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(71) Applicant: **SIGNIFY HOLDING B.V.** [NL/NL]; High Tech Campus 48, 5656 AE Eindhoven (NL).

(72) Inventors: **BLUSCHKE, Andreas, Felix, Alfred**; c/o High Tech Campus 7, 5656 AE Eindhoven (NL). **HIKMET, Rifat, Ata, Mustafa**; c/o High Tech Campus 7, 5656 AE Eindhoven (NL). **VAN BOMMEL, Ties**; c/o High Tech Campus 7, 5656 AE Eindhoven (NL).

(74) Agent: **VAN EEUWIJK, Alexander, Henricus, Walterus** et al.; High Tech Campus 7, 5656 AE Eindhoven (NL).

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(54) Title: A LIGHT GUIDE COUPLED LUMINAIRE

(57) Abstract: This invention relates to a lamp (100) and a fitting (200) that can be combined to provide a luminaire (300) for simultaneously providing illumination and wireless optical communication. The base (102) of the lamp (100) comprises a base light guide (104) and the fitting (200) comprises a fitting light guide (205). When the base (102) of the lamp (100) is inserted in the socket (201) of the fitting (200), the base center axis (105) of the lamp (100) substantially coincides with the fitting center axis (206) of the fitting (200). Also, the first end of the base light guide (106) optically couples with the first end of the fitting light guide (205).

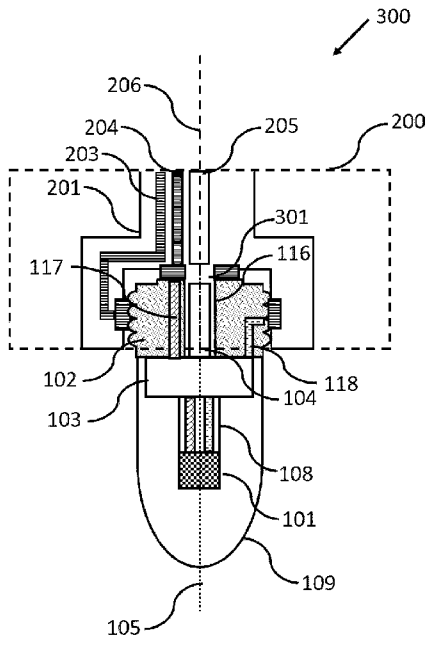

Figure 7

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A light guide coupled luminaire

FIELD OF INVENTION

This invention relates to a lamp and a fitting that can be combined to provide a luminaire for simultaneously providing illumination and wireless optical communication. Particularly, but not exclusively, this invention is concerned with a luminaire that can serve as a light source and an access point for optical wireless communication.

BACKGROUND OF THE INVENTION

The seamless internet connectivity that we enjoy today is enabled by the optical fiber network. Today optical fibers are connecting continents with the submarine communication cables. For long-distance communications, optical fibers offer several benefits over a copper based connection. Data in the form of optical signals when passing through the optical fiber suffers from significantly lower attenuation when compared to data in the form of electrical signals passing through the electrically conductive cables. This allows fewer repeaters when data transmission is spanned over a long distance. Besides, optical fibers offer higher bandwidths (data transfer rates) and immunity to electromagnetic interference. Also, optical fibers are flexible, therefore they can be bundled as cables.

The accessibility of optical fibers for communications has introduced a term called fiber to the x (FTTX). FTTX refers to different configurations of fiber deployment that includes, FTTN: fiber to the node, FTTC: fiber to the curb (within 300 m of a building), FTTB: fiber to the building and FTTH: fiber to the home. In the near future, FTTR: fiber to the room will become a reality as ITU-T is expected to deliver standards for this configuration of fiber deployment. FTTR will ensure uncompromised high bandwidth data communication available in every room of a home.

Optical fiber based communication can beneficially aid optical wireless communication (OWC) and radiofrequency (RF) wireless communication unlocking their true potential. Data reaching the OWC (e.g. LiFi) or RF (e.g. WiFi) access point modem by means of copper based wires can be limited in data rate, bandwidth, and riddled with undesirable interferences. For example, a Cat 6 Ethernet cable can support data transfer rates

up to 10 Gbps (Gigabit per second), while a single optical fiber can support data transfer up to 100 Tbps (Terabit per second).

SUMMARY OF THE INVENTION

The inventors have recognized that the FTTR will enable optical fibers reaching individual rooms of a home and a possible convenient point for the optical fiber can be a luminaire where electricity is available to provide dual functionality. This dual functionality is providing illumination and handling of data being relayed through the optical fiber. Therefore, the luminaire can act as an access point where it can provide light as well as data received by the optical fiber in the form of an optical signal or an RF signal or both. In place of OWC or RF transceiver and modem, the luminaire may also include other forms of sensors and measurement systems, and the data recorded with such systems can be transmitted to the optical fiber network with high speed and high reliability.

Therefore, the object of the present invention is to provide a light guide coupled luminaire that is configured to provide illumination and simultaneously send and receive optical signals to an information network, such as an optical fiber network.

According to a first aspect, the object of this invention is further achieved by a luminaire. The luminaire comprises a lamp and a fitting. A base of the lamp is inserted in a socket of the fitting, such that a base center axis of the lamp substantially coincides with a fitting center axis. The lamp comprises a base light guide that is at least partly arranged in a channel of the base. The fitting comprises a fitting light guide that is at least partly arranged in the fitting. And the first end of the base light guide is optically coupled with the first end of the fitting light guide.

The optical coupling may be on a non-contact optical interface between the base light guide and the fitting light guide with a gap comprising air. Hence, the light conduction path is unobstructed with an air gap and an optical signal from the fitting light guide will propagate towards the base light guide and vice versa.

The optical coupling between the base light guide and the fitting light guide may allow transmission of light, more specifically an optical signal from the lamp to the fitting, or from the fitting to the lamp.

The lamp comprises a light source and the base for securing the lamp in the fitting by inserting the base in the socket of the fitting. The base has a base electrode arrangement and the light source is electrically connected to the base electrode arrangement. The lamp further comprises an optoelectronic device that comprises at least one of an

electrical-to-optical transducer and an optical-to-electrical transducer for transmitting an optical signal and detecting an optical signal, respectively. The optoelectronic device is electrically connected to the base electrode arrangement. The base light guide is at least partly arranged in a direction substantially parallel to the base center axis such that the first end of the base light guide faces away from the optoelectronic device, a second end of the base light guide faces towards the optoelectronic device, and the second end of the base light guide is optically coupled with the optoelectronic device.

The light source of the lamp may be, but is not limited to, an LED for better energy efficiency and durability. The light source may also be of the incandescent, halogen, or compact fluorescent type.

The lamp can be secured in a fitting by inserting the base of the lamp into a socket of the fitting in order to provide an electrical connection and mechanical stability. The electrical connection is realized when the base electrode arrangement interfaces with the socket electrode arrangement.

In the context of the invention, the term 'light guide' should be interpreted broadly as a device for transmitting electromagnetic waves in the optical spectrum from one end to the other. An optical fiber may represent such a light guide that comprises a core comprising a light propagating medium and a cladding protecting the core where the transmission of light is based on total internal reflection. Typically, the core has a higher refractive index than the cladding for facilitating total internal reflection. Alternatively, a hollow structure with a reflective inner surface may be used for transmitting light from one end to the other. In this case, the channel having a reflecting inner surface by means of a metallic hollow tube or metallic foil may also represent a light guide.

In the context of the invention, the term 'optoelectronic device' refers to a device that comprises at least one of an electrical-to-optical and an optical-to-electrical transducer, or instruments that use such devices in their operation. An electrical-to-optical transducer may be an emitter and an optical-to-electrical transducer may be a detector. Therefore the optoelectronic device is capable of detecting an optical signal received through the light guide and to transmit back an optical signal through the light guide. An optical signal may be understood as an optical communication signal that is used in optical wireless communication.

In the context of the invention, the term 'transducer' refers to a device that converts energy from one form to another. In this case, it may be understood that a transducer

converts a signal, supposedly a communication signal in one form of energy to a signal in another.

The optical coupling between the base light guide and the optoelectronic device may be a direct optical coupling or an indirect optical coupling. For direct optical coupling, the base light guide may be directly attached to the detector(s) and/or the emitter(s) of the optoelectronic device. For indirect optical coupling, there may be a directional optical fiber coupler in between the base light guide and the detector(s) and/or the emitter(s) of the optoelectronic device.

The base of the lamp may have a first base side and an opposite second base side. The first base side may face towards the socket when the lamp is secured in the fitting, while the second base side may face the optoelectronic device. In such a configuration, the optoelectronic device may be located in a space enclosed by a lamp envelope and the base. A part of the optoelectronic device or the complete optoelectronic device may be also located within the base. The optoelectric device may be also physically located outside of a lamp envelope.

The base electrode arrangement is configured to electrically connect the light source and the optoelectronic device. The light source and the optoelectronic device may simultaneously operate or separately operate.

The base light guide has a base light guide center axis that may be substantially coincident with the base center axis of the lamp.

The base light guide may be a silica optical fiber or a plastic optical fiber.

The base light guide may be an annular light guide.

In geometry, an annular object is a ring shaped object. A hollow cylindrical light guide may be a suitable example of an annular light guide. Therefore, the annulus of such a light guide structure may be considered to have a rim that has the light guiding property. The base center axis of the lamp may coincide with the base light guide center axis of the annular base light guide. This rotational symmetry may allow the lamp to be easily aligned with the fitting optics or the fitting light guide when the lamp is replaced or reinstalled.

The base light guide may be an annular light guide that is shaped as a hollow truncated cone having a top and a bottom. The top of the cone comprises the second end of the base light guide that faces towards the optoelectronic device and the bottom of the cone comprises the first end of the base light guide that faces away from the optoelectronic device. The top of the cone is optically coupled with the optoelectronic device.

The top refers to the narrowing tapered end of a truncated cone. So light entering from the bottom side can be condensed towards the top side. Therefore, the detector(s) and/or the emitter(s) on the optoelectronic device may have a small footprint in case of direct optical coupling between the base light guide and the optoelectronic device.

The base light guide may be made from a polymer based optical material. For example, PMMA or silicone. This type of material allows easy and cheap fabrication of optical components using various molding techniques. One alternative may be silica based optical fiber.

The base of the lamp has a first base side and an opposite second base side. The first end of the base light guide may be recessed from the first base side.

The first base side refers to the base end that faces the socket of the fitting when the lamp is being secured in the socket. The second base side refers to the base side that faces the optoelectronic device. The first end of the base light guide may protrude from the first base side, or it may be flush with the first base side, or it may be recessed from the first base side. When the first end of the base light guide is flush with the first side of the base or when it is recessed from the first side of the base, the first end of the base light guide is unharmed when the lamp is being secured in the socket. Damage to the light guide end may severely reduce light coupling efficiency.

The channel of the base may have a reflective inner surface.

Light may also travel through the channel having a reflective inner surface by means of a metallic hollow tube or a metallic foil. Therefore, the metallic hollow tube or a metallic foil represents the base light guide located in the channel. In the case of a recessed first end of the base light guide, the reflective inner surface of the channel may help collect more light within the base light guide.

The light source may be a LED and an electronic driver for the LED may be integrated with the optoelectronic device.

In this case, the LED electronic driver may be integrated with the printed circuit board (PCB) of the optoelectronic device to make the lamp compact and efficient. The power source may be the same as well, arranged through the base electrode arrangement.

The optoelectronic device of the lamp may comprise at least one of an integrated RF transceiver and an integrated LiFi transceiver.

The optoelectronic device may comprise the necessary electronics to transform the optical data received by the base light guide into equivalent radiofrequency (RF) data and transmit the RF data by means of a radiofrequency (RF) antenna(s) to establish wireless

communication. These RF antennas may also support bidirectional high capacity wireless communication. The optoelectronic device may also comprise other forms of RF-enabled devices such as a Bluetooth enabled device to establish wireless communication between user mobile devices. The Bluetooth enabled device may also offer control of the optoelectronic device, such as control of the access point. These RF-enabled devices may also function as an indoor position system (IPS) and the data logged by the IPS may be fed back to the optical fiber network.

The optoelectronic device may also comprise an integrated LiFi transmitter(s), receiver(s), and LiFi electronics. Then the optical data received by the base light guide can be transformed by the optoelectronic device and then transmitted to a user using the LiFi transmitter. On the other hand, the data received by the receiver from a user may be transmitted back to the optical fiber network. The data transmission and reception by complete optical means may ensure unhindered high bandwidth and high data rate.

The lamp may be configured to serve as a WiFi access point as well as a LiFi access point while providing illumination.

The optoelectronic device of the lamp may comprise one or more optical sensors.

Various sensors may be integrated with the optoelectronic device. For example, light, color temperature, humidity, or passive infrared (PIR) detector for presence detection. The data logged by such a sensor may be fed back to the optical fiber network with high reliability and at a high data rate.

