuring mode and an angle-lock mode.

[0016] According to a further variation of the preferred embodiments, the first display device is adapted to indicate a low battery status of the laser level.

[0017] According to a further variation of the preferred embodiments, the laser level is adapted to work in an angle-lock mode in which the controller saves the tilt information into a memory which is connected to the controller.

[0018] Preferably, when the laser level is substantially at a saved tilt angle, only the middle lighting element is configured to be turned on. When the laser level is deviated from the saved tilt angle, only a side lighting element is configured to be turned on.

[0019] According to a further variation of the preferred embodiments, the laser level further contains a wireless module connected to the controller. The first and second display devices are implemented on a screen of a portable computing device.

[0020] Preferably, the wireless module is adapted to transfer the information of the tilt to the portable computing device wirelessly connected with the laser level.

[0021] Accordingly to a second aspect of the invention, there is disclosed a method of calibrating a laser level, which contains the steps of placing a laser module of the laser level on a fixture of which a levelness is known, attaching an electronic tilt sensor module to the laser module, using the electronic tilt sensor module to measure an angle difference between the levelness and a tilt of the electronic tilt sensor module, computing a compensation value for the laser module for the angle difference; and storing the compensation value into a memory of the electronic tilt sensor module.

[0022] Accordingly to a third aspect of the invention, there is disclosed a method of extending a line measurement by a laser level, which contains the steps of placing the laser level in front of a workpiece having a surface, pointing the laser level at a predetermined angle where the laser level emits a laser line along the predetermined angle, marking a physical line on the surface which substantially follows the laser line, saving the predetermined angle into a memory of laser level, moving the laser level to an end of the physical line; and adjusting the laser level to be at the predetermined angle, so that the line measurement is extended.

[0023] Preferably, the predetermined angle is inputted to the laser level through a portable device external to the laser level.

[0024] Accordingly to a fourth aspect of the invention, there is disclosed a method of making a parallel line measurement by a laser level, which contains the steps of placing the laser level in front of a workpiece having a surface, pointing the laser level at a predetermined angle where the laser level emits a laser line along the predetermined angle; marking a physical line on the surface which substantially follows the laser line; saving the predetermined angle into a memory of laser level; moving the laser level in an offset direction from the physical line; and adjusting the laser level to be at the predetermined angle, so that the laser line becomes parallel to the physical line.

[0025] Preferably, the predetermined angle is inputted to the laser level through a portable device external to the laser level.

[0026] Accordingly to a fifth aspect of the invention, there is disclosed a method of measure the height of a target, which contains the steps of measuring the horizontal distance between the target and a reference point, using a laser level to measure a first angle through the reference point to the lower corner at which the target intersects with a ground, transmitting a value of the first angle by the laser level to an external device, saving the value of the first angle in the external device and the laser level, using the laser level measure a second angle though the reference point to the upper corner at which the target intersects with a ceiling, transmitting a value of the second angle by the laser level to the external device, saving the value of the second angle in the external device and the laser level; and calculating the height of target using the following equation:

Height of target = (tan(first angle) + tan(second angle))* distance from the reference point to the target.

[0027] There are many advantages to the present invention. First of all, it is apparent that by replacing bubble vials in traditional laser level with electronic tilt sensors, such as accumulators, gravity sensors or gyrometers, the measurement of the tilt of the laser level becomes much more accurate. The user does not need to rely on their manual inspection of a relative position of the bubble in the tube of a bubble vial, but rather the electronics will do the job. As a result, even if the user's eyes are far away from the laser level, he/she can still easily spot the illumination of the LEDs which indicates the levelness or the amount of any tilt. It also makes it easier to calibrate the laser level in factory so that when the end-user receives the laser level, it is in a read-to-use status with calibrated measurement to ensure a precise reading. The elimination of a bubble vial also increases the durability during accidental fall-over condition, since the electronic components are less vulnerable as compared to a bubble vial.

[0028] The tilt information being digitized also enables it to be stored and reused, which greatly expands the application of the laser level. Just as in two examples described in embodiments of the present invention, the stored angle in the laser level can be used as a basis for second or subsequent measurements, so that an extended laser line can be based on a first marked physical line, or a parallel line can be based on the first marked physical line. There are many other possibilities of using the laser level to conduct complex measurement and alignment in indoor environments, which adds to the flexibility of the use of the laser level. For example, the measured tilt condition of the laser level can be transmitted wirelessly to an external computing device to process the data further.

BRIEF DESCRIPTION OF FIGURES

[0029] The foregoing and further features of the present invention will be apparent from the following description of preferred embodiments which are provided by way of example only in connection with the accompanying figures, of which:

[0030] Fig. 1 shows the appearance of a laser level according to a first embodiment of the present invention.

[0031] Fig. 2 shows separately the two indication modules of the laser level in Fig. 1.

[0032] Fig. 3 is the internal schematic diagram of components of the laser level in Fig. 1.

[0033] Fig. 4a illustrates a laser level placed on a table according to another embodiment of the present invention.

[0034] Fig. 4b illustrates the laser level of Fig. 4a which is now pressed against a wall and the laser beam pointing upwardly.

[0035] Fig. 4c illustrates the laser level of Fig. 4a which is now pressed against a wall and the laser beam pointing horizontally.

[0036] Fig. 5 illustrates different orientations of a laser level in an angle lock mode according to another embodiment of the present invention.

[0037] Figs. 6a-6c are illustrations showing the method of extending a laser line measurement according to another embodiment of the invention.

[0038] Fig. 7a-7c are illustrations showing the method of making a parallel line measurement by a laser level according to another embodiment of the invention.

[0039] Fig. 8 is a flowchart showing procedures for calibrating a laser level according to another embodiment of the invention.

[0040] Fig. 9 shows a laser level system including a laser level and a portable computing device according to another embodiment of the invention.

[0041] Fig. 10 shows how a laser level can be used to measure the height of a wall according to another embodiment of the present invention.

[0042] In the drawings, like numerals indicate like parts throughout the several embodiments described herein.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0043] In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word “comprise” or variations such as “comprises” or “comprising” is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

[0044] As used herein and in the claims, “couple” or “connect” refers to electrical coupling or connection either directly or indirectly via one or more electrical means unless otherwise stated.

[0045] Terms such as “horizontal”, “vertical”, “upwards”, “ downwards”, “above”, “below” and similar terms as used herein are for the purpose of describing the invention in its normal in-use orientation and are not intended to limit the invention to any particular orientation.

[0046] Referring now to Fig. 1, the first embodiment of the present invention is a laser level **21** which is suitable for a user to hold with his/her hand and which requires no wire connection to other devices. The laser level **21** contains a housing **20**, and first and second indication (for example LED or LCD) modules **24**, **26** configured on the housing **20**. Inside the housing **20** there are various components such as a battery, an electronic tilt sensor, a controller, a memory, and a laser module, all of which are not shown in Fig. 1. Nonetheless, Fig. 1 shows a laser line **22** as emitted by the laser module in the laser level **21**. The laser level **21** also contains a power switch (not shown) for controlling the power on/off of the laser level **21**, as well as a mode switch (not shown) for changing the working mode of the laser level **21**. Each of the first and second indication modules **24**, **26** contains five LEDs placed in a row, as will be described in more details later.

[0047] Turning now to Fig. 2, the first indication module **24** contains five LEDs **24a**, **24b**, **24c**, **24d** and **24e** as lighting elements, which are aligned in a row. Among them, LED **24c** is located in the middle of the row and is also referred to as a middle LED or a middle lighting element. The other LEDs **24a**, **24b**, **24d** and **24e** are located evenly on two sides of the LED **24c** and LEDs **24a**, **24b**, **24d** and **24e** are also referred to as side lighting elements. Similarly, the second indication module **26** contains five LEDs **26a**, **26b**, **26c**, **26d** and **26e** as lighting elements, which are aligned in a row. Among them, LED **26c** is located in the middle of the row and is also referred to as a middle lighting element. The other LEDs **26a**, **26b**, **26d** and **26e** are located evenly on two sides of the LED **26c** and LEDs **26a**, **26b**, **26d** and **26e** are also referred to as side lighting elements. Note that the first indication module **24** and the second indication module **26** are oriented to be perpendicular to each other on a same side of the housing **20** of the laser level **21**. The LEDs in each of the first indication module **24** and the second indication module **26** can be either mono-color LEDs (i.e. each LED displays only one color of light) or multi-color LEDs (i.e. each LED displays more than one color of light). However, it is preferable that the five LEDs in each of the first indication module **24** and the second indication module **26** are of the same type.

