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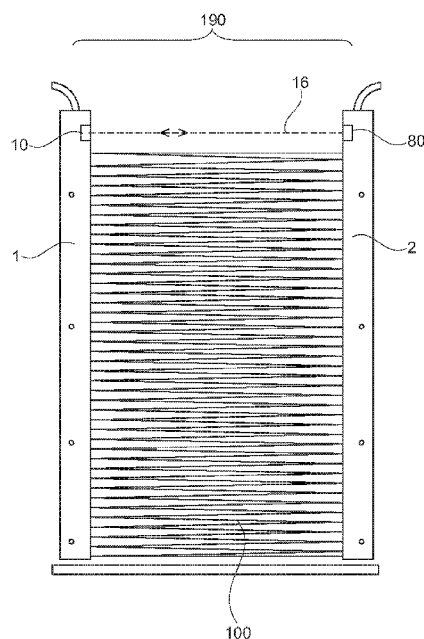


Fig. 2

(57) Abstract: In one aspect, the present invention provides a sliding door monitoring system comprising a time-of-flight ranging sensor (10) and a retroreflector (80), wherein the time-of-flight ranging sensor comprises a transmitter of electromagnetic radiation and a receiver of electromagnetic radiation, and the retroreflector is positioned to reflect electromagnetic radiation from the transmitter to the receiver. In another aspect, the present invention also provides a method of monitoring a sliding door in a door opening, wherein the method comprises transmitting electromagnetic radiation across a gap in the door opening, reflecting the electromagnetic radiation from across the gap, receiving the reflected electromagnetic radiation on the same side of the gap as its transmission, measuring a time of flight of the electromagnetic radiation from its transmission to its reception and, optionally, an amount of the reflected electromagnetic radiation, and determining a size of the gap from both the time of flight and the amount of reflected electromagnetic radiation thus measured.

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SLIDING DOOR SYSTEM AND METHOD

The present invention concerns a sliding door system and a method of monitoring a sliding door of the type found in elevator doorways, for example.

It is desirable for safety reasons to be able to confirm that a door opening across an elevator doorway is closed, for example before the elevator starts to move. Elevator doors are generally already provided with an interruptible curtain of electromagnetic radiation, which is typically infrared radiation, in order to ensure that there are no obstructions present in the doorway before the door closes. Such a curtain is generally provided by an array of transmitters of electromagnetic radiation, such as infrared LEDs, and an opposing array of receivers of electromagnetic radiation, such as infrared photodiodes, mounted on opposing sides of the elevator doorway, or both on the same side of the doorway with an opposing reflective strip. Such a curtain provides a yes-or-no determination of whether an obstruction is present in the doorway, but can only give a very limited indication of how far apart the doors are, for reasons that will be described below. In addition, such known systems are unable to sense the rate of door closing or opening.

Sensing systems for determining that an elevator doorway is closed do already exist, but these systems are generally at least partially mechanical in nature because they rely on physical touching of components or on moving parts, for example by counting cogs on a drive belt associated with movement of the sliding door or doors, in order to determine that the doorway is closed. Such prior art systems are consequently generally relatively large and expensive, and also prone to malfunction. It would therefore be desirable to provide a non-mechanical sliding door monitoring system able to determine that an elevator doorway is closed, since such a system could in principle be both cheaper and more reliable than a prior art system with mechanical components. Such a system would preferably be able to determine the size of a gap remaining across an elevator doorway by sensing the relative location of an opposing door or slam post or an obstacle between the doors. It may also be able to determine if the door is closing or closed and potentially able to determine the rate of closing

An alternative, non-mechanical arrangement, of sensing an opposing door or slam post uses ultrasound to determine the size of a gap remaining across an elevator doorway. Unfortunately, such an arrangement suffers from the problem that ultrasonic transducers are generally quite large, and are therefore generally too bulky to be mounted into the edge of a sliding door or a slam post. Laser diodes do not suffer from this problem, since they are

generally much smaller than ultrasonic transducers, but the beams of laser light they emit are generally too accurately pointed in only a single direction to be of any use in sensing the location of an opposing door or slam post. This is because if such a laser diode is mounted into the edge of a sliding door or slam post along with other components of an interruptible curtain of electromagnetic radiation across an elevator doorway, such as an array of transmitters or receivers of electromagnetic radiation, the array will have been installed with installation tolerances that typically allow for a tilt of each array of up to about 5 degrees, a rotation around a vertical axis of up to about 5 degrees, and a vertical displacement of up to about 10 mm in either direction. This makes the initial pointing and positioning of a laser diode installed along with the array of transmitters or receivers equally inaccurate, which has a knock-on effect on the accuracy with which the size of a gap across the doorway can be determined using the laser diode. In other words, an accurately pointed laser beam may return widely different estimations of the size of a gap remaining across an elevator doorway, depending upon how it has been installed, which will affect how it is reflected or received, provided that it can be received at all.

It is also hard to see how an existing interruptible curtain of electromagnetic radiation for detecting whether an obstruction is present in an elevator doorway could be used to determine the size of a gap remaining across the doorway by sensing the location of an opposing door or slam post using the arrays of transmitters and receivers of electromagnetic radiation themselves. This is because an elevator doorway may open by up to about 4 metres. Comparing relative intensities of the transmitted and the received electromagnetic radiation between fully open and fully closed positions therefore spans several orders of magnitude, giving a very wide dynamic range, and is also susceptible to noise from the environment at the low intensities of received radiation which correspond to the fully open position. These factors combine to make a reliable determination of the size of a gap remaining across the doorway based on the relative intensity of the transmitted and received radiation very difficult or impossible.

An object of the present invention, therefore, is to provide a method of monitoring a sliding door and a sliding door system which aim to address these problems with the known prior art systems. A further object of the present invention is to provide a sliding door type elevator with a door monitoring system according to aspects of the present invention.

Accordingly, in a first aspect, the present invention provides a sliding door system comprising: a first door and a second door; a time-of-flight ranging sensor and a retroreflector, wherein the time-of-flight ranging sensor comprises a transmitter of electromagnetic radiation and a

receiver of electromagnetic radiation and is positioned on said first door, and the retroreflector is positioned on the second door to reflect electromagnetic radiation from the transmitter to the receiver.

- 5 Preferably, the system further comprises a window transparent to the electromagnetic radiation, covering both the transmitter and the receiver, wherein the window comprises a pair of cones or frustums, each having a central axis aligned with a respective one of the transmitter and the receiver. If so, the pair of cones or frustums are preferably joined together to form a trough. The window preferably comprises a locator for aligning the window with the time-of-flight ranging sensor.

10 Preferably, the system further comprises a channel having a cover, wherein the channel contains a printed circuit board mounted with the time-of-flight ranging sensor and the cover comprises an aperture for receiving the window and a gasket interposed between the window and the aperture. The channel is preferably made of a metal and the cover is preferably made of a plastics material.

The retroreflector preferably comprises encapsulated lens tape. In an alternative preferred embodiment, the electromagnetic radiation is infrared and the retroreflector is made of a material which appears black in visible light.

The time-of-flight ranging sensor is preferably mounted in a sensing apparatus and the retroreflector is preferably mounted in an opposing reflecting apparatus movable relative to the sensing apparatus.

25 The sensing apparatus preferably comprises a first array of receivers of electromagnetic radiation and the reflecting apparatus preferably comprises a second array of transmitters of electromagnetic radiation, wherein the second array of transmitters and the first array of receivers provide an interruptible curtain of electromagnetic radiation there between. In an alternative embodiment, it is also possible, however, for the sensing apparatus to comprise the second array of receivers and for the reflecting apparatus to comprise the first array of receivers of electromagnetic radiation. In another alternative possible embodiment, the sensing apparatus may comprise both the first array of receivers and the second array of transmitters of electromagnetic radiation, and the reflecting apparatus may comprise a reflective strip for reflecting the electromagnetic radiation from the transmitters back to the receivers.

The sensing apparatus may be mounted to a first sliding door and the reflecting apparatus may be mounted to a second sliding door opposing the first sliding door or to a slam post opposing the first sliding door. Alternatively, the sensing apparatus may be mounted to a slam post and the reflecting apparatus may be mounted to a sliding door opposing the slam post.

5 At least one of the sliding door or doors may comprise a plurality of door panels movable relative to each other.

Preferably, the time-of-flight ranging sensor is mounted at a height of 1.6 metres or more, more preferably at a height of 1.7 metres or more, and most preferably at a height of 1.8
10 metres or more.

Preferably, the time-of-flight ranging sensor is oriented to transmit a beam of electromagnetic radiation substantially horizontally.

15 In one arrangement the system further includes a controller for receiving signals from said time-of-flight ranging sensor and for determining one or more movement characteristics of the doors.

The system may also include a door motor for causing opening and closing of said doors and
20 wherein said controller includes a control output for controlling the motor such as to control the opening and closing of said doors.

Advantageously, said controller may include a determinator for determining one or more of door speed, door direction, door open or closed status.

25

Preferably, said controller also include an output device for outputting a signal indicative of one or more of: door speed, door direction, door open/closed status. Said controller may include one or more of: an audio output, a visual output.

30 The present invention also encompasses an elevator comprising a sliding door monitoring system according to any aspect of the present invention.

In a third aspect, the present invention also provides an elevator door opening comprising a
35 sliding door monitoring system according the first aspect of the invention.