The fitting comprises the socket for securing the lamp in the fitting by receiving the base of the lamp through an opening of the socket. The socket has a socket electrode arrangement for making an electrical connection to the base electrode arrangement of the lamp. The fitting further comprises the fitting light guide that is at least partly arranged in the fitting in a direction substantially parallel to the fitting center axis such that the first end of the fitting light guide faces the opening of the socket.

In the context of the invention, the term ‘opening’ should be understood as the hollow area where the base of the lamp makes contact with the socket. Therefore, the first socket side faces the opening of the socket, while the opposite second socket side faces out of the fitting defining the end of the opening. The first end of the fitting light guide facing the opening is suggested, which means the fitting light guide may extend into the opening such that it does not extend beyond the second socket side. The fitting light guide may be an extension or a part of the fiber to the home (FTTH) or fiber to the room (FTTR) network.

Alternatively, the fitting light guide may be joined with the fiber to the home (FTTH) or fiber to the room (FTTR) network. Therefore, a second end of the fitting light guide may be optical coupled with a fiber to the home (FTTH) or fiber to the room (FTTR) network.

The fitting light guide may be made from a polymer based optical material. For example, PMMA or silicone. This type of material allows easy and cheap fabrication of optical components using various molding techniques. One alternative may be a silica based optical fiber.

The fitting light guide has a fitting light guide center axis that may be substantially coincident with the fitting center axis.

Also, the fitting light guide may be placed such that the fitting light guide center axis is not coincident but substantially parallel to the fitting center axis of the fitting.

The socket may have a first socket side and an opposite second socket side, wherein the first socket side faces the opening of the socket. The first end of the fitting light guide may protrude from the first socket side, or it may be flush with the first socket side, or it may be recessed from the first socket side.

When the first end of the fitting light guide is flush with the first socket side or when it is recessed from the first socket side, the first end of the fitting light guide is unharmed when the lamp is being secured in the socket. When the base light guide is recessed from the first base side and the fitting light guide is recessed from the first socket side, damage of the light guides upon securing the lamp in the fitting is best avoided. In such a case, the base light guide and the fitting light guide may be separated by an air gap after the lamp is secured in the fitting.

The fitting may have a lens at the first end of the fitting light guide.

Optical coupling efficiency between two light guides separated by an air gap may be improved using a lens. This lens may be a ball lens, a spheric lens, or an aspheric lens. The lens may be included in any one of the lamp and the fitting. The lens may be an integral part of any one of the base light guide and the fitting light guide. It may be convenient if the lamp has fewer components since the lamp is likely to be replaced at the end of its life. This may help reduce the cost.

Alternatively, the first end of the base light guide and the first end of the fitting light guide may have anti-reflection coating for improving optical coupling efficiency.

The optical coupling may be on a non-contact optical interface between the base light guide and the fitting light guide with a gap comprising air. This is realized when at least one of the base light guide and the fitting light guide is recessed over a certain distance

from the first base end or the first socket end, respectively, and when none of the base light guide and the fitting light guide protrudes from the first base end or the first socket end, respectively, over a larger distance. This ensures that the base light guide and the fitting light guide can not come in direct contact with each other. However, the light conduction path is unobstructed with an air gap and an optical signal from the fitting light guide will propagate towards the base light guide and vice versa.

The base light guide of the lamp may be a rotationally symmetric annular light guide located around the base center axis. In this case, the first end of the base light guide is shaped as a ring with a radius relative to the base center axis. The fitting light guide of the fitting may be located such that the first end of the fitting light guide is located at a separation distance from the fitting center axis. If the radius of the first end of the base light guide is substantially equal to the separation distance of the first end of the fitting light guide, the base light guide of the lamp may be easily aligned with the fitting light guide of the fitting. This allows flexibility for a user to replace the lamp after its end of life. The same flexibility is achieved when the configurations of the base light guide and the fitting light guide are reversed.

Alternatively, the fitting light guide may be shaped as an annular light guide having a fitting light guide center axis that substantially coincides with the fitting center axis. The base may have a base light guide is located at a distance from the base center axis such that the base light guide center axis is substantially parallel to the base center axis. The distance is substantially same as the radius of the fitting light guide with respect to the fitting center axis such that the first end of the fitting light guide is facing the first end of the base light guide that promotes good optical coupling.

Similar flexibility may be realized when the base light guide of the lamp has a first end that is substantially coincident on the base center axis and when the fitting light guide of the fitting has a first end that is substantially coincident on the fitting center axis.

One may also assume a direct physical contact between the light guides upon securing the lamp in the socket. In this case, the mechanical interfacing between the socket and the base has to be accurate enough such that the first end of the fitting light guide and the first end of the base light guide gracefully come in contact with each other.

According to a second aspect, the object of this invention is further achieved by a communication system that comprises an information network and one or more luminaires according to the third aspect. Besides being arranged to provide illumination, each

of the one or more luminaires is further arranged to provide access to the information network via the optoelectronic device.

The information network may be a representation of an optical fiber network. This information network may have access to the internet or a local area network. Such a network may have centralized or decentralized control of data. The luminaires are connected to this information network by means of light guides and therefore, the luminaires have access to optical data from this network. Therefore, the optoelectronic device of the luminaire may be configured to act as a wireless communication access point. And such a configuration may be arranged so that the lamp can provide illumination as well as WiFi or LiFi access point or both. For LiFi, two or more luminaires may be preferred to comprise the communication system.

Similarly, sensors may be integrated with the optoelectronic device of the luminaires. This may be a convenient solution for providing an indoor sensor network that is connected to the backbone optical fiber network creating a versatile communication system for highly reliable data and indoor or outdoor control services.

It should be noted that the invention relates to all possible combinations of features recited in the claims. Other objectives, features, and advantages of the present inventive concept will appear from the following detailed disclosure, from the attached claims as well as from the drawings. A feature described in relation to one of the aspects may also be incorporated in the other aspect, and the advantage of the feature is applicable to all aspects in which it is incorporated.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention as well as additional objects, features and advantages of the disclosed devices, methods, and systems, will be better understood through the following illustrative and non-limiting detailed description of embodiments of devices, methods, and systems, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

Fig. 1(a) and (b) show a cross-sectional view of a lamp with an annular light guide as the base light guide and a perspective view of the base light guide and the fitting light guide when the lamp is secured in the socket, respectively;

Fig. 2 shows a cross-sectional view of a fitting where the fitting light guide center axis is substantially parallel to the fitting center axis;

Fig. 3 shows a cross-sectional view of luminaire comprising the lamp as illustrated in Fig. 1(a) being secured in the socket of a fitting as illustrated in Fig. 2;

Fig. 4(a) and (b) show a cross-sectional view of a lamp with a hollow truncated cone shaped light guide as the base light guide and a perspective view of the base light guide and the fitting light guide when the lamp is secured in the socket, respectively;

Fig. 5 shows a cross-sectional view of a luminaire comprising the lamp as illustrated in Fig. 4(a) being secured in the socket of a fitting as illustrated in Fig. 2;

Fig. 6 (a) and (b) show cross-sectional views of a lamp with the base light guide coinciding with the base center axis and a fitting with a fitting light guide coinciding with the fitting center axis, respectively;

Fig. 7 shows a cross-sectional view of a luminaire comprising the lamp being secured in the socket of a fitting as illustrated in Fig 6(a) and (b);

Fig. 8 (a) and (b) show cross-sectional views of luminaire where the fitting light guide extends into the base of the lamp and where the base light guide extends into the socket, respectively;

Fig. 9 (a) and (b) show cross-sectional views of a luminaire with a channel in the base of the lamp having a reflective inner surface and with a channel representing a total internal reflective light guide, respectively;

Fig. 10(a) and (b) show cross-sectional views of luminaire where the fitting light guide comprising a lens and the lensed light guide is located on a fitting light guide center axis that is substantially parallel to the fitting center axis and where the lensed light guide is located on the fitting center axis, respectively;

Fig. 11 shows a cross-sectional view of a luminaire as illustrated in Fig. 7 with the optoelectronic device integrated with WiFi transceiver;

Fig. 12 shows a cross-sectional view of a luminaire as illustrated in Fig. 7 with the optoelectronic device integrated with Bluetooth enabled device;

Fig. 13 shows a cross-sectional view of a luminaire as illustrated in Fig. 7 with the optoelectronic device integrated with sensors;

Fig. 14 shows a cross-sectional view of a luminaire as illustrated in Fig. 7 with the optoelectronic device integrated with LiFi transceiver;

Fig. 15 shows a perspective view of a communication system comprising a luminaire connected to an information network as illustrated in Fig. 11, providing illumination and WiFi communication solutions to a user; and

Fig. 16 shows a perspective view of a communication system comprising two luminaires connected to an information network as illustrated in Fig. 14, providing illumination and LiFi communication solutions to a user.

As illustrated in the figures, the sizes of layers and regions are exaggerated for illustrative purposes and, thus, are provided to illustrate the general structures of embodiments of the present invention. Like reference numerals refer to like elements throughout.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which currently preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and fully convey the scope of the invention to the skilled person.

Figure 1(a) shows a cross-section view of lamp 100. The lamp comprises light source 101 for providing illumination. The light source 101 may be, but not limited to LED for better energy efficiency and durability. The light source may also be incandescent, halogen, or compact fluorescent type.

The lamp 100 further comprises a base 102 and an envelope 109. The base 102 comprises a base light guide 104 located in a channel 116 that has a form of an annular light guide as shown in Figure 1(b). This base light guide 104 has an annulus 110, which can be considered as the rim of the structure that has the light guiding property. The base center axis 105 of the lamp 100 coincides with the base light guide center axis 111 of the annular base light guide 104. In Figure 1(a), the envelope 109 together with the base 102 delimit a space that contains the light source 101 and the optoelectronic device 103. However, the optoelectronic device may be also situated outside of the envelope of a lamp.

The base 102 contains a base electrode arrangement comprising a pair of electrodes 117 and 119. These electrodes provide electrical means to power the optoelectronic device 103 and the light source 101 through the stem 108.

In Figure 1(a), the base 102 of the lamp 100 has a first base side 121 and an opposite second base side 122. The first base side 121 faces towards a socket when the lamp 100 is secured in a fitting, while the second base side 122 faces the optoelectronic device 103. The base light guide 104 has two ends: the first end of the base light guide 106 is facing

away from the optoelectronic device 103 and the second end of the base light guide 107 is facing towards the optoelectronic device 103. The first end of the base light guide 106 is slightly recessed from the first base side 121. The second end of the base light guide 107 is optically coupled with the optoelectronic device 103. Light as an optical signal entering from the first end of the base light guide 106 will propagate towards the second end of the base light guide 107 and vice versa.

The purpose of the optoelectronic device is to detect an optical signal received through the light guide and to transmit back an optical signal through the light guide. The optical coupling between the base light guide and the optoelectronic device may be a direct optical coupling or an indirect optical coupling. For direct optical coupling, the base light guide may be directly attached to the detector(s) and/or the emitter(s) of the optoelectronic device. For indirect optical coupling, there may be a directional fiber coupler in between the base light guide and the detector(s) and/or the emitter(s) of the optoelectronic device.

A LED electronic driver is needed for a LED based light source. In this case, the LED electronic driver can be integrated with the printed circuit board (PCB) of the optoelectronic device to make the lamp compact and efficient.

Figure 2 shows a cross-sectional view of a fitting 200 of a luminaire. The fitting 200 comprises a socket 201 for securing a lamp. A fitting provides electrical and mechanical solutions for a lamp via its base. The socket 201 is configured to receive the base of a lamp within the opening 202 of the socket 201. The socket 201 has a socket electrode arrangement comprising two electrodes 203 and 204 for making electrical connections to a base electrode arrangement of a lamp. The fitting light guide 205 is located on a fitting light guide center axis 208 that is substantially parallel to the fitting center axis 206. The first end of the fitting light guide 207 is arranged to face the opening 202 of the socket 201. The socket 201 has a first socket side 221 and an opposite second socket side 222. The first socket side 221 faces the opening 202 of the socket 201, while the second socket side 222 faces out of the fitting 200 defining the end of the opening 202. The first end of the fitting light guide may protrude from the first socket side, or it may be flush with the first socket side, or it may be recessed from the first socket side. In Figure 2, the first end of the fitting light guide 207 is shown to be slightly recessed from the first socket side 221.

Figure 3 shows a cross-sectional view of luminaire 300. This luminaire 300 comprises the lamp 100 as illustrated in Figure 1(a) being secured in the socket 201 of the fitting 200 as illustrated in Figure 2. The base 102 of the lamp 100 is secured in the socket

201 of the fitting 200. In this condition, the base center axis 105 of the lamp 100 substantially coincides with the fitting center axis 206 of the fitting 200.

The base light guide 104 of the lamp 100 is a rotationally symmetric annular light guide located around the base center axis 105. In this case, the base light guide 104 is shaped as a ring with a radius relative to the base center axis 105. The fitting light guide 205 of the fitting 200 is located at a separation distance from the fitting center axis 206 that is substantially equal to the radius of the base light guide 104 from the base center axis 105. Hence the base light guide 104 of the lamp 100 may be easily aligned with the fitting light guide 205. This allows flexibility for a user to replace the lamp 100 after its end of life.