[0048] Referring now to Fig. 3, the internal block diagram of the laser level **21** in Fig. 1 is shown. The laser level **21** contains a controller **30** as the central processing unit of the laser level **21**. The controller **30** is connected to various components including the first indication module **24**, the second indication module **26**, an electronic tilt sensor **32**, the laser module **36**, a mode switch **28** and a power switch **38**. In particular, the first indication module **24** and the second indication module **26** are connected wirely to the controller **30**. The electronic tilt sensor **32** can be an accumulator, a gravity sensor or a gyrometer. The electronic tilt sensor **32** is configured to measure a tilt of the laser level **21** (as the electronic tilt sensor **32** is fixed to the housing of the laser level, and to transmit measurement signals representing the tilt to the controller **30**. It should be noted that in this embodiment although single electronic tilt sensor **32** is configured to measure the tilt condition of the laser level, two separate display modules which are the first and second indication modules **24**, **26** are used to present the tilt angles in different planes. The first and second indication modules **24**, **26** are connected to the controller **30** and they are adapted to be driven by the controller **30** to display information about tilt angles measured by the electronic tilt sensor **32**, based on display signals sent from the controller **30**. The laser module **36** as mentioned is adapted to project a straight laser line on a surface for the user to inspect and use as a reference for measurement / marking. The laser module **36** for example is able to output a ground laser line which uses a lens to spread the laser in a waterfall manner. Alternatively, the laser module **36** is able to output a line laser which has a fan shape and which is able to project a straight laser line on the wall. The controller **30** is further connected to a memory **40** which is adapted to temporarily or permanently store data of the tilt angle for the laser level **21**. All the components described above are connected to the internal battery (not shown) of the laser level **21** in order for these components to properly function.

[0049] Now turning to the operation of the device described above. The laser level **21** described and illustrated in Figs. 1-3 is capable of detecting a tilt of the laser level **21** and presents such tilt condition to the user in two different planes at the same time. In use, the user powers on the laser level **21** by pressing once the power switch **38** in Fig. 2. The laser level **21** then enters a normal working mode, and the electronic tilt sensor **32** immediately starts to measure any tilt of the laser level **21**, and send measurement signals representing such tilt to the controller **30**. The controller **30** then converts the received measurement signals to display signals suitable for driving the first and second indication modules **24**, **26** respectively. The conversion may take into consideration of any compensation value stored in the memory **40** of the laser level **21**. Then, the first and second indication modules **24**, **26** would display, each by their five LEDs, a real-time tilt condition with regards to the tilt angles in the respective planes respectively. In the normal working mode, the angle of 0° can be considered as a predetermined angle since the angle of 0° indicates a levelness of the laser level **21**.

[0050] It should be noted that although the electronic tilt sensor **32** is able to measure an accurate value of the tilt angle, with the laser level in Figs. 1-3 it is not possible to display the actual tilt angle value. Rather, the five LEDs in each one of the first and second indication modules **24**, **26** will be selectively turned on, according to the different ranges in which the titling angle value falls into. Table 1 below shows such angles ranges according to the time of display by each of the LEDs in a row in the first indication module **24** or the second indication module **26**. There is no overlap in the angle ranges so in this normal mode there will be no two of LEDs in a row to be turned on at the same time. For example, when the middle LED is turned on, it means that the respective levelness as indicated by the first indication module **24** or the second indication module **26** is substantially achieved. When the leftmost LED is on, it means that the laser level is at an angle difference of $+0.75^{O}$ to $+1^{O}$ as compared to levelness. For the convenience of description, the five LEDs are designated by #1 to #5 in Table 1 respectively, which correspond respectively to five LEDs **24a**, **24b**, **24c**, **24d** and **24e** in the first indication module **24**, or respectively to five LEDs **26a**, **26b**, **26c**, **26d** and **26e** in the second indication module **26**.

LED	**#1**	**#2**	**#3**	**#4**	**#5**
Angle (degree)	$+0.76^{O}$ to $+1^{O}$	$+0.26^{O}$ to $+0.75^{O}$	+/- 0.25^{O}	-0.26^{O} to -0.75^{O}	-0.76^{O} to -1^{O}

Table 1

[0051] The above-mentioned power switch **38** has another function that by pressing the power switch **38** within 0.5 seconds, and once, it makes the laser level **21** to power off. On the other hand, the mode switch **28** is used to make the laser level **21** entering an angle-lock mode which is different from the normal working mode. The angle lock mode is entered by pressing down the mode switch **28** while the laser level **21** is in the normal working mode.

[0052] In addition to displays under the above normal working mode and angle lock mode, the first indication module **24** or the second indication module **26** may also automatically enters a low battery status mode. Table 2 below shows how the LEDs will behave when the battery voltage of the battery in the laser level is at different levels. For example, if the battery voltage is detected to be smaller than 1.9V, then this indicates a "no battery" status, and the LEDs (all LEDs of the first indication module **24** or the second indication module **26**) will blink 3 times and then the laser level will switch off.

Voltage level	**Level defined**	**After Power on:**	**Operation**
2.2V < V battery	Battery full	Normal operation	Normal operation
1.8V < V battery < 2.3V	Low battery	LED blink 3 times; then entering Normal operation	Normal operation
V battery <1.9V	No battery	LED blink 3 times then Switch off	Switch off

Table 2

[0053] Figs. 4a-4c show a laser level **121** which is slightly different from the laser level shown in Figs. 1-3 in appearance of the device, but their functions are substantially the same. The laser level **121** is capable of detecting a tilt condition of the laser level **121** with regards to a vertical axis. The vertical axis is defined as an axis which is parallel to the direction of gravity and which is perpendicular to the earth. As mentioned above, the laser level **21** uses two indication modules **124**, **126** to display the tilt angles in two different planes. The two planes are perpendicular to each other, but are both perpendicular in the earth.

[0054] Fig. 4a shows a scenario where the laser level **121** is laid down on a table which has a surface **142**. The table surface **142** is parallel to the earth, but a vertical axis **144** is perpendicular to the table surface **142**. In this case, the middle LED (not shown) which is the middle lighting element of both of the two indication modules **124**, **126** should be activated and illuminating a light. In the three-dimensional coordinate system XYZ defined by the laser level **121**, the activation of the middle LED in a first indication module **124** means that there is no tilt of the laser level **121** in the XZ plane with respect to the vertical axis **144** as shown in Fig. 4a, so the tilt angle in the XZ plane now equals to zero. In addition, the activation of the middle LED in a second indication module **126** means that there is no tilt of the laser level **121** in the YZ plane with respect to the vertical axis **144** as shown in Fig. 4a, so the tilt angle in the YZ plane now equals to zero. Lastly, there is no indication of any rotation or orientation of the laser level **121** in the XY plane, which is the horizontal plane in Fig. 4a. In Fig. 4a, the laser level is able to indicate the tilt in two planes XZ and YZ, where both XZ and YZ planes are perpendicular to the earth and being perpendicular to each other.

[0055] It should be noted that in Fig. 4a, both the first and second indication modules **124**, **126** indicating a zero tilt angle is due to the fact that the table surface **142** is horizontal and parallel to the earth. If the table surface **142** is not perfectly horizontal, but somehow inclined from the horizontal plane, then such inclination will be detected and shown by one or both of the first and second indication modules **124**, **126**. For the laser level **121** it is not possible to display the actual tilt angle value. Rather, the five LEDs in the first indication module **124** or the second indication module **126** will be selectively turned on, according to the different ranges in which the titling angle value falls into, similar to those mentioned above with respect to Table 1.

[0056] In Fig. 4b, the laser level **121** is aligned to a wall surface **146**, for example by pressing the laser level **121** against the wall surface **146** to ensure that a back side of the laser level **121** abuts the wall surface **146**. In this case, the first indication module **124** functions to indicate a tilt in the XY plane. When there is substantially not tilt of the laser level **121** with respect to the vertical axis **144** in the XY plane, then a middle LED (not shown) which is the middle lighting element of the first indication module **124** should be activated and illuminating a light, indicating that the laser level **121** achieves a substantial levelness. However, when there is in fact a tilt of the laser level **121** in the XY plane in Fig. 4b, then instead of the middle LED, one of the four side LEDs (not shown) will be activated to indicate the degree of tile according to Table 1 above. However, in the case of Fig. 4b, the second indication module **126** will always indicate a levelness (i.e. zero-degree tilt angle) by having its middle LED turned on, since the laser level **121** abuts the wall surface **146** so presumably there is no tilt in the YZ plane. In the case of Fig. 4b, the laser beam **122** emitted by the laser level **121** points upwardly substantially if the middle LED of the first indication module **124** is activated.