In a fifth aspect, the present invention further provides a method of monitoring a gap between sliding doors in a door opening, wherein the method comprises transmitting electromagnetic radiation from said first door across the gap in the door opening, reflecting the electromagnetic radiation from across the gap from a retroreflector positioned on said second door, receiving
5 the reflected electromagnetic radiation on the same side of the gap as its transmission, measuring the time of flight of the electromagnetic radiation from its transmission to its reception, and determining a size of the gap from the time of flight.

The method preferably further comprises deciding that the door opening is closed by the
10 sliding door if the size of the gap is determined to be less than a first predetermined amount.

The first predetermined amount is preferably less than or equal to 50 mm, more preferably less than or equal to 20 mm.

15 The method preferably further comprises initiating movement of an elevator carriage if it is decided that the door opening is closed by the sliding door.

The method preferably further comprises moving the sliding door at a first speed across the door opening if the size of the gap is determined to be more than or equal to a second
20 predetermined amount and at a second speed across the door opening if the size of the gap is determined to be less than the second predetermined amount. The second speed may, for example, be less than the first speed to provide a soft close, and therefore, improved safety for users.

25 The second predetermined amount may be greater than the first predetermined amount, for example 600 mm, but is preferably equal to the first predetermined amount.

The method may further comprise generating a signal indicative of the size of the gap across the door opening, and controlling the speed of movement of the sliding door on the basis of
30 the signal.

The method preferably further comprises verifying that the electromagnetic radiation received on the same side of the gap as its transmission has been reflected from across the gap and not by an obstruction within the gap by comparison with signals received from an interruptible
35 curtain of electromagnetic radiation provided across the gap to detect obstructions therein.

Further features and advantages of the present invention will become apparent from the following detailed description, which is given by way of example and in association with the accompanying drawings, in which:

5 Fig. 1 is a schematic perspective view from above of two time-of-flight ranging sensors mounted beside a pair of sliding doors;

Fig. 2 is a front elevational view of a first embodiment of a sliding door monitoring system comprising a sensing apparatus and a reflecting apparatus;

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Fig. 3 is an exploded perspective view of a first embodiment of a sensing apparatus comprising a time-of-flight ranging sensor;

15 Fig. 4 is an exploded perspective view from one side and in front of a second embodiment of a sensing apparatus comprising a time-of-flight ranging sensor;

Fig. 5 is an exploded perspective view from another side and behind of the sensing apparatus shown in Fig. 4;

20 Fig. 6 is a transverse cross-sectional view through a second embodiment of a sliding door monitoring system comprising a sensing apparatus and a reflecting apparatus;

Fig. 7 is a first transverse cross-sectional view through the sensing apparatus and reflecting apparatus shown in Fig. 6 each mounted to a respective one of a pair of sliding doors;

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Fig. 8 is a second transverse cross-sectional view through the sensing apparatus and reflecting apparatus shown in Fig. 6 each mounted to a respective one of a pair of sliding doors;

30 Fig. 9A is an isometric view of a time-of-flight ranging sensor;

Fig. 9B is a side elevational view of the time-of-flight ranging sensor shown in Fig. 9A;

35 Fig. 10 is a perspective view of a window for use with a time-of-flight ranging sensor in a sliding door monitoring system;

Fig. 11 is a side elevational view of the window shown in Fig. 10;

Fig. 12 is a front elevational view of the window shown in Figs. 10 and 11;

Fig. 13 is a top plan view of the window shown in Figs. 10 to 12; and

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Fig. 14 is a schematic representation of a control system associated with the above-described arrangement

Referring firstly to Fig. 1, there is shown a prior art sliding door system, in which two time-of-flight ranging sensors are mounted beside, but not on, a pair of sliding doors 170a, 170b. Each time-of-flight ranging sensor comprises a transmitter of electromagnetic radiation and a receiver of electromagnetic radiation. The sliding doors 170a, 170b slide across a door opening 110 to provide a gap 190 in the door opening 110 and may form part of an elevator carriage, for example. The time-of-flight ranging sensors may be mounted on an interior surface of the elevator carriage, such as its ceiling, or on an exterior surface, such as a ceiling of a lobby or corridor which the elevator serves.

In use, each time-of-flight ranging sensor transmits a respective beam 150a, 150b of electromagnetic radiation, which is typically infrared, downwardly, adjacent to an edge of the door opening 110. The time-of-flight ranging sensors are positioned as described and the beams 150a, 150b of electromagnetic radiation they transmit are oriented as also just described in order to detect whether a user 130 of the sliding doors 170a, 170b has interrupted one or both of the respective beams 150a, 150b in a manner such as is shown in Fig. 1. Each time-of-flight ranging sensor relies on the respective beam 150a, 150b of electromagnetic radiation transmitted therefrom being reflected by the user 130 and received by the receiver in the same time-of-flight ranging sensor as it was transmitted from, in order to detect whether the user 130 has interrupted the respective beam. If so, a control system for controlling movement of the sliding doors 170a, 170b across the door opening 110 can be programmed to protect the user 130 from injury. For example, if the sliding doors 170a, 170b are opening, the control system may stop or reverse movement of the sliding doors 170a, 170b, to prevent for example a finger of the user 130 from becoming trapped in the edge of the door opening 110 as the sliding doors 170a, 170b open.

Fig. 2 shows a first embodiment of a sliding door system comprising a sensing apparatus 1 and a reflecting apparatus 2. The sensing apparatus 1 comprises a time-of-flight ranging sensor 10 on a first door 70a and the reflecting apparatus 2 comprises a retroreflector 80 on a second door 70b. The reflecting apparatus 2 opposes the sensing apparatus 1 across a

gap 190 and is movable relative thereto. The time-of-flight ranging sensor 10 comprises both a transmitter and a receiver of electromagnetic radiation, and the retroreflector 80 is positioned to reflect electromagnetic radiation from the transmitter to the receiver. The time-of-flight ranging sensor 10 is oriented to transmit a beam 16 of electromagnetic radiation substantially horizontally. The time-of-flight ranging sensor 10 is preferably mounted at a height of 1.6 metres or more, more preferably at a height of 1.7 metres or more, and most preferably at a height of 1.8 metres or more, in order to minimize the chances that the beam 16 of electromagnetic radiation will be interrupted by users passing through the gap 190.

The electromagnetic radiation may have a wavelength of visible light or may be in the infrared part of the electromagnetic spectrum, for example. The retroreflector 80 may comprise encapsulated lens tape, of the type used on high-visibility jackets, which has excellent reflective properties to ensure good reflection of the beam 16 of electromagnetic radiation. Alternatively, if the electromagnetic radiation is in the infrared part of the electromagnetic spectrum, the retroreflector 80 may comprise a material which appears black in visible light, again to ensure good reflection of the beam 16 of electromagnetic radiation, whilst filtering out unwanted wavelengths of visible light.

Thus during operation of the sliding door monitoring system, a beam of electromagnetic radiation 16 is transmitted across the gap 190 by the transmitter of the time-of-flight ranging sensor 10, reflected from across the gap 190 by the retroreflector 80 and received by the receiver of the time-of-flight ranging sensor 10 on the same side of the gap 190 as its transmission. The time-of-flight ranging sensor 10 measures the time of flight of the electromagnetic radiation from its transmission to its reception and, optionally, may also measure the amount of the reflected electromagnetic radiation, and determines a size of the gap 190 from one or other or both the time of flight and the amount of reflected electromagnetic radiation thus measured.

The sliding door monitoring system may decide that the door opening is closed by the sliding door or doors if the size of the gap is determined to be less than a predetermined amount. Preferably, this predetermined amount is less than or equal to 50 mm, more preferably less than or equal to 20 mm.

The sensing apparatus 1 also comprises a first array of receivers of electromagnetic radiation and the reflecting apparatus 2 comprises a second array of transmitters of electromagnetic radiation. The second array of transmitters and the first array of receivers provides an interruptible curtain 100 of electromagnetic radiation therebetween for detecting an obstruction

in the gap 190. Correct operation of the sliding door monitoring system may be tested by verifying that the electromagnetic radiation received by the time-of-flight ranging sensor 10 has been reflected from across the gap 190 and not by an obstruction contained within the gap, by comparison with signals received from the curtain 100. In other words, if the curtain 100 is interrupted by an obstruction in the gap 190, this may indicate that the electromagnetic radiation received by the time-of-flight ranging sensor 10 has also been reflected by the obstruction, and not by the retroreflector 80. The sliding door monitoring system may then decide that the size of the gap it has determined is incorrect and that the door opening is not closed, even if the size of the gap was determined to be less than the predetermined amount.

Fig. 3 shows a first embodiment of the sensing apparatus 1. In this embodiment, the sensing apparatus 1 comprises a time-of-flight ranging sensor 10, a window 20, a gasket 30 and a cover 50. The time-of-flight ranging sensor 10 comprises a transmitter 12 of electromagnetic radiation and a receiver 14 of electromagnetic radiation. The window 20 is transparent to the electromagnetic radiation transmitted by the time-of-flight ranging sensor 10 and covers both the transmitter 12 and the receiver 14. The cover 50 comprises an aperture 52 for receiving the window 20, and the gasket 30 is interposed between the window 20 and the aperture 52 to seal the aperture 52 against ingress of dust and fluids, such as cleaning fluids or water for example. In an alternative possible embodiment to that shown in Fig. 3, the cover 50 may be transparent to the electromagnetic radiation transmitted and received by the time-of-flight ranging sensor 10, and the time-of-flight ranging sensor 10 may be mounted in contact with a rear face of the cover 50, obviating the need for the aperture 52 in cover 50, the window 20, and the gasket 30 interposed there between. However, whereas such an alternative possible arrangement guarantees protection against ingress of dust and fluids, it may be more difficult to achieve correct mounting of the time-of-flight ranging sensor 10 in contact with the rear face of cover 50.

