US 20230213729A1

(19) United States
(12) Patent Application Publication
Huang et al.

(10) Pub. No.: US 2023/0213729 A1
(43) Pub. Date: Jul. 6, 2023

(54) CAMERA DEVICE ASSEMBLED WITH LENS-TO-SENSOR DISTANCE THAT REDUCES AUTO-FOCUSING ACTUATION POWER

(71) Applicant: **META PLATFORMS TECHNOLOGIES, LLC**, Menlo Park, CA (US)

(72) Inventors: **Lidu Huang**, Danville, CA (US); **Honghong Peng**, Mountain View, CA (US); **Yizhi Xiong**, Foster City, CA (US); **Te Hu**, Kirkland, WA (US)

(21) Appl. No.: **17/568,595**

(22) Filed: **Jan. 4, 2022**

Publication Classification

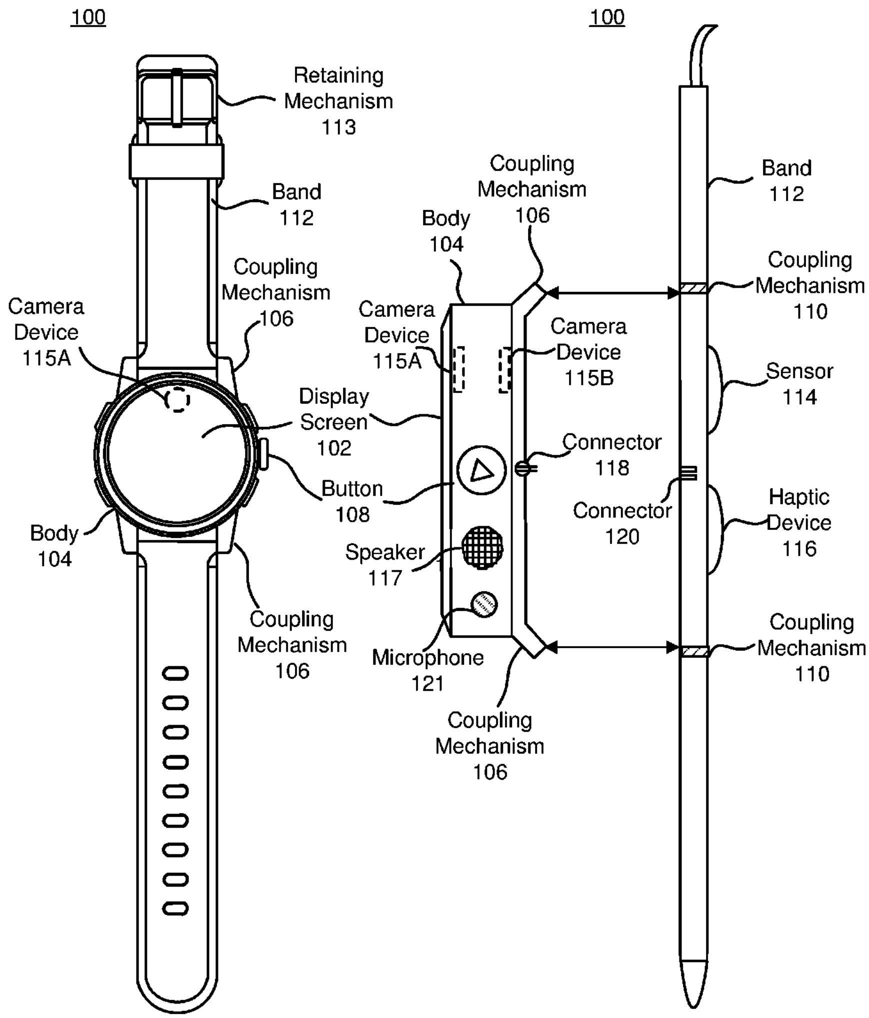
(51) **Int. Cl.**

G02B 7/09	(2006.01)
G02B 7/02	(2006.01)
G03B 13/36	(2006.01)

(52) **U.S. Cl.**
CPC ***G02B 7/09*** (2013.01); ***G02B 7/023*** (2013.01); ***G02B 7/028*** (2013.01); ***G03B 13/36*** (2013.01)

(57) **ABSTRACT**

Embodiments of the present disclosure relate to a camera device assembled to reduce an auto-focusing actuation power for the most typical use case. The camera device comprises an image sensor and a lens assembly in an optical series with the image sensor. During assembling of the camera device, the lens assembly is assembled within the camera device to have an optical axis parallel to gravity and positioned to have an offset along the optical axis relative to a support assembly. The offset is determined during assembling of the camera device such that, when the camera device is oriented with a rotated optical axis orthogonal to gravity, the lens assembly is positioned at a neutral position relative to the image sensor without activation applied to the lens assembly.



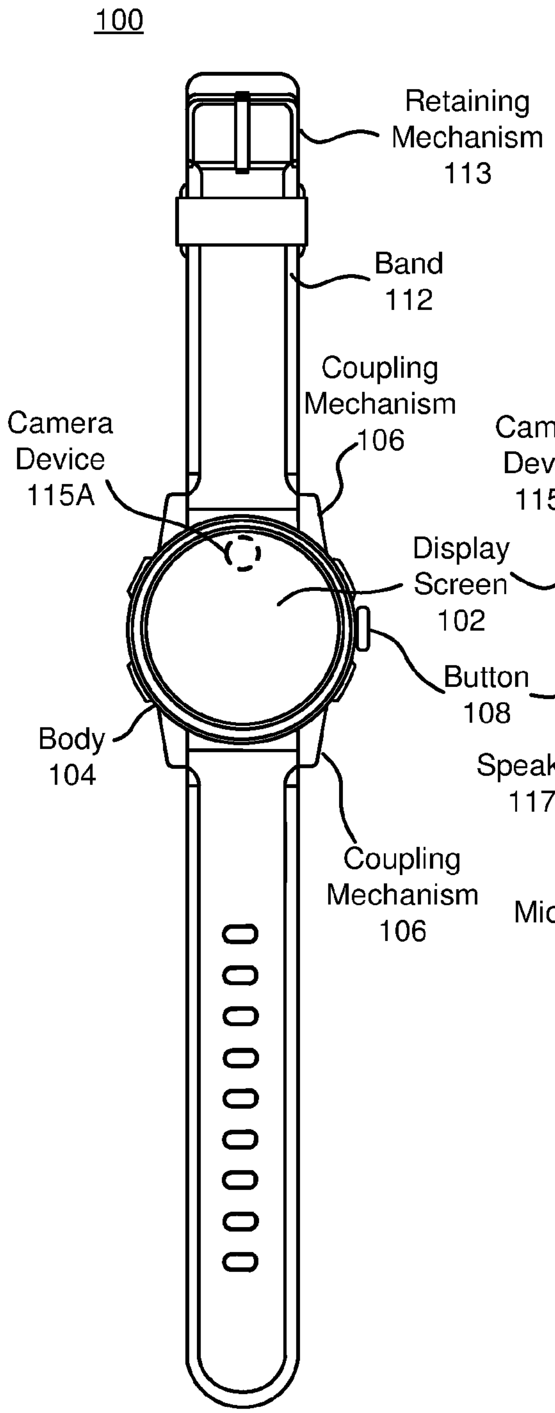

100
Retaining Mechanism 113
Band 112
Coupling Mechanism 106
Camera Device 115A
Display Screen 102
Button 108
Body 104
Coupling Mechanism 106

FIG. 1A

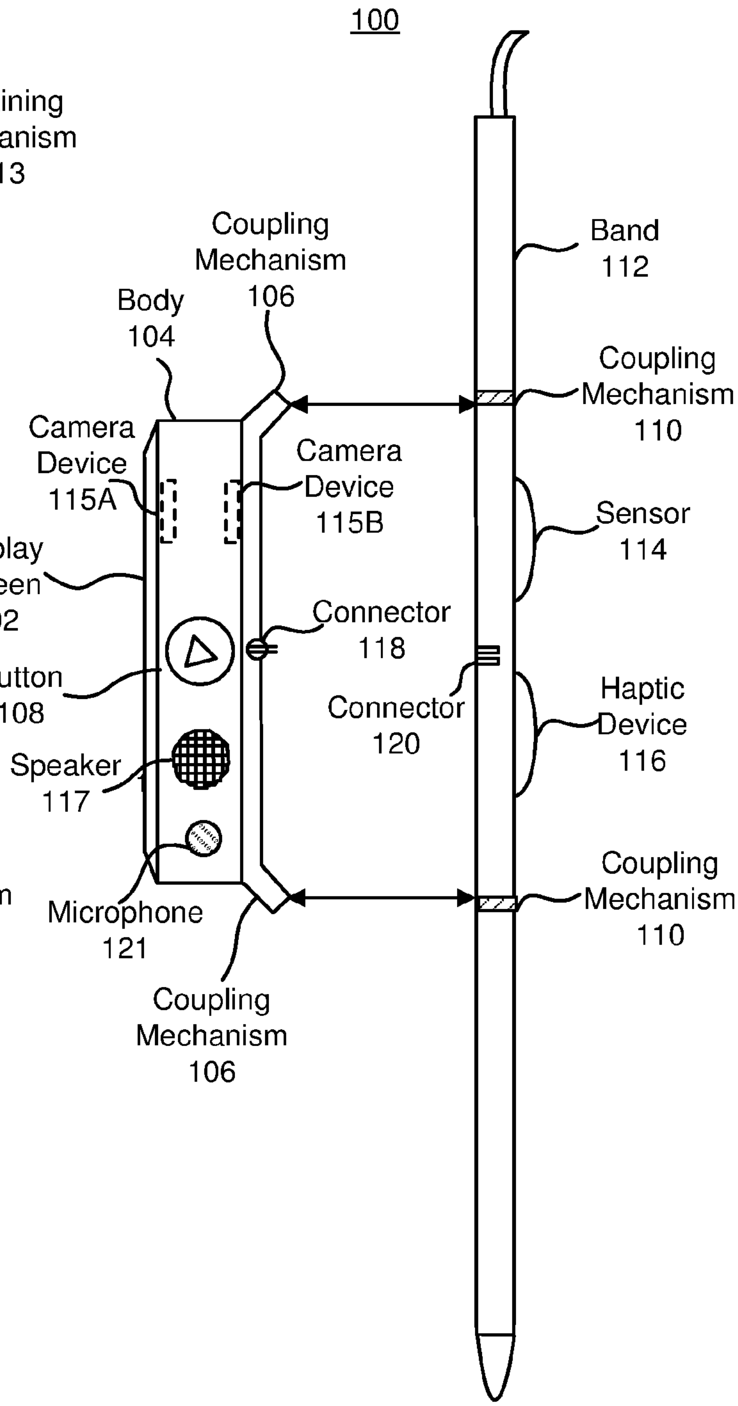

100
Coupling Mechanism 106
Body 104
Camera Device 115A
Camera Device 115B
Connector 118
Speaker 117
Microphone 121
Coupling Mechanism 106
Band 112
Coupling Mechanism 110
Sensor 114
Connector 120
Haptic Device 116
Coupling Mechanism 110