[0057] In Fig. 4c, the laser level **121** is again aligned to the wall surface **146**, but its orientation is different from that in Fig. 4b. In particular, the laser beam **122** emitted by the laser level **121** now points substantially to a horizontal direction. The laser level **121** is again pressed against the wall surface **146** to ensure that the back side of the laser level **121** abuts the wall surface **146**. In the case shown in Fig. 4c, the second indication module **126** functions to indicate a tilt in the XY plane, not the first indication module **124** as in Fig. 4b. When there is substantially not tilt of the laser level **121** with respect to the vertical axis **144** in the XY plane, then a middle LED (not shown) which is the middle lighting element of the second indication module **126** should be activated and illuminating a light, indicating that the laser level **121** achieves a substantial levelness. However, when there is in fact a tilt of the laser level **121** in the XY plane in Fig. 4c, then instead of the middle LED of the second indication module **126**, one of the four side LEDs (not shown) will be activated to indicate the degree of tile according to Table 1 above. However, in the case of Fig. 4c, the first indication module **124** will always indicate a levelness by having its middle LED turned on, since the laser level **121** abuts the wall surface **146** so presumably there is no tilt in the XZ plane.

[0058] Turning now to Fig. 5, which illustrated how a laser level **221** can be used to conduct an angle-lock operation. The laser level **221** has functions similar as the laser level described with reference to Figs. 1-3, and for example the laser level **221** can enter the angle-lock mode by pressing a mode switch as described above. Immediately upon entering into the angle lock mode, the previous tilt data detected by the electronic tilt sensor is saved in the memory (both not shown in Fig. 5) of the laser level **221**. In the angle-lock mode, the second indication module (not shown) which has a row of LEDs aligned along a direction parallel to the laser beam **248** is always on (with its all five LEDs **26a**-**26e** activated) to indicate to the user of the angle-lock mode. On the other hand, the five LEDs of the first indication module (not shown) which has a row of LEDs aligned along a direction parallel to the laser beam **248** be turned on according to different tilt angle measured by the electronic tilt sensor, as will be described in more details later. However, the angle lock mode can only be entered when the laser level **221** is aligned against a vertical wall surface, as shown in Fig. 5 as well in Figs. 4b and 4c. In other words, the laser level **221** is not allowed to enter angle-lock mode when the tilt detected by the electronic tilt sensor **32** is less than +/- 5° in any plane (such as the case shown in Fig. 4a), in which case the laser level **221** automatically goes back to the normal working mode.

[0059] Fig. 5 shows an example in which different orientations of the laser level **221** leads to different indication produced by the laser level **221** in the angle-lock mode. Among them, assume Position **221b** is the position in which the laser level **221** is at a desired angle in the plane parallel to the wall surface **242**. When the detected tilt angle is less than the predetermined angle (that is, the saved angle value in the memory of the laser level **221**), which is indicated by Position **221a**, the five LEDs in each one of the first indication modules **24**, **26** will be selectively turned on, according to the different ranges in which the titling angle value the predetermined angle falls into. Table 3 below shows such angles ranges according to the time of display by each of the LEDs in a row in the first indication module **24**. There is no overlap in the angle ranges so in this normal mode there will be no two of LEDs in a row to be turned on at the same time. For example, when the middle LED is turned on, it means that the respective levelness as indicated by the first indication module **24** is substantially achieved. When the leftmost LED is on, it means that the laser level is at an angle difference of $+0.75^{O}$ to $+1^{O}$ as compared to levelness. For the convenience of description, the five LEDs are designated by #1 to #5 in Table 3 respectively, which correspond respectively to five LEDs **24a**, **24b**, **24c**, **24d** and **24e** in the first indication module **24**.

LED	#1	#2	#3	#4	#5
Angle (degree)	$+0.76^{O}$ to $+1^{O}$	$+0.26^{O}$ to $+0.75^{O}$	$+/- 0.5^{O}$	-0.26^{O} to -0.75^{O}	-0.76^{O} to -1^{O}

Table 3

[0060] Table 4 below shows that only when the angle difference is $+/- 0.5^{O}$ with respect to the predetermined angle, will the middle LED be turned on. Position **221b** in Fig. 5 is illustrated as the position in which the detected tilt angle is equal to the predetermined angle.

Angle	#3
Indication (First indication module)	$+/- 0.5^{O}$

Table 4

[0061] Now turning to Figs. 6a-6c, an application of a laser level using the angle lock mode, according to an embodiment, will now be described. In Fig. 6a, a laser level **321** is firstly placed in front of a workpiece having a surface (not shown). Here, "in front" means that the laser level **321** approximates or contacts the surface, so that a laser line **322** emitted by the laser level **321** is substantially parallel to the surface. Then, the laser level **321** is moved or rotated by the user as necessary so that the laser level **321** is at a desired angle and is placed at a desired location on the surface. Then, along the laser line **322** the user marks (using a pen, a paint, carving, or any other physical means) a physical line **302** on the surface of the workpiece, as shown in Fig. 6b. The laser level **321** is then switched to an angle lock mode similar to the one described above, in which the desired angle is stored in memory of the laser level **321**. The desired angle is also called the predetermined angle in this embodiment. The user then moves the laser level **321** to a place near the end of the physical line **302**, and carefully adjusts the angle of the laser level **321** until it is at the predetermined angle, the determination of which is similar to the described operation in the angle lock mode above. Now as the laser line **322** has substantially the same angle as the physical line **302** on the surface, the laser line **322** appears as an extension of the physical line **302**, and the measurement by the laser level **321** is now extended, as shown in Fig. 6c.

[0062] Now turning to Figs. 7a-7c, another application of a laser level using the angle lock mode, according to an embodiment, will now be described. In Fig. 7a, a laser level **421** is firstly placed in front of a workpiece having a surface (not shown). Here, "in front" means that the laser level **421** approximates or contacts the surface, so that a laser line **222** emitted by the laser level **421** is substantially parallel to the surface. Then, the laser level **421** is moved or rotated by the user as necessary so that the laser level **421** is at a desired angle and is placed at a desired location on the surface. Then, along the laser line **422** the user marks (using a pen, a paint, carving, or any other physical means) a physical line **402** on the surface of the workpiece, as shown in Fig. 7b. The laser level **421** is then switched to an angle lock mode similar to the one described above, in which the desired angle is stored in memory of the laser level **421**. The desired angle is also called the predetermined angle in this embodiment. The user then moves the laser level **421** along a direction offset from the length direction of the physical line **402** to a new location, and then rotates the laser level **421** so that it becomes at the predetermined angle. Then, the user can mark a new physical line along with the laser line **222** at a new location. Fig. 7c shows a new physical line **403** generated through the above procedures. Fig. 7c also shows that the laser level **421** is moved to a further away location and is ready to be referenced for marking a new physical line.

[0063] Turning now to Fig. 8, which shows a calibration method for a laser level in factory according to an embodiment of the present invention. Firstly, in Step **504** a laser module as a part of the laser level is placed on a fixture of which a levelness is known. The fixture for example can be a desktop or a wall which has exactly the 0° inclination or 90° inclination. The fixture is required in this way as only with a known tilt angle can the calibration of the electronic tilt sensor be made. Next, in Step **506**, an electronic tilt sensor module is connected to the laser module. It should be noted that by saying an electronic tilt sensor module it includes a controller, a memory, and the electronic tilt sensor similar to those mentioned previously. Next, in Step **508**, the electronic tilt sensor module is activated to measure an angle difference between the levelness (either horizontal or vertical) and a tilt of the electronic tilt sensor module. Such a difference exists because when the laser module is placed on the fixture, and when the electronic tilt sensor module is placed on the laser module, the two modules cannot be perfectly aligned with the surface of the fixture. Next, in Step **510** the angle difference is used to calculate a compensation value for the laser module, and in Step **512** the compensation value is stored in the memory of the electronic tilt sensor module so that it can be used in the future. With such calibration done, when the end user received the laser level, every time the laser level is powered up, then the controller will get the compensated value from the memory, measures the tilt angle read out from the electronic tilt sensor(s), and then calculates the actual tilt information based on the compensation value and displays the actual tilt information.

