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(71) Applicant: **ROBERT BOSCH COMPANY LIMITED**
[CN/CN]; 21/F, 625 King's Road North Point, Hong Kong (CN).

(72) Inventors; and

(71) Applicants (for US only): **YUEN, Eric Hung-Ying**
[US/CN]; 21/F, 625 King's Road North Point, Hong Kong (CN). **CHAN, Wah Pong** [GB/CN]; 21/F, 625 King's Road North Point, Hong Kong (CN). **LAM, Yat Wah**
[CN/CN]; 21/F, 625 King's Road North Point, Hong Kong (CN).

(74) Agent: **NTD PATENT AND TRADEMARK AGENCY LIMITED**; 10th Floor, Block A, Investment Plaza, 27 Jinrongdajie, Xicheng District, Beijing 100033 (CN).

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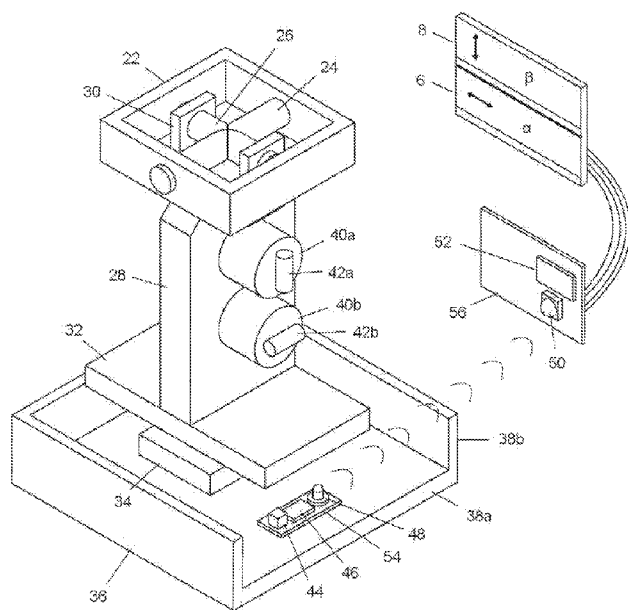


Figure 2

(57) Abstract: A multifunction laser leveling tool (1) is provided. The multifunction laser leveling tool (1) comprises: an outer casing (2); a pendulum carried by the outer casing (2) via a universal joint so that the pendulum is pivotable with respect to the outer casing (2) around a first axis and a second axis perpendicular to the first axis; a locking means for locking the pendulum to the outer casing (2) and releasing the pendulum therefrom; a first laser beam emitter (40a) attached to the pendulum for emitting a first laser plane; an angle sensing means (44) fixed relative to the outer casing (2) for measuring the orientation of the leveling tool (1); and a display module attached to the outer casing (2) for displaying the measured orientation of the leveling tool (1).

Multifunction Laser Leveling Tool

Technical Field

The invention relates to a multifunction laser leveling tool comprising improved functionalities for determining and displaying the orientation of a reference surface, determining and displaying the angle of a laser line, and generating a laser line with a predetermined angle.

Background Art

Laser leveling tools or levelers are generally used in construction and decoration industries. A conventional laser leveling tool comprises a frame, a pendulum universally suspended on the frame and defining a vertical plumb line, and at least one laser beam emitter mounted on the pendulum for emitting a laser plane which is projected onto an object to form a straight laser line, serving as a plumb or horizontal line for facilitating operation during construction or remodeling.

Current laser leveling tools generally only have a plumb and/or horizontal line generating function, which cannot meet all requirements in construction or remodeling operations.

For example, there are occasions that oblique lines with certain slopes should be generated. The slopes may include, such as the slope of a handicap ramp, the slope of a drainage pipe, or the slopes of other architectural features. In these cases, a laser leveling tool does not help; rather, a digital leveler or other means is generally used for generating such oblique lines. However, the position requirement of these sloped lines may be challenging when these lines are required on irregular surfaces or on exterior inaccessible heights such as a roof line of a house. In most cases, more than one person is needed to generate such lines.

Further, in some cases, the slope of an existing construction needs to be measured, such as the slope of a drainage pipe or the grading of a ramp. In these cases, a digital leveler, not a laser leveling tool, is needed but the measurement is made locally because it is limited by the length of the leveler. There are also occasions where the angle of a surface needs to be measured quickly. In this case, a spirit or digital leveler is used.

It is thus highly desired to have a multifunction tool which has at least the functions

described above: leveling, oblique line generating, and oblique angle measuring.

Summary of the Invention

In view of the problems existed in the prior art, an object of the invention is to provide a multifunction laser leveling tool which is able to generate a plumb or horizontal laser line onto an object, to generate an oblique laser line with a certain angle, to measure and display the angle of an oblique line or the orientation of a reference surface, etc.

For achieving this object, in one aspect, the present invention provides a multifunction laser leveling tool which comprises: an outer casing; a pendulum carried by the outer casing via a universal joint so that the pendulum is pivotable with respect to the outer casing around a first axis and a second axis perpendicular to the first axis; locking means configured for locking the pendulum to the outer casing and releasing the pendulum therefrom, wherein when the pendulum is released, the pendulum is in a plumb orientation and the first and second axes lie in a horizontal plane; a first laser beam emitter attached to the pendulum for emitting a first laser plane; angle sensing means fixed relative to the outer casing for measuring the orientation of the leveling tool or the orientation of the pendulum; and a display module attached to the outer casing for displaying the measured orientation of the leveling tool or the measured orientation of the pendulum.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises a housing fixedly mounted to the outer casing, the angle sensing means being carried by the housing.

In accordance with a preferred embodiment of the invention, the housing comprises a planar bottom wall parallel to the plane in which the first and second axes lie and surrounding side walls extending upwardly from the periphery of the bottom wall, the angle sensing means being carried by the bottom wall.

In accordance with a preferred embodiment of the invention, wherein the first laser plane is a horizontal plane when the pendulum is released, and the leveling tool further comprises a second laser beam emitter for emitting a second laser plane which is a longitudinal vertical plane when the pendulum is released.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises a third laser beam emitter which cooperates with the second laser beam emitter to increase the coverage of the second laser plane so that the

second laser plane includes an upper sector having preferable a 180-degree upward coverage.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises a fourth laser beam emitter for emitting a third laser plane which is a transverse vertical plane when the pendulum is released.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises a fifth laser beam emitter which cooperates with the fourth laser beam emitter to increase the coverage of the third laser plane so that the second laser plane includes an upper sector having preferable a 180-degree upward coverage.