Figs. 4 and 5 show a second embodiment of the sensing apparatus 1. In this embodiment, the sensing apparatus 1 comprises a time-of-flight ranging sensor 10, a window 20, a gasket 30 and a channel 40 having a cover 50. The cover 50 has a snap fit with the channel 40. The channel 40 may be made of a metal for strength and rigidity and the cover 50 may be made of a plastics material to allow the snap fit. The channel 40 contains a printed circuit board 60 which is mounted with the time-of-flight ranging sensor 10. As may be seen in Fig. 4, an inner surface of the channel 40 is provided with a groove to receive the printed circuit board 60 therein, as well as with a plurality of reinforcing ribs. An outer surface of the channel 40 comprises a flange 42 having one or more attachment points 44 for mounting the sensing apparatus 1 to a sliding door or a slam post, for example. As in the first embodiment of Fig. 3, the cover 50

comprises an aperture 52 for receiving the window 20, and the gasket 30 is interposed between the window 20 and the aperture 52 to seal the aperture 52 against ingress of fluids. If the channel 40 is made of a metal and the cover 50 is made of a plastics material, the gasket 30 helps to maintain a seal in the event of differential expansion of these two different materials under varying environmental conditions. Preferably, the gasket is made of a resilient material, such as foam or rubber.

Fig. 6 shows a cross-section through a second embodiment of a sliding door monitoring system comprising a sensing apparatus 1 such as that shown in Figs. 4 and 5 and a reflecting apparatus 2 comprising a retroreflector 80. Similarly to the sensing apparatus 1, the reflecting apparatus 2 comprises a channel 40 having a cover 50, which has a snap fit with the channel 40, and an outer surface of the channel 40 comprises a flange 42 having one or more attachment points 44 for mounting the reflecting apparatus 2 to a sliding door or a slam post, for example. An inner surface of the channel 40 of the reflecting apparatus 2 is also provided with a groove to receive a printed circuit board 60 therein, as well as with a plurality of reinforcing ribs. Although not shown as such in Fig. 6, the retroreflector 80 preferably extends across the full width of the reflecting apparatus 2, in order to maximize the chances of the beam of electromagnetic radiation transmitted from the time-of-flight ranging sensor 10 being reflected back to the sensor 10.

Figs. 7 and 8 show the sliding door system of Fig. 6 in which the sensor 10 and retroreflector 80 are mounted to a pair of sliding doors 70a, 70b. The sensing apparatus 1 and the reflecting apparatus 2 shown in Fig. 6 are each mounted to a respective one of the pair of sliding doors 70a, 70b by means of the attachment points 44. As may be seen in Figs. 7 and 8, the sensing apparatus 1 and the reflecting apparatus 2 are mounted behind opposing edges of the doors 70a, 70b by a distance of approximately 5 mm. Hence, even if the doors 70a, 70b are shut, so that the gap 190 between them is zero, the sensing apparatus 1 and the reflecting apparatus 2 do not touch each other. This is to prevent the sensing apparatus 1 and the reflecting apparatus 2 from being subjected to repeated knocks as the sliding doors 70a, 70b open and shut, in order to preserve their correct functioning.

Fig. 7 shows a cross-section through this sliding door monitoring system at the level of the time-of-flight ranging sensor 10 and the retroreflector 80, in other words, at the level of the beam 16 of electromagnetic radiation shown in Fig. 2. In contrast, Fig. 8 shows a cross-section through this sliding door monitoring system at the level of the interruptible curtain 100 in Fig. 2. Thus it may be seen in Fig. 8 that the respective printed circuit boards 60 in each of the sensing apparatus 1 and the reflecting apparatus 2 are respectively mounted with

receivers 90a and transmitters 90b of electromagnetic radiation to provide the interruptible curtain 100. In this embodiment, the receivers 90a are mounted on the same side of the gap 190 as the time-of-flight ranging sensor 10 in order that signals from the receivers 90a and from the time-of-flight ranging sensor 10 may be processed on the same printed circuit board 60 without the need for complicated wiring to transmit the signals across the gap 190.

Whereas Figs. 7 and 8 show an example in which an embodiment of the sliding door system in which the sensor and reflector are mounted to a pair of sliding doors, in other alternative embodiments, the sliding door monitoring system may be mounted across a door opening in which the sensing apparatus 1 is mounted to a sliding door and the reflecting apparatus 2 is mounted to a slam post opposing the sliding door, or in which the sensing apparatus 1 is instead mounted to a slam post and the reflecting apparatus 2 is mounted to a sliding door opposing the slam post. In other words, the sliding door monitoring system need not be mounted across a pair of sliding doors, but can also be mounted across an asymmetrical door opening having only a single sliding door, and in such a case, can be mounted in either orientation, with either the sensing apparatus 1 or the reflecting apparatus 2 mounted on the single sliding door. Moreover, the sliding door monitoring system can also be mounted across door openings in which the one or more sliding doors each comprise a plurality of door panels movable relative to each other.

The door opening may, for example, be an elevator door opening. The sliding door monitoring system may be mounted to one or more exterior sliding elevator doors, such as are found in a lobby or corridor which an elevator serves, or to one or more interior sliding elevator doors, such as are part of an elevator carriage, or, of course, to both.

As mentioned above, the sliding door monitoring system may decide that the door opening is closed by the sliding door or doors if the size of the gap 190 is determined to be less than a first predetermined amount. If the sliding door monitoring system decides that the door opening is indeed closed, it may then initiate movement of an elevator carriage. The sliding door monitoring system may further cause the sliding door or doors to be moved at a first speed across the door opening if the size of the gap is determined to be more than or equal to a second predetermined amount and at a second speed across the door opening if the size of the gap is determined to be less than the second predetermined amount. If so, the second predetermined amount is preferably equal to the first predetermined amount. In other words, the door or doors could, for example, be caused to move more rapidly if they are determined to be wider apart than if they are determined to be closer together, allowing for a soft close, and therefore, improved safety for users.

In one possible embodiment, electromagnetic radiation may be transmitted by a second time-of-flight ranging sensor (not shown in the drawings) in a direction away from the gap in the door opening, as well as from the time-of-flight ranging sensor 10 across the gap 190. In such a case, if the electromagnetic radiation is reflected from an obstruction and received by the time-of-flight ranging sensor 10 on the same side of the gap as its transmission, the sensor 10 may measure both a time of flight of the electromagnetic radiation from its transmission to its reception and an amount of the electromagnetic radiation reflected by the obstruction, and determine a distance to the obstruction from both the time of flight and the amount of reflected electromagnetic radiation thus measured. In such a case, the sliding door monitoring system could additionally prevent the sliding door or doors from closing and/or cause them to be opened if the distance to the obstruction is determined to be less than a predetermined value, such as 300 mm, for example.

Figs. 9A and 9B show in greater detail an example of a time-of-flight ranging sensor 10 which may be used in a sliding door system according to the invention. A suitable example of such a time-of-flight ranging sensor is a VL53L0X time-of-flight ranging sensor available from ST Microelectronics N.V. of Coppel, Texas, USA. As may be seen from Figs. 9A and 9B, the sensor 10 has a transmitter 12 of electromagnetic radiation and a receiver 14 of electromagnetic radiation, which are arranged beside each other on the same side of the sensor 10. The transmitter 12 projects a beam 16 of electromagnetic radiation in a cone of half-angle of about 17.5 degrees and the receiver 14 can receive electromagnetic radiation in a cone of half-angle of about 12.5 degrees. The overall dimensions of the time-of-flight ranging sensor 10 are less than about 10 mm in all directions. In operation, the time-of-flight ranging sensor 10 may transmit and receive a signal to the retroreflector 80 for self-test, even if the door opening is determined to be closed.

Figs. 10 to 13 show in greater detail an example of a window 20 which may be used in a sliding door system according to the invention. The window 20 comprises a pair of cones or frustums 21a, 21b, each having a central axis 22a, 22b. The pair of cones or frustums 21a, 21b ensure that the beam 16 of electromagnetic radiation can be projected from the transmitter 12 in a cone as described above and that the electromagnetic radiation reflected from the retroreflector 80 can be received in the cone of the receiver 14. The pair of cones or frustums 21a, 21b are joined together to form a trough 23. In a preferred embodiment, if the beam 16 of electromagnetic radiation is in the infrared part of the electromagnetic spectrum, the window is preferably coloured to appear red in the visible part of the spectrum to filter out unwanted wavelengths.

When the window 20 is assembled in a sliding door monitoring system with a time-of-flight ranging sensor 10, the central axes 22a, 22b are each aligned with a respective one of the transmitter 12 and the receiver 14 of the time-of-flight ranging sensor 10. In order to ensure correct alignment of the window 20 with the time-of-flight ranging sensor 10 is this manner, the window 20 is provided with a pair of locators 24a, 24b for engagement with suitable features of the time-of-flight ranging sensor 10. In the example of the window shown in Figs. 10 to 13, the locators 24a, 24b are a pair of integrally moulded pins. The window 20 further comprises a lip or rim 25 for engagement with the gasket 30 described above.