[0064] Turning to Fig. 9, which shows a laser level **621** communicable wirelessly with an external device **650** according to another embodiment of the present invention. The external device **650** is a portable computing device which for example is a laptop computer, a tablet, a mobile phone, a Personal Digital Assistant (PDA), or other computing devices. The laser level **621** is equipped with a wireless transceiver (e.g. Bluetooth module, not shown)) which allows the laser level **621** to communicate with the external device **650** which also contains a compatible wireless transceiver. In cooperation with the external device **650**, the laser level **621** can implement further functions. Firstly, the tilt data measured by the electronic tilt sensor in the laser level **621** could be transmitted to the external device **650** in digital format, so that the latter could precisely display the exact angle value on a screen of the external device **650**, as compared to the relative "rough" display of the tilt condition by a laser level which only has a few LEDs. The above processes are performed by a dedicated software apps installed on the external device **650**. Nonetheless, the laser level with LEDs is no doubt more convenient for use by the user than having to use an external device. The external device **650** can also send commands to the laser level **621** through the wireless interface. For example, the external device **650** can control the laser level **621** to switch between a normal working mode and an angle-lock mode. The external device **650** may also be used as an input device for inputting for example a predetermined angle value for the angle-lock mode.

[0065] Fig. 10 shows an example of application that the external device **650** and the laser level **621** could be suited for. The external device **650** and the laser level **621** are used for calculating the height **652** of a wall **642** of an interior space. The method of calculation is explained as follows. Firstly, the user sets a reference point **658** (not shown)which is separated from the wall **642.** There is no requirement on the position of the reference point **658** as the distance **654** between the reference point **658** and the wall **642** will be measured later. Then, the user measures, using the laser level **621**, a first angle **656** though the reference point **658** to the lower corner at which the wall **642** intersects with a ground **660**. The value of the first angle **656** is transmitted by the laser level **621** to the external device **650** and is saved in the external device **650** and the laser level **621**. Preferably, the screen of the external device **650** also displays in real-time the value of the first angle **656**. Next, the user measures, using the laser level **621**, a second angle **662** though the reference point **658** to the upper corner at which the wall **642** intersects with a ceiling **664**. The value of the first angle **662** is transmitted by the laser level **621** to the external device **650** and is saved in the external device **650** and the laser level **621**. Preferably, the screen of the external device **650** also displays in real-time the value of the second angle **662**. Subsequently, the user measures the distance **654** for example by using a laser distance measuring device (not shown), or by a ruler. In the final step, the user then calculate the height **652** of the wall **642** using the equation:

Height of the wall = (tan(first angle) + tan(second angle))* distance from the reference point to the wall [1]

[0066] The calculation using Eq. [1] can be done by the user, or can be done automatically by the software apps installed in the external device **650**. The exact value of the height **652** is then displayed to the user on the screen of the external device **650**.

[0067] The exemplary embodiments of the present invention are thus fully described. Although the description referred to particular embodiments, it will be clear to one skilled in the art that the present invention may be practiced with variation of these specific details. Hence this invention should not be construed as limited to the embodiments set forth herein.

[0068] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only exemplary embodiments have been shown and described and do not limit the scope of the invention in any manner. It can be appreciated that any of the features described herein may be used with any embodiment. The illustrative embodiments are not exclusive of each other or of other embodiments not recited herein. Accordingly, the invention also provides embodiments that comprise combinations of one or more of the illustrative embodiments described above. Modifications and variations of the invention as herein set forth can be made without departing from the spirit and scope thereof, and, therefore, only such limitations should be imposed as are indicated by the appended claims.

[0069] For example, in the laser level shown in Figs. 1-3, there are two electronic tilt sensor and two indication modules respectively. However, the number of the electronic tilt sensor and that of the indication module is not limited. Rather, according to application requirements, there can be more or less electronic tilt sensors, and/or indication module, on a single laser level.

[0070] Similarly, although the above embodiment shows five LEDs in an indication module, more or less LEDs can be configured in an indication module without departing from the essence of this invention. More LEDs for example may increase the resolution of the tilt angle that the laser level may display.

[0071] The above embodiment shows five LED in a row (i.e. along a straight line). However, in other variants of the invention the LEDs may also be aligned along different directions, such as along a curve, or along a bent line. Any geometrical alignment of the plurality of LEDs is possible if there is a need. Lastly, the above embodiment described various display patterns of LEDs in an indication module, for example the running pattern or a “floating” pattern (which corresponds to the normal working mode as described for Fig. 3). However, such implementations should not be viewed as limits to the present invention, as other dynamic effects exhibited by indication module can also be adopted to indicate the tilt angle.

[0072] The display modules configured on the laser level as described above are Indication module with multiple LEDs aligned in a row. However, those skilled in the art should realize that other types of display device could also be used for the laser level, for example LCD device.

[0073] In addition, although in the embodiments described above the user is informed of the tilt angle (at least roughly) by the illumination pattern displayed by the LEDs. However, in other variations of the invention different types of user notification can be utilized, such as audiable alert.

CLAIMS

What is claimed is:

1. A laser level comprising
   a) a housing,
   b) an electronic tilt sensor located in the housing;
   c) a controller to which the electronic tilt sensor is connected; the controller communicable with a first display device and a second display device; and
   d) a laser module which is adapted to project a straight ground laser line on a flat surface;

   wherein the electronic tilt sensor is adapted to detect a tilt of the laser level, and provide a measurement signal to the controller; the controller adapted to provide a display signal to the first and second display devices to display information about the tilt.
2. The laser level according to claim 1, wherein the first and second display devices are mounted on the housing and connected to the controller wirely.
3. The laser level according to claim 2, the first and second display devices are configured to display levelness of a tilt angle for the ground laser line with respect to a vertical axis, in two planes respectively.
4. The laser level according to claim 3, wherein the vertical axis is perpendicular to the earth; the two planes being perpendicular to each other, as well as being both perpendicular to the earth.
5. The laser level according to claim 1, wherein the first and second display devices each further comprises a plurality of lighting elements; the plurality of lighting elements adapted to provide a varying light pattern to indicate information about the tilt angle.
6. The laser level according to claim 5, wherein the plurality of lighting elements is aligned in a row and comprises a middle lighting element and two side lighting elements.
7. The laser level according to claim 6, wherein the middle lighting element is configured to be activated when the laser level is at substantially at a predetermined

tilt angle; one said side lighting elements configured to be activated when the laser level is deviated from the predetermined tilt angle.

8. The laser level according to claim 7; wherein the predetermined tilt angles are 0°, 180° or ±90° with respect to a vertical axis.
9. The laser level according to claim 1, further comprises a user switch which is adapted to power on/off of the laser level, and a mode switch which is adapted to switch between a normal measuring mode and an angle-lock mode.
10. The laser level according to claim 1, wherein the first display device is adapted to indicate a low battery status of the laser level.
11. The laser level according to claim 6, wherein the laser level is adapted to work in an angle-lock mode in which the controller saves the tilt information into a memory which is connected to the controller.
12. The laser level according to claim 11, wherein when the laser level is substantially at a saved tilt angle, only the middle lighting element is configured to be turned on; when the laser level is deviated from the saved tilt angle, only a side lighting element configured to be turned on.
13. The laser level according to claim 1, further comprises a wireless module connected to the controller; the first and second display devices being implemented on a screen of a portable computing device.
14. The laser level according to claim 13, wherein the wireless module is adapted to transfer the information of the tilt to the portable computing device wirelessly connected with the laser level.
15. A method of calibrating a laser level, comprising:
    a) placing a laser module of the laser level on a fixture of which a levelness is known;
    b) attaching an electronic tilt sensor module to the laser module;
    c) using the electronic tilt sensor module to measure an angle difference between the levelness and a tilt of the electronic tilt sensor module;
    d) computing a compensation value for the laser module for the angle difference; and
    e) storing the compensation value into a memory of the electronic tilt sensor module.