FIG. 1B

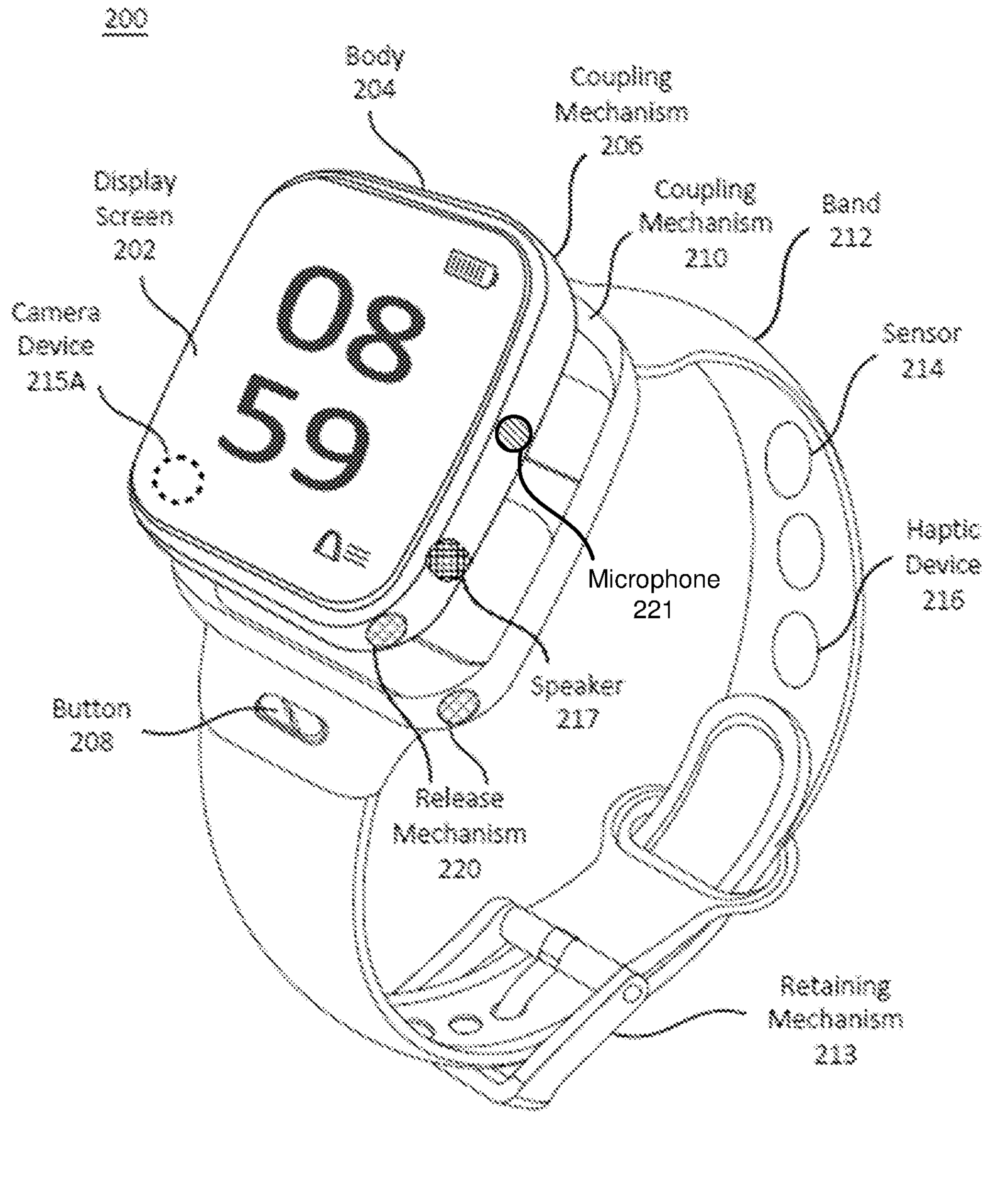

200
Body 204
Coupling Mechanism 206
Display Screen 202
Coupling Mechanism 210
Band 212
Camera Device 215A
Sensor 214
08
59
Microphone 221
Haptic Device 216
Speaker 217
Button 208
Release Mechanism 220
Retaining Mechanism 213

FIG. 2

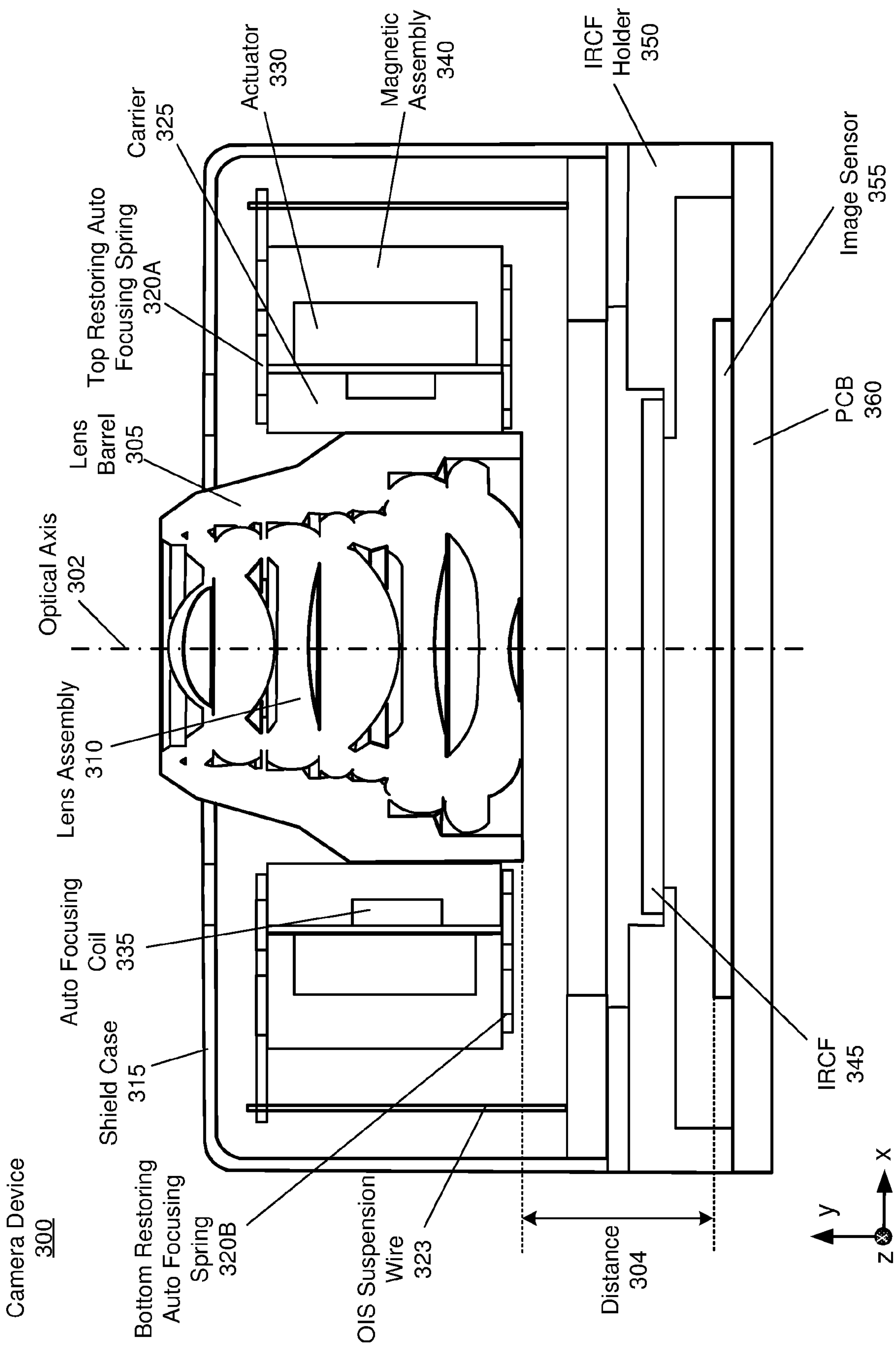

Camera Device
300
Bottom Restoring Auto Focusing Spring 320B
OIS Suspension Wire 323
Distance 304
Shield Case 315
Auto Focusing Coil 335
Lens Assembly 310
Optical Axis 302
Lens Barrel 305
Top Restoring Auto Focusing Spring 320A
Carrier 325
Actuator 330
Magnetic Assembly 340
IRCF Holder 350
Image Sensor 355
PCB 360
IRCF 345
z
y
x