Figure 14 is a schematic representation of a control system when incorporated with the present invention and provides a sliding door system as described above together with a controller 200 for receiving signals from said time-of-flight ranging sensor 10 and for determining one or more movement characteristics of the doors 70a, 70b. Also shown as part of the system is a door motor 210 for causing opening and closing of said doors 70a, 70b and the controller 200 includes a control output 212 for controlling the motor 210 such as to control the opening and closing of said doors 70a, 70b as and when required. The controller 200 includes a determinator 214 for determining one or more of door speed, door direction, door open or closed status from sensor data provided from one or more sensors 10 via data line 216. The controller 200 may include an output device 218 for outputting a signal 218a, 218b, 218c indicative of one or more of: door speed, door direction, door open/closed status and may also provide one or more of: an audio output, a visual output signals 218d, 218e. Each of the outputs 218a to 218e may be connected to respective warning devices shown schematically at 230a to 230e for providing visual or audio warnings or displays as and when required. Such warnings may include visual display warnings showing door position or closeness to the closed position, door speed or door direction, door closed or open state etc. the controller may also be programmed to provide lift movement initiation instructions upon determining the state of the doors such as, for example, to initiate audio warnings specifying "doors closing" or "danger, do not enter lift" or to commence lift movement instructions. The controller 214 may also be operably linked to a lift operating system shown at 240 which may take control of other aspects of lift operation. The present invention may be applied to door openings with one or more sliding doors other than just elevator doors, such as entrance doors to rooms or buildings.

A sliding door monitoring system according to the present invention may be used in combination with another device for confirming closure of sliding doors, such as a mechanical

drive which confirms door closure by counting cogs on a drive belt associated with movement of the sliding door or doors, in order to ensure that such another device is working correctly.

Moreover, whereas various optional features of the invention have been described above in particular combinations by way of example only, such optional features may be combined in other ways without restriction to the scope of the invention, which is defined by the appended claims.

CLAIMS

1. A sliding door system (1, 2) comprising:
a first door (70a) and a second door (70b);
5 a time-of-flight ranging sensor (10); and
a retroreflector (80);
wherein the time-of-flight ranging sensor (10) comprises a transmitter (12) of
electromagnetic radiation and a receiver (14) of electromagnetic radiation and is
positioned on said first door (70a) , and the retroreflector (80) is positioned on the second
10 door (70b) to reflect electromagnetic radiation from the transmitter (12) to the receiver
(14).
2. A sliding door system according to claim 1, further comprising a window (20) transparent
to the electromagnetic radiation, covering both the transmitter (12) and the receiver (14),
15 wherein the window (20) comprises a pair of cones or frustums (21a, 21b), each having
a central axis (22a, 22b) aligned with a respective one of the transmitter (12) and the
receiver (14).
3. A sliding door system according to claim 2, wherein the pair of cones or frustums (21a,
20 21b) are joined together to form a trough (23).
4. A sliding door system according to claim 2 or claim 3, wherein the window (20)
comprises a locator (24a, 24b) for aligning the window (20) with the time-of-flight ranging
sensor (10).
- 25 5. A sliding door system according to any one of claims 2 to 4, comprising a channel (40)
having a cover (50), wherein the channel contains a printed circuit board (60) mounted
with the time-of-flight ranging sensor (10) and the cover (50) comprises an aperture (52)
for receiving the window (20) and a gasket (30) interposed between the window (20)
30 and the aperture (52).
6. A sliding door system according any one of the preceding claims, wherein the
retroreflector (80) comprises encapsulated lens tape.
- 35 7. A sliding door system according any one of claims 1 to 6, wherein the electromagnetic
radiation is infrared and the retroreflector (80) appears black in visible light.

8. A sliding door system according any one of the preceding claims, wherein the time-of-flight ranging sensor (10) is mounted in a sensing apparatus (1) and the retroreflector (80) is mounted in an opposing reflecting apparatus (2) movable relative to the sensing apparatus (1).
- 5
9. A sliding door system according to claim 8, wherein the sensing apparatus (1) comprises a first array of receivers (90a) of electromagnetic radiation and the reflecting apparatus (2) comprises a second array of transmitters (90b) of electromagnetic radiation, the second array of transmitters (90b) and the first array of receivers (90a) providing an interruptible curtain (100) of electromagnetic radiation therebetween.
- 10
10. A sliding door system according to claim 8 or claim 9, wherein the sensing apparatus (1) is mounted to a first sliding door (70a) and the reflecting apparatus (2) is mounted to a second sliding door (70b) opposing the first sliding door (70a) or to a slam post opposing the first sliding door (70a).
- 15
11. A sliding door system according to claim 10, wherein at least one of the first and second sliding doors (70a, 70b) comprises a plurality of door panels movable relative to each other.
- 20
12. A sliding door system according to claim 8 or claim 9, wherein the sensing apparatus (1) is mounted to a slam post and the reflecting apparatus (2) is mounted to a sliding door (70b) opposing the slam post.
- 25
13. A sliding door system according to claim 12, wherein the sliding door (70b) comprises a plurality of door panels movable relative to each other.
14. A sliding door system according to any one of claims 10 to 13, wherein the time-of-flight ranging sensor (10) is mounted at a height of 1.6 metres or more.
- 30
15. A sliding door system according to any one of claims 10 to 14, wherein the time-of-flight ranging sensor (10) is oriented to transmit a beam of electromagnetic radiation (16) substantially horizontally.
- 35
16. A sliding door system according to any one of claims 1 to 15 and including a controller (200) for receiving signals from said time-of-flight ranging sensor (10) and for determining one or more movement characteristics of the doors (70a, 70b).

17. A sliding door system according to any one of claims 1 to 16 and including a door motor (210) for causing opening and closing of said doors (70a, 70b) and wherein said controller (200) includes a control output for controlling the motor (210).
- 5
18. A sliding door system according to any one of claims 1 to 17 and including a determinator (214) for determining one or more of door speed, door direction, door open or closed status.
- 10
19. A sliding door system according to any one of claims 1 to 18 and including an output device for outputting a signal (218a, 218b, 218c) indicative of one or more of: door speed, door direction, door open/closed status.
20. A sliding door system according to any one of claims 1 to 19 and including one or more
- 15 of: an audio output (230b), a visual output (230a).
21. An elevator comprising a sliding door monitoring system according to any one of claims 1 to 20.
- 20
22. A method of monitoring a gap (190) between sliding doors (70a, 70b) in a door opening (110), the method comprising:
transmitting electromagnetic radiation from a first door across the gap (190);
reflecting the electromagnetic radiation from across the gap from a retroreflector positioned on said second door (70b);
25 receiving the reflected electromagnetic radiation on the same side of the gap as its transmission;
measuring the time of flight of the electromagnetic radiation from its transmission to its reception; and
determining a size of the gap (190) from the time of flight.
- 30
23. A method according to claim 22, further comprising deciding that the door opening is closed by the sliding door if the size of the gap is determined to be less than a first predetermined amount.
- 35
24. A method according to claim 23, wherein the first predetermined amount is less than or equal to 50 mm.

25. A method according to claim 22 or claim 23, further comprising initiating movement of an elevator carriage if it is decided that the door opening is closed by the sliding door.
- 5 26. A method according to any one of claims 22 to 25, further comprising moving the sliding door at a first speed across the door opening if the size of the gap is determined to be more than or equal to a second predetermined amount and at a second speed across the door opening if the size of the gap is determined to be less than the second predetermined amount.
- 10 27. A method according to claim 26, wherein the second speed is less than the first speed.
28. A method according to any one of claims 22 to 27, further comprising generating a signal indicative of the size of the gap across the door opening; and controlling a speed of the sliding door on the basis of the signal.
- 15 29. A method according to any one of claims 22 to 28, further comprising verifying that the electromagnetic radiation received on the same side of the gap as its transmission has been reflected from across the gap and not by an obstruction within the gap by comparison with signals received from an interruptible curtain (100) of electromagnetic radiation provided across the gap to detect obstructions therein.
- 20

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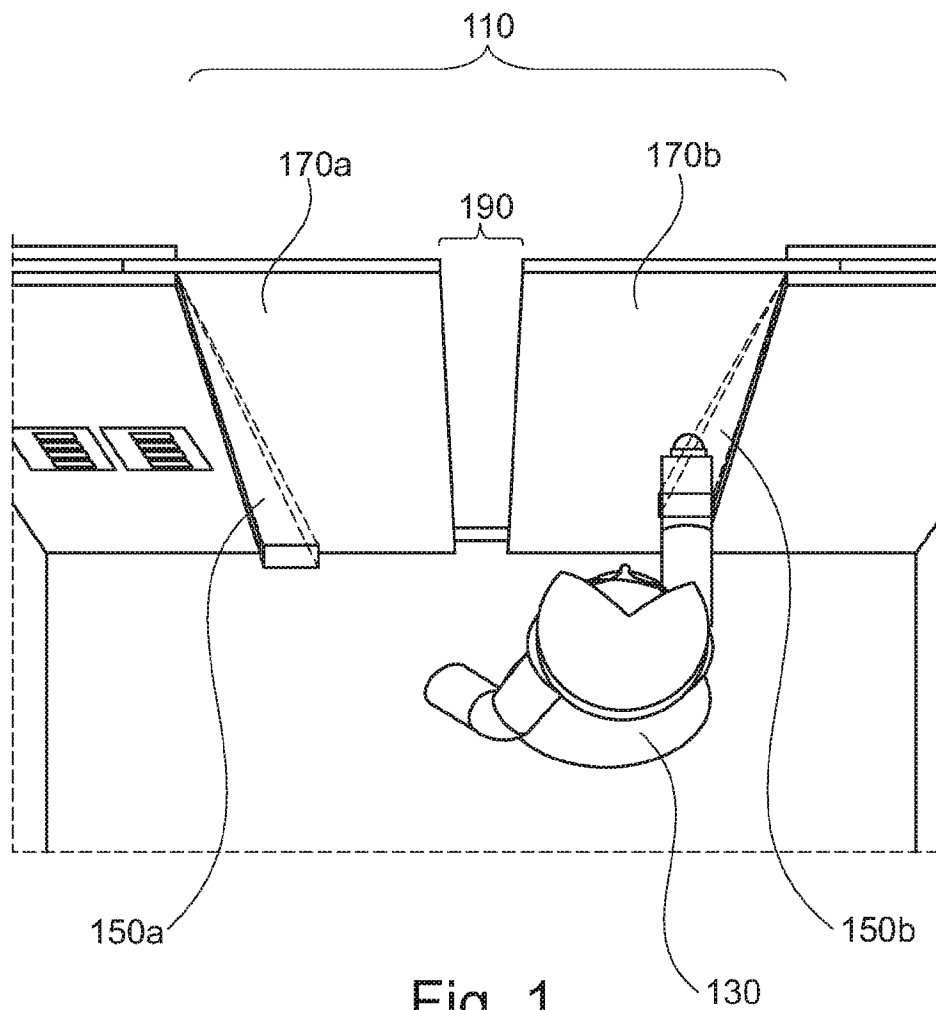