When the first end of the base light guide 106 is flush with the first base side 121 or when it is recessed from the first base side 121 (as in Figure 1(a) and Figure 3), the first end of the base light guide 106 is unharmed when the lamp 100 is being secured in the socket 201. When the base light guide 104 is recessed from the first base side 121 (Figure 1(a)) and the fitting light guide 205 is recessed from the first socket side221 (Figure 2), damage of the light guides upon securing the lamp in the fitting is best avoided. In such a case, the base light guide 104 and the fitting light guide 205 is separated by an air gap 301 after the lamp 100 is secured in the socket 201.

Also, the base light guide 104 is arranged to be optically coupled with the fitting light guide 205 as shown in Figure 3. This optical coupling is based on a non-contact optical interface between the base light guide 104 and the fitting light guide 205 with a gap 301 comprising air. The light conduction path is unobstructed and an optical signal from the fitting light guide 205 will propagate towards the base light guide 104 and vice versa.

One may also assume a direct contact between the light guides upon securing the lamp in the socket. In this case, the mechanical interfacing between the socket and the base has to be accurate enough such that the first end of the fitting light guide and the first end of the base light guide gracefully come in contact with each other.

In Figure 4(a) a cross-sectional view of a lamp 100 with the base light guide 104 in the shape of a hollow truncated cone is shown. In Figure 4(b) a perspective view of the base light guide 104 and the fitting light guide 205 is shown when the lamp 100 is secured in a socket. The base light guide center axis 111 substantially coincides with the base center axis 105 of the lamp 100. This base light guide 104 has an annulus 112 that tapers from the bottom 115 toward the top 114. The annulus 112 can be considered as the rim of the structure having the light guiding property. The top 114 of the cone comprises the second end of the base light guide 107 that faces towards the optoelectronic device 103 and the bottom

115 of the cone comprises the first end of the base light guide 106 that faces away from the optoelectronic device 103. The top 114 of the cone is optically coupled with the optoelectronic device 103. The bottom 115 of the cone comprising the first end of the base light guide 106 is slightly recessed from the first base side 121.

Figure 5 shows a cross-sectional view of a luminaire 300 comprising the lamp 100 as illustrated in Figure 4(a) being secured in the socket 201 of a fitting 200 as illustrated in Figure 2. In this condition, the base center axis 105 of the lamp 100 substantially coincides with the fitting center axis 206 of the fitting 200. Also, the bottom 115 comprising the first end of the base light guide 106 is arranged to be optically coupled with the first end of the fitting light guide 207 as shown in Figure 4(b). This is because the fitting light guide 205 of the fitting 200 is located at a separation distance from the fitting center axis 206 that is substantially equal to the radius of the base light guide 104 from the base center axis 105. Hence the base light guide 104 of the lamp 100 may be easily aligned with the fitting light guide 205. This allows flexibility for a user to replace the lamp 100 after its end of life. This optical coupling is based on a non-contact optical interface between the base light guide 104 and the fitting light guide 205 with a gap 301 comprising air.

Since the base light guide 104 has a second annulus 112 that tapers from the bottom 115 toward the top 114, light entering from the bottom 115 may be condensed towards the top 114. Therefore, the detector(s) and/or the emitter(s) on the optoelectronic device 103 may have a small footprint in the case of direct optical coupling between the base light guide 104 and the optoelectronic device 103.

The base light guides 104 shown in Figure 1(b) and Figure 4(b) may be made from a polymer based optical material. For example, PMMA or silicone. This type of material allows easy and cheap fabrication of optical components using various molding techniques. The fitting light guide as shown in Figure 2 may be a plastic optical fiber (POF). One alternative may be a silica based optical fiber.

Figure 6 (a) shows a cross-sectional view of a lamp 100 with the base light guide 104 coinciding with the base center axis 105. The base 102 of the lamp 100 has a first base side 121 and an opposite second base side 122. The first base side 121 faces towards a socket when the lamp 100 is secured in a fitting, while the second base side 122 faces the optoelectronic device 103. The base light guide 104 has two ends: the first end of the base light guide 106 is facing away from the optoelectronic device 103 and the second end of the base light guide 107 is facing towards the optoelectronic device 103. The first end of the base light guide 106 is slightly recessed from the first base side 121. The second end of the base

light guide 107 is optically coupled with the optoelectronic device 103. Light as an optical signal entering from the first end of the base light guide 106 will propagate towards the second end of the base light guide 107 and vice versa. The lamp 100 further comprises a light source 101 and an envelop 109. The envelop 109 together with the base 102 delimit a space that contains the light source 101 and the optoelectronic device 103. The base 102 contains a base electrode arrangement comprising a pair of electrodes 117 and 118. These electrodes provide electrical means to power the optoelectronic device 103 and the light source 101 through the stem 108.

Figure 6 (b) shows a cross-sectional view of a fitting 200 with the fitting light guide 205 coinciding with the fitting center axis 206. The fitting 200 comprises a socket 201 for securing a lamp. The socket 201 has a first socket side 221 and an opposite second socket side 222. The first socket side 221 faces the opening 202 of the socket 201, while the second socket side 222 faces out of the fitting 200 defining the end of the opening 202. The first end of the fitting light guide 207 is arranged to face the opening 202 but recessed from the first socket side 221.

Figure 7 shows a cross-sectional view of a luminaire 300. This luminaire 300 comprises the lamp 100 as illustrated in Figure 6(a) being secured in the socket 201 of the fitting 200 as illustrated in Figure 6(b). In this case, the base light guide 104 coincides with the base center axis 105 and the fitting light guide 205 coincides with the fitting center axis 206. The first end of the base light guide 106 is arranged to be optically coupled with the first end of the fitting light guide 207. The optical coupling is a non-contact optical interface between the base light guide 104 and the fitting light guide 205 with a gap 301 comprising air. This is because the first end of the base light guide 106 is recessed from the first base side 121 and the first end of the fitting light guide 207 is recessed from the first socket side 221. Therefore, the fitting light guide 205 is not in direct contact with the base light guide 104. However, the light conduction path is unobstructed and an optical signal from the fitting light guide 205 will propagate towards the base light guide 104 and vice versa. An optical signal from the fitting light guide 205 will propagate towards the base light guide 104 as the light conduction path is unobstructed. The base light guide 104 is located on the base center axis 105 and the fitting center axis 206. Hence the base light guide 104 of the lamp 100 may be easily aligned with the fitting light guide 205. So the user may easily replace the lamp 100 after the end of life of the lamp 100 is reached. Also, a small footprint for the detector(s) and/or emitter(s) on the optoelectronic device 103 may be realized.

Figure 8(a) shows a cross-sectional view of a luminaire 300 with the fitting light guide 205 extending into the base 102 of the lamp 100. And Figure 8(b) shows a cross-sectional view of a luminaire 300 with the base light guide 104 extending into the socket 201. These combinations illustrate the flexibility and low tolerances for manufacturing inaccuracies for such a luminaire 300.

Figure 9(a) shows a cross-sectional view of a luminaire 300. The lamp 100 base 102 comprises a channel 116 for containing the base light guide 104. The first end of the base light guide 106 is recessed from the first base end 121. The first end of the fitting light guide 207 is slightly recessed from the first socket side 221 such that there is a substantial gap 301 between the light guides. A smaller gap 301 may be preferred for reducing the optical coupling loss. In the case of a larger gap 301 between light guides, the wall of the channel 116 containing the light guide may have a reflecting inner surface such that loss of light may be prevented and light coupling efficiency may be improved.

Figure 9(b) shows a cross-sectional view of a luminaire 300 with a channel 116 having a reflective inner surface. The reflective inner surface can be realized by means of a metallic hollow tube or a metallic foil in the channel 116. The first end of the fitting light guide 207 is slightly recessed from the first socket side 221. In this case, the channel 116 with a reflective inner surface may serve a light guide. The light entering into the channel 116 from the fitting light guide 205 may be guided towards the optoelectronic device 103.

Figure 10(a) shows a cross-sectional view of a luminaire 300 where the fitting light guide 205 comprising a lens 302 and the lens integrated fitting light guide 205 is located on a fitting light guide center axis 208 which is substantially parallel to the fitting center axis 206. Figure 10(b) shows a cross-sectional view of a luminaire 300 where the fitting light guide 205 comprising a lens 302 and the lens integrated fitting light guide 205 is located on the fitting center axis 206.

Optical coupling efficiency between the base and the fitting light guides 104 and 205, respectively separated by an air gap 301 may be improved using a lens 302. This lens 301 may be a ball lens, a spheric lens, or an aspheric lens. The lens 302 may be included in any one of the lamp 100 and the fitting 200. The lens may be an integral part of any one of the base light guide 104 and the fitting light guide 205. It may be convenient if the lamp 100 has fewer components since the lamp 100 is likely to be replaced at the end of its life. This may help reduce the cost.

Alternatively, the first end of the base light guide and the first end of the fitting light guide may be provided with anti-reflection coatings for improving optical coupling efficiency.

Figure 11 shows a cross-sectional view of a luminaire 300 as illustrated in Figure 7 with the optoelectronic device 103 integrated with WiFi transceiver.

The fitting light guide 205 may transfer and receive optical data from an optical fiber network connected to the internet. The optoelectronic device 103 may comprise necessary electronics to transform the optical data into equivalent radiofrequency (RF) data and transmit with radiofrequency (RF) antennas to establish wireless communication. These RF antennas may also support bidirectional high capacity wireless communication. Therefore, the luminaire may serve as a WiFi access point.

Figure 12 shows a cross-sectional view of a luminaire 300 as illustrated in Figure 7 with the optoelectronic device 103 integrated with Bluetooth enabled device.

The integrated Bluetooth enable device may offer access point control via the optoelectronic device 103. The optoelectronic device 103 may also contain other forms of RF-enabled devices besides Bluetooth to establish wireless communication between user devices. These RF-enabled devices may also function as an indoor position system (IPS) through the luminaire 300 and the data logged by the IPS is fed back to the optical fiber network.

Figure 13 shows a cross-sectional view of a luminaire 300 as illustrated in Figure 7 with the optoelectronic device 103 integrated with sensors 304.

Various sensors may be integrated with the optoelectronic device 103. For example, light, color temperature, humidity, or passive infrared (PIR) detector for presence detection. The data logged by such a sensor 304 may be fed back to the optical fiber network with high reliability and at a high data rate.

Figure 14 shows a cross-sectional view of a luminaire 300 as illustrated in Figure 7 with the optoelectronic device 103 integrated with LiFi transceiver.

In this case, the optoelectronic device 103 is integrated with the LiFi transmitter(s) 305 and receiver(s) 306. The optoelectronics device 103 may further comprise necessary electronics to transform the optical data received by the base light guide. Then these data may be transmitted to a user by the LiFi transmitter 305. On the other hand, the data received by the receiver 306 from a user may be transmitted back to the optical fiber network. The data transmission and reception by complete optical means may ensure unhindered high bandwidth and high data rate.

Figure 15 shows a perspective view of a communication system 400 comprising a luminaire 300 connected to an information network as illustrated in Figure 11, providing illumination and WiFi communication solutions to a user.

The information network may be a representation of an optical fiber network. The optical fiber network may provide access to a local area network and/or the internet. In this figure, this luminaire 300 is shown to establish WiFi communication with a mobile device 406 held by user 405, besides being arranged to provide illumination. There may be more luminaires 300 depending on the need.

Figure 16 shows a perspective view of a communication system 400 comprising two luminaires 300 as illustrated in Figure 14, providing illumination and LiFi communication solutions to a user.

The luminaires 300 with LiFi may have limited fields of view 403 and 404. Within these fields of view 403 and 404, a user 405 may establish a connection to the internet using their handheld mobile device 406. Multiple luminaires 300 may be used to increase the coverage area and may potentially ensure high bandwidth and high data rate communication system 400. The luminaire 300 may also provide the so-called hybrid WiFi and LiFi communication solutions.

Similar to this scenario, sensors integrated with luminaires 300 may be a convenient solution for providing an indoor or outdoor sensor network that is connected to the backbone optical fiber network creating a versatile communication system 400 for highly reliable data and indoor or outdoor control services. The control services may include illumination control, environmental control, or access point control depending on occupancy.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb “to comprise” and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article “a” or “an” preceding an element does not exclude the presence of a plurality of such elements.

The mere fact that certain features are recited in mutually different dependent claims does not indicate that a combination of these features cannot be used to advantage. The various aspects discussed above can be combined in order to provide additional advantages. Further, the person skilled in the art will understand that two or more embodiments may be combined.

CLAIMS:

1. A luminaire (300) comprising a lamp (100) and a fitting (200),

wherein a base (102) of the lamp (100) is inserted in a socket (201) of the fitting (200), such that a base center axis (105) of the lamp (100) substantially coincides with a fitting center axis (206) of the fitting (200),

wherein the lamp (100) comprises a base light guide (104) that is at least partly arranged in a channel (116) of the base (102),

wherein the fitting (200) comprises a fitting light guide (205) that is at least partly arranged in the fitting (200), and

wherein a first end of the base light guide (106) is optically coupled with a first end of the fitting light guide (205).