FIG. 3

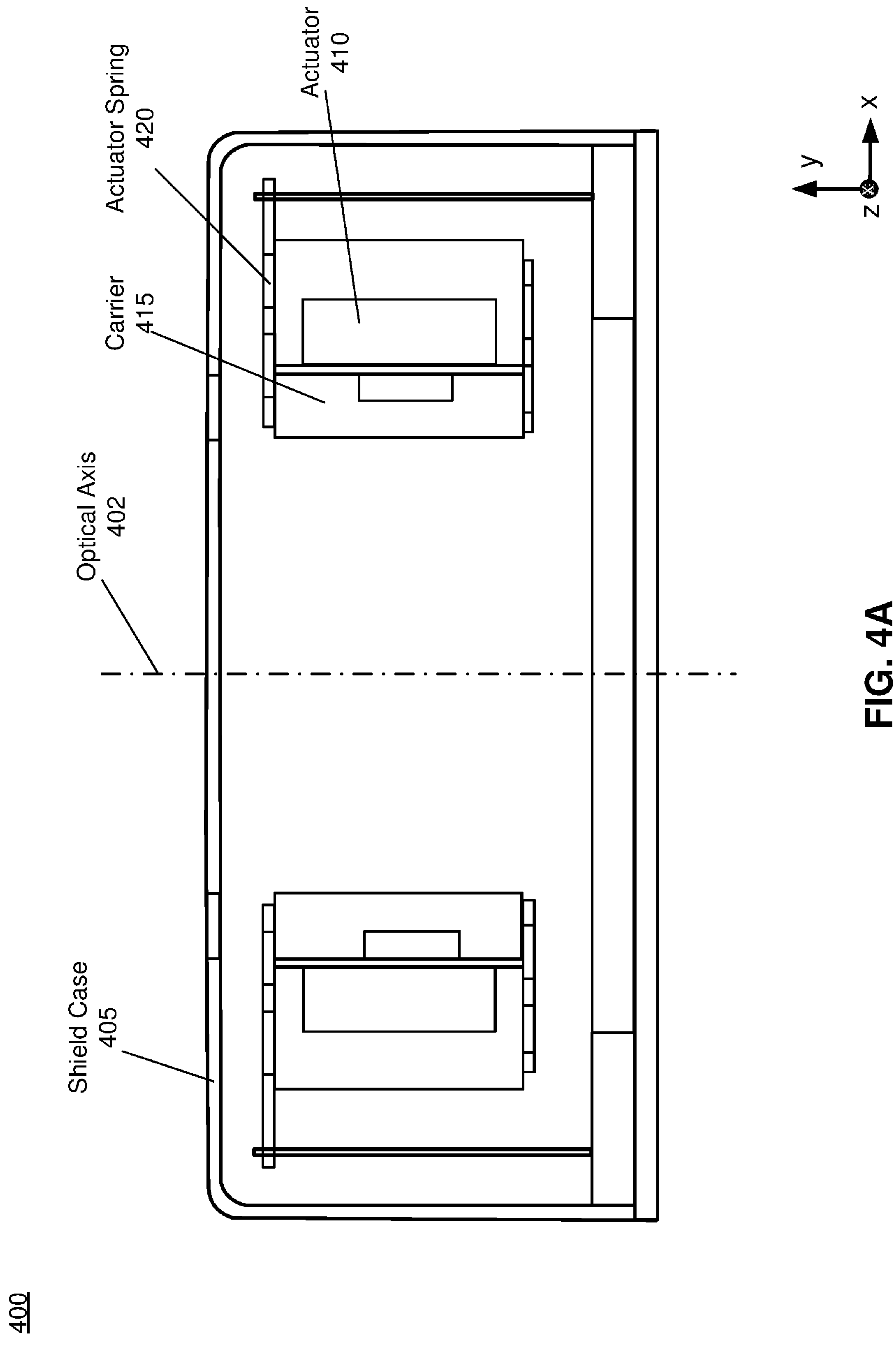

400
Shield Case
405
Optical Axis
402
Carrier
415
Actuator Spring
420
Actuator
410
x
y
z

FIG. 4A

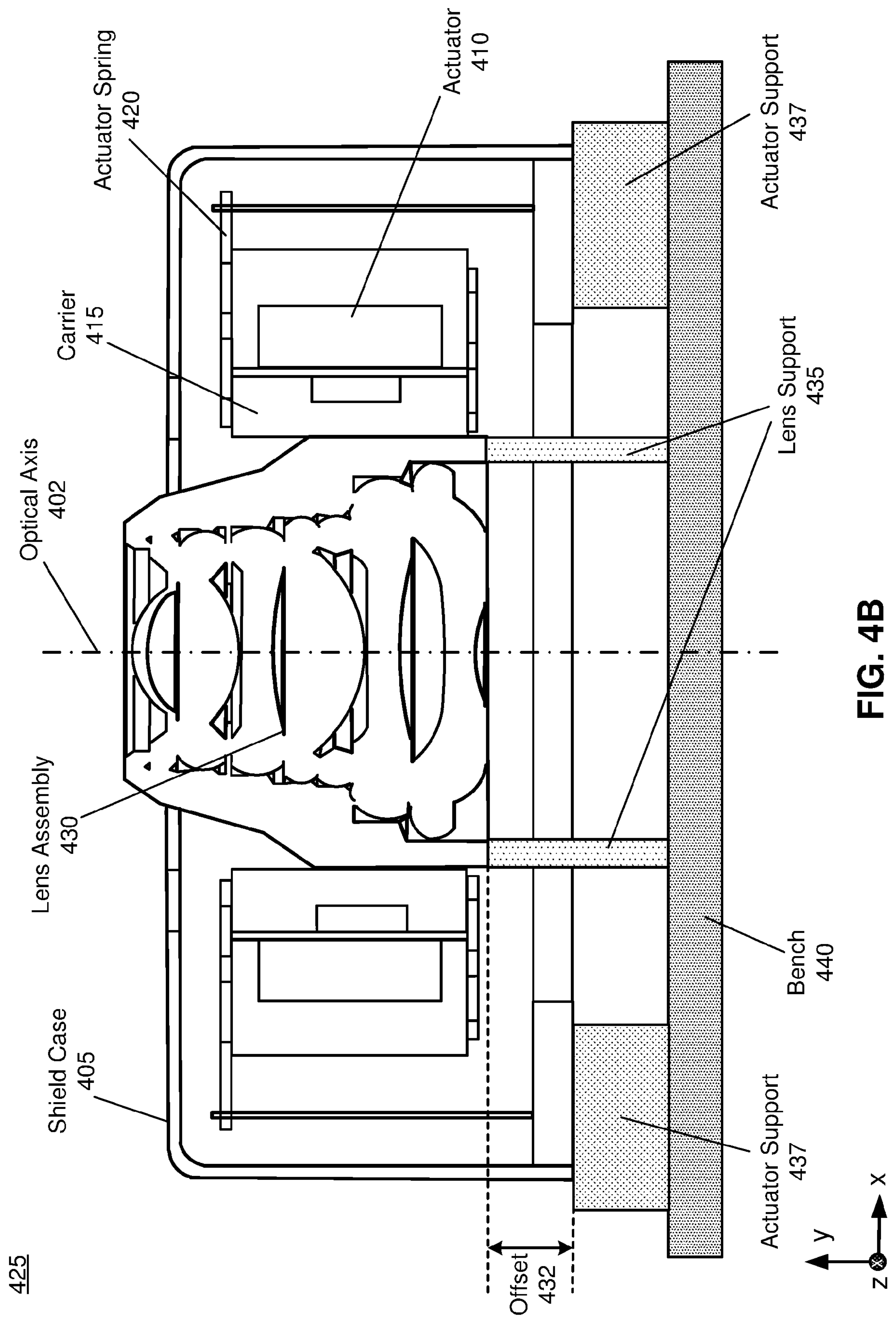

425
Actuator Spring 420
Actuator 410
Carrier 415
Optical Axis 402
Lens Assembly 430
Shield Case 405
Actuator Support 437
Lens Support 435
Bench 440
Actuator Support 437
Offset 432
y
x
z

FIG. 4B

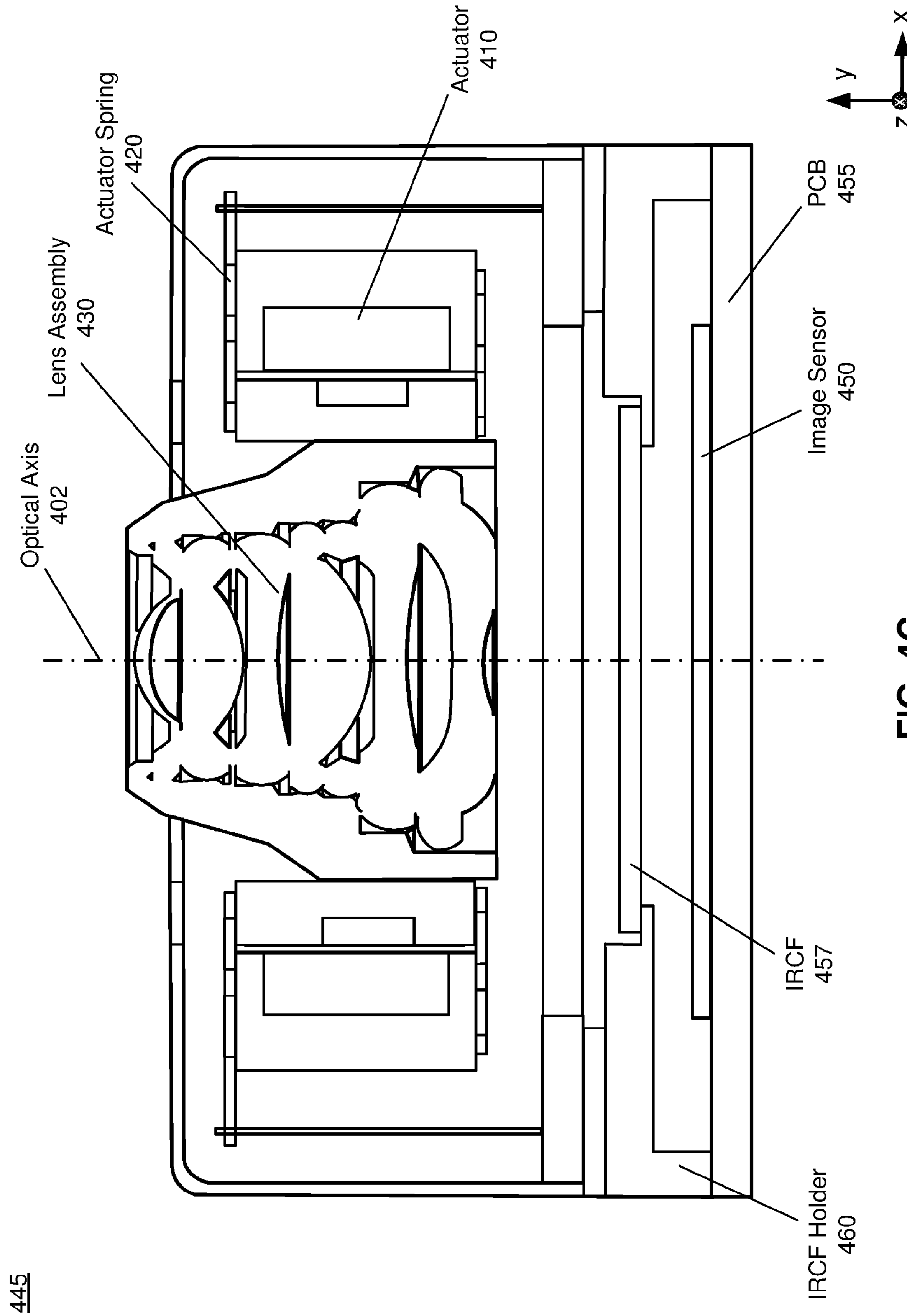

445
Optical Axis
402
Lens Assembly
430
Actuator Spring
420
Actuator
410
PCB
455
Image Sensor
450
IRCF
457
IRCF Holder
460
x
y
z

FIG. 4C

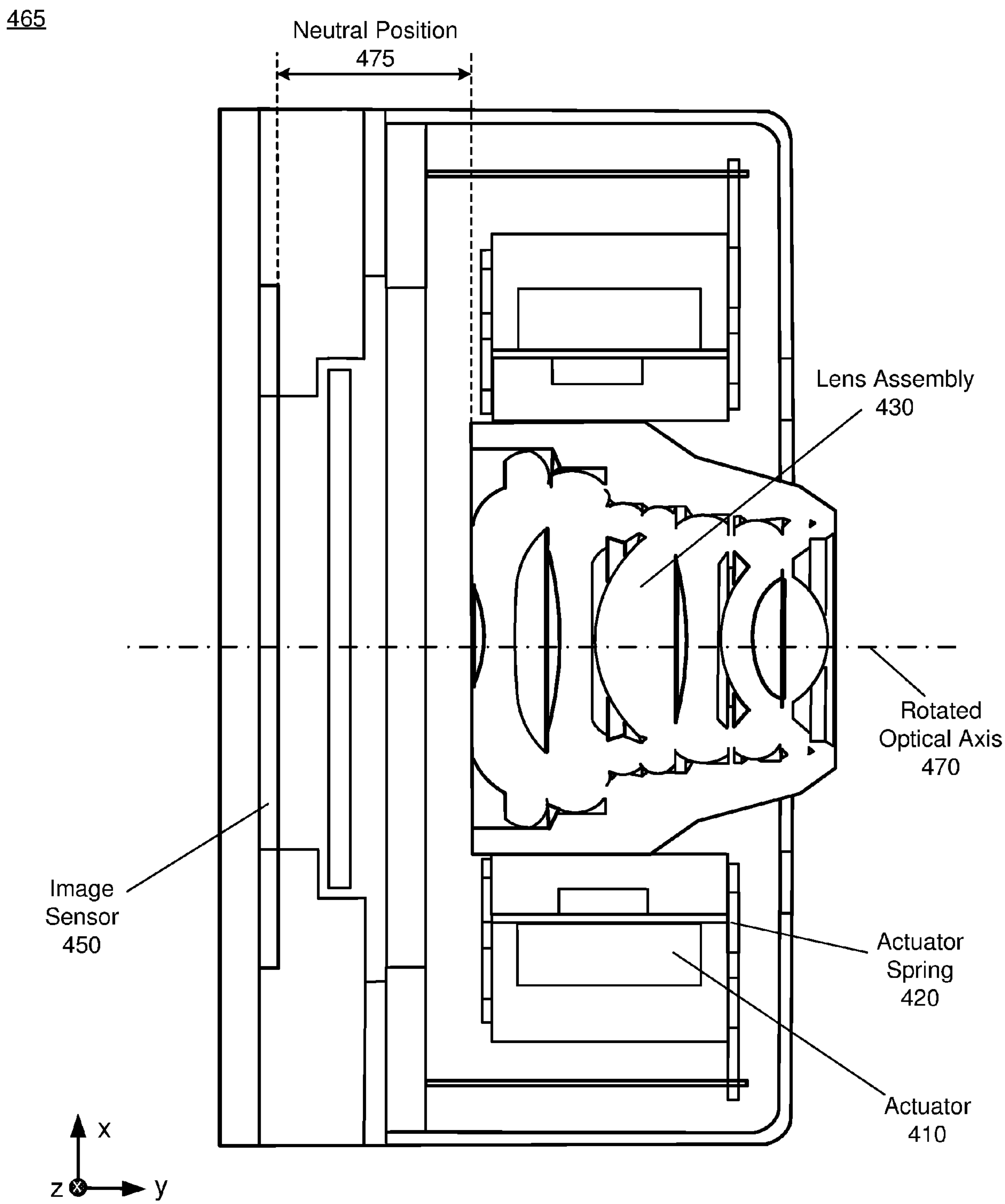

465
Neutral Position
475
Lens Assembly
430
Rotated
Optical Axis
470
Image
Sensor
450
Actuator
Spring
420
Actuator
410
x
z
y