In accordance with a preferred embodiment of the invention, the angle sensing means comprises:

one, two or three single axis accelerometers, a single-axis accelerometer, or a two-axis or three-axis accelerometer; or

two single-axis bubble vials or a single circular bubble vial; or

a capacitive angle sensor.

In accordance with a preferred embodiment of the invention, the display module comprises a screen on which the measured orientation of the angle sensing means is displayed and a display module driver which drives the screen.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises a microcontroller unit for processing and/or digitizing signals from the angle sensing means and output digitized data to the display module driver.

In accordance with a preferred embodiment of the invention, the angle sensing means and microcontroller unit are integrated on the same printed circuit board which is attached to the outer casing, preferably to the housing, if any.

In accordance with a preferred embodiment of the invention, the angle sensing means and microcontroller unit are integrated on separate printed circuit boards, the printed circuit board carrying the angle sensing means being attached to the outer casing, preferably to the housing, if any, and the printed circuit board carrying the microcontroller unit being attached to the outer casing, preferably to the housing, if any,

or to the pendulum.

In accordance with a preferred embodiment of the invention, the angle sensing means is in communication with the microcontroller unit via a signal transmitter attached to the outer casing, preferably to the housing, if any, and a signal receiver attached to the outer casing, preferably to the housing, if any, or to the pendulum, or via a connection wire or cable.

In accordance with a preferred embodiment of the invention, a signal transmitted from the signal transmitter to the signal receiver is in infrared or radio frequency.

In accordance with a preferred embodiment of the invention, the leveling tool has a home position in which the angle sensing means is in a horizontal plane in the condition that the multifunction laser leveling tool is supported by a horizontal supporting surface.

In accordance with a preferred embodiment of the invention, the outer casing comprises feet by means of which the home position of the leveling tool is defined, all the feet having fixed heights, or at least one of the feet having an adjustable height.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool comprises a spirit mode in which the angle sensing means is calibrated to the orientation of a reference surface on which the multifunction laser leveling tool stands and the display module displays the orientation of the reference surface.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises a leveling operation mode in which the pendulum is released by the locking means and the first laser plane emitted by the first laser beam emitter is projected onto an objective surface to form a horizontal laser line thereon.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises an oblique line generating operation mode in which an oblique laser line can be formed on an objective surface by the steps of:

- 1) setting the multifunction laser leveling tool onto a reference surface, with the pendulum being released by the locking means;
- 2) then locking the pendulum by the locking means; and
- 3) then tilting the multifunction laser leveling tool to desired orientation so that the first laser plane is projected forwards onto the objective surface and forming an oblique laser line thereon.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises an oblique angle measuring operation mode in which the oblique angle of a line to be measured can be obtained by the steps of:

- 1) setting the multifunction laser leveling tool onto a reference surface, with the pendulum being released by the locking means, to obtain a first measured orientation of the leveling tool;
- 2) then locking the pendulum by the locking means;
- 3) then tilting the multifunction laser leveling tool until the first laser plane passes through the line to be measured and obtaining a second measured orientation of the leveling tool; and
- 4) then calculating the oblique angle of the line to be measured from the difference between the first and second measured orientations of the leveling tool.

In accordance with a preferred embodiment of the invention, the multifunction laser leveling tool further comprises calculating means for calculating the oblique angle from the first and second measured orientations of the leveling tool.

It can be seen that the multifunction laser leveling tool of according to the invention has multiple functions: generating a horizontal laser line onto an objective surface; generating an oblique laser line onto an objective surface; measuring and displaying the angle of an oblique line; and measuring and displaying the orientation of a surface. In this way, the multifunction laser leveling tool of the invention significantly facilitates the leveling and measuring operations.

Brief Description of the Drawings

The invention will be further understood by reading the following detailed description with reference to the drawings in which:

Figure 1 is a schematic isometric view of a multifunction laser leveling tool according to a preferred embodiment of the invention;

Figure 2 is a schematic isometric view of major functional components, according to a preferred embodiment of the invention, of the laser leveling tool shown in Figure 1;

Figure 3 is a schematic isometric view of major functional components, according to another preferred embodiment of the invention, of the laser leveling tool shown in

Figure 1;

Figure 4 is a schematic isometric view of major functional components, according to yet another preferred embodiment of the invention, of the laser leveling tool shown in Figure 1;

Figure 5 is a schematic view showing an operation mode of the laser leveling tool of the invention; and

Figure 6 is a schematic view showing another operation mode of the laser leveling tool of the invention.

Detailed Description of Preferred Embodiments

Now a multifunction laser leveling tool according to preferred embodiments of the invention will be described with reference to the drawings.

As shown in Figure 1, a multifunction laser leveling tool 1 comprises an outer casing 2 for accommodating functional components of the tool.

Three feet 3 are attached to the bottom of the outer casing 2 for supporting the outer casing 2 on a reference surface (not shown). The feet may each have a fixed height. However, in a preferred embodiment, at least one of the feet 3 has an adjustable height, so that the orientation of the outer casing with respect to the reference surface can be changed by adjusting the height of the at least one of the feet. Preferably, at least two, or all of the feet 3, have adjustable heights. The height of an adjustable foot can be adjusted manually or by means of electrical driving means.

It can be understood that the shape and the number of the feet are not limited to those illustrated in Figure 1, and a skilled in the art can design the feet with any suitable shape and number only if they can support the outer casing on a reference surface in stable and fixed or adjustable manner.

Figure 1 also shows a locking lever 4 which is accessible from outside. The locking lever 4 is manipulated to pivot between and stop at a locking position as shown by solid lines in Figure 1 and indicated by “Lock” and an unlocking or releasing position as shown by dashed lines in Figure 1 and indicated by “Unlock”. The locking lever 4 may be provided on any location which is easy accessible by a user, for example, on a side wall or a back wall of the outer casing 2. The function of the locking lever 4 will be described below.

Figure 1 also shows a screen of a display module. The screen comprises two sections 6 and 8 as will be described. The screen is arranged in a location which is easy to be seen, for example, on a top wall of the outer casing 2. It can be understood that the screen may alternatively comprise other number of section(s).

Angle or orientation information sensed by the multifunction laser leveling tool can be displayed by the screen using any one of the following technologies: LCD, LED, TFT, CSTN, or OLED display panel.

The multifunction laser leveling tool 1 is able to emit at least one laser plane. In the embodiment shown in Figure 1, the multifunction laser leveling tool 1 can emit a first laser plane 10 and a second laser plane 12. The second laser plane 12 forms an angle with respect to (for example, perpendicular to, as preferred) the first laser plane 10.