2. The luminaire (300) according to claim 1, wherein the lamp (100) comprises a light source (101) and the base (102) for securing the lamp (100) in the fitting (200) by inserting the base (102) in the socket (201) of the fitting (200),

wherein the base (102) has a base electrode arrangement (117, 118) and the light source (101) is electrically connected to the base electrode arrangement (117, 118),

wherein the lamp (100) further comprises an optoelectronic device (103) that comprises at least one of an electrical-to-optical transducer and an optical-to-electrical transducer for transmitting an optical signal and detecting an optical signal, respectively,

wherein the optoelectronic device (103) is electrically connected to the base electrode arrangement (117, 118), and

wherein the base light guide (104) is at least partly arranged in a direction substantially parallel to the base center axis (105) such that the first end of the base light guide (106) faces away from the optoelectronic device (103), a second end of the base light guide (107) faces towards the optoelectronic device (103), and the second end of the base light guide (107) is optically coupled with the optoelectronic device (103).

3. The luminaire (300) according to any one of the preceding claims, wherein the base light guide (104) has a base light guide center axis (111) that is substantially coincident with the base center axis (105) of the lamp (100).

4. The luminaire (300) according to any one of the preceding claims, wherein the base light guide (104) is an annular light guide.

5. The luminaire (300) according to claim 4, wherein the base light guide (104) is shaped as a hollow truncated cone having a top (114) and a bottom (115), and wherein the top (114) comprises the second end of the base light guide (107), and the bottom (115) comprises the first end of the base light guide (106).

6. The luminaire (300) according to any one of the preceding claims, wherein the base (102) has a first base side (121) and an opposite second base side (122), and wherein the first end of the base light guide (106) is recessed from the first base side (121).

7. The luminaire (300) according to any one of the preceding claims, wherein the channel (116) has a reflective inner surface.

8. The luminaire (300) according to any one of the claims from 2 to 7, wherein the light source (101) is a LED, and wherein an electronic driver for the LED is integrated with the optoelectronic device (103).

9. The luminaire (300) according to any one of the claims from 2 to 8, wherein the optoelectronic device (103) comprises at least one of an integrated RF transceiver and an integrated LiFi transceiver.

10. The luminaire (300) according to any one of the claims from 2 to 9, wherein the optoelectronic device (103) comprises one or more optical sensors.

11. The luminaire (300) according any one of the preceding claims, wherein the fitting (200) comprises the socket (201) for securing the lamp (100) in the fitting (200) by receiving the base (102) of the lamp (100) through an opening (202) of the socket (201),

wherein the socket (201) has a socket electrode arrangement (203, 204) for making an electrical connection to the base electrode arrangement (117, 118) of the lamp (100), and

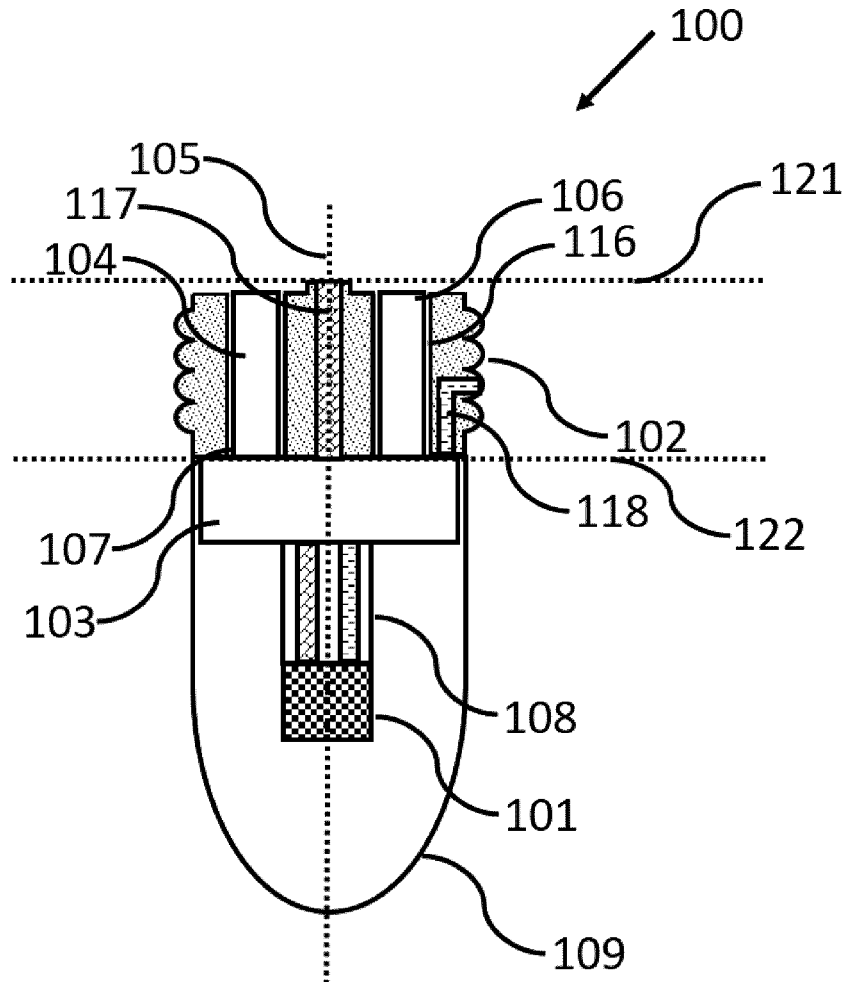
wherein the fitting light guide (205) is at least partly arranged in the fitting (200) in a direction substantially parallel to the fitting center axis (206) such that the first end of the fitting light guide (207) faces the opening (202) of the socket (201).

12. The luminaire (300) according any one of the preceding claims, , wherein the fitting light guide (205) has a fitting light guide center axis (208) that is substantially coincident with the fitting center axis (206).

13. The luminaire (300) according any one of the preceding claims, wherein the socket (201) has a first socket side (221) and an opposite second socket side (222), wherein the first socket side (221) faces the opening (202) of the socket (201), and wherein the first end of the fitting light guide (207) is recessed from the first socket side (221).

14. The luminaire (300) according any one of the preceding claims wherein the fitting (200) has a lens (302) at the first end of the fitting light guide (207).

15. A communication system (400) comprising an information network and one or more luminaires (300) according to any one of the preceding claims, wherein each of the one or more luminaires (300) is arranged to provide access to the information network via the optoelectronic device (105).


100
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103
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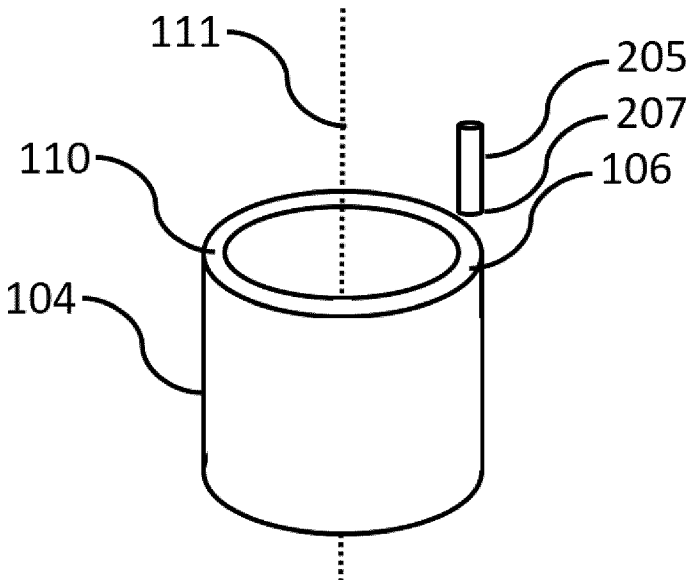
101
109

(a)


111
205
207
110
106
104

(b)

Figure 1

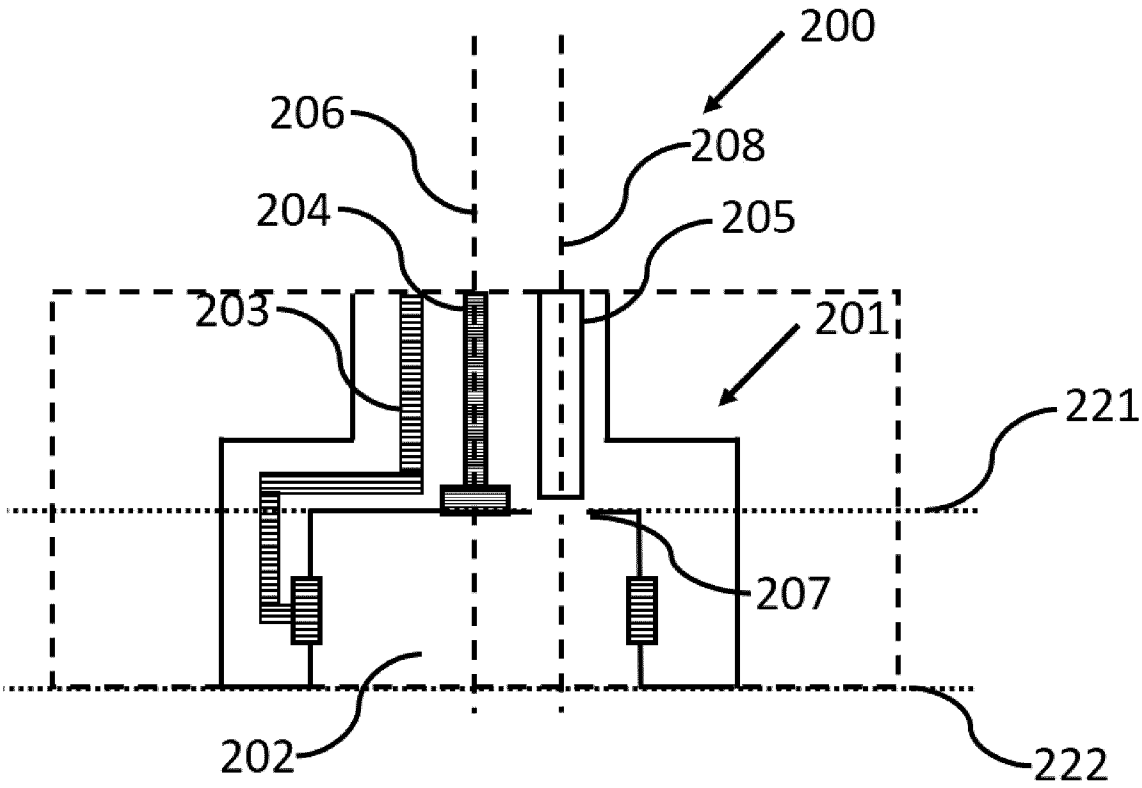
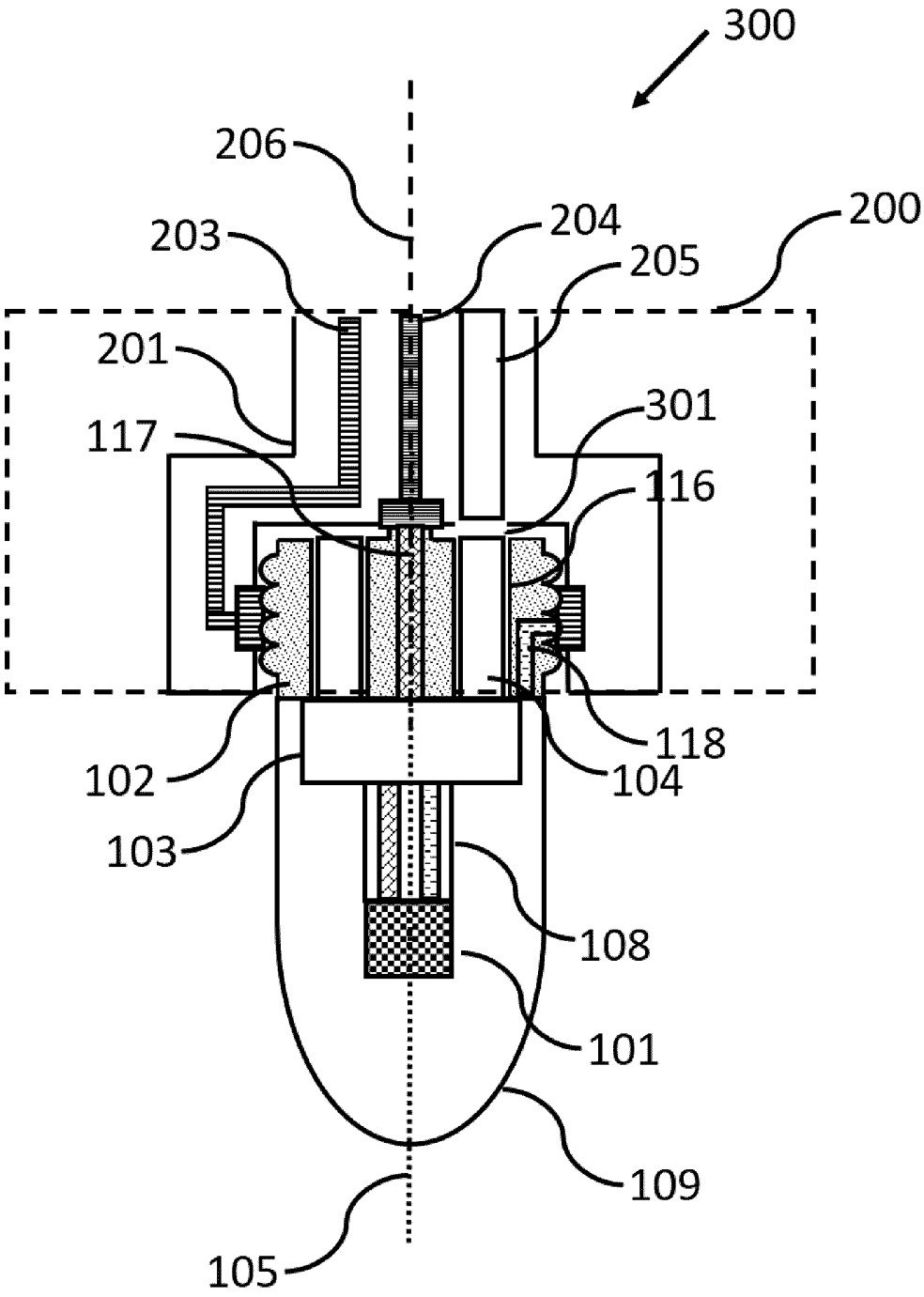