FIG. 4D

500

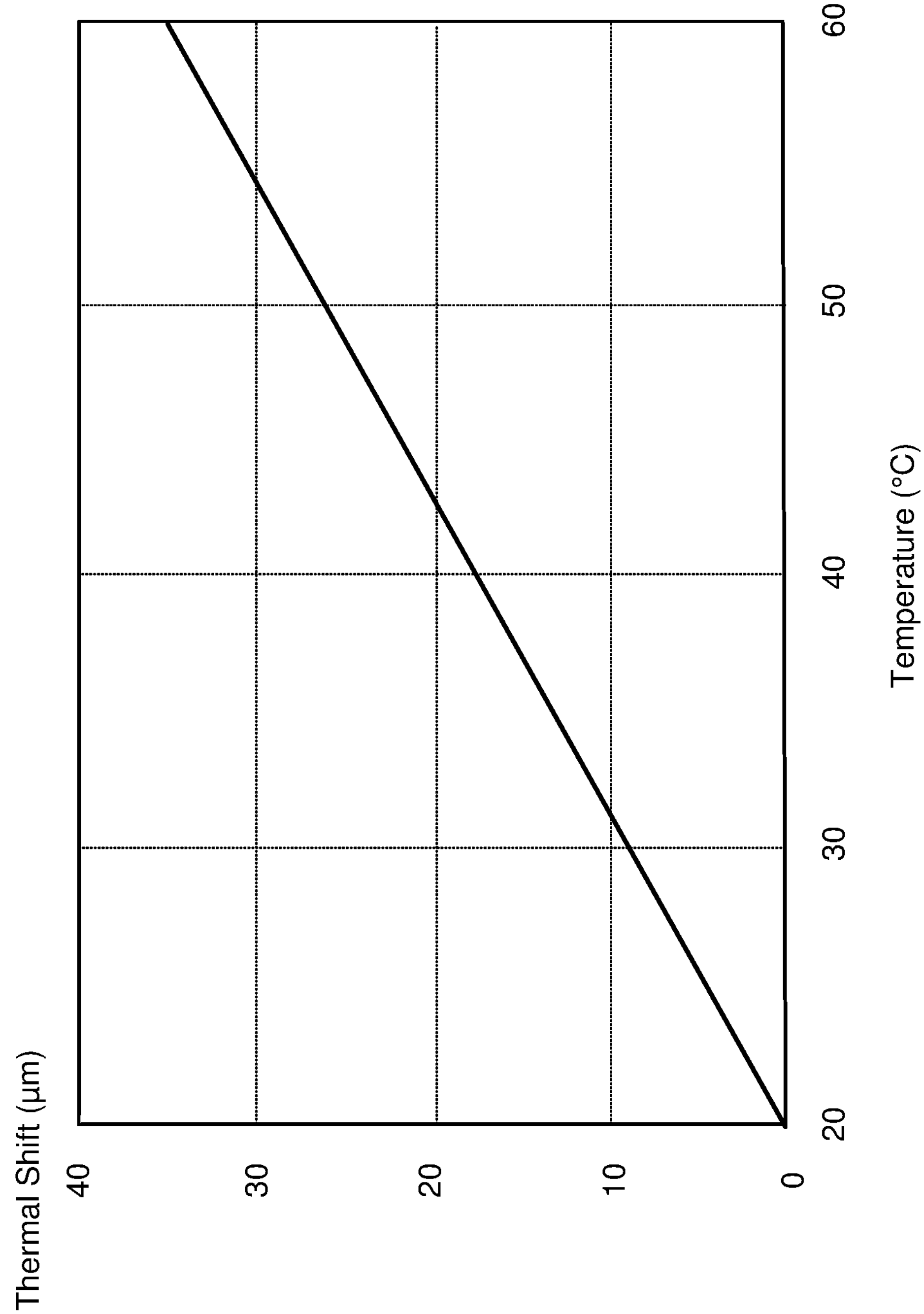


FIG. 5

600

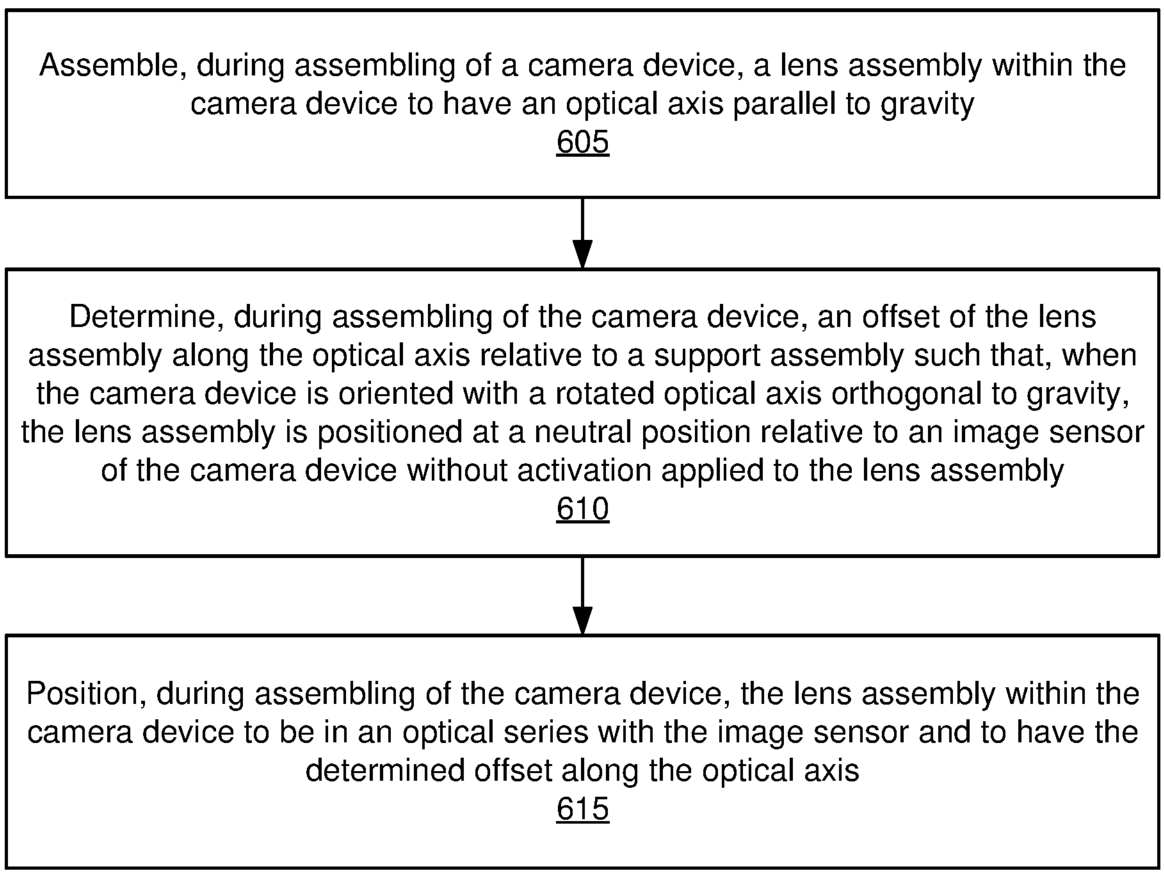

Assemble, during assembling of a camera device, a lens assembly within the camera device to have an optical axis parallel to gravity
605
Determine, during assembling of the camera device, an offset of the lens assembly along the optical axis relative to a support assembly such that, when the camera device is oriented with a rotated optical axis orthogonal to gravity, the lens assembly is positioned at a neutral position relative to an image sensor of the camera device without activation applied to the lens assembly
610
Position, during assembling of the camera device, the lens assembly within the camera device to be in an optical series with the image sensor and to have the determined offset along the optical axis
615

FIG. 6

CAMERA DEVICE ASSEMBLED WITH LENS-TO-SENSOR DISTANCE THAT REDUCES AUTO-FOCUSING ACTUATION POWER

FIELD OF THE INVENTION

[0001] The present disclosure relates generally to assembling of a camera device, and specifically relates to a camera device assembled with a specific lens-to-sensor distance that reduces an auto-focusing actuation power.

BACKGROUND

[0002] It is desired that for the most typical use case of a camera device, a lens in the camera device is at its near hyperfocal position relative to an image sensor so that a minimum (e.g., zero-level or near zero-level) auto-focusing actuation power is consumed for focusing of the lens. In the most typical use case of the camera device, the camera device is facing forward with its lens in horizontal posture in optical series with the image sensor. However, when the lens is in the horizontal posture, the lens is typically not at its hyperfocal position. There are two primary causes that affect a distance between the lens and the image sensor in the camera device, which then affect a level of auto-focusing actuation power consumed to bring the lens in its hyperfocal position. The first cause is movement of the lens (i.e., auto-focusing actuator movement) between an upward (vertical) posture of the lens and a forward (horizontal) posture of the lens. The lens is typically combined with a carrier, and, at the upward posture of the camera device, the carrier is shifted downward due to gravity. The second cause is a thermal shift of the lens during typical operations of the camera device. The lens design and its performance are commonly tested at a room temperature, e.g., around 23° C. However, the camera device can often operate at higher temperatures (e.g., around 45 to 50° C.) when placed inside an electronic wearable device (e.g., smartwatch). The higher temperatures of an interior of the electronic wearable device may cause additional shifting (i.e., thermal shifting) of the camera lens relative to the image sensor as well as a modified (e.g., longer) focal distance of the camera lens due to a change of the camera lens shape.

SUMMARY

[0003] Embodiments of the present disclosure relate to a camera device assembled such that to reduce (and in some cases minimize) auto-focusing actuation power for the most typical use case of the camera device. The camera device comprises an image sensor and a lens assembly in an optical series with the image sensor. During assembling of the camera device, the lens assembly is assembled within the camera device to have an optical axis parallel to gravity and positioned to have an offset along the optical axis relative to a support assembly. The offset is determined during assembling of the camera device such that, when the camera device is oriented with a rotated optical axis orthogonal to gravity, the lens assembly is positioned at a neutral position relative to the image sensor without activation applied to the lens assembly. The camera device may be part of a wristband system, e.g., a smartwatch or some other electronic wearable device.

[0004] Embodiments of the present disclosure further relate to a method of assembling a camera device to reduce (and in some cases minimize) an auto-focusing actuation power for the most typical use case of the camera device. The method comprises: assembling a lens assembly within the camera device to have an optical axis parallel to gravity, determining an offset of the lens assembly along the optical axis relative to a support assembly such that, when the camera device is oriented with a rotated optical axis orthogonal to gravity, the lens assembly is positioned at a neutral position relative to the image sensor without activation applied to the lens assembly, and positioning the lens assembly within the camera device to be in an optical series with an image sensor of the camera device and to have the determined offset along the optical axis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1**A is a top view of an example wristband system, in accordance with one or more embodiments.

[0006] FIG. **1**B is a side view of the example wristband system of FIG. **1**A.

[0007] FIG. **2** is a perspective view of another example wristband system, in accordance with one or more embodiments.

[0008] FIG. **3** is a cross section of an example structure of a camera device, in accordance with one or more embodiments.

[0009] FIG. **4**A is a cross section of an example shield case of a camera device during assembling of the camera device, in accordance with one or more embodiments.

[0010] FIG. **4**B is an example cross section of the camera device with a lens assembly during assembling of the camera device, in accordance with one or more embodiments.

[0011] FIG. **4**C is a cross section of the camera device having the lens assembly assembled in an upward (vertical) posture and aligned with an image sensor during assembling of the camera device, in accordance with one or more embodiments.

