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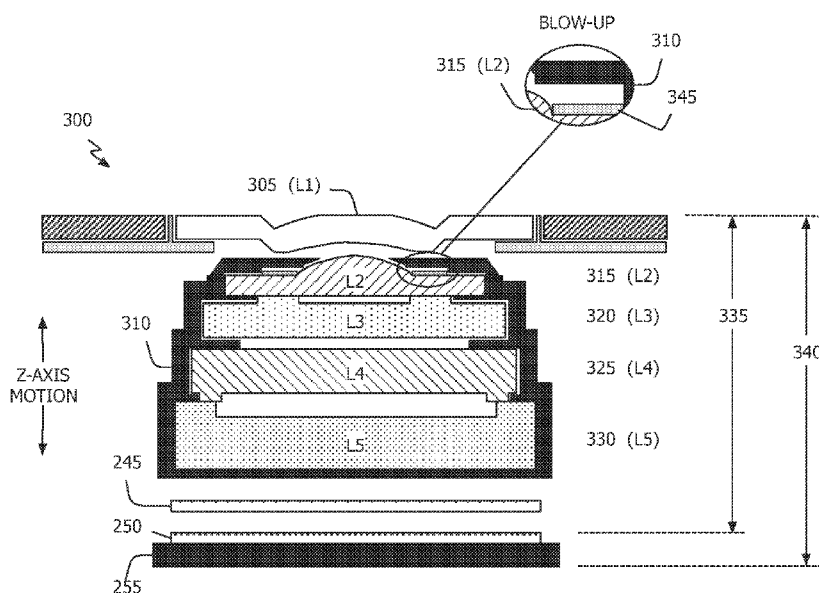
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(54) **Title:** COMPACT OPTIC DESIGN FOR DIGITAL IMAGE CAPTURE DEVICES**FIG. 3**

(57) **Abstract:** A compact optic design is disclosed in which an image capture device's cover glass (or other transparent material) is imbued with optic power and affixed directly to the device's housing. A lens barrel, in which one or more additional lens elements are mounted, may be aligned with the optical lens formed by the cover glass and an image sensor to provide a complete camera module.

Compact Optic Design for Digital Image Capture Devices

Background

[0001] This disclosure relates generally to the field of optics. More particularly, this disclosure relates to a novel and highly beneficial techniques for fashioning an optical stack or camera module.

[0002] Camera modules for mobile telephone and other small form-factor electronic devices are one of the key components in controlling device thickness. Referring to FIG. 1, a prior art mobile telephone handset's rear-facing camera module **100** is typically mounted between the unit's back-plate **105** (including surface-flush cover glass **110**) and front cover **115**; using the maximum space within the device's housing, thereby controlling the device's overall thickness. Camera module **100** also includes front or first lens **120** and, typically, one or more additional lenses (not shown) housed within lens barrel **125**. Lens barrel **125**, in turn, is moved toward and away from cover glass **110** by actuator mechanism **130** so as to focus incoming light through infrared cutoff filter (IRCF) **135** and onto the surface of sensor array **140**. In practice, cover glass **110** is spaced at a sufficient distance from lens barrel **125** (*i.e.*, the top of lens **120**) such that when barrel **125** travels from its infinity position (furthest from glass plate

110) to its macro position (closest to glass plate **110**) there is no contact between the two surfaces.

[0003] Thickness **145** of camera module **100** is controlled by several factors, a primary consideration among which is the module's overall optical track **150**, defined as the distance from the camera's optical sensor surface **140** to the outer surface or top of its first lens element **120**. This latter distance is fixed by the limits of Maxwell's equations (for a given sensor and pixel size). It would be beneficial to provide a means to reduce the overall camera height or thickness **145** so as to permit the design of thinner products, resulting in lower mass and improved product aesthetics.

Summary

[0004] In one embodiment the inventive concept provides a compact optic design for use in electronic devices. The disclosed design permits the design and manufacture of digital image capture devices that are thinner and/or lighter than comparable prior art devices. One particular embodiment provides an image capture system that includes a first lens member fixed to and flush with an external surface of an electronic device (*e.g.*, a mobile telephone, a personal music player, a personal digital assistant, and various forms of computer systems including desktop, laptop and tablet computer systems). A lens assembly that

includes or more additional lens elements (each of which are in fixed relationship to one another) is axially aligned with, and in a movable relationship to, the first lens element. In one embodiment, the lens assembly may be a lens or lens barrel. A light sensor may then be positioned so that light passing through the axially aligned lenses (*i.e.*, the first lens and the one or more additional lens elements mounted in the lens assembly) is focused on light collecting sites of the sensor. Illustrative light sensors include, but are not limited to, charge-coupled device (**3D**) and complementary metal–oxide–semiconductor (CMOS) active pixel sensors.