Fig. 1

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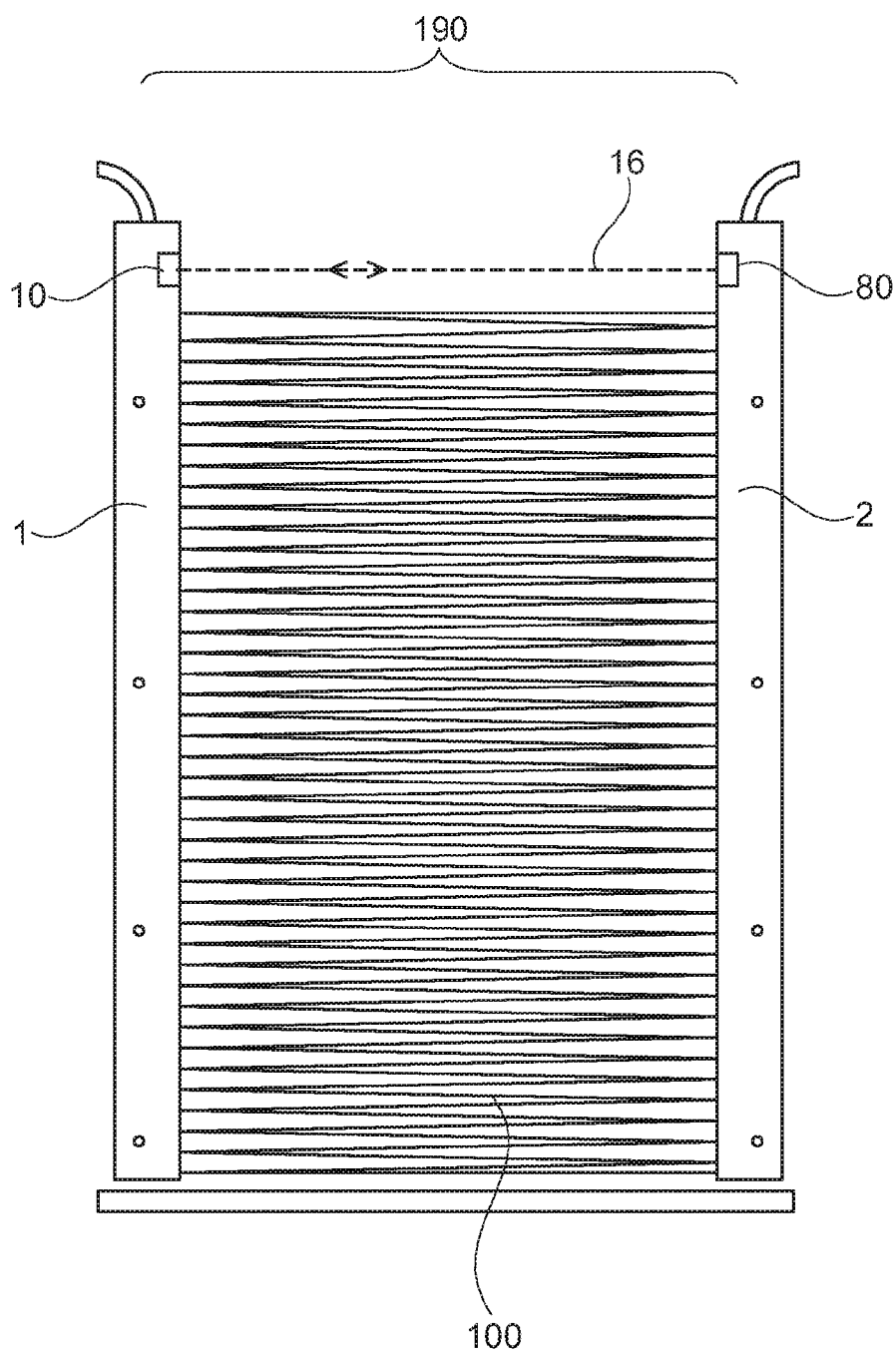