In Figure 1, a coordinate system comprising orthogonal axes X, Y and Z is shown, where in X axis represents a lateral (right-left) direction, Y axis represents a longitudinal (front-back) direction, and Z axis represents a vertical direction.

In the embodiment shown in Figure 1, the locking lever 4 is in the locking position, and the multifunction laser leveling tool 1 directly faces towards an objective wall (not shown). The multifunction laser leveling tool 1 is in an orientation tilted around X axis by an angle β and tilted around Y axis by an angle α , by adjusting at least one of the feet 3. In this state, the multifunction laser leveling tool 1 emits the first and second laser planes 10 and 12 forwards, which are perpendicular to each other in this case and are projected on to objective wall obliquely to form oblique laser lines 14 and 16 respectively thereon. The laser lines 14 and 16 are displaced from imaginary horizontal and vertical lines 18 and 20 by oblique angles θ and θ' respectively.

The tilting angles α and β are sensed as will be described and are displayed on the sections 6 and 8 of the screen respectively.

It can be understood that the oblique angles θ and θ' of the laser lines are functions of the tilting angles α and β . When the Y axis is substantially perpendicular to the objective wall, the oblique angles θ and θ' can be determined as being substantially equal to the tilting angle α . However, when the tilting angle β is large enough, the effect of the tilting angle β to the determination of the oblique angles θ and θ' should be considered. For this end, the multifunction laser leveling tool 1 may comprise calculating means for calculating the oblique angles θ and θ' based on the tilting angles α and β .

Figure 2 shows major functional components, according to a preferred embodiment of the invention, of the multifunction laser leveling tool 1. A frame 22 is fixedly mounted to the outer casing 2 and carries a pendulum via a universal joint. The universal joint comprises a pair of orthogonal shafts 24 and 26 which are integrated with each other. The shaft 24 extends substantially in the X direction and is rotatably carried at its opposite ends by the frame 22. The shaft 26 is fixed to the shaft 24 and extends substantially in the Y direction.

The pendulum comprises a vertical pendulum body 28, a pair of suspension parts 30 extended upwardly from a top end of the pendulum body 28 and rotatably suspended on opposite ends of the shaft 26, a horizontal platform 32 attached to a bottom end of the pendulum body 28, and a damping block 34 attached to the bottom surface of the platform 32.

By means of the universal joint, the pendulum is able to pivot around shafts 24 and 26 with respect to the frame 22 (also with respect to the outer casing 2).

The multifunction laser leveling tool 1 comprises locking means for fixedly locking the pendulum to the outer casing 2. The locking means comprises the above described locking lever 4 and a locking mechanism (not shown) provided in the outer casing 2. The locking mechanism is actuated by means of the locking lever 4 and in turn acts on the pendulum. When the locking lever 4 is manipulated to move into its locking position, the locking mechanism is driven into a locking state to lock the pendulum fixedly with respect to the outer casing. On the other hand, when the locking lever 4 is manipulated to move into its unlocking or releasing position, the locking mechanism is driven into an unlocking or releasing state to unlock or release the pendulum so that the pendulum is free to pivot in two directions with respect to the outer casing. The structure of the locking mechanism is well known in the art and is thus not described here.

When the pendulum is released by the locking means, the pendulum comes to a plumb orientation by its weight. The damping block 34 helps the pendulum to reach and keeps its plumb orientation by magnetic interaction with a magnet (not shown) disposed in outer casing 2, as well known in the art.

The laser leveling tool 1 further comprises a housing 36 fixedly connected to or forming integrally with the frame 22 and thus also fixedly mounted to the outer casing 2. The housing 36 comprises a planar bottom wall 38a under the pendulum and surrounding side walls 38b extending upwardly from the whole periphery of the bottom wall 38a.

Some portions of the side walls are omitted in Figure 2 (also in Figures 3 and 4) for showing the internal space of the housing 36.

A pair of first and second laser beam emitting assemblies 40a and 40b are attached to the pendulum. The first laser beam emitting assembly 40a comprises a first cylindrical lens 42a for emitting the first laser plane 10, and the second laser beam emitting assembly 40b comprises a second cylindrical lens 42b for emitting the second laser plane 12. When the pendulum is in its unlocked or released state, the first laser plane 10 is a forward horizontal plane and the second laser plane 12 is a forward vertical plane.

The multifunction laser leveling tool 1 may additionally comprise a third laser beam emitting assembly (not shown), which cooperates with the second laser beam emitting assembly 40b to increase the coverage of the second laser plane 12 so that the second laser plane 12 includes an upper sector having preferable a 180-degree upward coverage.

The multifunction laser leveling tool 1 may further comprise a fourth laser beam emitting assembly (not shown) to emit a third laser plane (not shown) which may form an angle with (for example, perpendicular to) each of the first and second laser planes.

Further, the multifunction laser leveling tool 1 may additionally comprise a fifth laser beam emitting assembly (not shown), which cooperates with the fourth laser beam emitting assembly to increase the coverage of the third laser plane so that the third laser plane includes an upper sector having preferable a 180-degree upward coverage.

Each laser plane may be emitted within a fan angle. At least one of the laser planes may have a 180-degree plane coverage or a 360-degree full plane coverage when necessary.

In a preferred embodiment, at least one of the angles formed between each pair of the first to third laser planes is adjustable.

Angle sensing means in the form of an angle sensor 44 is carried by the bottom wall 38a of the housing 36, for sensing the tilt angles or orientation of the housing 36 as well as sensing the orientation of the pendulum which is in the locked state. The angle sensor 44 may comprise one single-axis accelerometer, two single-axis accelerometers, three single-axis accelerometers, a two-axis or three-axis accelerometer, a capacitive angle sensor, or any other suitable type of angle sensors.

A microcontroller unit (MCU) 46 is also carried by the bottom wall 38a of the housing

36 for conditioning, processing and/or digitizing signals from the angle sensor to generate digitized orientation data.

The display module comprises the screen having sections 6 and 8 as described above and a display module driver 52 connected with the screen via wires and drives the screen to operate.

The microcontroller unit 46 is communicated with the display module driver 52 using wireless transmission, for example, via a signal transmitter 48 and a corresponding signal receiver 50, to transfer signals representing the tilt angles of the housing determined by the angle sensor 44 to the signal receiver 50. The signal transmitter 48 is carried by the bottom wall 38a of the housing 36, and the signal receiver 50 is arranged near the display module driver 52. The signals transmitted by the signal transmitter and receiver can be in infrared (IR) or radio frequency (RF) with any transmission frequency from a few MHz to a few GHz, and the transmission technology can be analog or digital nature.