[0012] FIG. **4**D is a cross section of the camera device with the lens assembly in a forward (horizontal) posture when the camera device is fully assembled, in accordance with one or more embodiments.

[0013] FIG. **5** is a graph illustrating a thermal shift of a lens assembly in a camera device as a function of an operating temperature of the camera device, in accordance with one or more embodiments.

[0014] FIG. **6** is a flowchart illustrating a process of assembling a camera device to have a specific distance between a lens assembly and an image sensor that reduces an auto-focusing actuation power, in accordance with one or more embodiments.

[0015] The figures depict various embodiments for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein.

DETAILED DESCRIPTION

[0016] Embodiments of the present disclosure relate to a camera device with a lens assembly assembled with a predetermined offset along an optical axis in an upward (or vertical) posture of the camera device such that the lens assembly with a small amount of actuation or no amount of activation is at a target position in a forward (or horizontal) posture of the camera device where the lens assembly is focused at a hyperfocal distance. The camera device may be part of an electronic wearable device (e.g., a smartwatch). The camera device is assembled with the optical axis being substantially parallel to gravity (i.e., the lens is at the upward posture). During assembling of the camera device, the lens assembly is positioned (i.e., the offset is introduced) within the camera device, such that, during operation while the camera is poised (i.e., oriented with an optical axis orthogonal to gravity) to take an image of a local area, the lens assembly with a small amount of activation or no amount of actuation is positioned at a neutral position. During assembling of the camera device, the lens assembly was positioned within the camera device such that the neutral position corresponds to the target position where the lens assembly is focused at the hyperfocal distance. Moreover, the positioning of the lens assembly during assembling of the camera device may also account for thermal effects of operation of the camera device, such that the target position is calibrated to occur over a specific temperature range.

[0017] Embodiments of the present disclosure further relate to a method for lens assembly position control for achieving a least actuation power consumption (e.g., zero-level actuation power) when (i) a camera device is in its most typical use posture (i.e., horizontal posture of the camera device and the lens assembly); and (ii) the camera device is operating at higher temperatures (e.g., around 45° C. to 50° C., which is a typical ambient condition for the camera device inside an electronic wearable device). For these two combined use cases, a reduced level (e.g., zero-level) of auto-focusing actuation force is applied to focus the lens assembly at a hyperfocal distance for the most typical use posture (i.e., horizontal or forward posture) of the camera device and the lens assembly.

[0018] The camera device may be incorporated into a small form factor electronic device, such as an electronic wearable device. Examples of electronic wearable devices include a smartwatch or a head-mount display (HMD). The electronic device can include other components (e.g., haptic devices, speakers, etc.). And, the small form factor of the electronic device provides limited space between the other components and the camera device. In some embodiments, the electronic device may have limited power supply (e.g., due to being dependent on a re-chargeable battery).

[0019] In some embodiments, the electronic wearable device may operate in an artificial reality environment (e.g., a virtual reality environment). The camera device of the electronic wearable device may be used to enhance an artificial reality application running on an artificial reality system (e.g., running on an HMD device worn by the user). The camera device may be disposed on multiple surfaces of the electronic wearable device such that data from a local area, e.g., surrounding a wrist of the user, may be captured in multiple directions. For example, one or more images may be captured describing the local area and the images may be sent and processed by the HMD device prior to be presented to the user.

[0020] Embodiments of the present disclosure may include or be implemented in conjunction with an artificial reality system. Artificial reality is a form of reality that has been adjusted in some manner before presentation to a user, which may include, e.g., a virtual reality (VR), an augmented reality (AR), a mixed reality (MR), a hybrid reality, or some combination and/or derivatives thereof. Artificial reality content may include completely generated content or generated content combined with captured (e.g., real-world) content. The artificial reality content may include video, audio, haptic feedback, or some combination thereof, any of which may be presented in a single channel or in multiple channels (such as stereo video that produces a three-dimensional effect to the viewer). Additionally, in some embodiments, artificial reality may also be associated with applications, products, accessories, services, or some combination thereof, that are used to create content in an artificial reality and/or are otherwise used in an artificial reality. The artificial reality system that provides the artificial reality content may be implemented on various platforms, including an electronic wearable device (e.g., headset) connected to a host computer system, a standalone electronic wearable device (e.g., headset, smartwatch, bracelet, etc.), a mobile device or computing system, or any other hardware platform capable of providing artificial reality content to one or more viewers.

[0021] FIG. **1**A is a top view of an example wristband system **100**, in accordance with one or more embodiments. FIG. **1**B is a side view of the example wristband system **100** of FIG. **1**A. The wristband system **100** is an electronic wearable device and may be worn on a wrist or an arm of a user. In some embodiments, the wristband system **100** is a smartwatch. Media content may be presented to the user wearing the wristband system **100** using a display screen **102** and/or one or more speakers **117**. However, the wristband system **100** may also be used such that media content is presented to a user in a different manner (e.g., via touch utilizing a haptic device **116**). Examples of media content presented by the wristband system **100** include one or more images, video, audio, or some combination thereof. The wristband system **100** may operate in an artificial reality environment (e.g., a virtual reality environment, an augmented reality environment, a mixed reality environment, or some combination thereof).

[0022] In some examples, the wristband system **100** may include multiple electronic devices (not shown) including, without limitation, a smartphone, a server, a head-mounted display (HMD), a laptop computer, a desktop computer, a gaming system, Internet of things devices, etc. Such electronic devices may communicate with the wristband system **100** (e.g., via a personal area network). The wristband system **100** may have sufficient processing capabilities (e.g., CPU, memory, bandwidth, battery power, etc.) to offload computing tasks from each of the multiple electronic devices to the wristband system **100**. Additionally or alternatively, each of the multiple electronic devices may have sufficient processing capabilities (e.g., CPU, memory, bandwidth, battery power, etc.) to offload computing tasks from the wristband system **100** to the electronic device(s).

[0023] The wristband system **100** includes a watch body **104** coupled to a watch band **112** via one or more coupling mechanisms **106**, **110**. The watch body **104** may include, among other components, one or more coupling mechanisms **106**, one or more camera devices **115** (e.g., camera device **115**A and **115**B), the display screen **102**, a button **108**, a connector **118**, a speaker **117**, and a microphone **121**. The watch band **112** may include, among other components, one or more coupling mechanisms **110**, a retaining mechanism **113**, one or more sensors **114**, the haptic device

116, and a connector 120. While FIGS. 1A and 1B illustrate the components of the wristband system 100 in example locations on the wristband system 100, the components may be located elsewhere on the wristband system 100, on a peripheral electronic device paired with the wristband system 100, or some combination thereof. Similarly, there may be more or fewer components on the wristband system 100 than what is shown in FIGS. 1A and 1B. For example, in some embodiments, the watch body 104 may include a port for connecting the wristband system 100 to a peripheral electronic device and/or to a power source. The port may enable charging of a battery of the wristband system 100 and/or communication between the wristband system 100 and a peripheral device. In another example, the watch body 104 may include an inertial measurement unit (IMU) that measures a change in position, an orientation, and/or an acceleration of the wristband system 100. The IMU may include one or more sensors, such as one or more accelerometers, one or more gyroscopes, one or more magnetometers, another suitable type of sensor that detects motion, a type of sensor used for error correction of the IMU, or some combination thereof.

[0024] The watch body 104 and the watch band 112 may have any size and/or shape that is configured to allow a user to wear the wristband system 100 on a body part (e.g., a wrist). The wristband system 100 may include the retaining mechanism 113 (e.g., a buckle) for securing the watch band 112 to the wrist of the user. The coupling mechanism 106 of the watch body 104 and the coupling mechanism 110 of the watch band 112 may attach the watch body 104 to the watch band 112. For example, the coupling mechanism 106 may couple with the coupling mechanism 110 by sticking to, attaching to, fastening to, affixing to, some other suitable means for coupling to, or some combination thereof.

[0025] The wristband system 100 may perform various functions associated with the user. The functions may be executed independently in the watch body 104, independently in the watch band 112, and/or in communication between the watch body 104 and the watch band 112. In some embodiments, a user may select a function by interacting with the button 108 (e.g., by pushing, turning, etc.). In some embodiments, a user may select a function by interacting with the display screen 102. For example, the display screen 102 is a touchscreen and the user may select a particular function by touching the display screen 102. The functions executed by the wristband system 100 may include, without limitation, displaying visual content to the user (e.g., displaying visual content on the display screen 102), presenting audio content to the user (e.g., presenting audio content via the speaker 117), sensing user input (e.g., sensing a touch of button 108, sensing biometric data with the one or more sensors 114, sensing neuromuscular signals with the one or more sensors 114, etc.), capturing audio content (e.g., capturing audio with microphone 121), capturing data describing a local area (e.g., with a front-facing camera device 115A and/or a rear-facing camera device 115B), communicating wirelessly (e.g., via cellular, near field, Wi-Fi, personal area network, etc.), communicating via wire (e.g., via the port), determining location (e.g., sensing position data with a sensor 114), determining a change in position (e.g., sensing change(s) in position with an IMU), determining an orientation and/or acceleration (e.g., sensing orientation and/or acceleration data with an IMU), providing haptic feedback (e.g., with the haptic device 116), etc.

[0026] The display screen 102 may display visual content to the user. The displayed visual content may be oriented to the eye gaze of the user such that the content is easily viewed by the user. Traditional displays on wristband systems may orient the visual content in a static manner such that when a user moves or rotates the wristband system, the content may remain in the same position relative to the wristband system causing difficulty for the user to view the content. The displayed content may be oriented (e.g., rotated, flipped, stretched, etc.) such that the displayed content remains in substantially the same orientation relative to the eye gaze of the user (e.g., the direction in which the user is looking). The displayed visual content may also be modified based on the eye gaze of the user. For example, in order to reduce the power consumption of the wristband system 100, the display screen 102 may dim the brightness of the displayed content, pause the displaying of video content, or power down the display screen 102 when it is determined that the user is not looking at the display screen 102. In some examples, one or more sensors 114 of the wristband system 100 may determine an orientation of the display screen 102 relative to an eye gaze direction of the user.

[0027] The position, orientation, and/or motion of eyes of the user may be measured in a variety of ways, including through the use of optical-based eye-tracking techniques, infraredbased eye-tracking techniques, etc. For example, the front-facing camera device 115A and/or rear-facing camera device 115B may capture data (e.g., visible light, infrared light, etc.) of the local area surrounding the wristband system 100 including the eyes of the user. The captured data may be processed by a controller (not shown) internal to the wristband system 100, a controller external to and in communication with the wristband system 100 (e.g., a controller of an HMD), or a combination thereof to determine the eye gaze direction of the user. The display screen 102 may receive the determined eye gaze direction and orient the displayed content based on the eye gaze direction of the user.

[0028] In some embodiments, the watch body 104 may be communicatively coupled to an HMD. The front-facing camera device 115A and/or the rear-facing camera device 115B may capture data describing the local area, such as one or more wide-angle images of the local area surrounding the front-facing camera device 115A and/or the rear-facing camera device 115B. The wide-angle images may include hemispherical images (e.g., at least hemispherical, substantially spherical, etc.), 180-degree images, 360-degree area images, panoramic images, ultra-wide area images, or a combination thereof. In some examples, the front-facing camera device 115A and/or the rear-facing camera device 115B may be configured to capture images having a range between 45 degrees and 360 degrees. The captured data may be communicated to the HMD and displayed to the user on a display screen of the HMD worn by the user. In some examples, the captured data may be displayed to the user in conjunction with an artificial reality application. In some embodiments, images captured by the front-facing camera device 115A and/or the rear-facing camera device 115B may be processed before being displayed on the HMD. For example, certain features and/or objects (e.g., people, faces, devices, backgrounds, etc.) of the captured data may be subtracted, added, and/or enhanced before displaying on the HMD.