Fig. 2

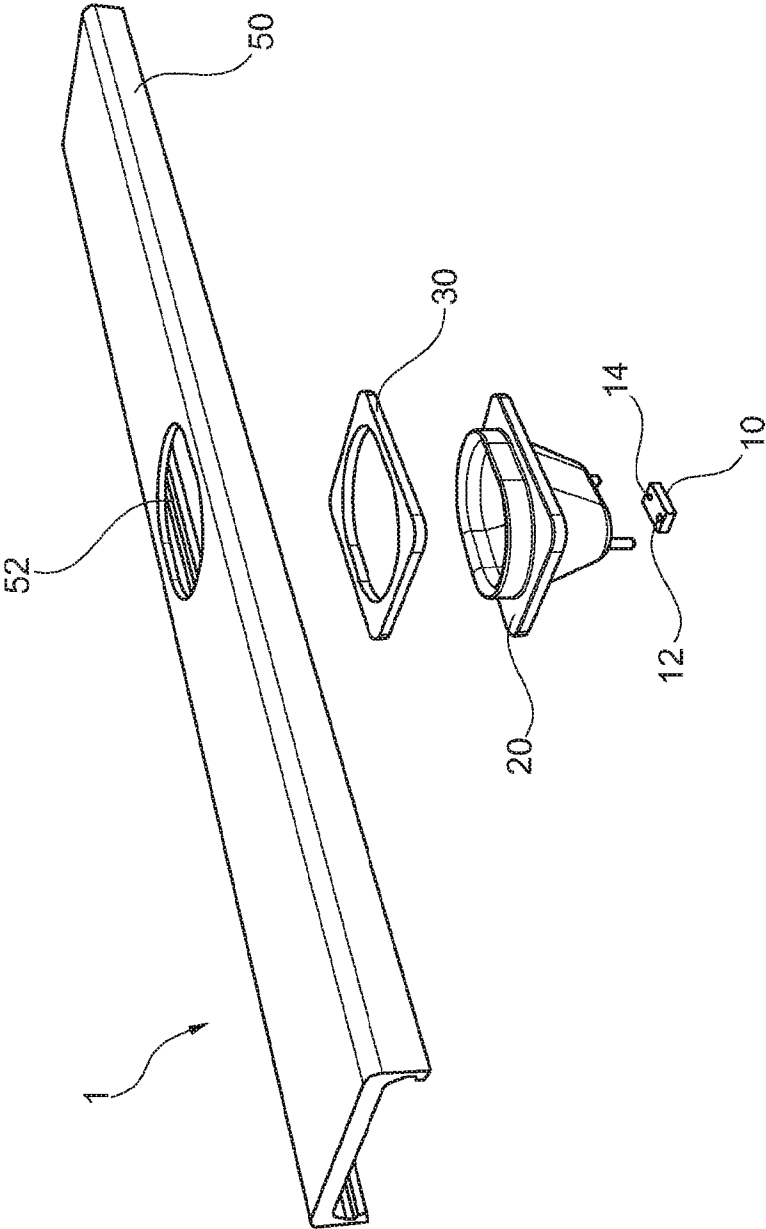


Fig. 3

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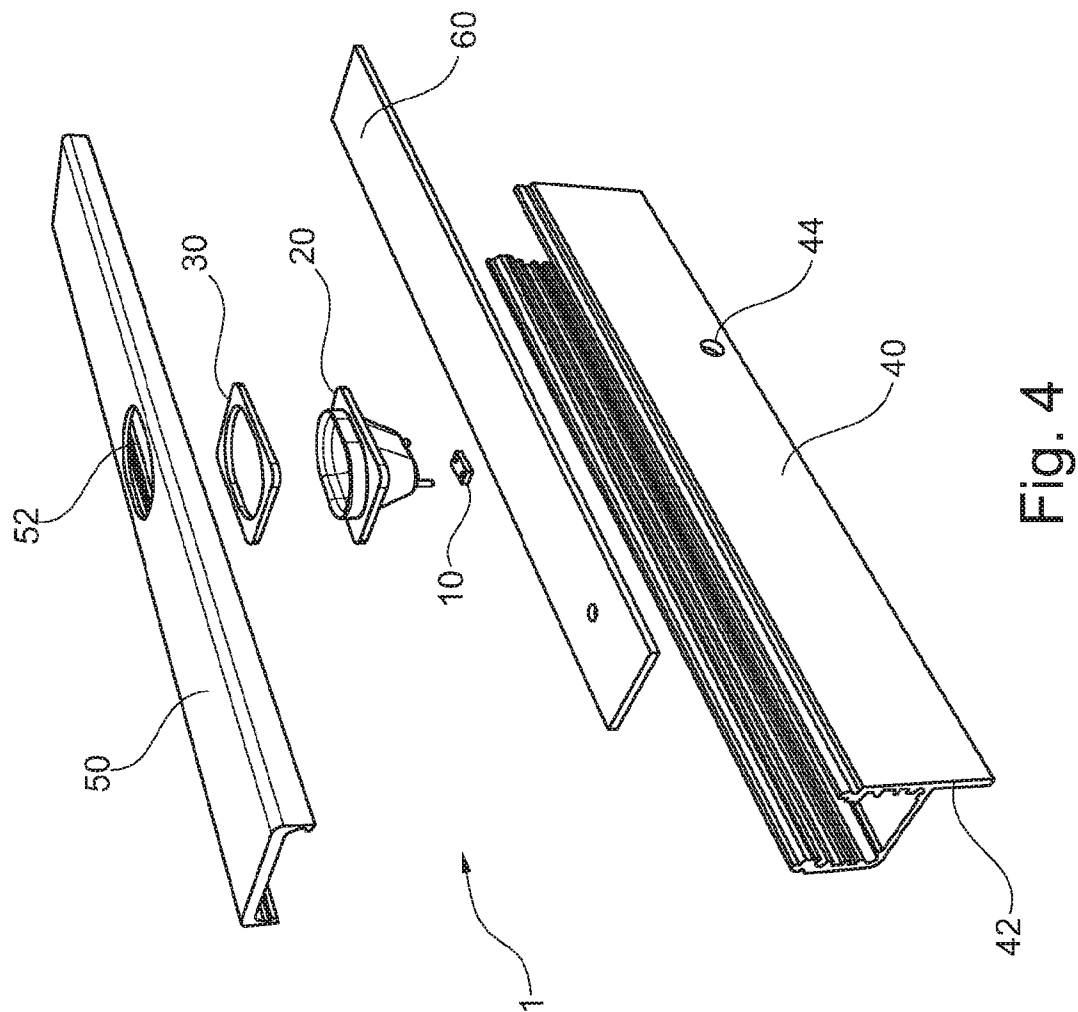


Fig. 4

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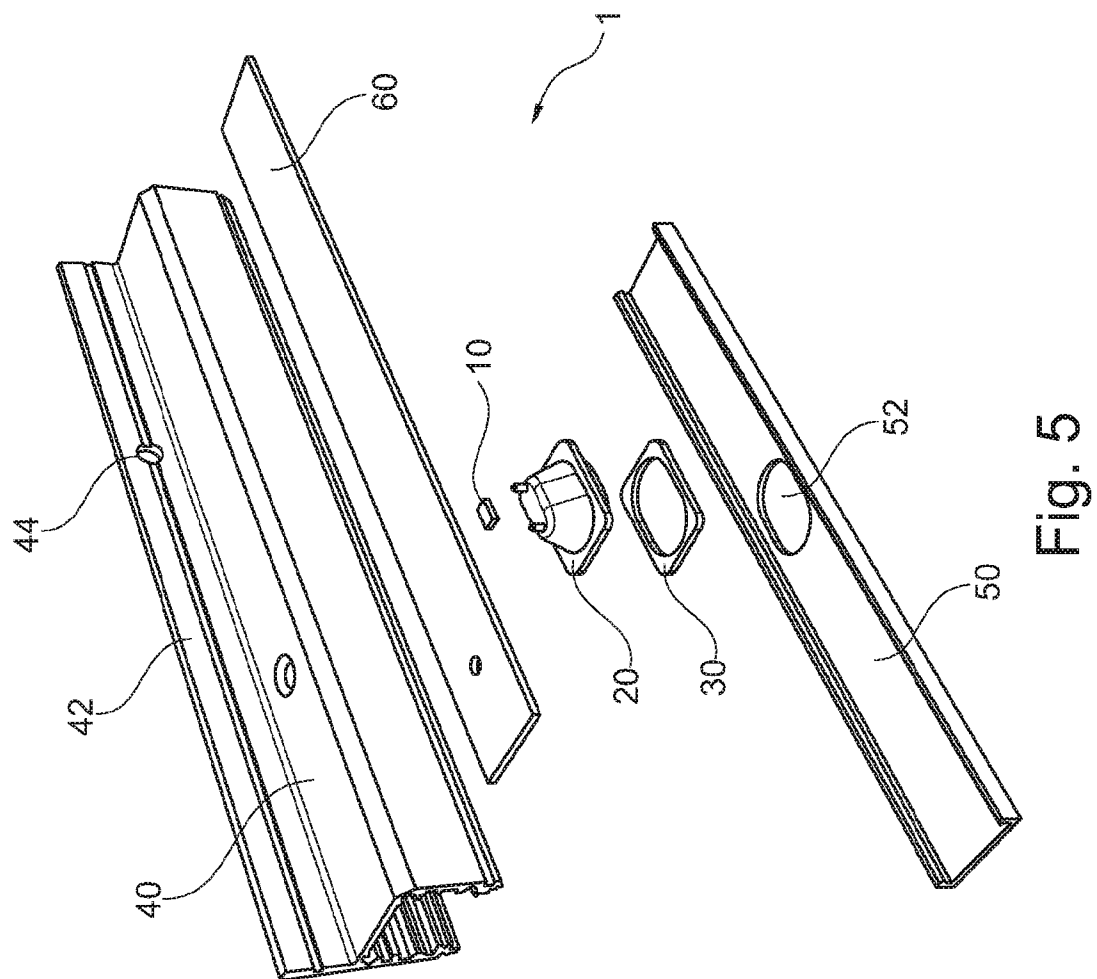