The signal transmitter 48 sends the digitized orientation data from the microcontroller unit 46 to the signal receiver 50, and the display module driver 52 receives the digitized orientation data from the signal receiver 50 and controls the screen to display the digitized orientation data.

The angle sensor 44, the microcontroller unit 46 and the signal transmitter 48 are integrated on a printed circuit board 54 to form a PCB assembly. The PCB assembly is attached to the bottom wall 38a of the housing 36.

Power is fed to the PCB assembly via thin wires. The signal from the angle sensor can be raw signal such as voltage or current. Some accelerometer has a built-in signal conditioning circuit to convert the raw signal to digital signal.

The signal receiver 50 and the display module driver 52 are integrated on a printed circuit board 56 which may be attached to the housing 36 or to the outer casing 2, preferably, near the screen. Alternatively, the printed circuit board 56 which may be attached to a portion of the pendulum, for example, the platform 32.

Figure 3 shows major functional components, according to another preferred embodiment of the invention, of the multifunction laser leveling tool 1.

The embodiment shown in Figure 3 is different with that shown in Figure 2 mainly in

that the angle sensing means for sensing the orientation of the housing (also the orientation of the pendulum in the locked state) comprises two single-axis bubble vials 58 and 60. The principle axes of the two bubble vials can be orthogonal to each other or they can be at any angle. In the embodiment shown in Figure 3, the principle axis of the bubble vial 58 is in the Y direction, and the principle axis of the bubble vial 60 is in the X direction. The bubble vials 58 and 60 are integrated on the printed circuit board 54, and the microcontroller unit 46 and the display module driver 52 are integrated on the printed circuit board 56. The printed circuit board 54 is provided with suitable sensors (not shown) for sensing the position of the bubble in each bubble vial according to the tilt angles of the housing and thus determining the latter. The microcontroller unit 46 is communicated with the sensors for the bubble vials 58 and 60 by connection wires or cables for receiving signals representing the tilt angles of the housing determined by the sensors. Alternatively, the microcontroller unit 46 is communicated with the sensors for the bubble vials 58 and 60 via wireless transmission (such as infrared or radio frequency means). The printed circuit board 54 is attached to the bottom wall 38a of the housing 36, and the printed circuit board 56 is attached to the housing 36 or to the outer casing 2 or to a portion of the pendulum, for example, the platform 32.

Other aspects of the embodiment shown in Figure 3 are similar to that shown in Figure 2 and will not be described here.

Figure 4 shows major functional components, according to yet another preferred embodiment of the invention, of the multifunction laser leveling tool 1.

The embodiment shown in Figure 4 is different with that shown in Figure 3 mainly in that the microcontroller unit 46 is integrated on the printed circuit board 54 together with the bubble vials 58 and 60 and corresponding sensors (not shown) for them, and is communicated with the display module driver 52, which is integrated on the printed circuit board 56, by wires to transfer signals representing the tilt angles of the housing determined by the sensors to the printed circuit board 56.

Other aspects of the embodiment shown in Figure 4 are similar to that shown in Figure 3 and will not be described here.

A skilled in the art can design different structures and configurations for the functional components of the multifunction laser leveling tool 1 based on the principle of the invention as disclosed here. For example, features in an embodiment shown in one of Figures 3-5 may be used in other embodiments.

In general, the first and second laser planes 10 and 12 have a fixed relationship with the orientation of the pendulum. Therefore, the measured orientation information (or angles) of the housing (also of the pendulum in the locked state) displayed by the display module is indirect or direct indication of the laser line angles.

The multifunction laser leveling tool 1 of the invention has a spirit operation mode for quickly measuring orientations of surfaces. In the spirit operation mode, the angle sensing means is calibrated to the angles of a reference surface on which the feet of the multifunction laser leveling tool 1 stand. The display module displays the angles of the reference surface.

The multifunction laser leveling tool 1 has a home position in which the angle sensing means is in a horizontal plane (angles α and β are both zero) in the condition that the multifunction laser leveling tool is supported on a horizontal supporting surface.

For a multifunction laser leveling tool 1 having fixed feet 3, in the spirit operation mode, the output of the angle sensing means can be calibrated to the offset due to the fixed feet which are supported by the surface.

On the other hand, for a multifunction laser leveling tool 1 having at least two adjustable feet, the home position of the multifunction laser leveling tool 1 can be achieved by adjusting the heights of the adjustable feet. In this configuration, pre-calibration is needed before the multifunction laser leveling tool 1 is to be used in the spirit operation mode. The pre-calibration is performed in a way that, by adjusting the heights of the at least two adjustable feet, the angles displayed are the same as the angles of a known surface supporting the leveling tool (for example, in the home position of the multifunction laser leveling tool 1, angles α and β are both zero when the multifunction laser leveling tool 1 is put on a known horizontal surface). Then, by comparing the difference between the displayed angles of the known surface and the displayed angles of the reference surface to be measured, the real angles of the reference surface can be calculated out.

For facilitating the spirit operation of a multifunction laser leveling tool 1 having adjustable feet, the adjustable feet preferably have preset neutral positions in which the multifunction laser leveling tool 1 is in its home position. When the adjustable feet are in their neutral positions and the multifunction laser leveling tool 1 is put on a horizontal surface, the displayed angles α and β are both zero.

Further, the multifunction laser leveling tool 1 of the invention has a leveling operation mode, as schematically shown in Figure 5. For testing the operation and function of the multifunction laser leveling tool 1, a traditional laser leveling tool 80 may also be arranged as a reference. The reference laser leveling tool 80 emits a horizontal laser plane 82. The horizontal laser plane 82 is projected onto an objective wall 86, which is in front of the reference laser leveling tool 80, and forms a horizontal laser line 84 thereon.

The multifunction laser leveling tool 1 of the invention is oriented to be facing towards the objective wall 86. The multifunction laser leveling tool 1 is in the leveling operation mode in which the pendulum is released from the locking means, and is thus free to rotate with respect to the outer casing and will always be rested at the equilibrium plumb position. In this position, the multifunction laser leveling tool 1 emits horizontal and/or vertical laser planes 10 and/or 12 which are projected onto the objective wall 86 and forms a horizontal laser line 14 and/or a vertical laser line 16 thereon respectively.

Further, the multifunction laser leveling tool 1 of the invention has an oblique line generating operation mode as schematically shown in Figure 6.