Figure 2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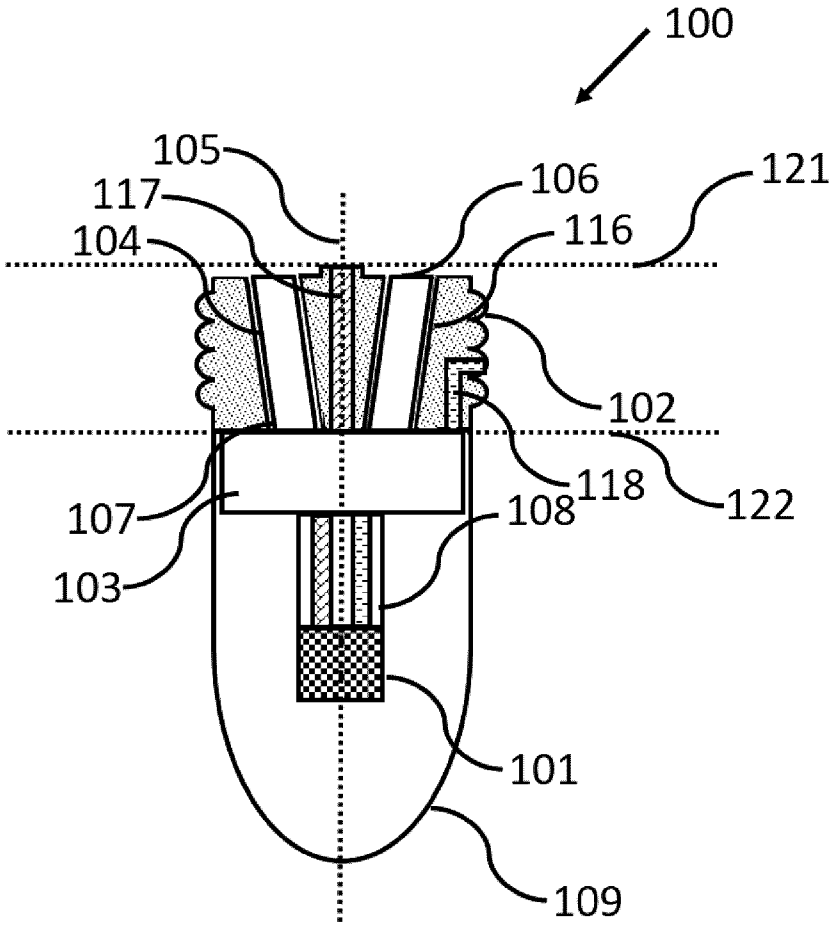
105

Figure 3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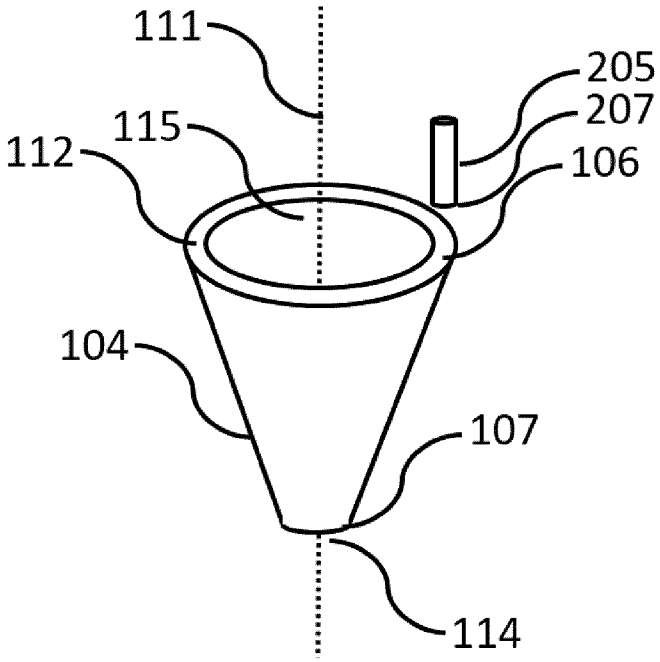
101
109

(a)


111
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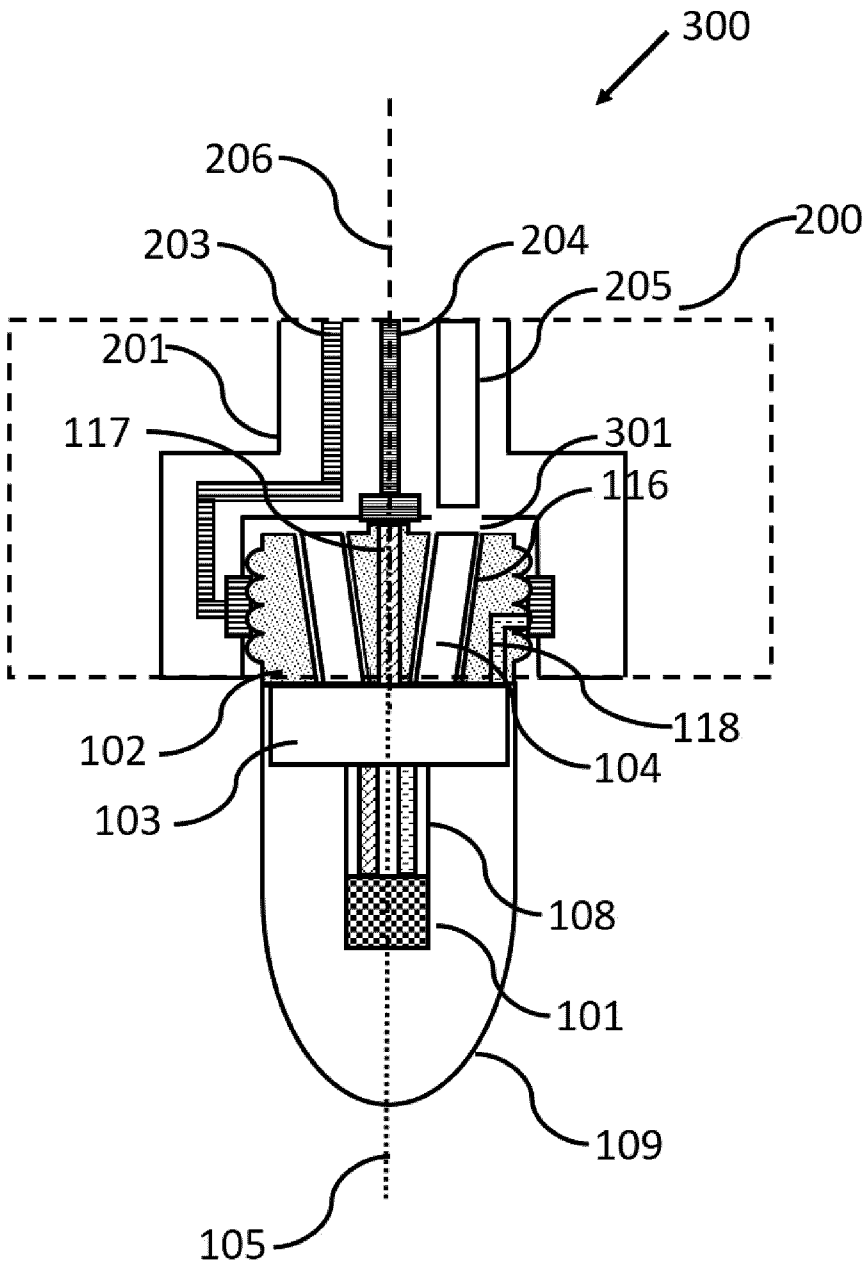
104
107
114

(b)

Figure 4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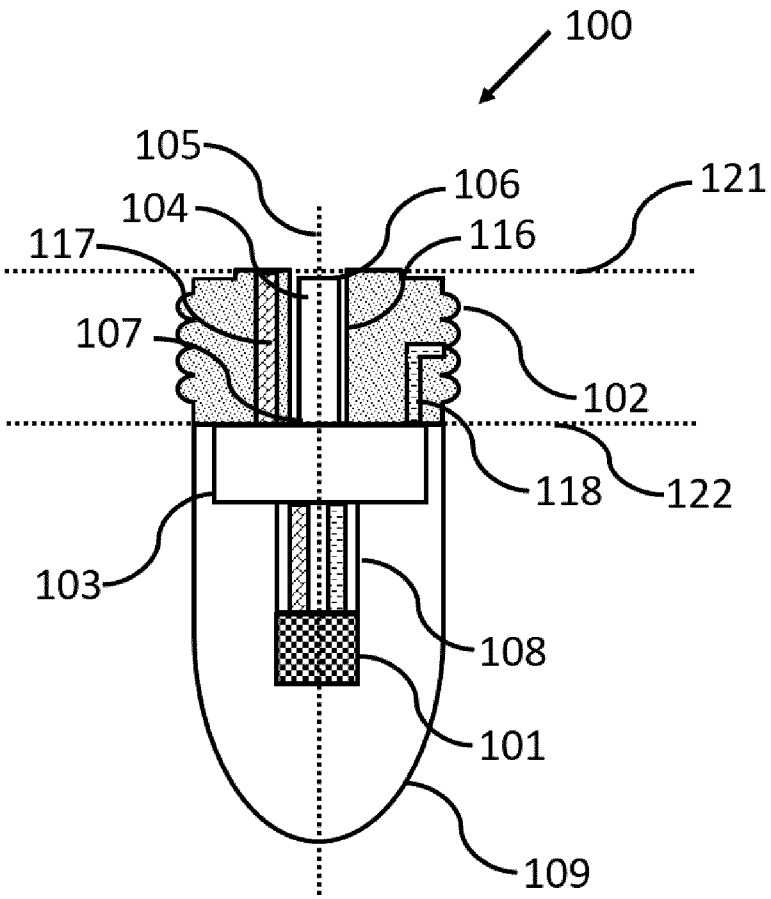
105

Figure 5


100
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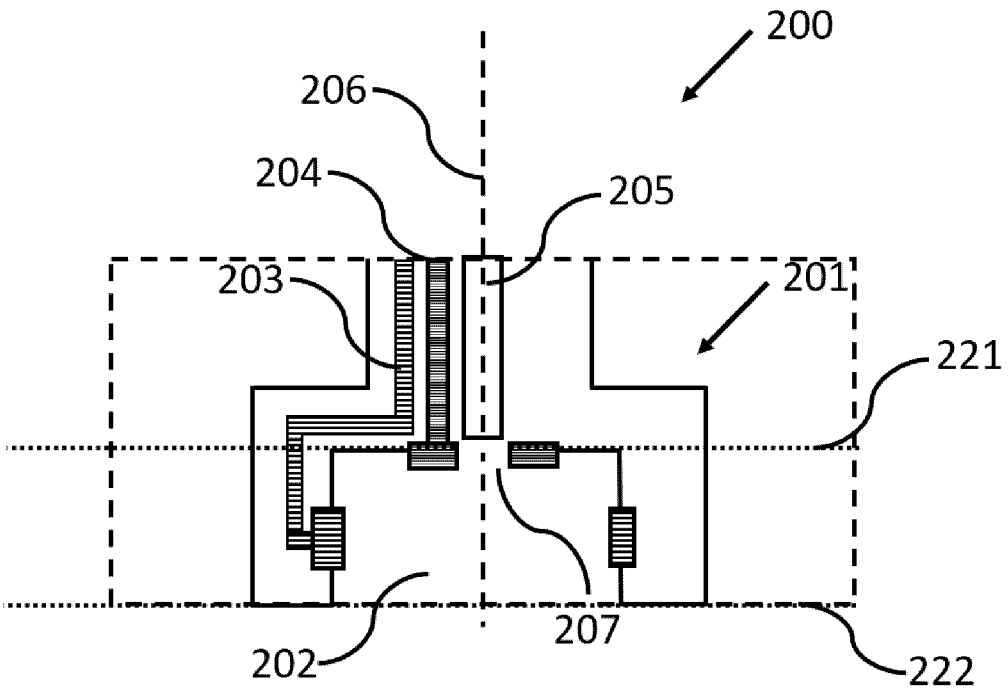
(a)