[0005] In another embodiment, an infrared cutoff filter (IRCF) element may be positioned between the bottom of the lens assembly (*i.e.*, the side away from the first lens element) and the light sensor. In still another embodiment, an aperture stop may be fixed to a surface of a lens in the lens assembly that is closest to the first lens element. In yet another embodiment, a mechanical stop may be added to a surface of the lens assembly and/or the backside of the device's external surface (*i.e.*, the same surface to which the first lens is flush). The mechanical stop providing a mechanism to prevent any lens in the lens assembly from physically contacting the first lens.

Brief Description of the Drawings

- [0006]** Figure **1** shows, in block diagram form, a prior art camera assembly.
- [0007]** Figures **2A** and **2B** show, in block diagram form, a camera module in accordance with one embodiment.
- [0008]** Figure **3** shows, in block diagram form, a camera module in accordance with a second embodiment.
- [0009]** Figures **4A** and **4B** show two approaches to providing a mechanical stop in accordance with this disclosure.
- [0010]** Figure **5** presents illustrative opto/mechanical properties for a multi-lens optical system such as that shown in FIG. **3**.
- [0011]** Figure **6** shows, in block diagram form, an illustrative multi-function electronic device in accordance with one embodiment.

Detailed Description

- [0012]** This disclosure pertains to systems and methods to reduce the height, size or thickness of an image capture device. In general, techniques are disclosed for fashioning a camera module that is more compact than that available in the prior art. More particularly, a compact optic design is disclosed wherein a device's cover glass (or other transparent material) is imbued with optic power and affixed directly to

the device's housing. A lens barrel, in which one or more additional lens elements can be mounted, may be optically aligned with the lens/cover glass and an image sensor to provide a complete camera module. As used herein, a "lens" is an optical element that has a finite focal length. At present, the disclosed embodiments can provide a 10% - 15% reduction in the camera module's overall height and system thickness in comparison to conventional designs having similar optic capabilities (*e.g.*, number of lens elements).

[0013] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the inventive concept. As part of this description, some of this disclosure's drawings represent structures and devices in block diagram form in order to avoid obscuring the invention. In the interest of clarity, not all features of an actual implementation are described in this specification. Moreover, the language used in this disclosure has been principally selected for readability and instructional purposes, and may not have been selected to delineate or circumscribe the inventive subject matter, resort to the claims being necessary to determine such inventive subject matter. Reference in this disclosure to "one embodiment" or to "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in

at least one embodiment of the invention, and multiple references to “one embodiment” or “an embodiment” should not be understood as necessarily all referring to the same embodiment.

[0014] It will be appreciated that in the development of any actual implementation (as in any development project), numerous decisions must be made to achieve the developers’ specific goals (*e.g.*, compliance with system- and business-related constraints), and that these goals may vary from one implementation to another. It will also be appreciated that such development efforts might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the design and implementation of camera or optic systems having the benefit of this disclosure. Further, the application in which the disclosed embodiments are described is a mobile telephone. No such limitation is inherent in the described technology. By way of example only, a camera module in accordance with this disclosure could also be implemented in any small form-factor digital device incorporating image capture capability. By way of example, stand-alone digital cameras, portable music players, personal digital assistants, laptop/notebook computer systems, and tablet computer systems.

[0015] Referring to FIG. **2A**, rear-facing mobile telephone **200** is shown having camera module **205** and flash unit **210**. Front facing

elements such as speaker **215**, view screen **220** and control button **225** are shown as dotted lines. Various other controls are shown as raised black regions spaced about the device's periphery (*e.g.*, power and volume controls). An integrated optic design that includes camera module **205** is shown in cross-section in FIG. **2B**. As with prior art camera units, camera module **205** may be juxtaposed or sandwiched between device **200's** back-plate **230** and front face **255**. Unlike the prior art, camera module **205** employs a lens coincident with the device's back-plate **230**. By coincident, it is meant that a lens surface (see discussion below) is substantially flush with a device's external surface. In one embodiment, a lens element may be affixed directly to the back-plate or device housing. Also shown in FIG. **2B** is lens barrel **240** (minus an actuator mechanism such as that shown in FIG. **1, 130**), IRCF **245**, optical sensor **250**, front plate **255** and the top-most portion of a lens mounted in lens barrel **245**.