In this operation mode, when the pendulum is locked fixedly in position by the locking means, i.e., in a locked mode, the pendulum is no longer free to rotate due to gravity. The first and second laser lines 14 and 16 formed on the objective wall 86 can be adjusted to any orientation by adjusting the adjustable feet 3 or the reference surface of the multifunction laser leveling tool. Figure 6 shows that the first laser line 14 forms an angle θ with the horizontal laser line 84 formed on the objective wall 86 by the reference laser leveling tool 80. The slopes or oblique angles of the laser lines relative to the true vertical and horizontal are indicated by the display module. To obtain the most accurate reading, the multifunction laser leveling tool 1 should face the objective surface directly, at a 90-degree incident angle. Otherwise, the calculating means described above is required for calculating the true oblique angles.

The multifunction laser leveling tool 1 of the invention further has an oblique angle measuring operation mode in which the oblique angle of a line to be measured can be obtained. This oblique angle measuring operation mode can be understood from Figure 6. Specifically, when there is an oblique line on the objective wall, by adjusting the multifunction laser leveling tool 1 in a way similar to those described above with reference to Figure 6 so that the first laser line 14 or the second laser line 16 formed on

the objective wall coincides with the oblique line, the oblique angle of the oblique line can be derived, either directly or after calculating by the calculating means, from the difference between measured angles or orientations of the housing (before and after adjusting).

It can be seen that the multifunction laser leveling tool of according to the invention has integrated several functions in the same tool. These functions comprise at least: generating at least a horizontal laser line onto an objective surface; generating at least one oblique laser line onto an objective surface; measuring and displaying the angle of an oblique line; and measuring and displaying the orientation of a surface. Thus, the multifunction laser leveling tool of the invention significantly facilitates the leveling and measuring operations in various industries, especially in construction industry.

Further, according to the invention, the angle sensing means is attached to the outer casing or to the housing which is fixed to the outer casing. When comparing with the solution where the angle sensing means is attached to the pendulum, the mounting of the angle sensing means becomes easier, and the interference of the angle sensing means to the operation of the pendulum is reduced. Meanwhile, the spirit operation of the leveling tool is simplified.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. The attached claims and their equivalents are intended to cover all the modifications, substitutions and changes as would fall within the scope and spirit of the invention.

CLAIMS

1. A multifunction laser leveling tool comprising:

an outer casing;

a pendulum carried by the outer casing via a universal joint so that the pendulum is pivotable with respect to the outer casing around a first axis and a second axis perpendicular to the first axis;

locking means configured for locking the pendulum to the outer casing and releasing the pendulum therefrom, wherein when the pendulum is released, the pendulum is in a plumb orientation and the first and second axes lie in a horizontal plane;

a first laser beam emitter attached to the pendulum for emitting a first laser plane;

angle sensing means fixed relative to the outer casing for measuring the orientation of the leveling tool or the orientation of the pendulum; and

a display module attached to the outer casing for displaying the measured orientation of the leveling tool or the measured orientation of the pendulum.

2. The multifunction laser leveling tool of claim 1, further comprising a housing fixedly mounted to the outer casing, the angle sensing means being carried by the housing.

3. The multifunction laser leveling tool of claim 2, wherein the housing comprises a planar bottom wall parallel to the plane in which the first and second axes lie and surrounding side walls extending upwardly from the periphery of the bottom wall, the angle sensing means being carried by the bottom wall.

4. The multifunction laser leveling tool of any one of claims 1 to 3, wherein the first laser plane is a horizontal plane when the pendulum is released, and the leveling tool further comprises a second laser beam emitter for emitting a second laser plane which is a longitudinal vertical plane when the pendulum is released.

5. The multifunction laser leveling tool of claim 4, further comprising a third laser beam emitter which cooperates with the second laser beam emitter to increase the coverage of the second laser plane so that the second laser plane includes an upper sector having preferable a 180-degree upward coverage.

6. The multifunction laser leveling tool of claim 4 or 5, further comprising a fourth laser

beam emitter for emitting a third laser plane which is a transverse vertical plane when the pendulum is released.

7. The multifunction laser leveling tool of claim 6, further comprising a fifth laser beam emitter which cooperates with the fourth laser beam emitter to increase the coverage of the third laser plane so that the second laser plane includes an upper sector having preferably a 180-degree upward coverage.

8. The multifunction laser leveling tool of any one of claims 1 to 7, wherein the angle sensing means comprises:

one, two or three single axis accelerometers, a single-axis accelerometer, or a two-axis or three-axis accelerometer; or

two single-axis bubble vials or a single circular bubble vial; or

a capacitive angle sensor.

9. The multifunction laser leveling tool of any one of claims 1 to 8, wherein the display module comprises a screen on which the measured orientation of the angle sensing means is displayed and a display module driver which drives the screen.

10. The multifunction laser leveling tool of claim 9, further comprising a microcontroller unit for processing and/or digitizing signals from the angle sensing means and output digitized data to the display module driver.

11. The multifunction laser leveling tool of claim 10, wherein the angle sensing means and microcontroller unit are integrated on the same printed circuit board which is attached to the outer casing, preferably to the housing, if any.

12. The multifunction laser leveling tool of claim 10, wherein the angle sensing means and microcontroller unit are integrated on separate printed circuit boards, the printed circuit board carrying the angle sensing means being attached to the outer casing, preferably to the housing, if any, and the printed circuit board carrying the microcontroller unit being attached to the outer casing, preferably to the housing, if any, or to the pendulum.

13. The multifunction laser leveling tool of claim 12, wherein the angle sensing means is in communication with the microcontroller unit via a signal transmitter attached to the outer casing, preferably to the housing, if any, and a signal receiver attached to the outer casing, preferably to the housing, if any, or to the pendulum, or via a connection wire or

cable.

14. The multifunction laser leveling tool of claim 13, wherein a signal transmitted from the signal transmitter to the signal receiver is in infrared or radio frequency.

15. The multifunction laser leveling tool of any one of claims 1 to 14, wherein the leveling tool has a home position in which the angle sensing means is in a horizontal plane in the condition that the multifunction laser leveling tool is supported by a horizontal supporting surface.

16. The multifunction laser leveling tool of claim 15, wherein the outer casing comprises feet by means of which the home position of the leveling tool is defined, all the feet having fixed heights, or at least one of the feet having an adjustable height.

17. The multifunction laser leveling tool of any one of claims 1 to 16, comprising a spirit mode in which the angle sensing means is calibrated to the orientation of a reference surface on which the multifunction laser leveling tool stands and the display module displays the orientation of the reference surface.