200
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203
201
221
207
202
222

(b)

Figure 6

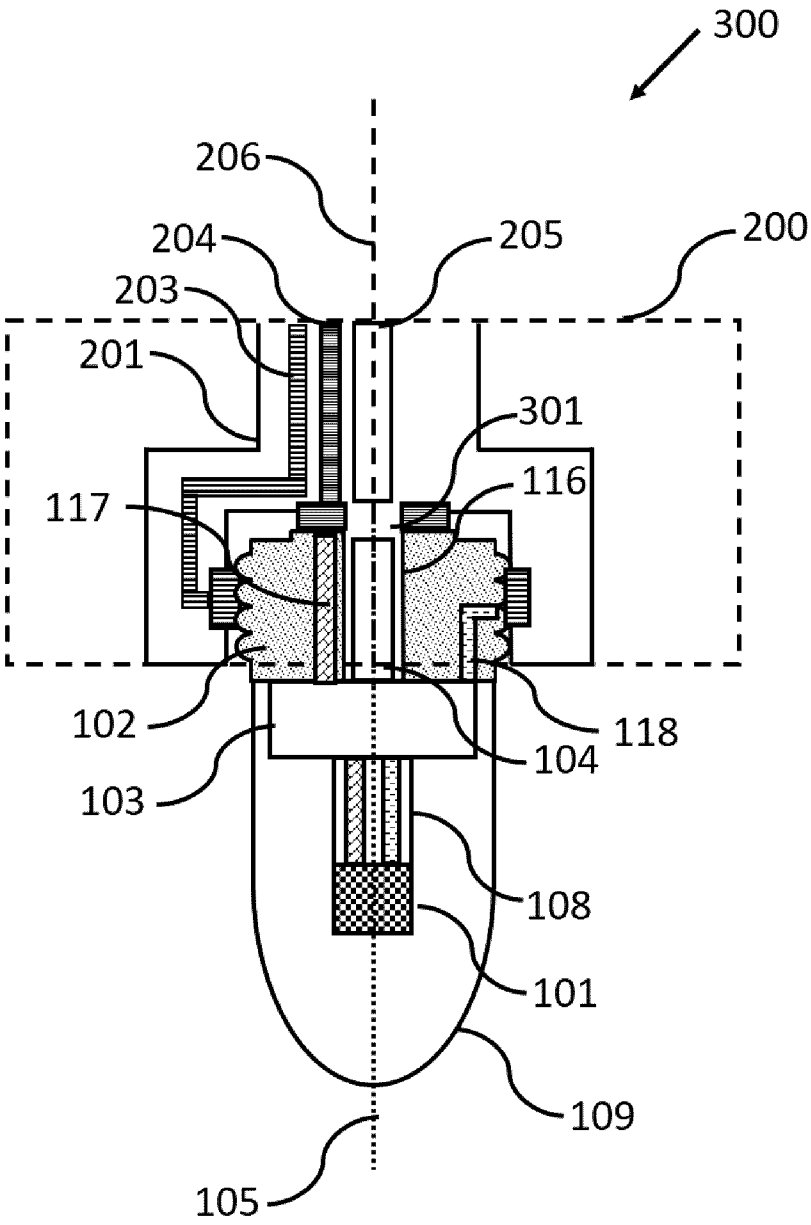
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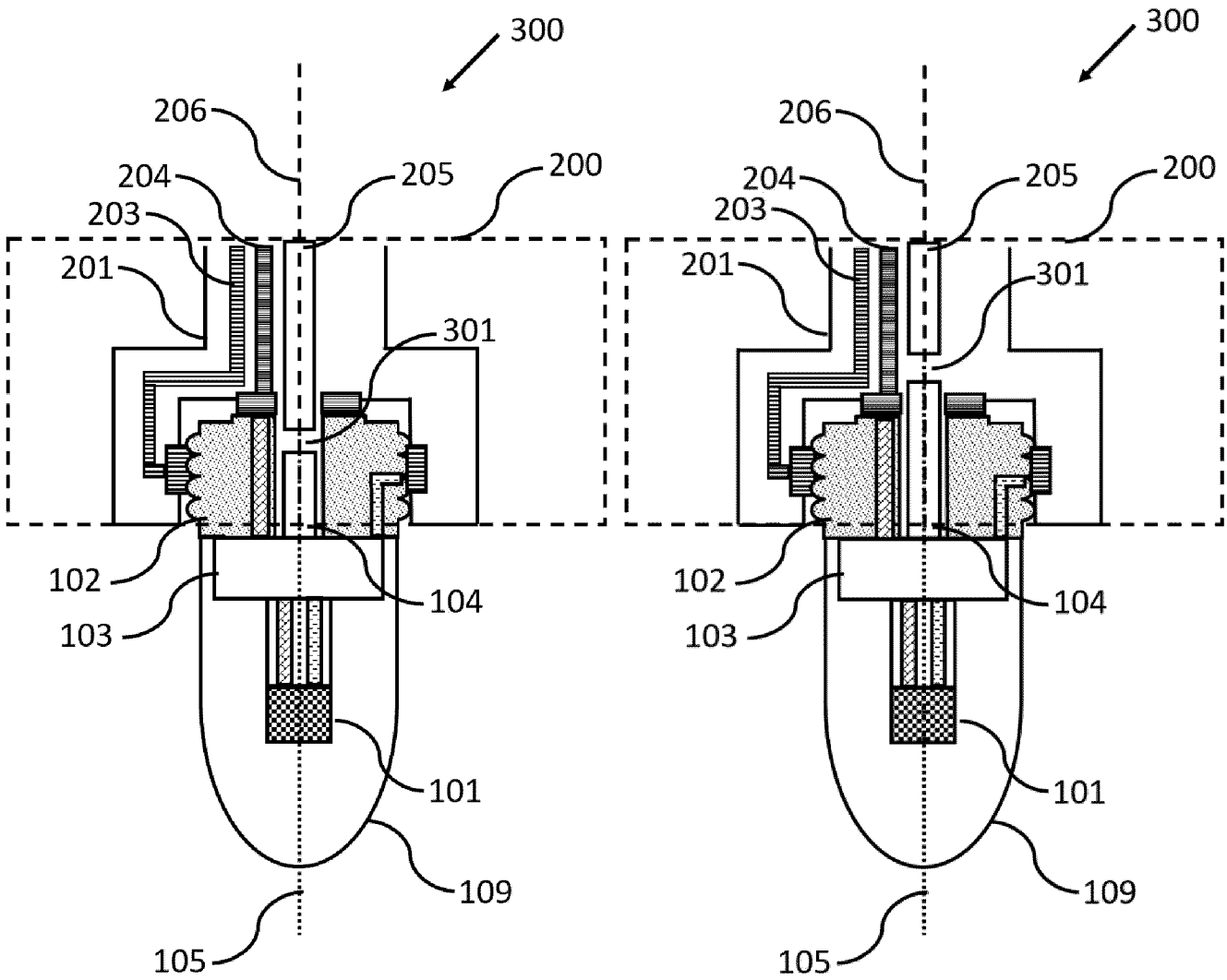
Figure 7


300
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(a)
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301
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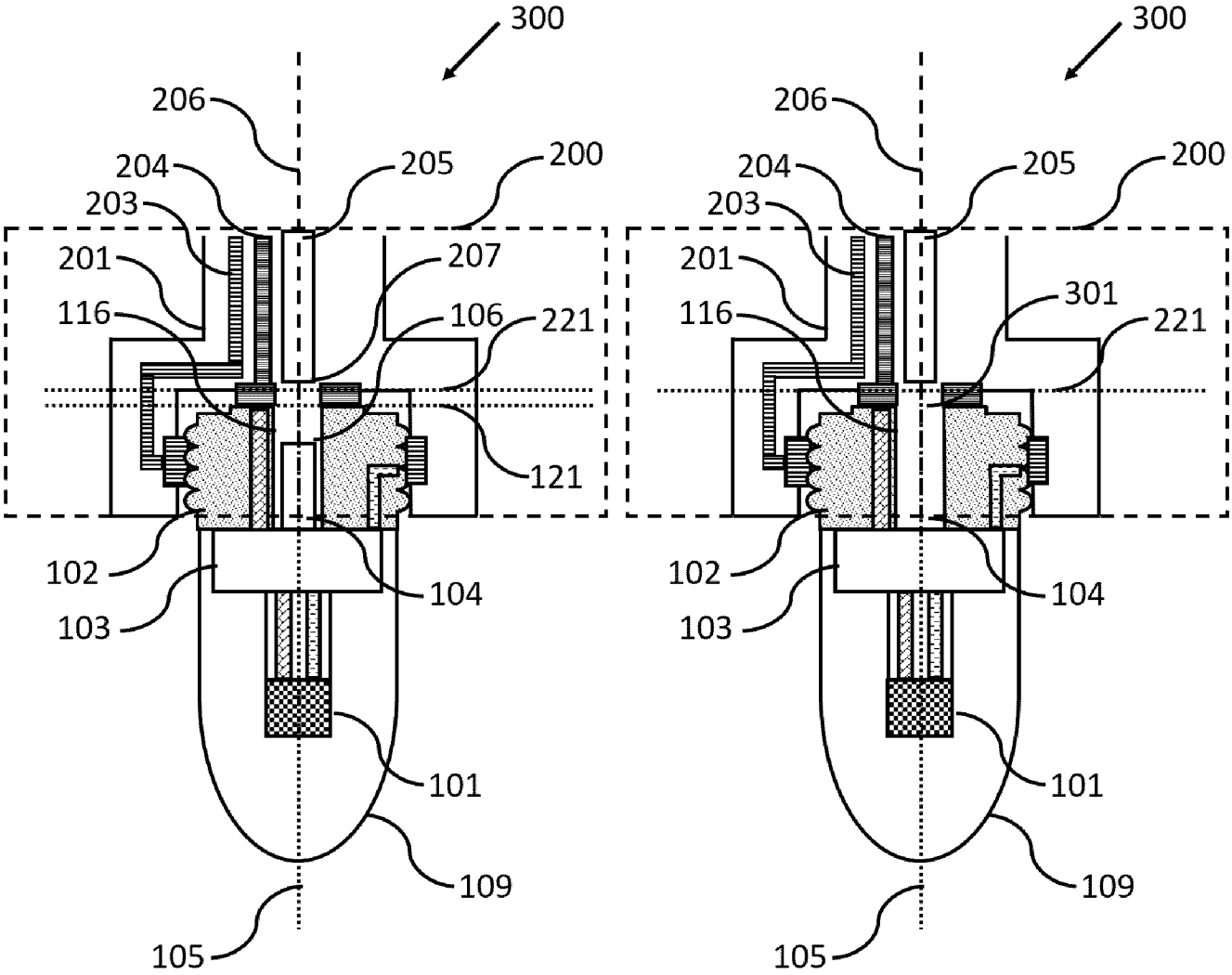
104
103
101
109
105
(b)