Fig. 5

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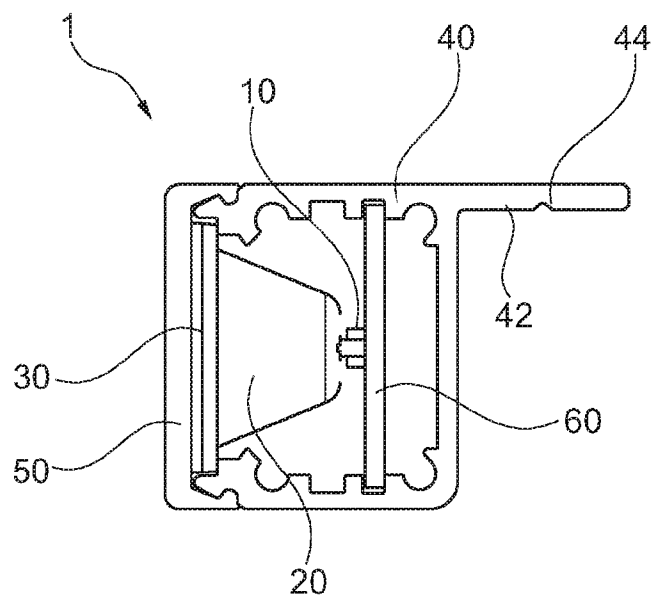
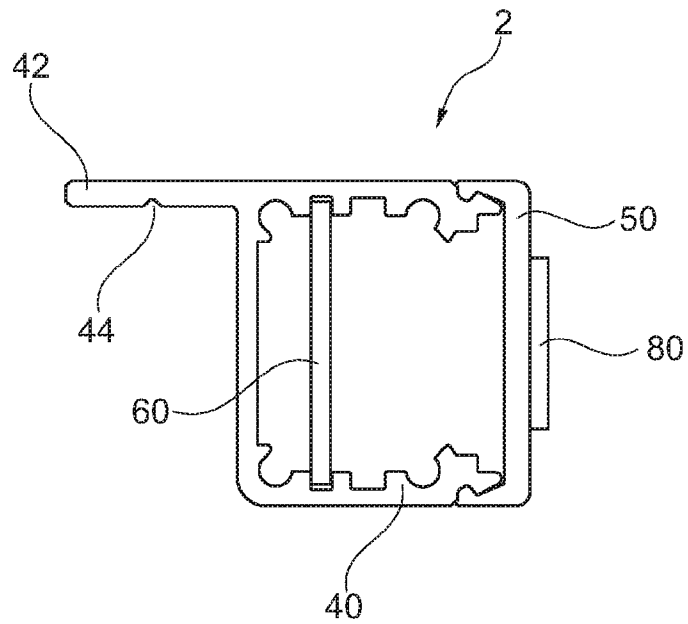
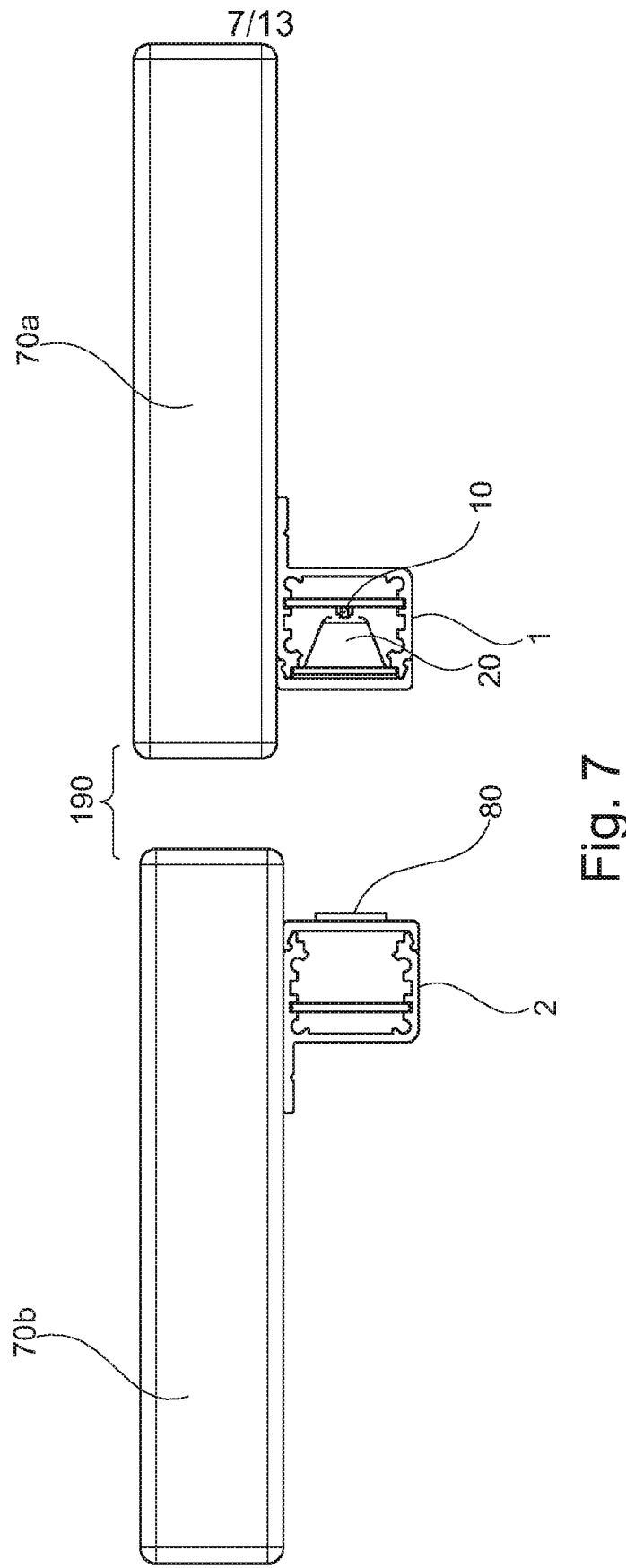
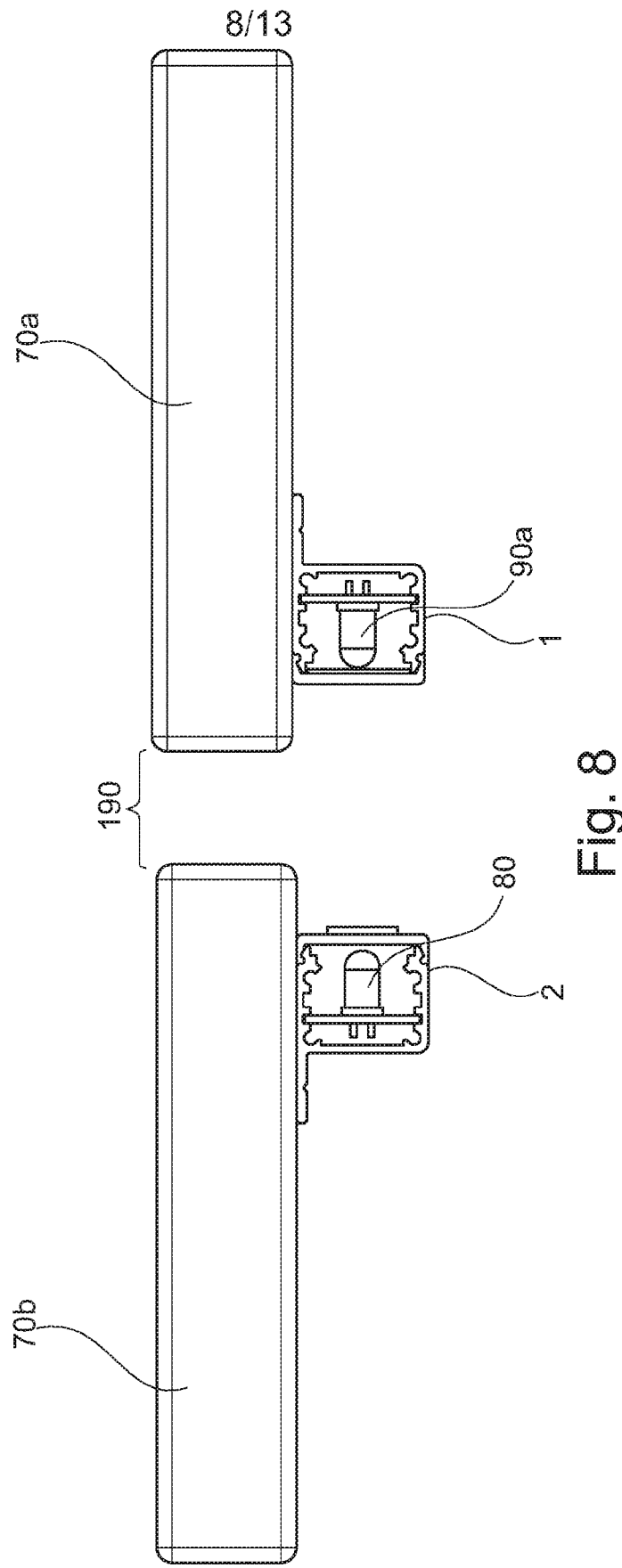


Fig. 6





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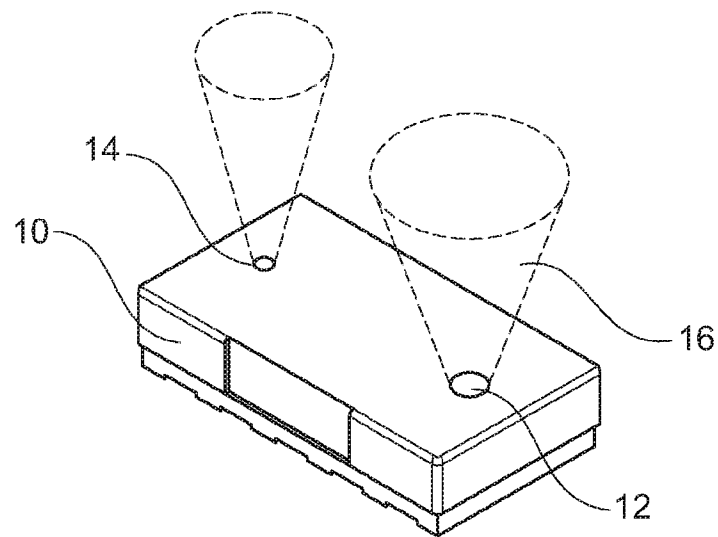


Fig. 9A

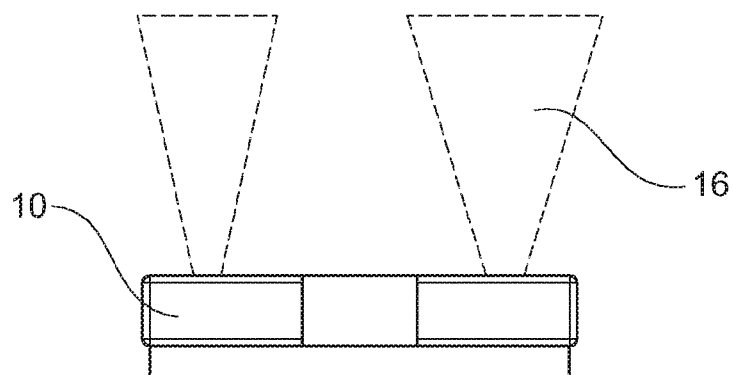


Fig. 9B

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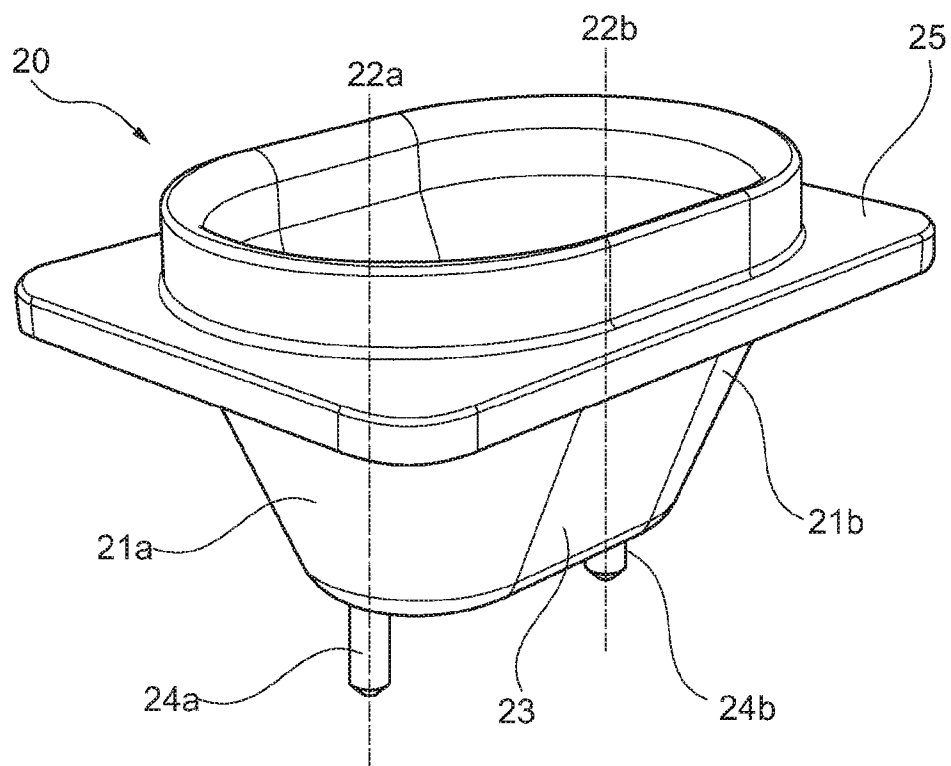