18. The multifunction laser leveling tool of claim 17, further comprising a leveling operation mode in which the pendulum is released by the locking means and the first laser plane emitted by the first laser beam emitter is projected onto an objective surface to form a horizontal laser line thereon.

19. The multifunction laser leveling tool of claim 17 or 18, further comprising an oblique line generating operation mode in which an oblique laser line can be formed on an objective surface by the steps of:

- 1) setting the multifunction laser leveling tool onto a reference surface, with the pendulum being released by the locking means;
- 2) then locking the pendulum by the locking means; and
- 3) then tilting the multifunction laser leveling tool to desired orientation so that the first laser plane is projected forwards onto the objective surface and forming an oblique laser line thereon.

20. The multifunction laser leveling tool of any one of claims 17 to 19, further comprising an oblique angle measuring operation mode in which the oblique angle of a line to be measured can be obtained by the steps of:

- 1) setting the multifunction laser leveling tool onto a reference surface, with the pendulum being released by the locking means, to obtain a first measured orientation of the leveling tool;
 - 2) then locking the pendulum by the locking means;
 - 3) then tilting the multifunction laser leveling tool until the first laser plane passes through the line to be measured and obtaining a second measured orientation of the leveling tool; and
 - 4) then calculating the oblique angle of the line to be measured from the difference between the first and second measured orientations of the leveling tool.
21. The multifunction laser leveling tool of claim 20, further comprising calculating means for calculating the oblique angle from the first and second measured orientations of the leveling tool.