16. A method of extending a line measurement by a laser level, comprising:
    a) placing the laser level in front of a workpiece having a surface;
    b) pointing the laser level at a predetermined angle; the laser level emitting a laser line along the predetermined angle; marking a physical line on the surface which substantially follows the laser line;
    c) saving the predetermined angle into a memory of laser level;
    d) moving the laser level to an end of the physical line; and
    e) adjusting the laser level to be at the predetermined angle, so that the line measurement is extended.
17. The method of claim 16, wherein the predetermined angle is inputted to the laser level through a portable device external to the laser level.
18. A method of making a parallel line measurement by a laser level, comprising:
    a) placing the laser level in front of a workpiece having a surface;
    b) pointing the laser level at a predetermined angle; the laser level emitting a laser line along the predetermined angle;
    c) marking a physical line on the surface which substantially follows the laser line;
    d) saving the predetermined angle into a memory of laser level;
    e) moving the laser level in an offset direction from the physical line; and
    f) adjusting the laser level to be at the predetermined angle, so that the laser line becomes parallel to the physical line.
19. The method of claim 18, wherein the predetermined angle is inputted to the laser level through a portable device external to the laser level.
20. A method of measure the height of a target, comprising the steps:
    a) measuring the horizontal distance between the target and a reference point;
    b) using a laser level to measure a first angle through the reference point to the lower corner at which the target intersects with a ground;
    c) transmitting a value of the first angle by the laser level to an external device;
    d) saving the value of the first angle in the external device and the laser level;
    e) using the laser level measure a second angle though the reference point to the upper corner at which the target intersects with a ceiling;
    f) transmitting a value of the second angle by the laser level to the external device;

g) saving the value of the second angle in the external device and the laser level; and

h) calculating the height of target using the following equation:

Height of target = (tan(first angle) + tan(second angle))* distance from the reference point to the target.

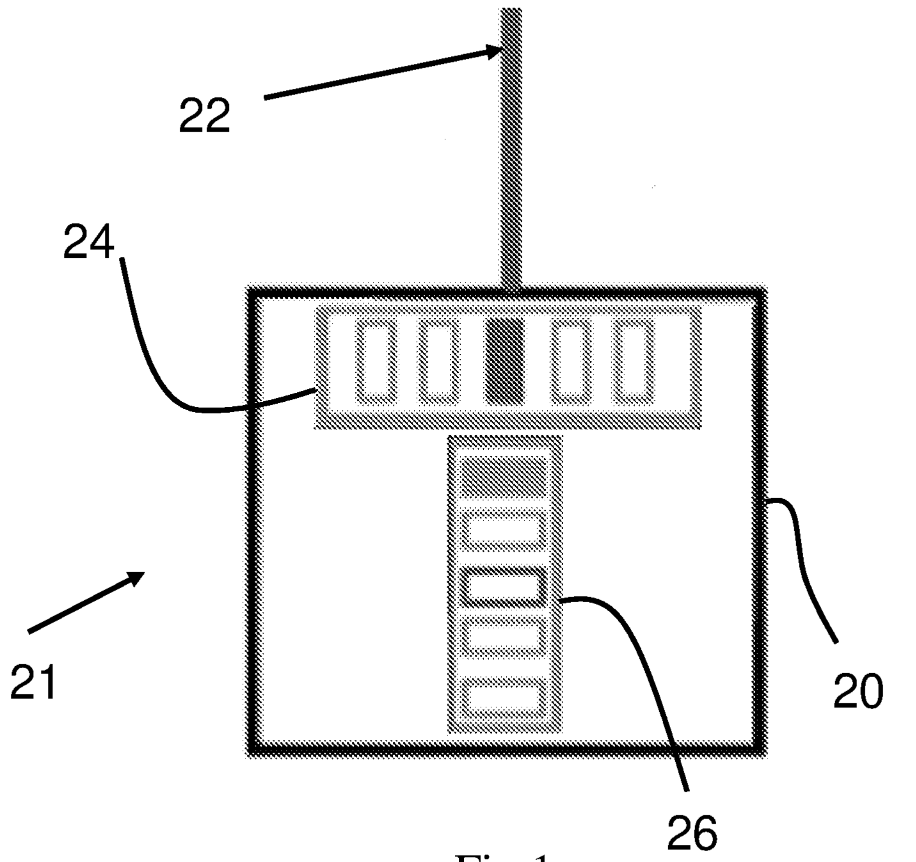

Fig.1

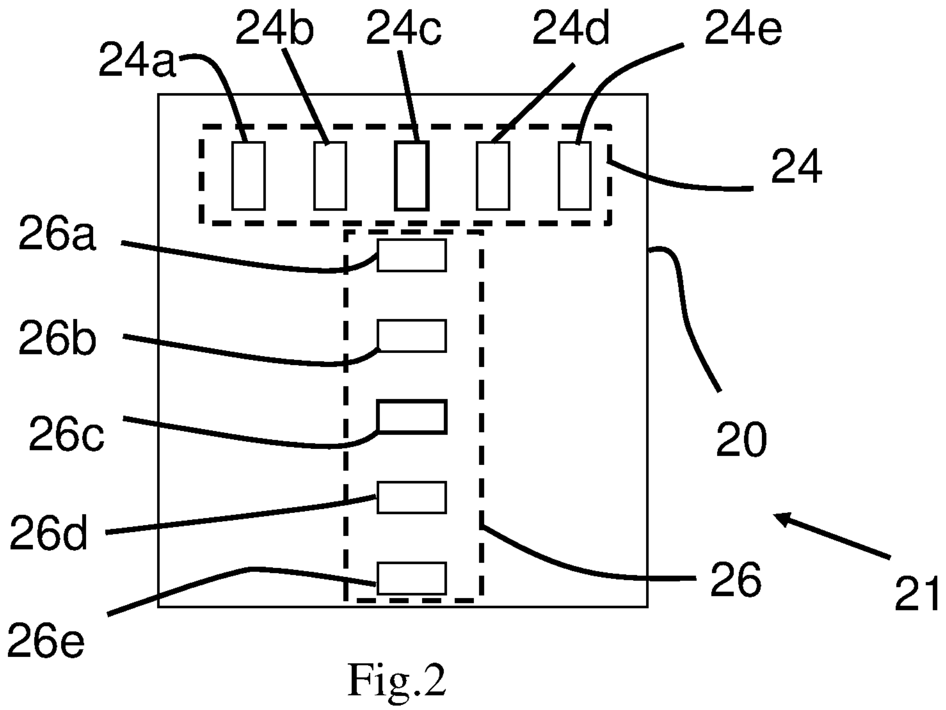

Fig.2

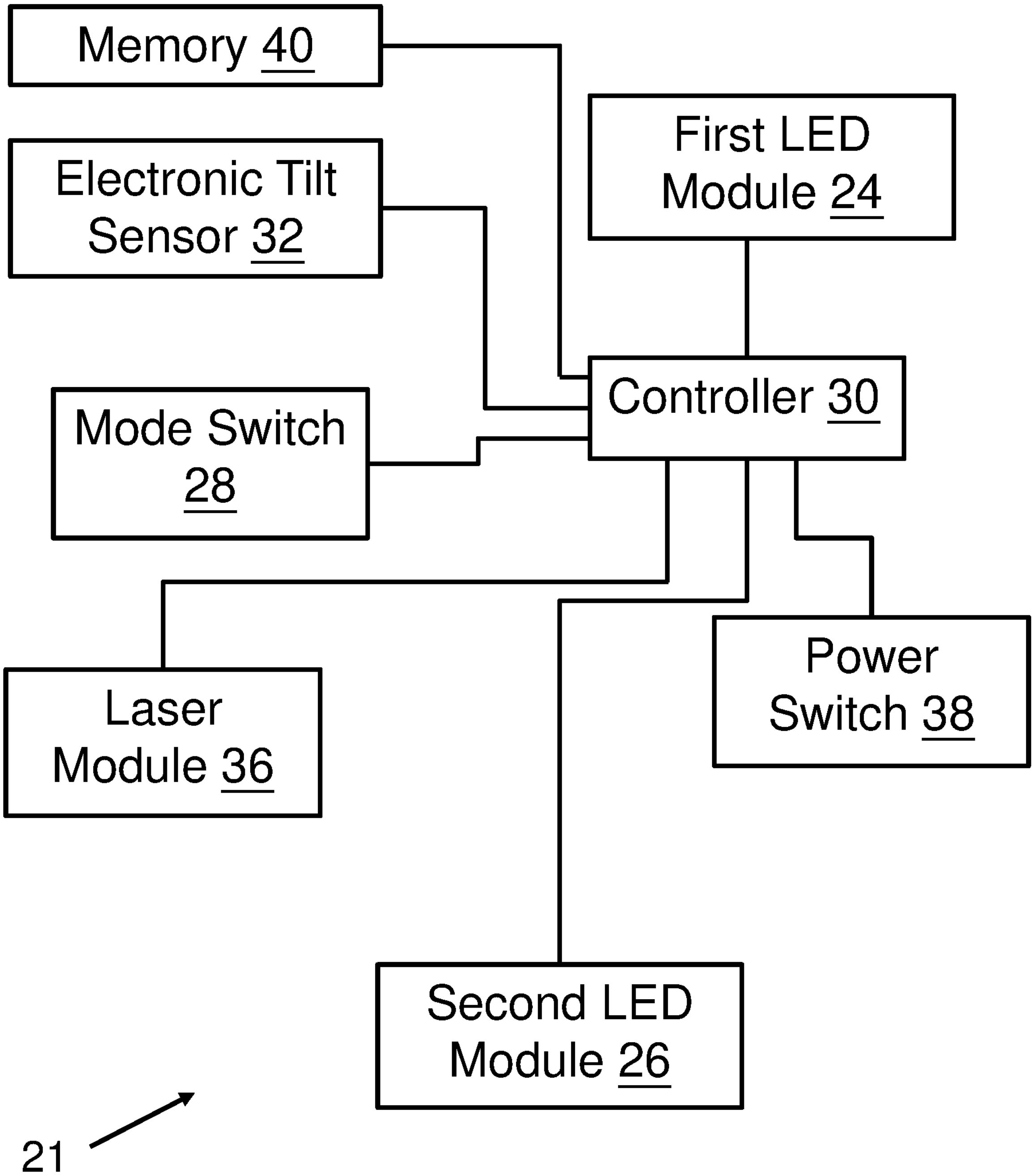
Memory 40
Electronic Tilt Sensor 32
First LED Module 24
Mode Switch 28
Controller 30
Laser Module 36
Power Switch 38
Second LED Module 26
21