[0016] Referring to FIG. **3**, camera module **300** in accordance with one embodiment includes lens 1 (L1) **305** affixed to or made part of the device's back-plate **230**. Illustrative camera module **300** employs lens barrel **310** to house an additional four lens: lens 2 (L2) **315**, lens 3 (L3) **320**, lens 4 (L4) **325**, and lens 5 (L5) **330**. As in FIG. **2**, a complete system would also include IRCF **245**, optical sensor **250** and the device's front plate **255**.

[0017] Together, lens L1 **305** and lens barrel **310** (housing lenses L2 **315** – L5 **330**) form a 5-lens stack having an overall optical track **335** and device thickness **340**. Incorporating lens L1 **305** into the device's back-plate in accordance with this disclosure allows the lens barrel to be thinner (it now only has to host four lenses rather than 5 as in a prior art 5-lens camera module). This, in turn, permits the module's overall thickness **340** to be less than that of a prior art 5-lens module. The same may be said for all comparable devices. That is, a device in accordance with FIG. **3** having "n" lens elements will be thinner than a prior art device having "n" lens elements.

[0018] Also highlighted in FIG. **3** (see blow-up) is a novel position for aperture stop **345**. As shown, aperture stop **345** may be affixed directly to lens element L2 **315**. In prior art barrel designs the aperture stop is generally molded into the top surface of the lens barrel. In this position, the aperture stop could interfere with the free movement of lens L2 **315** to L5 **330** as the barrel is moved closer to lens L1 **305** (thereby limiting the close-in or macro focus capability of the camera assembly). In one embodiment, aperture stop **345** may be formed from a thin metal plate and affixed directly to the top of lens L2 **315** (*i.e.*, on the surface closest to lens L1 **305**). In another embodiment, aperture stop **345** may be made of any suitably opaque material. In this implementation, lens barrel **310** may

only be needed to ensure lens concentricity and provide resistance from axial forces induced during assembly of the lens elements.

[0019] Referring again to FIG. 3, the illustrated embodiment may rely on the physical contact between lens L2 **315** and lens L1 **305** to limit the movement of lens barrel **310** in one direction along the z-axis. In another embodiment, material may be added to either lens barrel **310** or back-plate **230** to act as a mechanical stop. Figures **4A** and **4B** show two illustrative embodiments using this approach. In FIG. **4A**, material **400** may be added to lens barrel **310** so that this material contacts back-plate **230** before lens L2 **315** contacts lens L1 **305**. In FIG. **4B**, the same effect is provided by adding material **405** directly to back-plate **230**.

[0020] Referring to FIG. 3, in one embodiment lens member L1 **305** may be fashioned from glass for abrasion resistance and be sufficiently thick so as to provide sufficient mechanical strength for the device's intended use. Lens member L1 **305** may also have one or more anti-reflective coatings and, perhaps, one or more additional hard coats to protect the anti-reflective layers (*e.g.*, a diamond-like coating). It may also be valuable to provide lens member L1 **305** with limited optical power so that de-centers and axial position variances between lens L1 **305** and the lenses mounted in lens barrel **310** due to fabrication processes may yield an acceptable operational device (*e.g.*, in quality and yield). It has been

found that when the optic power of lens L1 **305** is relatively small, fabrication of the camera module **205** becomes easier. In one embodiment, the ratio of focal length between the first lens (*e.g.*, lens L1 **305**) and that provided by lens barrel **310** is substantial, *e.g.*, ten-to-one. In other embodiments, this ratio may be less (generally providing a higher quality image at the expense of fabrication difficulty) or more (providing a lower quality camera module). For example, it has been determined that when lens L1 **305** is aspherical, the camera device's image quality is better. FIG. 5 provides illustrative opto/mechanical properties for a 5-lens optical system such as that shown in FIG. 3.

[0021] In one embodiment, a support structure may be insert-molded with the lens element that is coincident with a device's external surface (*e.g.*, lens L1 **305**). An advantage of this approach is that a low compliance joint is created ensuring minimal displacement of the lens toward the device's interior (*i.e.*, toward lens L2 **315**) under external loading. In another embodiment, the first lens element (*i.e.*, lens L1 **305**) may be affixed into a support structure using pressure-sensitive adhesive or epoxy. In both embodiments, the support structure itself may, for example, be molded plastic or machined alloy.