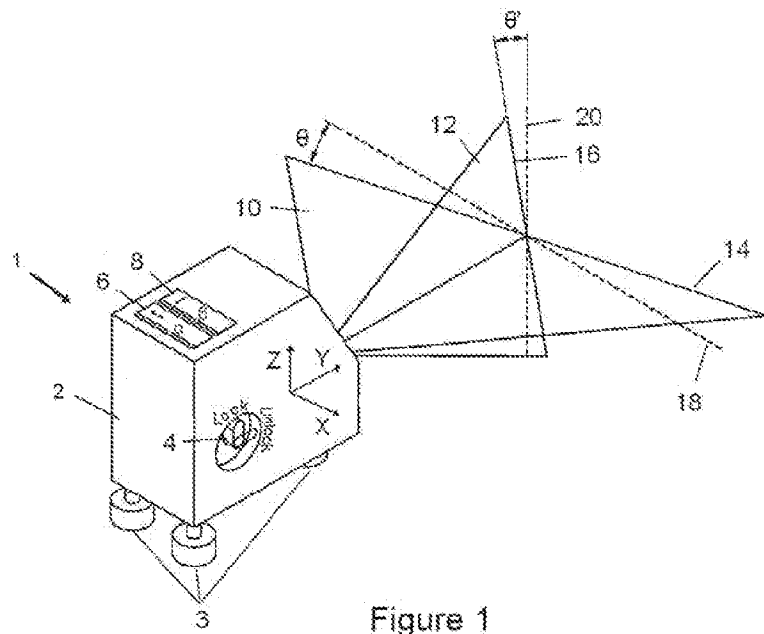


Figure 1

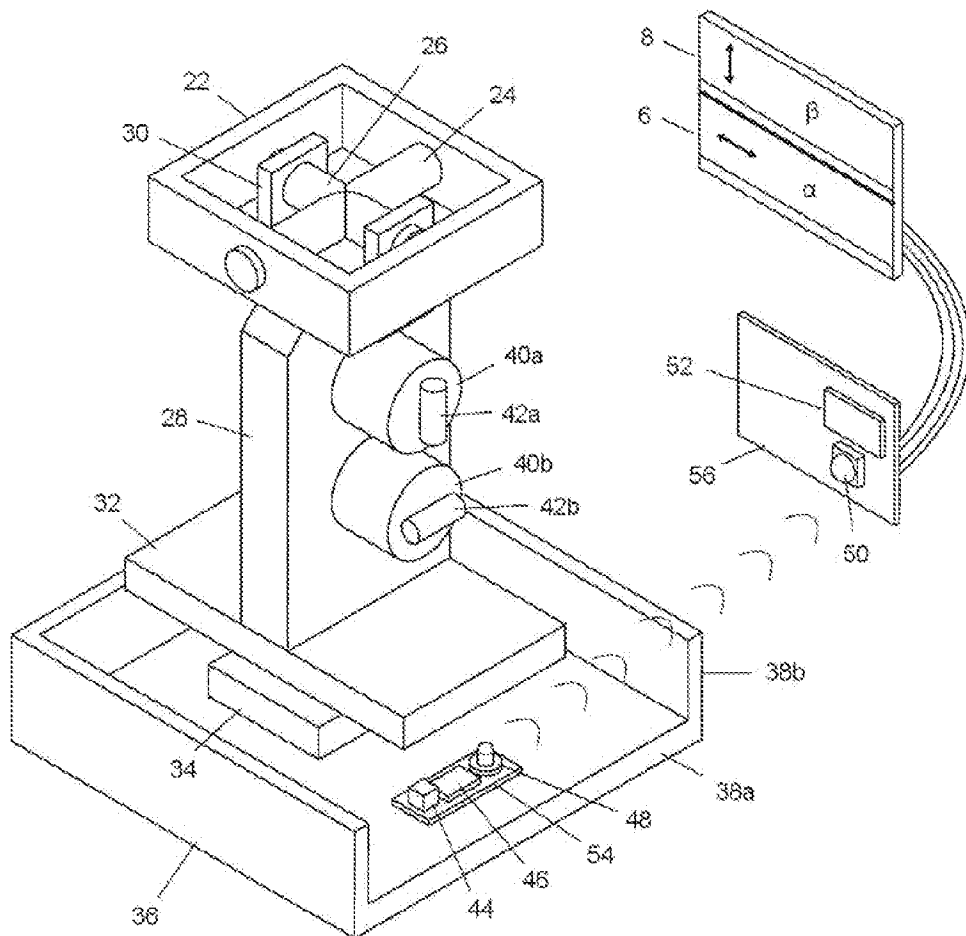


Figure 2

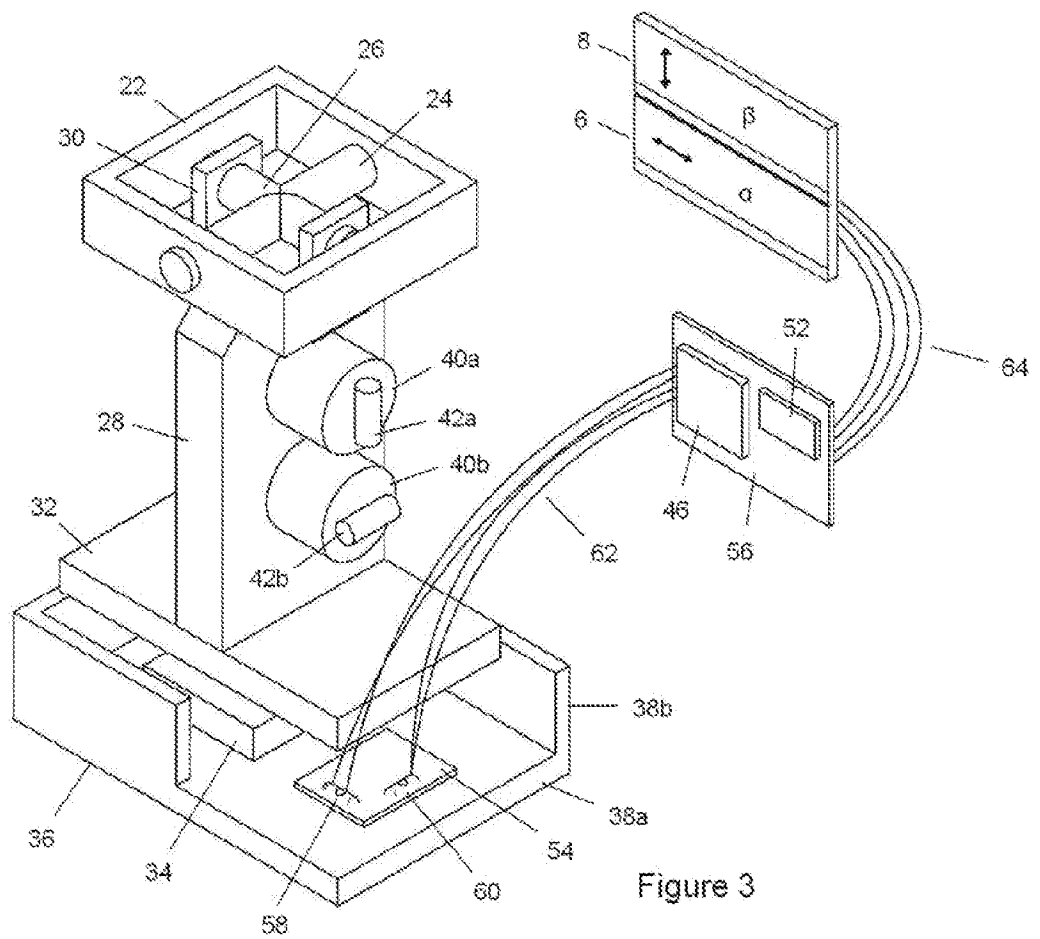


Figure 3

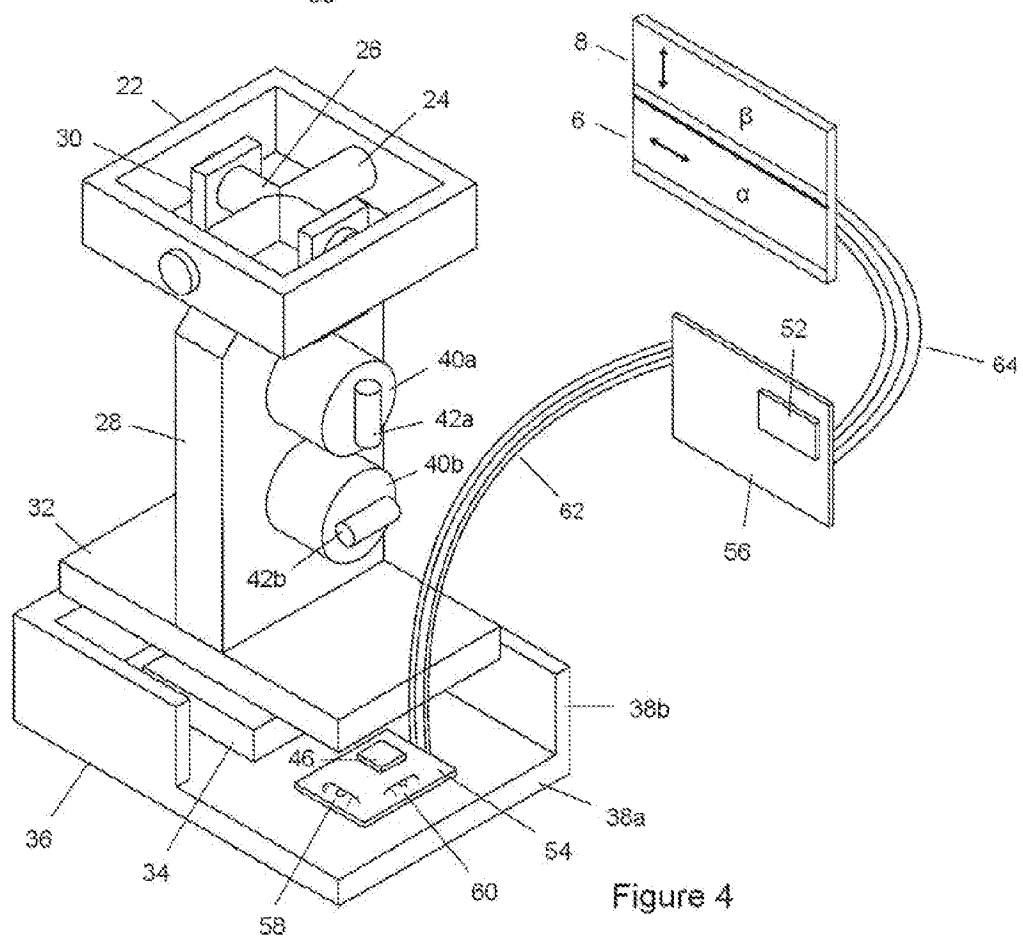


Figure 4

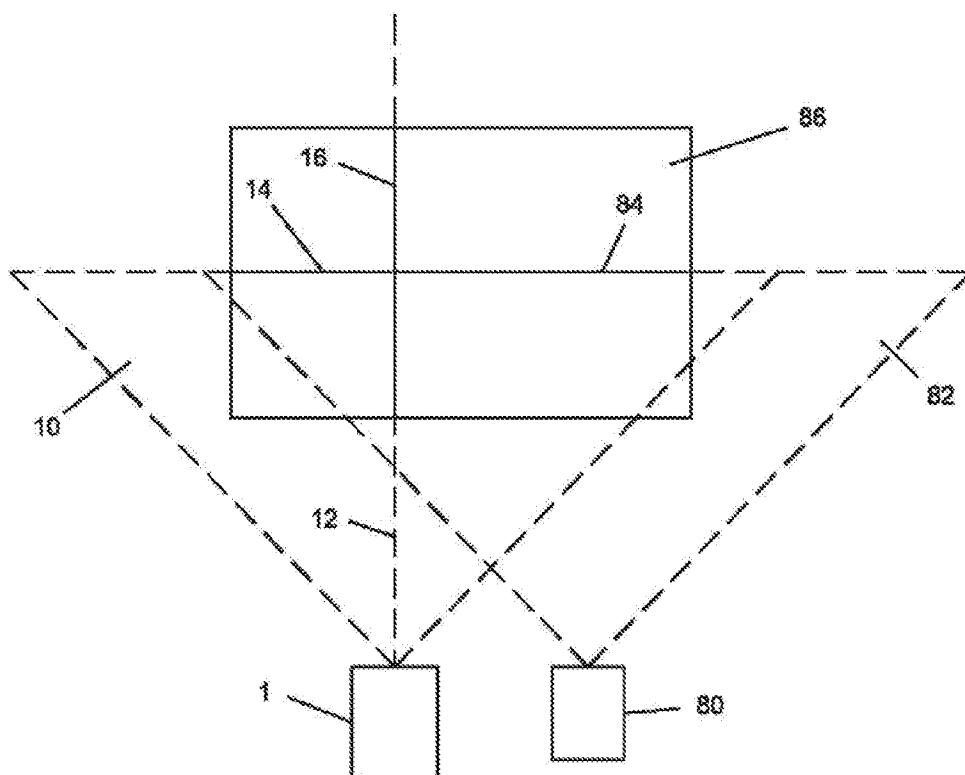


Figure 5

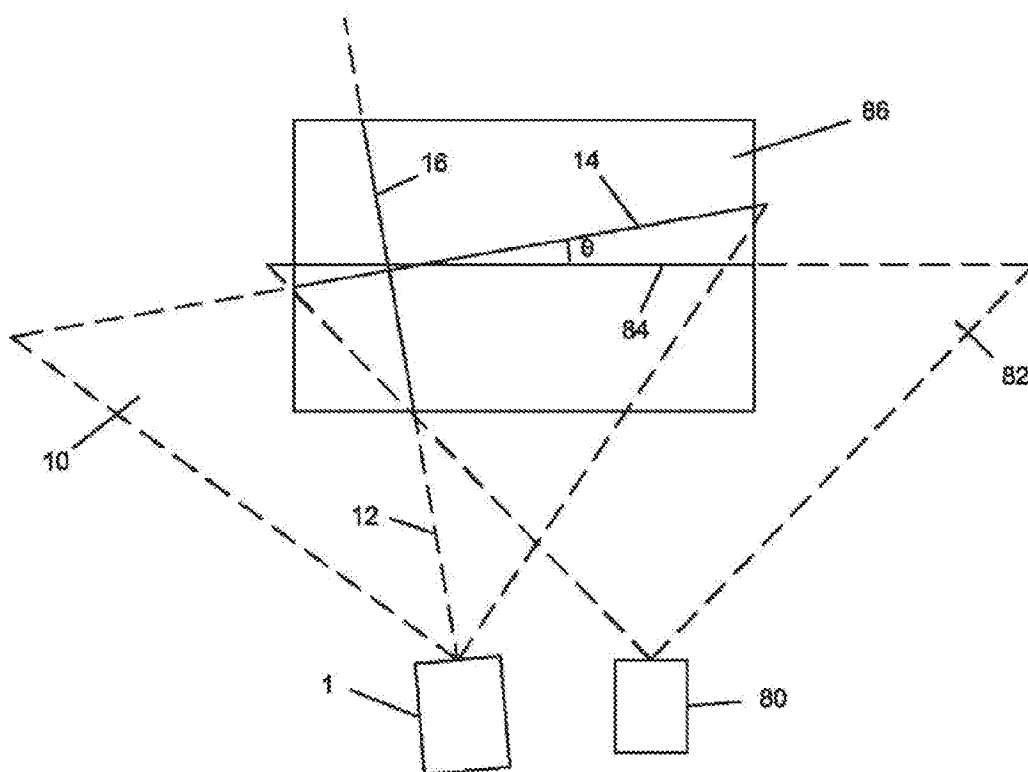


Figure 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/090416

A. CLASSIFICATION OF SUBJECT MATTER

G01C 15/00(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)

G01

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)

CNABS, CNTXT, VEN: pendulum, lock+, laser, gravitation, gravity, weight, plumb

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013120271 A1 (ROBERT BOSCH COMPANY LTD) 22 August 2013 (2013-08-22) claims 1-15, description, pages 2-12 and figures 1-6	1-21
X	CN 201297572 Y (BLACK & DECKER INC) 26 August 2009 (2009-08-26) description, page 3, line 25-page 6, line 27, page 14, line 24-page 9, line 15, figures 1A-4B	1-15, 17-21
Y	CN 201297572 Y (BLACK & DECKER INC) 26 August 2009 (2009-08-26) description, page 3, line 25-page 6, line 27, page 14, line 24-page 9, line 15, figures 1A-4B	16
Y	CN 201255639 Y (SHEN, JIANMING) 10 June 2009 (2009-06-10) description, page 4, lines 1-11, figures 1, 7	16
A	CN 1458499 A (WU, XIONG) 26 November 2003 (2003-11-26) the whole document	1-21
A	US 6763595 B1 (PLS PACIFIC LASER SYSTEMS) 20 July 2004 (2004-07-20) the whole document	1-21



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	“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
“E” earlier application or patent but published on or after the international filing date	“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
“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)	“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
“O” document referring to an oral disclosure, use, exhibition or other means	“&” document member of the same patent family
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

31 July 2014

Date of mailing of the international search report

03 September 2014

Name and mailing address of the ISA/

STATE INTELLECTUAL PROPERTY OFFICE OF THE
P.R.CHINA(ISA/CN)
6,Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088 China

Facsimile No. (86-10)62019451

Authorized officer

CHENG,Can

Telephone No. (86-10)62085714

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/CN2013/090416

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