[0029] In accordance with embodiments of the present disclosure, components of the front-facing camera device **115**A and the rear-facing camera device **115**B are assembled such that the front-facing camera device **115**A and the rear-facing camera device **115**B are capable of taking pictures capturing data describing the local area. At least one lens of the front-facing camera device **115**A and at least one lens of the rear-facing camera device **115**B can be automatically positioned at their target positions. A target position in a forward (or horizontal) posture of the front-facing camera device **115**A may correspond to a position at which the at least one lens of the front-facing camera device **115**A is focused at its preferred focal distance (e.g., distance in the order of several decimeters). A target position in a forward (or horizontal) posture of the rear-facing camera device **115**B may correspond to a position at which the at least one lens of the rear-facing camera device **115**B is focused at its hyperfocal distance in the local area (e.g., distance of approximately 1.7 meter).

[0030] FIG. **2** is a perspective view of another example wristband system **200**, in accordance with one or more embodiments. The wristband system **200** includes many of the same components described above with reference to FIGS. **1**A and **1**B, but a design or layout of the components may be modified to integrate with a different form factor. For example, the wristband system **200** includes a watch body **204** of a different shape and a watch band **212** with a different layout of components (e.g., a different location for a sensor **214** and a haptic device **216** on the watch band **212**). FIG. **2** illustrates a coupling mechanism **206**, a camera device **215**A, a display screen **202**, a button **108**, a speaker **117**, a microphone **221**, and a release mechanism **220** associated with the watch body **204**. FIG. **2** further illustrates a coupling mechanism **210**, a retaining mechanism **213**, the sensor **114**, the haptic device **116**, and a release mechanism **220** associated with the watch band **212**. In some embodiments, another camera device may be located on an underside of the watch body **204** and is not shown in FIG. **2**. In some embodiments, one or more additional sensors **214** (not shown) may be included on the watch body **204** or the watch band **212**. As the wristband system **100** and the wristband system **200** are of a small form factor to be easily and comfortably worn on a wrist of a user, the corresponding camera devices **115**, **215** and various other components of the wristband system **100** described above are designed to be of an even smaller form factor and are positioned close to each other.

[0031] In accordance with embodiments of the present disclosure, components of the camera device **215** are assembled such that when the camera device **215** is at the forward (horizontal) posture to take a picture capturing data describing the local area, a lens of the camera device **215** is automatically positioned (e.g., with no amount of activation power) at a target position. The target position in the forward (or horizontal) posture of the camera device **215** corresponds to a position at which the lens of the camera device **215** is focused at a hyperfocal distance in the local area.

[0032] FIG. **3** is a cross section of an example structure of a camera device **300**, in accordance with one or more embodiments. The camera device **300** may be an embodiment of the camera devices **115**, **215**. The camera device **300** may capture data (e.g., one or more images) of a local area surrounding the camera device **300**. The camera device **300** shown in FIG. **3** includes a lens barrel **305**, a lens assembly **310**, a shield case **315**, one or more top restoring auto focusing springs **320**A, one or more bottom restoring auto focusing springs **320**B, one or more optical image stabilization (OIS) suspension wires **323**, a carrier **325**, one or more actuators **330**, one or more auto focusing coils **335**, a magnetic assembly **340**, an infrared cut-off filter (IRCF) **345**, an IRCF holder **350**, an image sensor **355**, and a printed circuit board (PCB) **360**. The one or more top restoring auto focusing springs **320**A together with the one or more bottom restoring auto focusing springs **320**B are collectively referred to herein as "one or more restoring auto focusing springs **320**." In alternative configurations, different and/or additional components may be included in the camera device **300**. For example, in some embodiments, the camera device **300** may include a controller (not shown in FIG. **3**). In alternative embodiments, the controller may be part of some other system (e.g., a wristband system the camera device **300** is coupled to).

[0033] The camera device **300** is configured to have both a focusing assembly and a stabilization assembly. The focusing assembly is configured to cause a translation of the lens barrel **305** in a direction parallel to an optical axis **302** of the lens assembly **310**. The focusing assembly provides an auto focus functionality for the camera device **300**. The focusing assembly includes the one or more restoring auto focusing springs **320**, the one or more OIS suspension wires **323**, and a plurality of magnets included in the magnetic assembly **340**. The stabilization assembly is configured to cause a translation of the lens barrel **305** (and, in some embodiments, the magnetic assembly **340** and the lens barrel **305**) in one or more directions perpendicular to the optical axis **302**. The stabilization assembly provides an OIS functionality for the camera device **300** by stabilizing an image projected through the lens barrel **305** to the image sensor **355**. The stabilization assembly includes the lens barrel **305**, the shield case **315**, and the magnetic assembly **340**.

[0034] The lens barrel **305** is a mechanical structure or housing for carrying one or more lenses of the lens assembly **310**. The lens barrel **305** is a hollow structure with an opening on opposite ends of the lens barrel **305**. The openings may provide a path for light (e.g., visible light, infrared light, etc.) to transmit between a local area and the image sensor **355**. Inside the lens barrel **305**, one or more lenses of the lens assembly **310** are positioned between the two openings. The lens barrel **305** may be manufactured from a wide variety of materials ranging from plastic to metals. In some embodiments, one or more exterior surfaces of the lens barrel **305** are coated with a polymer (e.g., a sub-micron thick polymer). The lens barrel **305** may be rotationally symmetric about the optical axis **302** of the one or more lenses of the lens assembly **310**.

[0035] The lens barrel **305** may be coupled to the magnetic assembly **340** by the one or more restoring auto focusing springs **320**. For example, the one or more restoring auto focusing springs **320** are coupled to the lens barrel **305** and the magnetic assembly **340**. In some embodiments, the magnetic assembly **340** is coupled to the shield case **315**. In another example (not illustrated), the one or more restoring auto focusing springs **320** are coupled to the shield case **315** directly and the lens barrel **305**. The one or more restoring auto focusing springs **320** are configured to control a positioning of the lens barrel **305** along the optical axis **302**. For example, the plurality of restoring auto focusing springs **320** may control the positioning of the lens barrel **305** such that when current is not supplied to the one or more auto focusing coils **335** the lens barrel **305** is in a neutral position. In some embodiments, the one or more restoring auto focusing springs **320** may be shape-memory alloy (SMA) wires. The neutral position of the lens barrel **305** is a positioning of the lens barrel **305** when the camera device **300** is not undergoing focusing (via the focusing assembly) nor stabilizing (via the stabilization assembly). The one or more restoring auto focusing springs **320** can ensure the lens barrel **305** does not fall out or come into contact with the image sensor **355**. In some embodiments, the one or more restoring auto focusing springs **320** are conductors and may be coupled to the one or more auto focusing coils **335**. In these embodiments, the plurality of restoring auto focusing springs **320** may be used to provide current to the one or more auto focusing coils **335**. The one or more restoring auto focusing springs **320** may be coupled to the one or more OIS suspension wires **323** that provide current to the one or more restoring auto focusing springs **320** so that the one or more restoring auto focusing springs **320** can facilitate auto focusing of the lens assembly **310**. The one or more OIS suspension wires **323** may be positioned symmetrically about the optical axis **302**.

[0036] The shield case **315** may enclose some of the components of the camera device **300** as illustrated in FIG. **3**. In other embodiments (not shown), the shield case **315** may encloses all of the components of the camera device **300**. As illustrated in FIG. 3A, the shield case **315** partially encloses the lens barrel **305**. The shield case **315** provides a space in which the lens barrel **305** can translate along the optical axis **302** and/or translate in a direction perpendicular to the optical axis **302**. In some embodiments, the shield case **315** provides a space in which the lens barrel **305** rotates relative to one or more axes that are perpendicular to the optical axis **302**. In some embodiments, the shield case **315** may be rectangular-shaped as illustrated. In alternative embodiments, the shield case **315** may be circular, square, hexagonal, or any other shape. In embodiments where the camera device **300** is part of another electronic device (e.g., a smartwatch), the shield case **315** may couple to (e.g., be mounted on, affixed to, attached to, etc.) another component of the electronic device, such as a frame of the electronic device. For example, the shield case **315** may be mounted on a watch body (e.g., the watch body **104**) of the smartwatch. The shield case **315** may be manufactured from a wide variety of materials ranging from plastic to metals. In some examples, the shield case **315** is manufactured from a same material as the material of the electronic device the shield case **315** is coupled to such that the shield case **315** is not distinguishable from the rest of the electronic device. In some embodiments, the shield case **315** is manufactured from a material that provides a magnetic shield to surrounding components of the electronic device. In these embodiments, the shield case **315** may be a shield can. In some embodiments, one or more interior surfaces of the shield case **315** are coated with a polymer similar to the lens barrel **305** described above.

[0037] The carrier **325** is directly coupled to the lens barrel **305**. For example, the carrier **325** comprises a first side in direct contact with a surface of the lens barrel **305** and a second side opposite the first side. In some embodiments, the carrier **325** is coupled to the lens barrel **305** by an adhesive. The one or more auto focusing coils **335** may be affixed to the second side of the carrier **325**. The carrier **325** has a curvature that conforms to the curvature of the lens barrel **305**. In some embodiments, more than one carrier **325** may be directly coupled to the lens barrel **305**. In these embodiments, the number of carriers **325** may match a number of auto focusing coils **335** and the carriers **325** may be positioned at unique locations around the lens barrel **305** such that a carrier **325** is positioned between a corresponding auto focusing coil **335** and the lens barrel **305**. In some embodiments, the restoring auto focusing springs **320** may be coupled to the carrier **325**.

[0038] The one or more auto focusing coils **335** are configured to conduct electricity by being supplied with a current. The one or more auto focusing coils **335** may be positioned symmetrically about the optical axis **302**. For example, the one or more auto focusing coils **335** may consist of two individual coils positioned symmetrically about the optical axis **302**, as illustrated in FIG. **3**. The one or more auto focusing coils **335** are coupled to the one or more actuators **330** and provide the current to the one or more actuators **330**.

[0039] The one or more actuators **330** are configured to provide auto focusing to the one or more lenses of the lens assembly **310**. The one or more actuators **330** consume an auto focusing actuation power while providing auto focusing to the one or more lenses of the lens assembly **310**. To reduce (and in some cases minimize) a level of the auto focusing actuation power consumption (e.g., to achieve the zero level auto focusing actuation power), relative positions of the lens assembly, the carrier **325** and the one or more actuators **330** along the optical axis **302** are controlled during assembling of the camera device **300**. During assembling of the camera device **300**, the relative positions of the lens assembly **310**, the carrier **325** and the one or more actuators **330** along the optical axis **302** may be controlled by using a lens spacer (not shown in FIG. **3**). The lens spacer may be configured to hold the one or more lenses of the lens assembly **310** in place when the lens assembly **310** and the lens barrel **305** are ready to be bonded to the carrier **325** during assembling of the camera device **300**.

[0040] A relative position of the lens assembly **310** along the optical axis **302** may be determined during assembling of the camera device **300** by following variables. The first variable may be related to an effective back focal length (BFL) of the lens assembly **310**. The effective BFL of the lens assembly **310** may depend on a distance from each lens in the lens assembly **310** to the image sensor **355**. The effective BFL of the lens assembly **310** can be defined by design of each individual lens in the lens assembly **310**. The second variable may be related to a displacement of the carrier **325** under gravity at the upright posture of the camera device **300**, i.e., the posture of the camera device **300** as illustrated in FIG. **3**. The carrier **325** moves downward under gravity during assembling of the camera device **300** with the actuator **330** being at an upward (or vertical) posture. The displacement of the carrier **325** under gravity may be determined by a weight of the carrier **325** and a stiffness of the one or more restoring auto focusing springs **320**. The third variable may be related to a springback displacement of the lens assembly **310** and the carrier **325** at the most typical use posture of the camera device **300** (i.e., the forward or horizontal posture as shown in FIG. 4D) when the one or more lenses of the lens assembly **310** are in the forward (horizontal) posture. In such case, the lens assembly **310** moves away from the image sensor **355** due to an actuator spring force. The springback displacement may be determined by a weight of the actuator **330**, and a spring constant of the one or more restoring auto focusing springs **320**. The fourth variable may be related to a thermal shift of the one or more lenses of the lens assembly **310** at an expected operating temperature of the camera device **300**. The expected operating temperature of the camera device **300** is typically elevated when the camera device **300** operates inside an electronic wearable device (e.g., a smartwatch). The fifth variable may be related to a modified (e.g., longer) focal distance of the one or more lenses of the lens assembly **310** due to a change of shape(s) of the one or more lenses caused by the elevated operating temperature of the camera device **300**.