[0022] Because lens member L1 **305** is mechanically separated from the lenses mounted in lens barrel **310**, it may be beneficial during

assembly operations to ensure these lenses are properly aligned. In one embodiment, lens alignment may be achieved using an active alignment process. During active alignment, image sensor **250** is activated and the position of first lens member L1 **305** is moved in the x, y and z directions until a suitable position is achieved (*e.g.*, an acceptable position along the lens assemblies “through-focus curve” is found).

[0023] Referring to FIG. 6, a simplified functional block diagram of illustrative electronic device **600** is shown according to one embodiment. Electronic device **600** may be, for example, a mobile telephone, a personal digital assistant, a personal music player or the like. Device **600** may include processor **605**, display **610**, user interface **615**, graphics hardware **620**, device sensors **625** (*e.g.*, proximity sensor/ambient light sensor, accelerometer and/or gyroscope), microphone **630**, audio codec(s) **635**, speaker(s) **640**, communications circuitry **645**, digital image capture unit **650** (including a camera module in accordance with this disclosure), video codec(s) **655**, memory **660**, storage **665**, and communications bus **670**. Electronic device **600** may be, for example, a personal digital assistant (PDA), personal music player, a mobile telephone, or a notebook, laptop or tablet computer system.

[0024] Processor **605** may execute instructions necessary to carry out or control the operation of many functions performed by device **600**.

Processor **605** may, for instance, drive display **610** and receive user input from user interface **615**. User interface **615** can take a variety of forms, such as a button, keypad, dial, a click wheel, keyboard, display screen and/or a touch screen. Processor **605** may be a system-on-chip such as those found in mobile devices and include a dedicated graphics processing unit (GPU). Processor **605** may be based on reduced instruction-set computer (RISC) or complex instruction-set computer (CISC) architectures or any other suitable architecture and may include one or more processing cores. Graphics hardware **620** may be special purpose computational hardware for processing graphics and/or assisting processor **605** process graphics information. In one embodiment, graphics hardware **620** may include a programmable graphics processing unit (GPU).

[0025] Sensor and camera circuitry **650** may utilize the compact optic design disclosed herein to capture still and video images. Output from camera circuitry **650** may be processed, at least in part, by video codec(s) **655** and/or processor **605** and/or graphics hardware **620**, and/or a dedicated image processing unit incorporated within circuitry **650**. Images so captured may be stored in memory **660** and/or storage **665**. Memory **660** may include one or more different types of media used by processor **605**, graphics hardware **620**, and image capture circuitry **650** to perform device functions. For example, memory **660** may include memory

cache, read-only memory (ROM), and/or random access memory (RAM).

Storage **665** may store media (*e.g.*, audio, image and video files), computer program instructions or software, preference information, device profile information, and any other suitable data. Storage **665** may include one or more non-transitory storage mediums including, for example, magnetic disks (fixed, floppy, and removable) and tape, optical media such as CD-ROMs and digital video disks (DVDs), and semiconductor memory devices such as Electrically Programmable Read-Only Memory (EPROM), and Electrically Erasable Programmable Read-Only Memory (EEPROM).

Memory **660** and storage **665** may be used to retain computer program instructions or code organized into one or more modules and written in any desired computer programming language. When executed by, for example, processor **605** such computer program code may implement one or more of the methods described herein.

[0026] It is to be understood that the above description is intended to be illustrative, and not restrictive. The material has been presented to enable any person skilled in the art to make and use the invention as claimed and is provided in the context of particular embodiments, variations of which will be readily apparent to those skilled in the art (*e.g.*, some of the disclosed embodiments may be used in combination with each other). By way of example, camera modules in accordance with this

disclosure are not limited to rear-facing camera modules or modules utilizing a 5-lens assembly as illustrated in FIG. 3. In addition, a lens member coincident with a device's external surface (*e.g.*, lens member L1 **305 230** and device surface **230**) may have more or less curvature (*i.e.*, more or less optic power) and may be spherical or aspherical depending on the designer's specific goals and the ability of her manufacturing and/or assembly processes to produce a properly aligned camera unit. Further, the type of light sensor (*e.g.*, sensor **250**) is immaterial to the disclosed techniques. Accordingly, the scope of the invention therefore should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein."