Fig. 10

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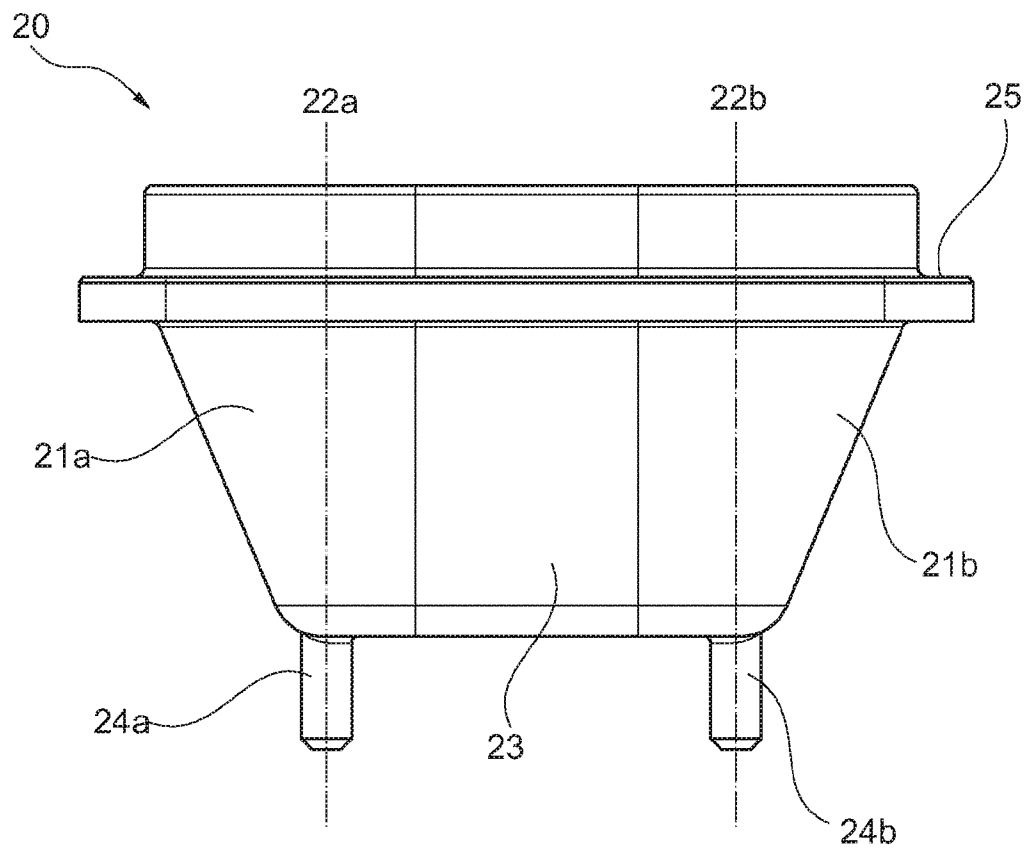


Fig. 11

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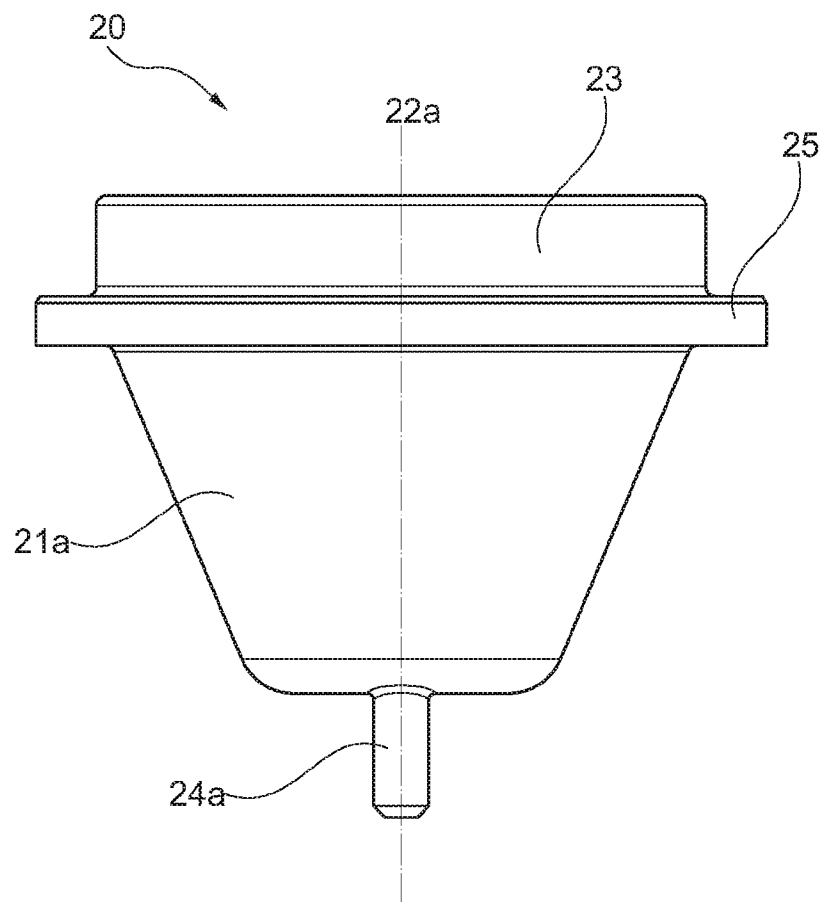


Fig. 12

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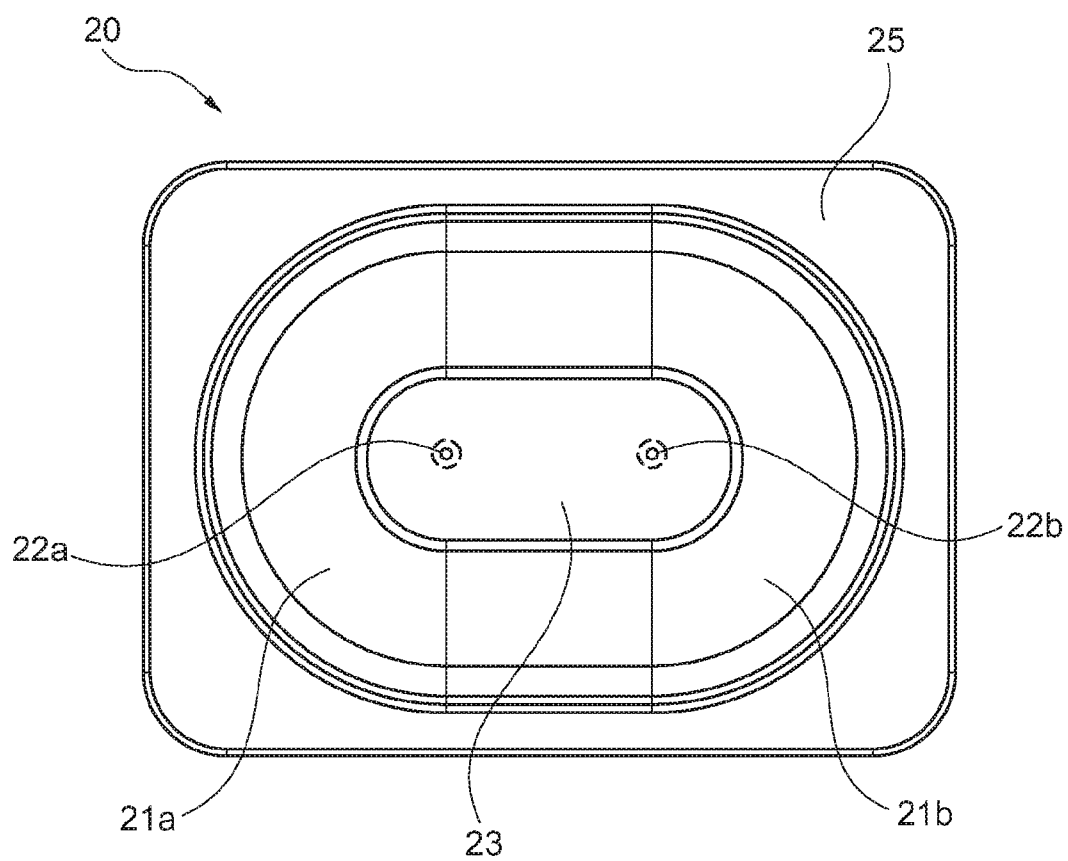


Fig. 13