[0041] There are two primary causes affecting actuation power consumption in order to bring the lens assembly **310** at a hyperfocal position within the camera device **300** when the camera device **300** is at its forward (horizontal) posture: (i) a movement of the camera device **300** from an upward (vertical) posture to a forward (horizontal) posture; and (ii) a thermal shift of the one or more lenses of the lens assembly **310** at an expected operating temperature of the camera device **300** within an electronic wearable device. The upward (vertical) posture of the camera device **300** corresponds to a posture of the camera device **300** where the optical axis **302** is substantially parallel to gravity (e.g., parallel to y axis in FIG. **3**). The forward (horizontal) posture of the camera device **300** corresponds to a posture of the camera device **300** with a rotated optical axis substantially perpendicular to the optical axis **302** (i.e., parallel to x axis in FIG. **3**). The hyperfocal position of the lens assembly **310** corresponds to a position of the lens assembly **310** within the camera device **300** at which the lens assembly **310** is focused at a hyperfocal distance within a local area (e.g., 1.7 meter) when the camera device **300** is at the forward posture.

[0042] Embodiments of the present disclosure relate to assembling the camera device **300** in order to achieve a specific distance **304** between the lens assembly **310** and the image sensor **355** along the optical axis **302**, when the camera device **300** is at the upward posture. By setting the distance **304** during assembling of the camera device **300**, the lens assembly **310** is at the hyperfocal position while consuming an auto focusing actuation power below a defined threshold level when the camera device **300** is at the forward posture. In some embodiments, when the camera device **300** is at the forward posture, the lens assembly **310** is automatically at the hyperfocal position without consuming any auto focusing actuation power. The distance **304** between the lens assembly **310** and the image sensor **355** can be defined as a distance along the optical axis **302** between a surface of the image sensor **355** oriented toward the lens assembly **310** and a surface of a lens in the lens assembly **310** nearest to the surface of the image sensor **355**. The specific value of the distance **304** can be determined during assembling of the camera device **300** by considering: (i) a posture difference of the actuator **330** with and without the lens assembly **310**; and (ii) a thermal shift the one or more lenses of the lens assembly **310** assuming a typical system interior temperature near the camera device **300** in the range of approximately, e.g., 40° C. to 50° C.

[0043] The magnetic assembly **340** includes a magnet holder for holding a plurality of magnets. The magnet holder may provide a rigid structure to support the plurality of magnets. In some embodiments, the magnet holder may enclose all sides of the magnets. In other embodiments, the magnet holder may enclose all sides of the magnets except for a side facing the one or more auto focusing coils **335**. In some embodiments, one or more exterior surfaces of the magnetic assembly **340** are coated with a polymer similar to the lens barrel **305** described above.

[0044] The plurality of magnets of the magnetic assembly **340** generate magnetic fields that can be used for translating the lens barrel **305** along the optical axis **302** (e.g., focusing the camera device **300**) and/or perpendicular to the optical axis **302** (e.g., providing OIS for the camera device **300**). The magnetic fields used for focusing the camera device **300** can be applied in the forward (horizontal) posture of the camera device **300**, e.g., to focus the lens assembly **310** at the hyperfocal distance without consuming any auto focusing actuation power.

[0045] Each magnet of the plurality of magnets may be a different size or the same size. In some embodiments, each magnet is curved about the optical axis **302** conforming to the curvature of the one or more auto focusing coils **335** and the lens barrel **305**. In some embodiments, each magnet is straight. For example, at least two opposing sides of each magnet are parallel to a plane that is parallel to the optical axis **302**. Each magnet of the plurality of magnets may include rectangular cross sections with one axis of a cross section being parallel to the optical axis **302** and another axis of the cross section being perpendicular to the optical axis **302**. In some embodiments, each magnet may include other types of cross sectional shapes such as square or any other shape that includes at least one straight-edged side that faces the one or more auto focusing coils **335**. Each magnet is a permanent magnet that is radially magnetized with respect to the optical axis **302**. The magnets may be positioned symmetrically about the optical axis **302**.

[0046] The image sensor **355** captures data (e.g., one or more images) describing a local area. The image sensor **355** may include one or more individual sensors, e.g., a photodetector, a CMOS sensor, a CCD sensor, some other device for detecting light, or some combination thereof. The individual sensors may be in an array. For a camera device **300** integrated into an electronic device, the local area is an area surrounding the electronic device. The image sensor **355** captures light from the local area. The image sensor **355** may capture visible light and/or infrared light from the local area surrounding the electronic device. The visible and/or infrared light is focused from the local area to the image sensor **355** via the lens barrel **305**. The image sensor **355** may include various filters, such as the IRCF **345**. The IRCF **345** is a filter configured to block the infrared light from the local area and propagate the visible light to the image sensor **355**. The IRCF **345** may be placed within the IRCF holder **350**.

[0047] The PCB **360** is positioned below the image sensor **355** along the optical axis **302**. The PCB **360** is a stationary component of the camera device **300** and provides mechanical support (e.g., by acting as a base) for the camera device **300**. The PCB **360** may provide electrical connections for one or more components of the camera device **300**. In some embodiments, a controller may be located on the PCB **360** and the PCB **360** electrically connects the controller to various components (e.g., the one or more auto focusing coils **335**) of the camera device **300**. In other embodiments (not shown), the controller may be located in a different location within the camera device **300** or external to the camera device **300**.

[0048] FIG. **4**A is a cross section **400** of an example shield case **405** of a camera device during assembling of the camera device, in accordance with one or more embodiments. The shield case **405** may be an embodiment of the shield case **315** of the camera device **300** in FIG. **3**. The shield case **405** in FIG. **4**A is illustrated for the step of assembling the camera device prior to positioning of a lens barrel and a lens assembly within the camera device. As shown in FIG. **4**A, an actuator **410** is in the upward (vertical) posture and ready for module assembly, i.e., assembling of a lens barrel (i.e., an embodiment of the lens barrel **310**) and a lens assembly (i.e., an embodiment of the lens assembly **305**). Note that a carrier **415** may be at a lower relative position along an optical axis **402** due to gravity. A displacement of the carrier **415** due to gravity may be determined by one or more features (e.g., a stiffness) of an actuator spring **420**. The actuator **410**, the carrier **415** and the actuator spring **420** may be embodiments of the actuator **330**, the carrier **325**, and the restoring auto focusing spring **320**, respectively.

[0049] FIG. **4**B is an example cross section **425** of the camera device with a lens assembly **430** during assembling of the camera device, in accordance with one or more embodiments. The lens assembly **430** may be an embodiment of the lens assembly **305**. A specific height (e.g., an offset **432**) of the lens assembly **430** along the optical axis **402** may be achieved during assembling of the camera device by using a support assembly. The support assembly may be configured as an assembly that supports the lens assembly **430**, e.g., to hold one or more lenses of the lens assembly **430** in position for, e.g., glue bonding during assembling of the camera device. In one or more embodiments, the support assembly includes a lens support **435** and an actuator support **437** placed on top of a bench **440**. Alternatively, the support assembly may include one or more additional or different components not shown in FIG. **4**B. A cross section of the lens support **435** (not shown in FIG. **4**B) may be cylindrically shaped (e.g., ring shaped), and a cross section of the actuator support **437** (not shown in FIG. **4**B) may be rectangularly shaped.

[0050] The offset **432** may be defined as a distance between an inner surface of the actuator support **437** coupled to the shield case **405** and a surface of a lens in the lens assembly **430** closest to the inner surface of the actuator support **437**. The amount of offset **432** may be controlled during assembling of the camera device based on specific heights of the lens support **435** and the actuator support **437** along the optical axis **402** The achieved offset **432** of the lens assembly **430** would reduce (and in some cases minimize) an auto-focusing actuation power for the most typical use case of the camera device, i.e., for forward (horizontal) posture of the camera device. In some embodiments, the offset **432** of the lens assembly **430** along the optical axis **402** is determined so that no auto-focusing actuation power is applied to focus the lens assembly **430** at the hyperfocal distance when the camera device is at the forward posture. In other words, by determining one or more specific heights of one or more components of the support assembly (e.g., the lens support **435** and the actuator support **437**) along the optical axis **402** and setting the offset **432**, the lens assembly **430** may be automatically in its hyperfocal position without applying any auto-focusing actuation power. The auto-focusing actuation power can be defined as a power consumed by the actuator **410** and the actuator spring **420** for moving the one or more lenses of the lens assembly **430** in order to bring the lens assembly **430** at the hyperfocal position within the camera device when the lens assembly **430** is in the horizontal (forward) posture having a rotated optical axis perpendicular to the optical axis **402** (i.e., perpendicular to gravity).

[0051] The offset **432** of the lens assembly **430** relative to the support assembly introduced during assembling of the camera device may provide that the lens assembly **430** would be at the hyperfocal position within the camera device while consuming an auto-focusing actuation power below a defined threshold level when the camera device and the lens assembly **430** are moved from the vertical (upward) posture to the horizontal (forward) posture. In some embodiments, the introduced offset **432** ensures that the lens assembly **430** is already at the hyperfocal position within the camera device without any consumption of the auto-focusing actuation power when the camera device is moved from the vertical posture to the horizontal posture. As discussed above, the introduced offset **432** may be determined during assembling of the camera device based on the following variables: (i) an effective BFL of the lens assembly **430**; (ii) a displacement of the carrier **415** under gravity at the upright posture of the camera device; and (iii) a springback displacement of the lens assembly **430** and the carrier **415** at the most typical use posture (i.e., horizontal or forward posture) of the camera device; and (iv) a thermal shift of the one or more lenses of the lens assembly **430** at an expected operating temperature of the camera device within an electronic wearable device.

[0052] FIG. **4**C is a cross section **445** of the camera device having the lens assembly **430** assembled in the upward posture and aligned with an image sensor **450** during assembling of the camera device, in accordance with one or more embodiments. The active alignment may be performed during this step of assembling the camera device to align an actuator assembly (i.e., the actuator **410** with the actuator spring **420**) and the lens assembly **430** with a PCB sensor assembly (i.e., the image sensor **450** positioned on top of a PCB **455**) and an IRCF **457** placed in an IRCF holder **460**, e.g., to align various assemblies relative to the optical axis **402**. The lens assembly **430** is positioned perpendicular to a plane of the image sensor **450**. Additionally, the optical axis **402** of the lens assembly **430** is positioned at a geometrical center of the image sensor **450**. The image sensor 450 and the PCB **455** may be embodiments of the image sensor **355** and the PCB **360**, respectively. Additionally, the IRCF **457** and the IRCF holder **460** may be embodiments of the IRCF **345** and the IRCF holder **350**, respectively.