Claims

1. An image capture system, comprising:

a first lens member coincident with and fixedly attached to an external surface of an electronic device;

one or more additional lens members in fixed relation to each other and in movable relation, and axially aligned, to the first lens element; and

a sensor having light sensitive elements on a first surface, wherein the first surface is substantially orthogonal to the axially aligned first and additional lens members.
2. The image capture system of claim 1, wherein the one or more additional lens members are mounted in a lens barrel.
3. The image capture system of claim 2, further comprising an infrared cutoff filter (IRCF) juxtaposed between the lens barrel and the sensor.

4. The image capture system of claim 1, wherein the first lens member has a focal length that is greater than the aggregate focal length of the one or more additional lens members.

5. The image capture system of claim 4, wherein the first lens member has a focal length that is substantially larger than the aggregate focal length of the one or more additional lens members.

6. The image capture system of claim 1, further comprising an aperture stop fixedly attached to a surface of one of the one or more additional lens members.

7. The image capture system of claim 6, wherein the one or more lens members comprises a second lens member having a first surface oriented toward the first lens member, and wherein the aperture stop is coincident with the first surface of the second lens member.

8. The image capture system of claim 7, wherein the aperture stop is fixedly attached directly to the first surface of the second lens member.

9. The image capture system of claim 1, wherein the first lens member comprises a support structure into which the first lens has been insert-molded.

10. The image capture system of claim 1, further comprising a mechanical element configured to prevent any one of the one or more lenses from physically contacting the first lens.

11. The image capture system of claim 10, wherein the one or more additional lens members are mounted in a lens barrel, the lens barrel having a top surface, the top surface being oriented toward the first lens, and wherein the mechanical element is affixed to the top surface of the lens barrel.

12. The image capture system of claim 1, comprising one of a mobile telephone, a tablet computer system, a notebook computer system, a personal music player, and a desktop computer system.

13. An image capture system, comprising:

a first lens member coincident with and fixedly attached to an external surface of an electronic device;

one or more additional lens members mounted in a lens assembly, wherein the lens assembly maintains each of the one or more additional lens members in fixed relation to each other, the lens assembly in movable relation, and axially aligned to, the first lens element; and

a sensor having light sensitive elements on a first surface, wherein the first surface is substantially orthogonal to the axially aligned to the first and additional lens members.

14. The image capture system of claim 13, wherein the first lens member has a focal length that is greater than the aggregate focal length of the one or more additional lens members housed in the barrel assembly.

15. The image capture system of claim 13, wherein the one or more additional lens members comprises one lens member that is closest to the first lens member, the one lens member having a surface oriented toward the first lens member, the image capture system further comprising an aperture stop fixedly attached to the surface of the one lens member oriented toward the first lens member.

16. The image capture system of claim 13, further comprising a mechanical stop configured to prevent any one of the one or more lenses mounted in the lens assembly from physically contacting the first lens.

17. The image capture system of claim 16, wherein the mechanical stop comprises a component affixed to, or made part of, the lens barrel.

18. The image capture system of claim 13, comprising one of a mobile telephone, a tablet computer system, a notebook computer system, a personal music player, and a desktop computer system.

AMENDED CLAIMS

received by the International Bureau on 28 February 2014 (28.02.14)

1. An image capture system, comprising:
 - a first lens member coincident with and fixedly attached to an external surface of an electronic device;
 - one or more additional lens members in fixed relation to each other and in movable relation, and axially aligned, to the first lens element; and
 - a sensor having light sensitive elements on a first surface, wherein the first surface is in fixed spatial relationship to the first lens member and substantially orthogonal to the axially aligned first and additional lens members.
2. The image capture system of claim 1, wherein the one or more additional lens members are mounted in a lens barrel.
3. The image capture system of claim 2, further comprising an infrared cutoff filter (IRCF) juxtaposed between the lens barrel and the sensor.

4. The image capture system of claim 1, wherein the first lens member has a focal length that is greater than the aggregate focal length of the one or more additional lens members.

5. The image capture system of claim 4, wherein the first lens member has a focal length that is substantially larger than the aggregate focal length of the one or more additional lens members.

6. The image capture system of claim 1, further comprising an aperture stop fixedly attached to a surface of one of the one or more additional lens members.

7. The image capture system of claim 6, wherein the one or more lens members comprises a second lens member having a first surface oriented toward the first lens member, and wherein the aperture stop is coincident with the first surface of the second lens member.