Fig.3

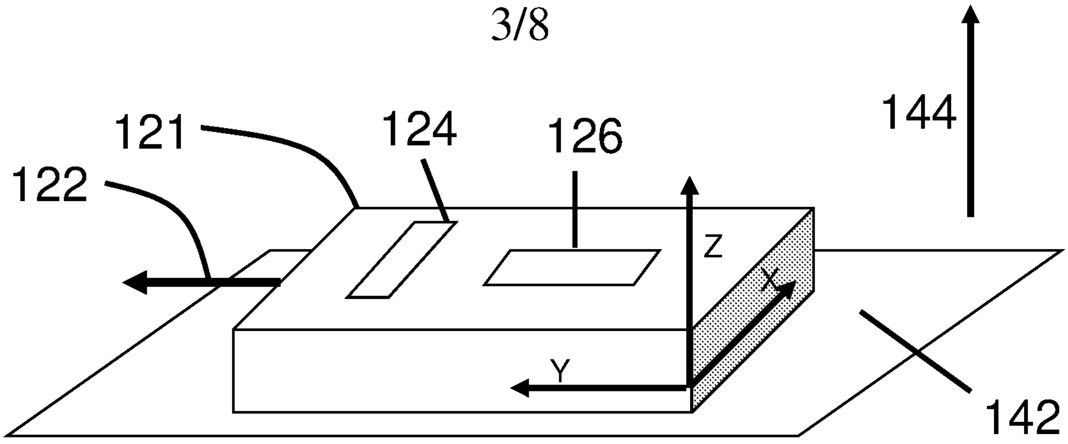

Fig.4a

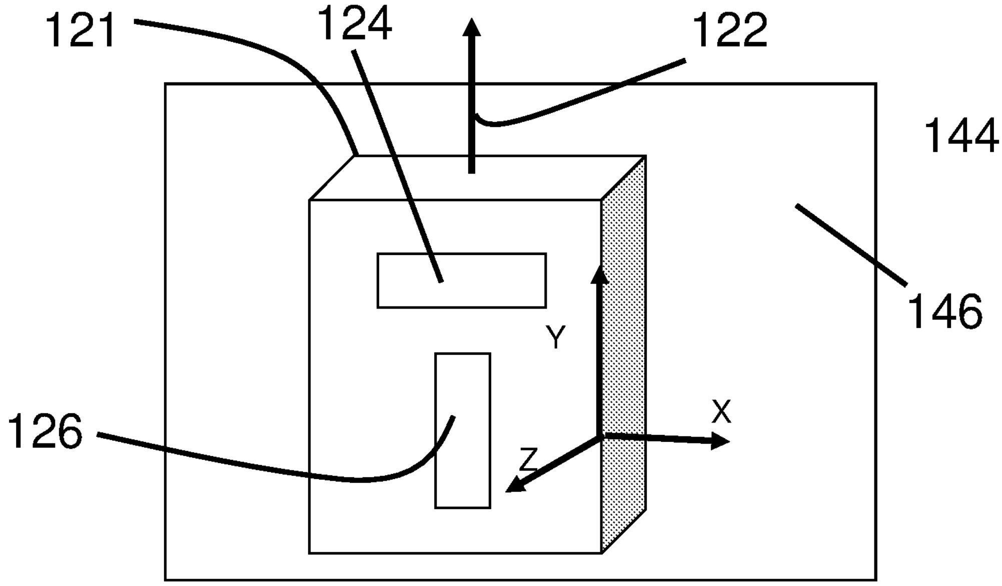

Fig.4b

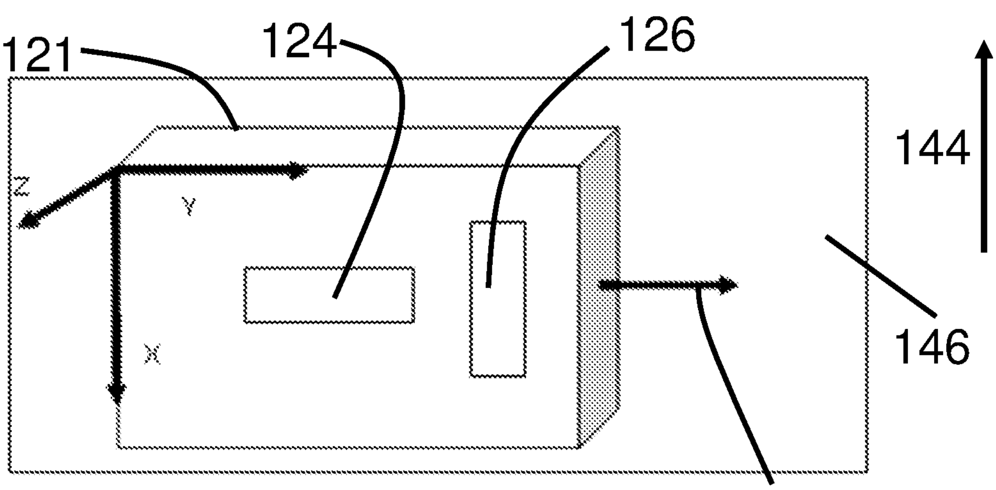

Fig.4c

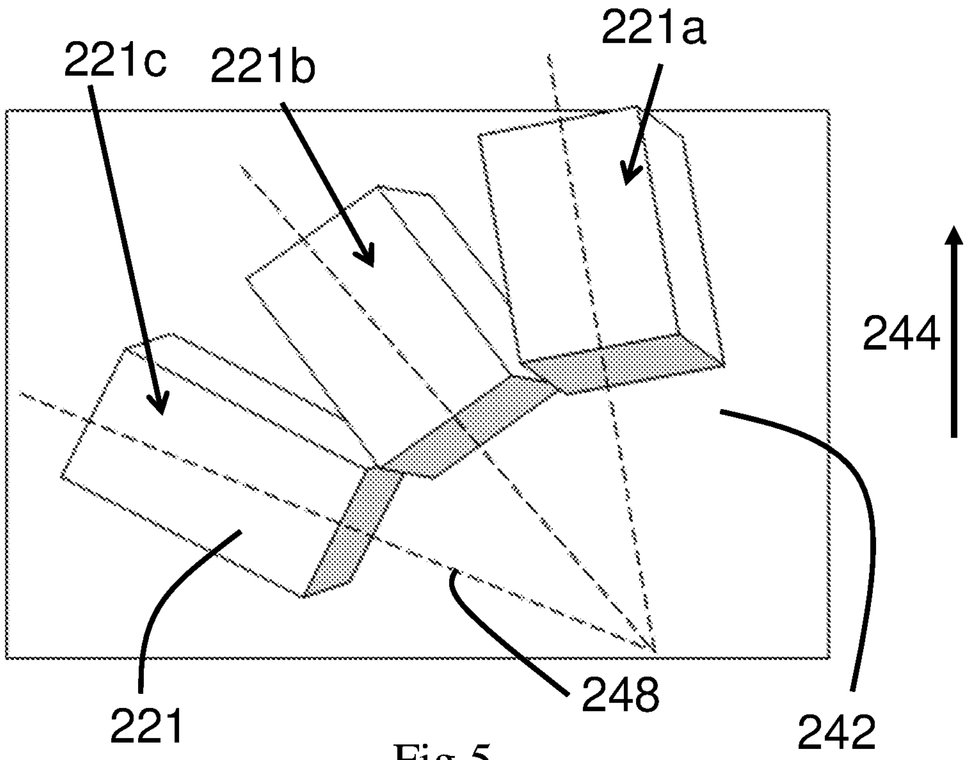

Fig.5

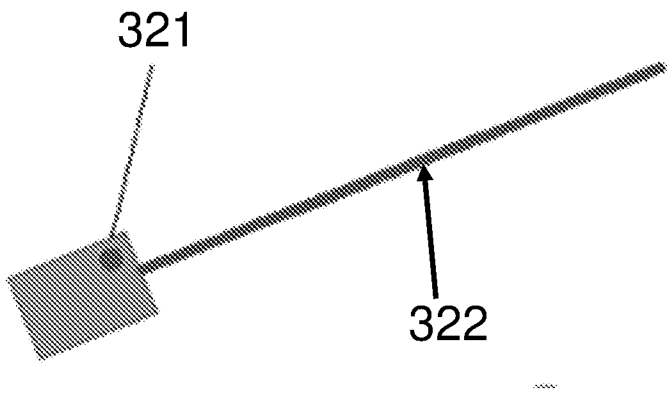

Fig.6a

Fig.6b

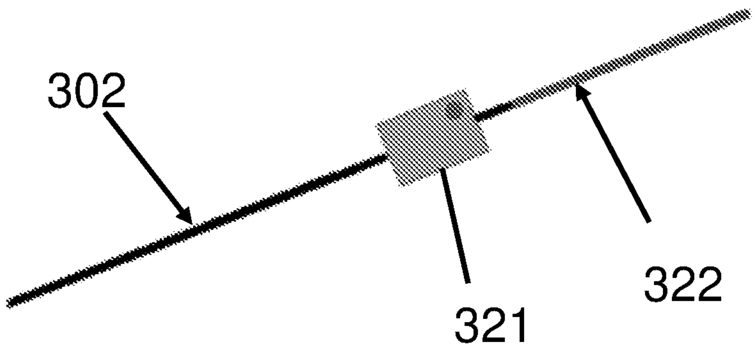

Fig.6c

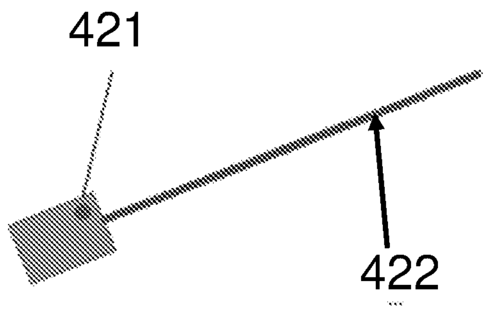

Fig.7a

Fig.7b

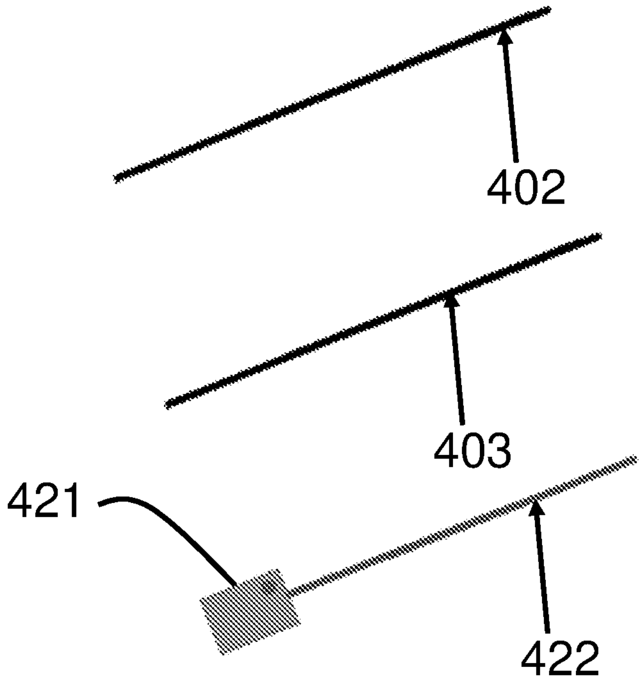

Fig.7c

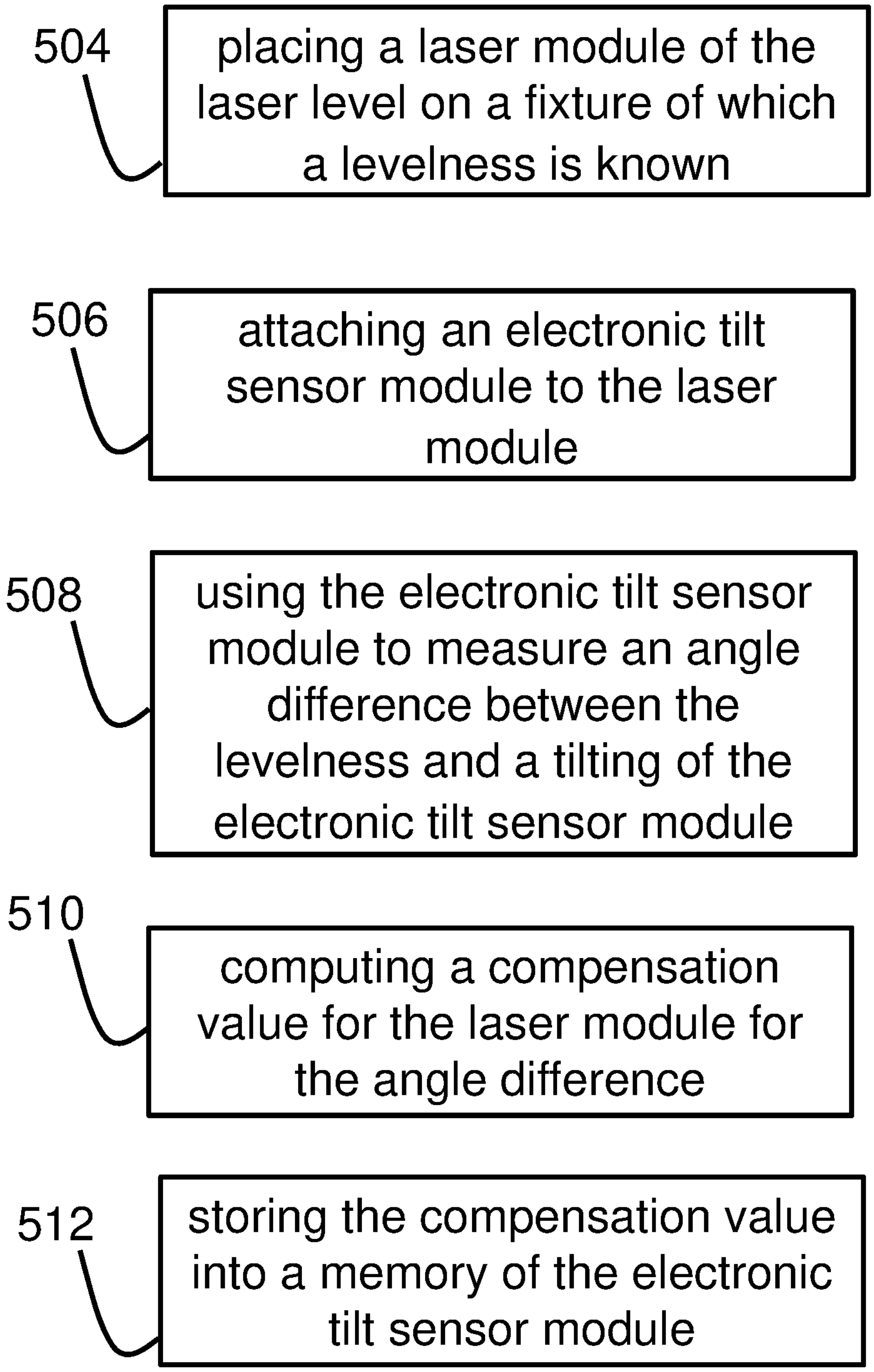
504
placing a laser module of the laser level on a fixture of which a levelness is known
506
attaching an electronic tilt sensor module to the laser module
508
using the electronic tilt sensor module to measure an angle difference between the levelness and a tilting of the electronic tilt sensor module
510
computing a compensation value for the laser module for the angle difference
512
storing the compensation value into a memory of the electronic tilt sensor module