[0053] FIG. **4**D is a cross section **465** of the camera device with the lens assembly **430** in a forward (horizontal) posture when the camera device is fully assembled, in accordance with one or more embodiments. The cross section **465** of the camera device corresponds to the most typical use case of the camera device at which the one or more lenses of the lens assembly **430** are also in the horizontal posture. Note that, in the forward (horizontal) posture of the camera device and the lens assembly **430**, the lens assembly **430** moves away from the image sensor **450** (along a rotated optical axis **470**) by the actuator spring **420**. The rotated optical axis **470** corresponds to an optical axis perpendicular to the optical axis **402** in FIGS. **4**A-**4**C (i.e., orthogonal to gravity). The distance **304** in FIG. **3** set during assembling of the camera device may be determined such that, when the camera device is oriented with the rotated optical axis **470** along a defined direction (e.g., along y axis in FIG. **4**D), the lens assembly **430** is positioned at a neutral position **475** relative to the image sensor **450** with a level of auto focusing activation power below a defined threshold level (e.g., the level of auto focusing activation power is zero-level). In some embodiments, the rotated optical axis **470** is orthogonal to gravity (e.g., gravity being oriented along x axis). The neutral position **475** may correspond to a target position of the lens assembly **430** at which the lens assembly **430** is focused at the hyperfocal distance within a local area surrounding the camera device. For example, the hyperfocal distance may be defined as a distance of approximately 1.7 meter, which corresponds to the most typical use case of the camera device when taking images of the local area. In some embodiments, the target position of the lens assembly **430** corresponds to some other focal position of the lens assembly **430** different than the hyperfocal position. Thus, in some embodiments, by setting the specific distance **304** during assembling of the camera device, no auto-focusing actuation power is consumed by the actuator **410** and the actuator spring **420** when the camera device is moved to the forward (horizonal) posture as the lens assembly **430** has already been positioned at the neutral position **475** (i.e., target position) relative to the image sensor **450** thus achieving a focus of the lens assembly **430** at the hyperfocal distance.

[0054] As aforementioned, positioning of a lens assembly during assembling of a camera device (e.g., the camera device **300**) may also account for thermal effects of operation of the camera device, such that the target position of the lens assembly is calibrated to occur over a specific temperature range. FIG. **5** is a graph **500** illustrating a thermal shift of a lens assembly (e.g., the lens assembly **310** or the lens assembly **430**) in a camera device (e.g., the camera device **300**) as a function of an operating temperature of the camera device, in accordance with one or more embodiments. Typically, performance of the lens assembly in the camera device are tested at an ambient (room) temperature, e.g., at a temperature in a defined vicinity of 23° C. However, the camera device can commonly operate at higher temperatures inside an electronic wearable device (e.g., smartwatch), which leads to a thermal shift of the lens assembly. For example, it can be expected that the camera device operates inside the electronic wearable device at temperatures in a defined vicinity of 45° C. (e.g., 45° C. ± 5° C.). Based on the graph **500**, it is therefore expected that the lens assembly moves approximately 20 μm away from an image sensor within the camera device during the typical use case of the camera device for the lens assembly to keep focus onto the image sensor. Therefore, during assembling the camera device, the expected thermal shift (e.g., of approximately 20 μm) may be considered when determining a distance (e.g., the distance **304**) between the lens assembly and the image sensor. The distance may be increased by the expected thermal shift of the lens assembly relative to the image sensor (e.g., increased by approximately 20 μm).

[0055] Additionally, a focal distance of the lens assembly may be modified (e.g., become longer) as shape(s) of one or more lenses in the lens assembly may change due to higher operating temperatures of the camera device. The modified focal distance of the lens assembly at the higher operating temperatures may be considered when determining the distance between the lens assembly and the image sensor during assembling of the camera device. Thus, the distance may be additionally adjusted (e.g., increased) by a specific amount to counter the effect of a modified (e.g., longer) focal distance of the lens assembly **310** at the higher operating temperatures.

[0056] FIG. **6** is a flowchart illustrating a process **600** of assembling a camera device to have a specific distance between a lens assembly and an image sensor that reduces (and in some cases minimizes) an auto-focusing actuation power, in accordance with one or more embodiments. Steps of the process **600** of assembling the camera device may be performed by one or more components of a manufacturing system configured for assembling of the camera device. Embodiments may include different and/or additional steps of the process **600**, or perform the steps of the process **600** in different orders.

[0057] At **605**, during assembling of the camera device, the lens assembly is assembled within the camera device to have an optical axis parallel to gravity. In one embodiment, the lens assembly includes a single optical lens. In another embodiments, the lens assembly includes a plurality of optical lenses in an optical series.

[0058] At **610**, during assembling of the camera device, an offset of the lens assembly along the optical axis relative to a support assembly is determined such that, when the camera device is oriented with a rotated optical axis positioned along a defined direction (e.g., orthogonal to gravity), the lens assembly is positioned at a neutral position relative to the image sensor without activation applied to the lens assembly. The neutral position may correspond to a target position where the lens assembly is focused at a hyperfocal distance, i.e., the neutral position may be a target distance between the lens assembly and the image sensor. During assembling of the camera device, the support assembly coupled to the lens assembly and the carrier may control the offset of the lens assembly along the optical axis. The support assembly may comprise a lens support and an actuator support.

[0059] The offset may be determined based at least in part on an effective BFL of the lens assembly. Alternatively or additionally, the offset may be determined based at least in part on a displacement of a carrier of the lens assembly under gravity at an upward posture of the camera device, and the displacement depends on a weight of the carrier and a stiffness of a spring of an actuator coupled to the lens assembly. Alternatively or additionally, the offset may be determined based at least in part on a displacement between the lens assembly and the carrier at a forward posture of the camera device, and the displacement depends on a weight of the actuator and a spring constant of the actuator. Alternatively or additionally, the offset may be determined based in part on an expected thermal shift of the lens assembly along the rotated optical axis at an operating temperature of the camera device within a defined temperature range.

[0060] At **615**, during assembling of the camera device, the lens assembly is positioned within the camera device to be in an optical series with an image sensor of the camera device and to have the determined offset along the optical axis.

Additional Configuration Information

[0061] The foregoing description of the embodiments has been presented for illustration; it is not intended to be exhaustive or to limit the patent rights to the precise forms disclosed. Persons skilled in the relevant art can appreciate that many modifications and variations are possible considering the above disclosure.

[0062] Some portions of this description describe the embodiments in terms of algorithms and symbolic representations of operations on information. These algorithmic descriptions and representations are commonly used by those skilled in the data processing arts to convey the substance of their work effectively to others skilled in the art. These operations, while described functionally, computationally, or logically, are understood to be implemented by computer programs or equivalent electrical circuits, microcode, or the like. Furthermore, it has also proven convenient at times, to refer to these arrangements of operations as modules, without loss of generality. The described operations and their associated modules may be embodied in software, firmware, hardware, or any combinations thereof.

[0063] Any of the steps, operations, or processes described herein may be performed or implemented with one or more hardware or software modules, alone or in combination with other devices. In one embodiment, a software module is implemented with a computer program product comprising a computer-readable medium containing computer program code, which can be executed by a computer processor for performing any or all the steps, operations, or processes described.

[0064] Embodiments may also relate to an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, and/or it may comprise a general-purpose computing device selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a non-transitory, tangible computer readable storage medium, or any type of media suitable for storing electronic instructions, which may be coupled to a computer system bus. Furthermore, any computing systems referred to in the specification may include a single processor or may be architectures employing multiple processor designs for increased computing capability.

[0065] Embodiments may also relate to a product that is produced by a computing process described herein. Such a product may comprise information resulting from a computing process, where the information is stored on a non-transitory, tangible computer readable storage medium and may include any embodiment of a computer program product or other data combination described herein.

[0066] Finally, the language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the patent rights. It is therefore intended that the scope of the patent rights be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments is intended to be illustrative, but not limiting, of the scope of the patent rights, which is set forth in the following claims.

What is claimed is:

1. A camera device comprising:

an image sensor; and

a lens assembly in an optical series with the image sensor, wherein during assembling of the camera device,

the lens assembly is assembled within the camera device to have an optical axis parallel to gravity and positioned to have an offset along the optical axis relative to a support assembly, and

the offset is determined such that, when the camera device is oriented with a rotated optical axis orthogonal to gravity, the lens assembly is positioned at a neutral position relative to the image sensor without activation applied to the lens assembly.

2. The camera device of claim **1**, wherein the neutral position corresponds to a target position where the lens assembly is focused at a hyperfocal distance.

3. The camera device of claim **1**, wherein the neutral position corresponds to a target distance between the lens assembly and the image sensor.

4. The camera device of claim **1**, wherein the offset is determined during assembling of the camera device based in part on an expected thermal shift of the lens assembly along the rotated optical axis at an operating temperature of the camera device within a defined temperature range.

5. The camera device of claim **1**, wherein, during assembling of the camera device, the support assembly coupled to the lens assembly controls the offset along the optical axis.

6. The camera device of claim **1**, wherein the offset is determined during assembling of the camera device based at least in part on an effective back focal length of the lens assembly.

7. The camera device of claim **1**, wherein the support assembly comprises a lens support and an actuator support.

8. The camera device of claim **1**, wherein:

the offset is determined during assembling of the camera device based at least in part on a displacement of a carrier of the lens assembly under gravity at an upward posture of the camera device; and

the displacement depends on a weight of the carrier and a stiffness of a spring of an actuator coupled to the lens assembly.

9. The camera device of claim **1**, wherein:

the offset is determined during assembling of the camera device based at least in part on a displacement between the lens assembly and a carrier of the lens assembly at a forward posture of the camera device; and

the displacement depends on a weight of an actuator coupled to the lens assembly and a spring constant of the actuator.

10. The camera device of claim **1**, wherein the camera device is part of a smartwatch.

11. A method of assembling a camera device, the method comprising:

assembling a lens assembly within the camera device to have an optical axis parallel to gravity;

determining an offset of the lens assembly along the optical axis relative to a support assembly such that, when the camera device is oriented with a rotated optical axis orthogonal to gravity, the lens assembly is positioned at a neutral position relative to the image sensor without activation applied to the lens assembly; and

positioning the lens assembly within the camera device to be in an optical series with an image sensor of the camera device and to have the determined offset along the optical axis.

12. The method of claim **11**, wherein the neutral position corresponds to a target position where the lens assembly is focused at a hyperfocal distance.

13. The method of claim **11**, wherein the neutral position corresponds to a target distance between the lens assembly and the image sensor.

14. The method of claim **11**, further comprising:

determining the offset during assembling of the camera device based in part on an expected thermal shift of the lens assembly along the rotated optical axis at an operating temperature of the camera device within a defined temperature range.

15. The method of claim **11**, further comprising:

controlling, during assembling of the camera device, the offset along the optical axis using the support assembly coupled to the lens assembly.

16. The method of claim **11**, further comprising:

determining the offset during assembling of the camera device based at least in part on an effective back focal length of the lens assembly.

17. The method of claim **11**, further comprising:

determining the offset during assembling of the camera device based at least in part on a displacement of a carrier of the lens assembly under gravity at an upward posture of the camera device, the displacement depending on a weight of the carrier and a stiffness of a spring of an actuator coupled to the lens assembly.

18. The method of claim **11**, further comprising:

determining the offset during assembling of the camera device based at least in part on a displacement between the lens assembly and a carrier of the lens assembly at a forward posture of the camera device, the displacement depending on a weight of an actuator coupled to the lens assembly and a spring constant of the actuator.

19. A wristband system comprising:

a camera device including an image sensor and a lens assembly in an optical series with the image sensor, wherein during assembling of the camera device,

the lens assembly is assembled within the camera device to have an optical axis parallel to gravity and positioned to have an offset along the optical axis relative to a support assembly, and

the offset is determined such that, when the camera device is oriented with a rotated optical axis orthogonal to gravity, the lens assembly is positioned at a neutral position relative to the image sensor without activation applied to the lens assembly.

20. The wristband system of claim **19**, wherein the offset is determined during assembling of the camera device based at least in part on an expected thermal shift of the lens assembly along the rotated optical axis at an operating temperature of the camera device within a defined temperature range.

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