8. The image capture system of claim 7, wherein the aperture stop is fixedly attached directly to the first surface of the second lens member.

9. The image capture system of claim 1, wherein the first lens member comprises a support structure into which the first lens has been insert-molded.

10. The image capture system of claim 1, further comprising a mechanical element configured to prevent any one of the one or more lenses from physically contacting the first lens.

11. The image capture system of claim 10, wherein the one or more additional lens members are mounted in a lens barrel, the lens barrel having a top surface, the top surface being oriented toward the first lens, and wherein the mechanical element is affixed to the top surface of the lens barrel.

12. The image capture system of claim 1, comprising one of a mobile telephone, a tablet computer system, a notebook computer system, a personal music player, and a desktop computer system.

13. An image capture system, comprising:

a first lens member coincident with and fixedly attached to an external surface of an electronic device;

one or more additional lens members mounted in a lens assembly, wherein the lens assembly maintains each of the one or more additional lens members in fixed relation to each other, the lens assembly in movable relation, and axially aligned to, the first lens element; and

a sensor having light sensitive elements on a first surface, wherein the first surface is in fixed spatial relationship to the first lens member and substantially orthogonal to the axially aligned to the first and additional lens members.

14. The image capture system of claim 13, wherein the first lens member has a focal length that is greater than the aggregate focal length of the one or more additional lens members housed in the barrel assembly.

15. The image capture system of claim 13, wherein the one or more additional lens members comprises one lens member that is closest to the first lens member, the one lens member having a surface oriented toward the first lens member, the image capture system further comprising an aperture stop fixedly attached to the surface of the one lens member oriented toward the first lens member.

16. The image capture system of claim 13, further comprising a mechanical stop configured to prevent any one of the one or more lenses mounted in the lens assembly from physically contacting the first lens.

17. The image capture system of claim 16, wherein the mechanical stop comprises a component affixed to, or made part of, the lens barrel.

18. The image capture system of claim 13, comprising one of a mobile telephone, a tablet computer system, a notebook computer system, a personal music player, and a desktop computer system.