Figure 8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103
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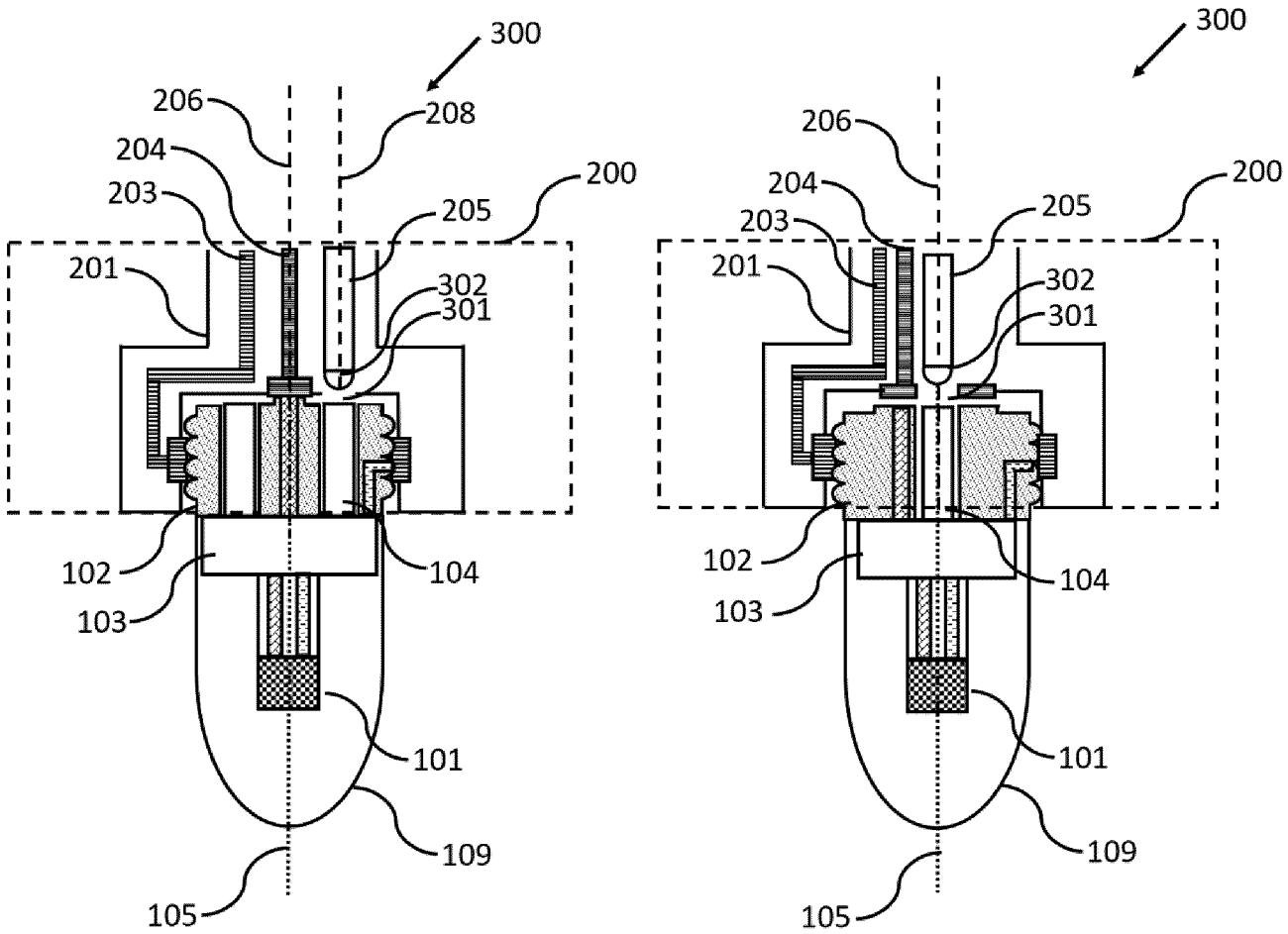
109
105

(a) (b)

Figure 9


300
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208
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102
104
103
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105
(a)
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204
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201
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104
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101
109
105
(b)