Fig.8

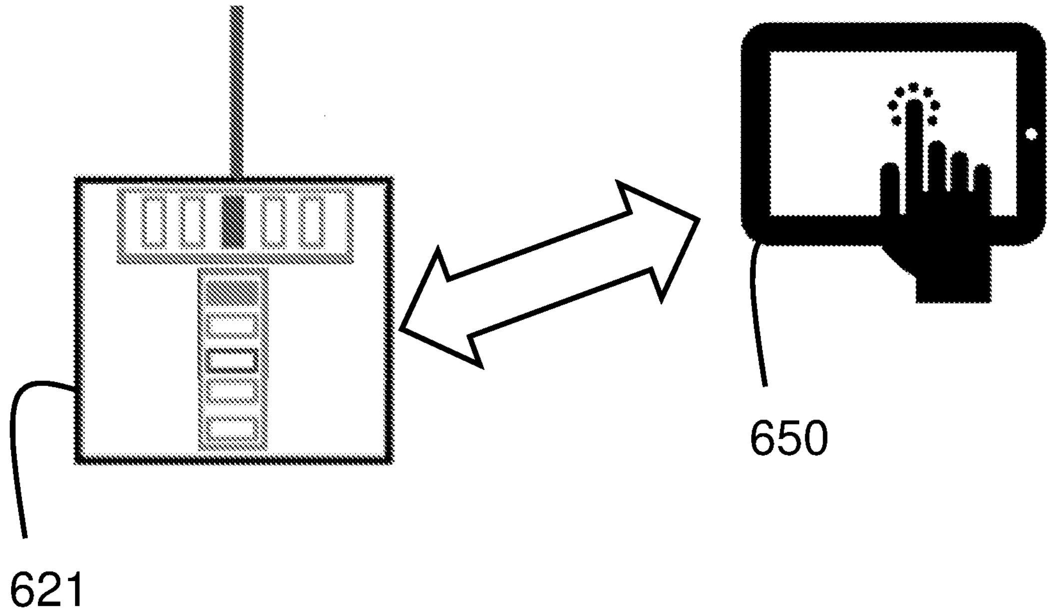

Fig.9

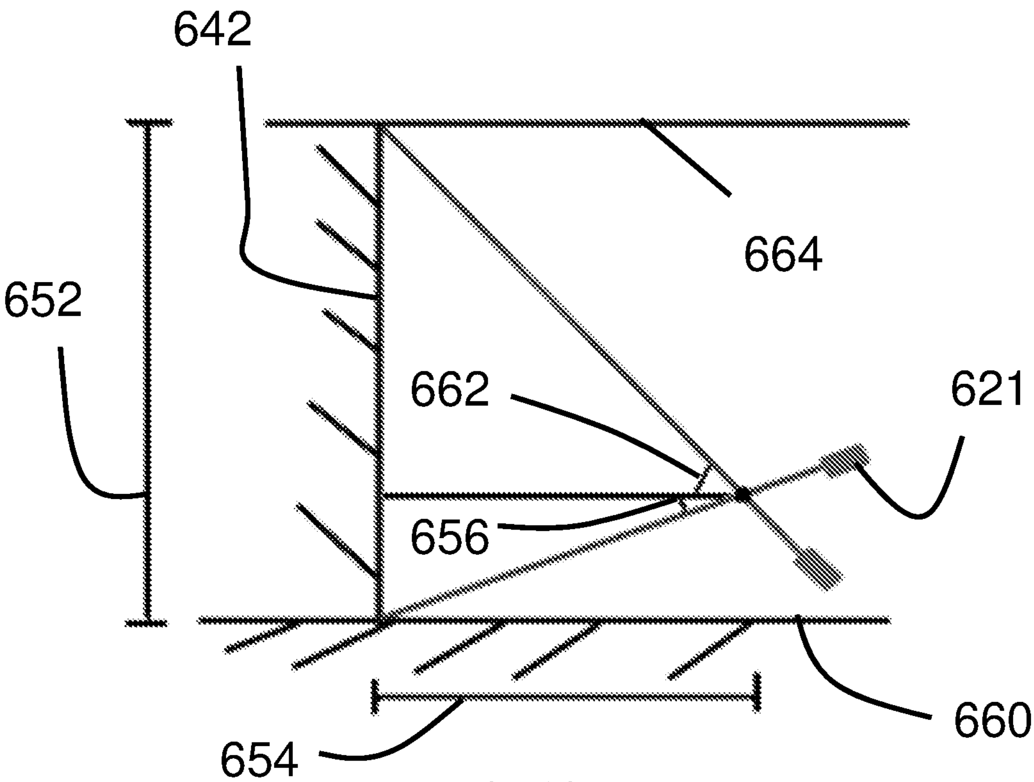

Fig.10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/109608

A. CLASSIFICATION OF SUBJECT MATTER

G01C 9/06(2006.01)i; G01C 9/00(2006.01)i; G01D 18/00(2006.01)i

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)

G01C 9/-; G01D 18/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC, CNABS, CNPAT:TTI; laser, level+, tilt OR angle OR inclin+, LED? OR LCD? OR display+, calibrat+ OR compensat+, extend+ 2d line, parallel 2d line, height

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 204666140 U (UNIV. SHAOXING) 23 September 2015 (2015-09-23) the description, paragraphs [0024]-[0030], and figures 1-2	1-6, 9-10, 13-14
X	CN 2509562 Y (LEI, WEIWU) 04 September 2002 (2002-09-04) the description, page 3 paragraph 8 - page 5 paragraph 4, and figure 2	15
Y	CN 204666140 U (UNIV. SHAOXING) 23 September 2015 (2015-09-23) the description, paragraphs [0024]-[0030], and figures 1-2	11
Y	CN 2509562 Y (LEI, WEIWU) 04 September 2002 (2002-09-04) the description, page 3 paragraph 8 - page 5 paragraph 4, and figure 2	11
A	CN 2509562 Y (LEI, WEIWU) 04 September 2002 (2002-09-04) the description, page 3 paragraph 8 - page 5 paragraph 4, and figure 2	16-19
A	CN 203719651 U (CHENG, WEI) 16 July 2014 (2014-07-16) the description, paragraphs [0008]-[0012], and figure 1	20
A	CN 101535764 A (TRIMBLE KAISERSLAUTERN G.M.B.H.) 16 September 2009 (2009-09-16) the whole document	1-20

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

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

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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 June 2019	**01 July 2019**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China	**YIN,Mei**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53962626**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 201476784 U (NEW PACIFIC DIVISION IND. CO., LTD.) 19 May 2010 (2010-05-19) the whole document	1-20
A	US 5983510 A (WU, CHYI-YIING ET AL.) 16 November 1999 (1999-11-16) the whole document	1-20
A	EP 3093615 A1 (BANG, SO YOON) 16 November 2016 (2016-11-16) the whole document	1-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2018/109608

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	204666140	U	23 September 2015	CN	104880174	A	02 September 2015
CN	2509562	Y	04 September 2002		None		
CN	203719651	U	16 July 2014		None		
CN	101535764	A	16 September 2009	US	7861427	B2	04 January 2011
				DE	112006004097	B4	11 April 2013
				US	2010064534	A1	18 March 2010
				DE	112006004097	T5	10 September 2009
				DE	112006004097	C5	02 November 2017
				CN	101535764	B	16 January 2013
				WO	2008052590	A1	08 May 2008
CN	201476784	U	19 May 2010		None		
US	5983510	A	16 November 1999		None		
EP	3093615	A1	16 November 2016	WO	2016148364	A1	22 September 2016
				KR	10-2017-0002924	A	09 January 2017
				KR	10-1741091	B1	29 May 2017