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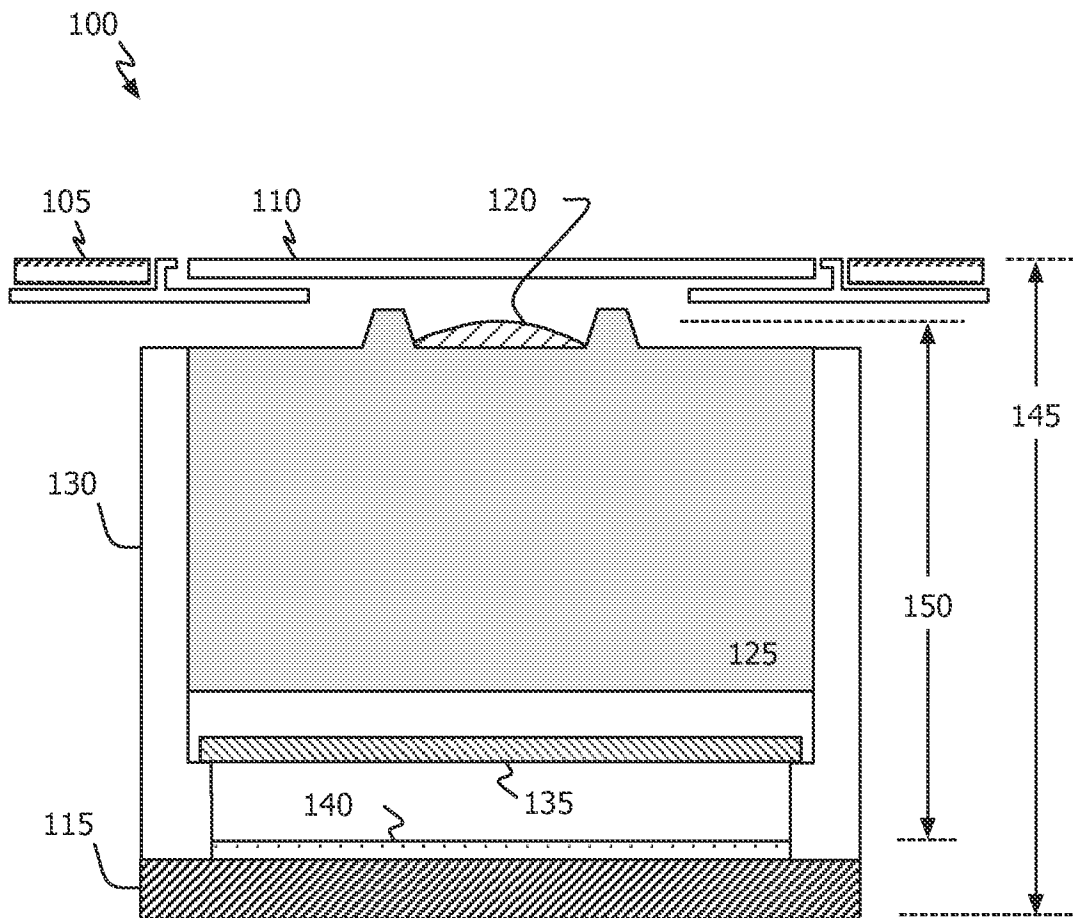
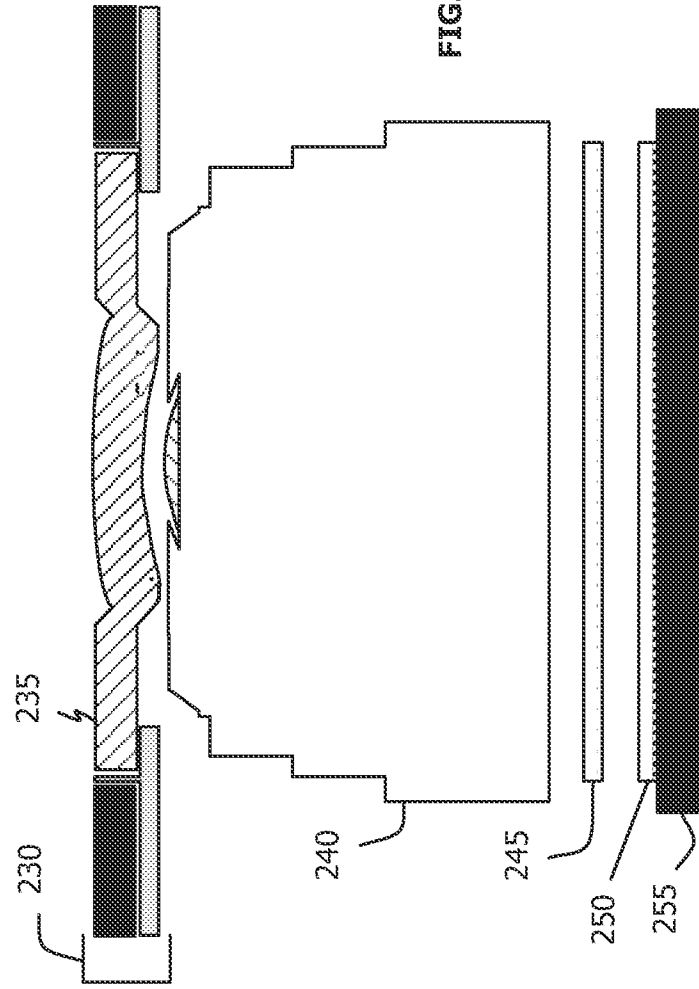
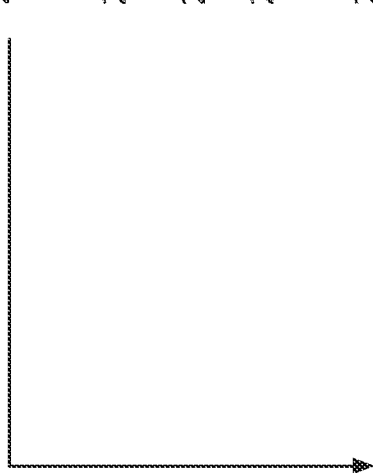
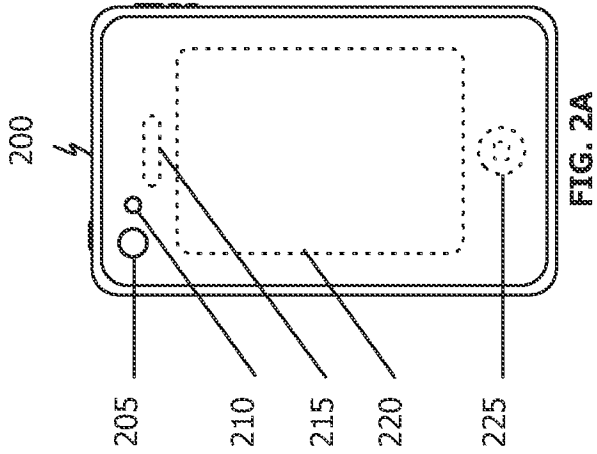