Figure 10

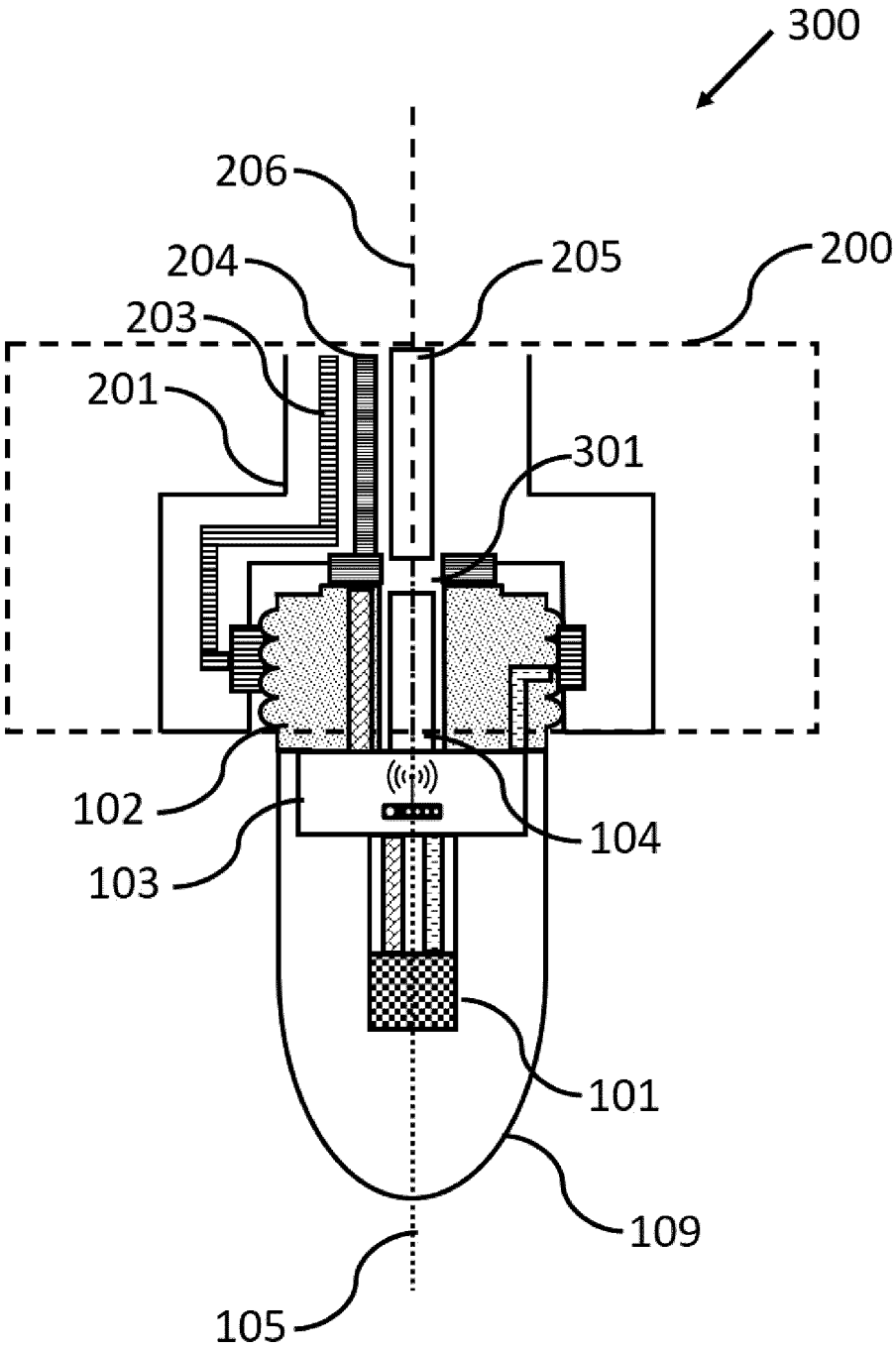

Figure 11

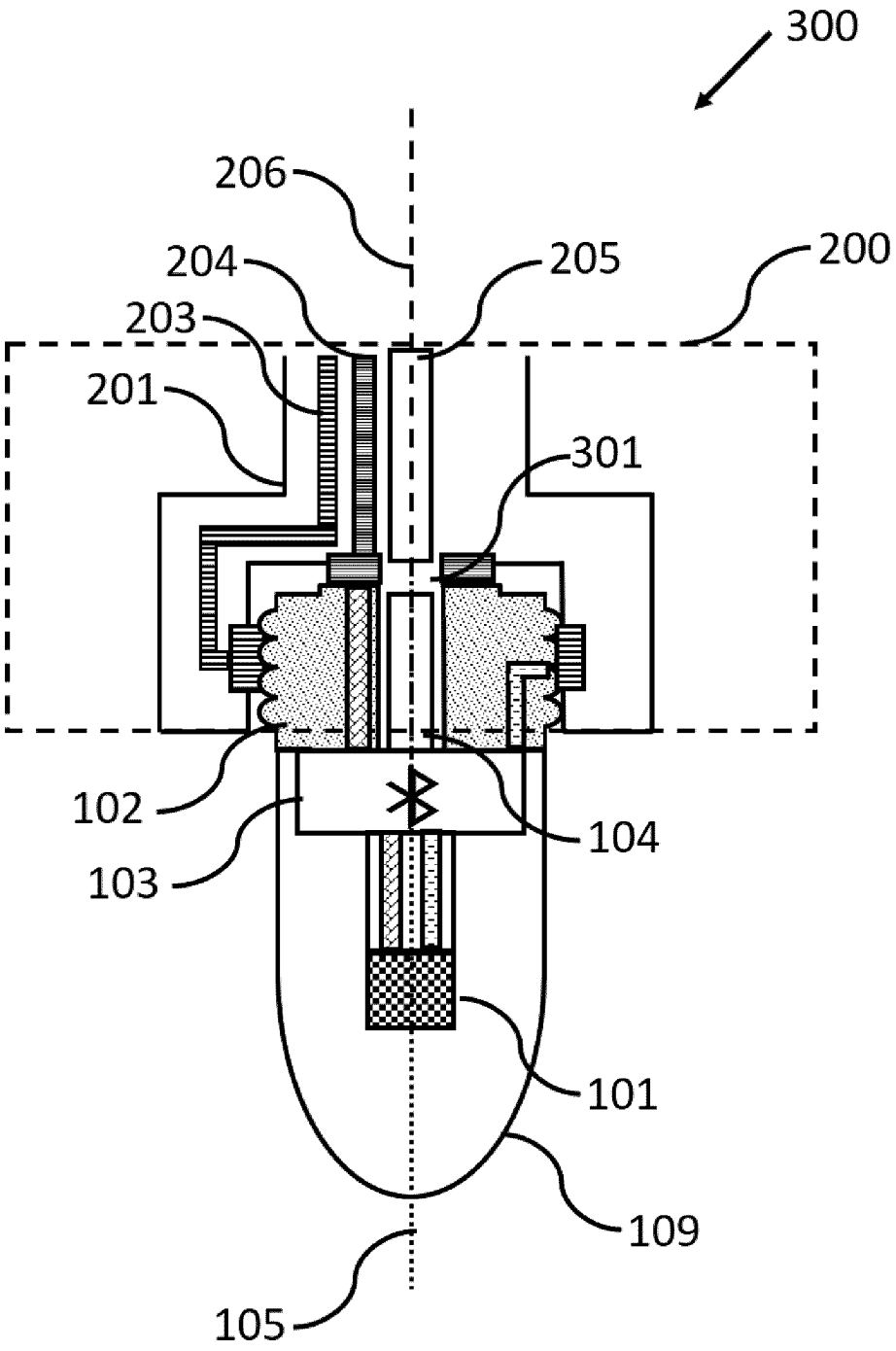

Figure 12

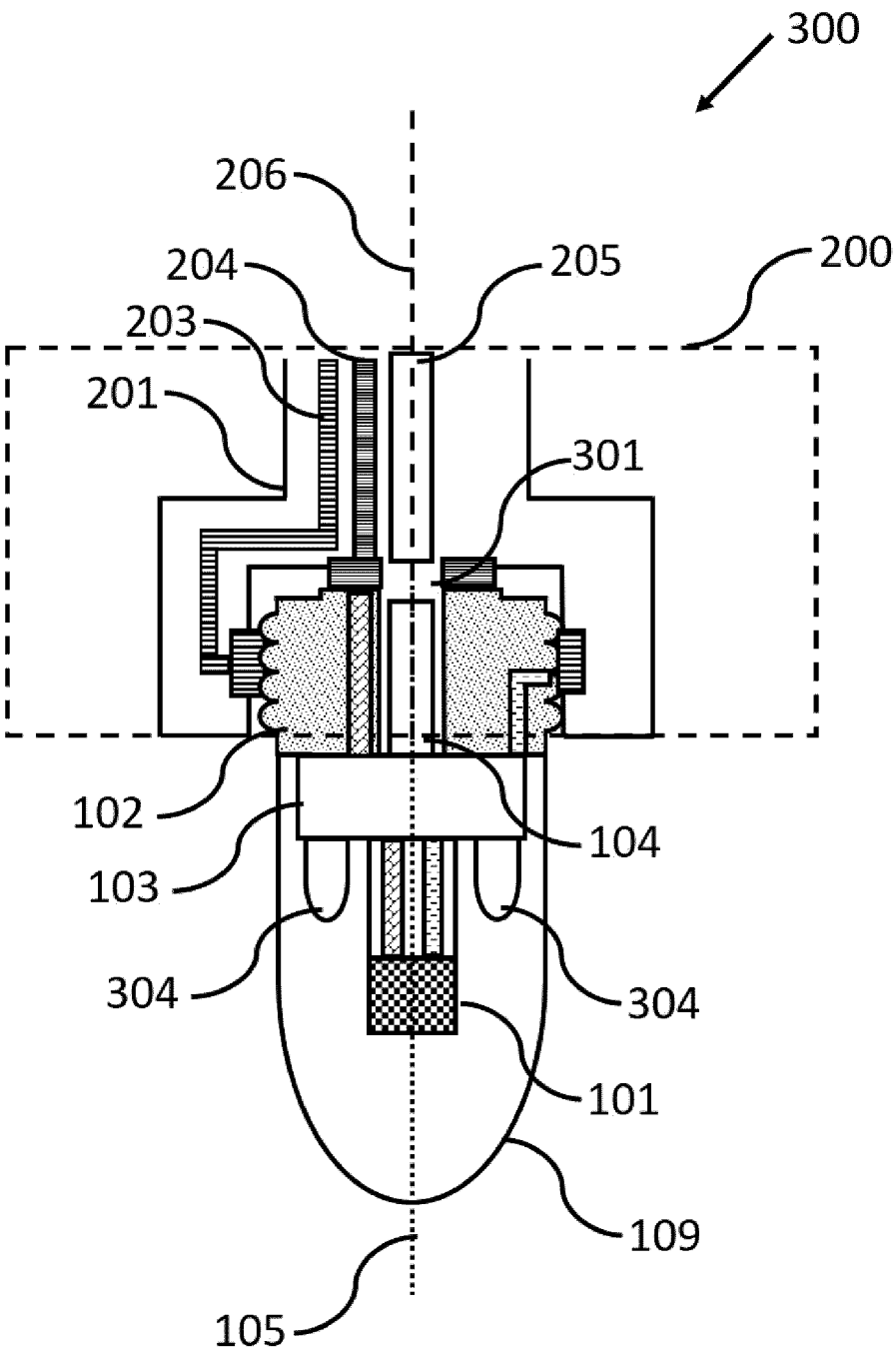

Figure 13

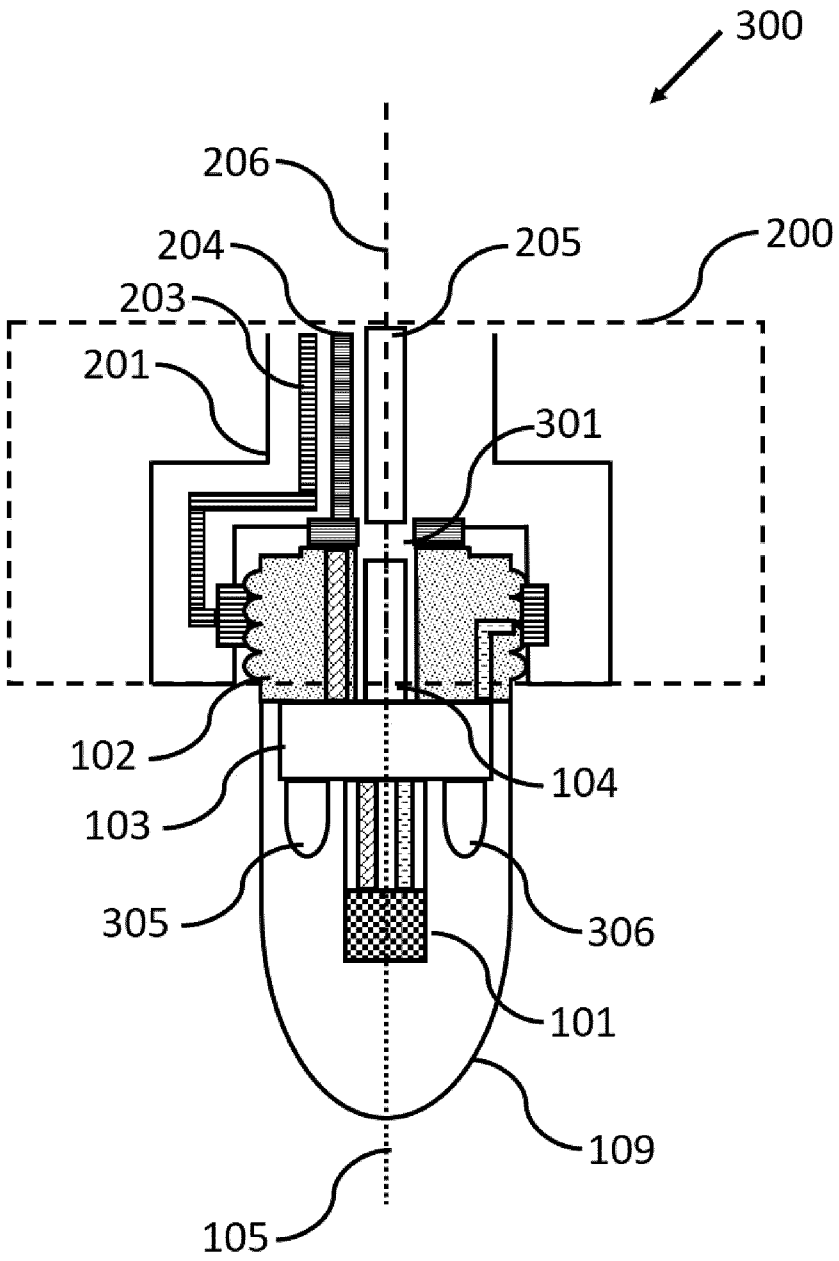

Figure 14

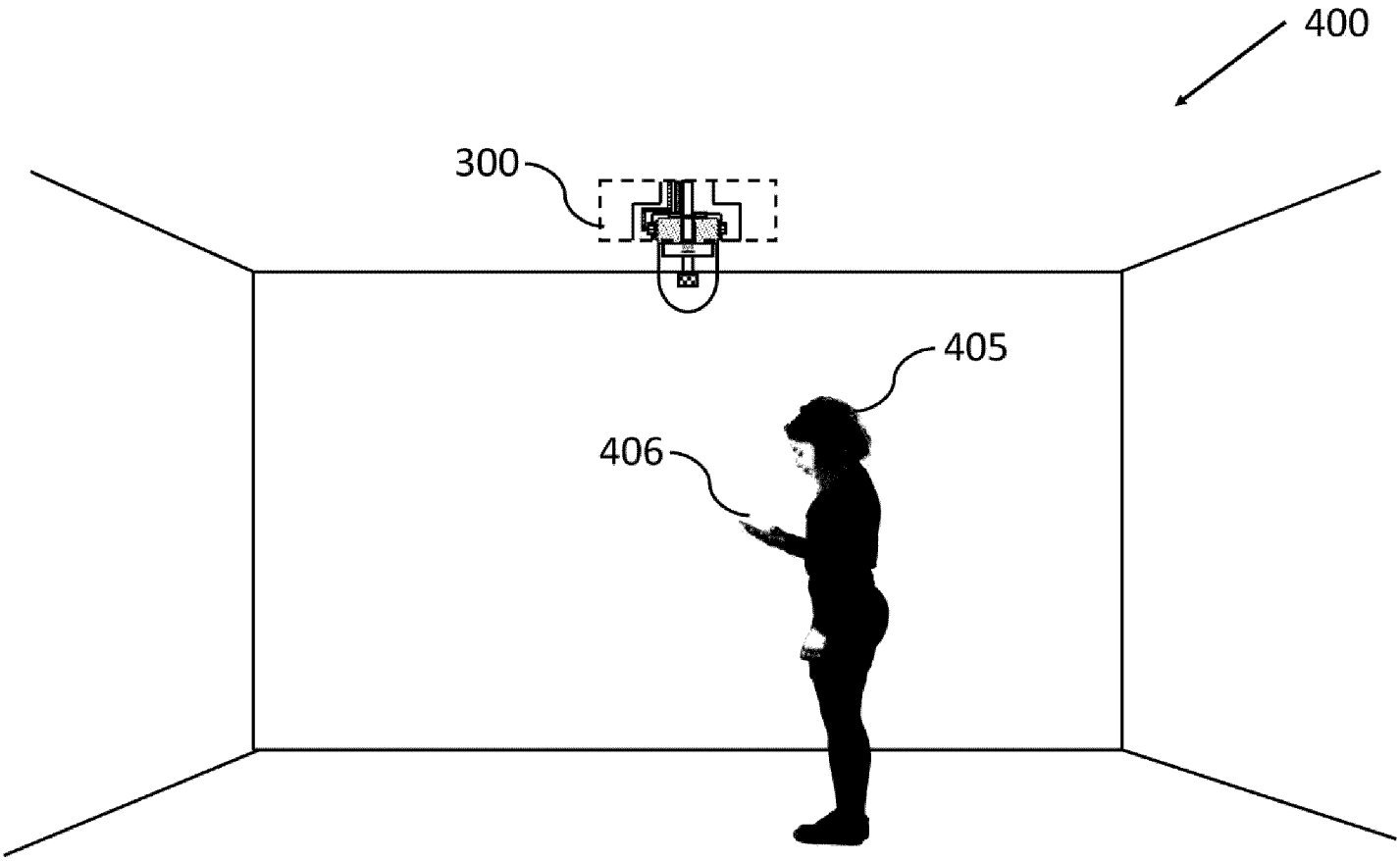

Figure 15

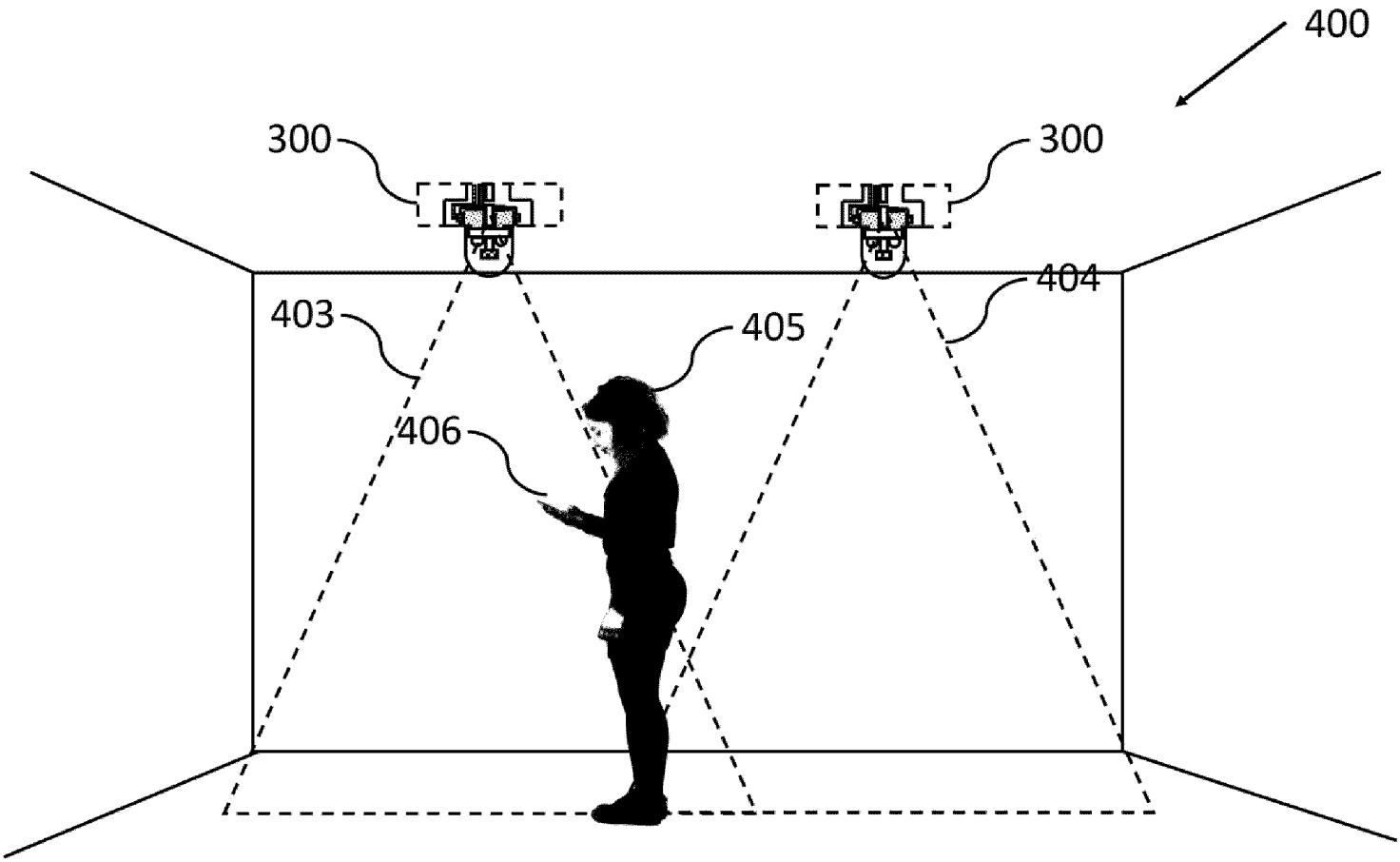

Figure 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/068171

A. CLASSIFICATION OF SUBJECT MATTER
INV. G08C23/06 H04B10/114 F21K9/238 F21K9/61
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G08C H04B F21K G02B

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7 543 957 B1 (BALAZS LASZLO [HU] ET AL) 9 June 2009 (2009-06-09) column 5, line 52 - column 7, line 11; figures 8, 9	1,3-7, 11-14
A	US 2011/227510 A1 (ELBERBAUM DAVID [JP]) 22 September 2011 (2011-09-22) paragraph [0052] - paragraph [0057]; figures 2A-D, 3A-F, 4A-F paragraph [0048] - paragraph [0051]; figures 1A-D	1,2, 8-13,15
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☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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25 August 2021	02/09/2021

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2021/068171

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