FIG. 1
(Prior Art)



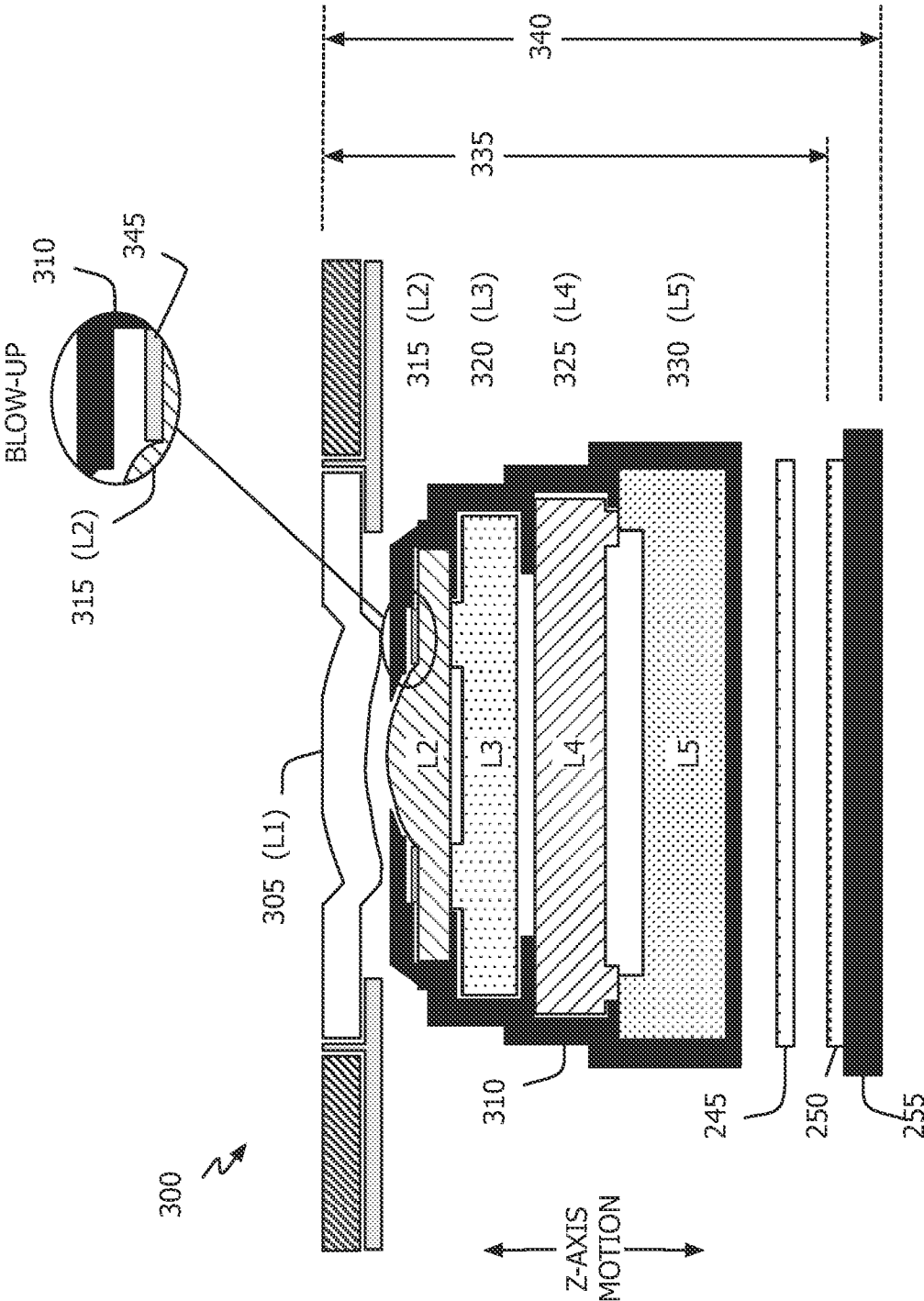


FIG. 3

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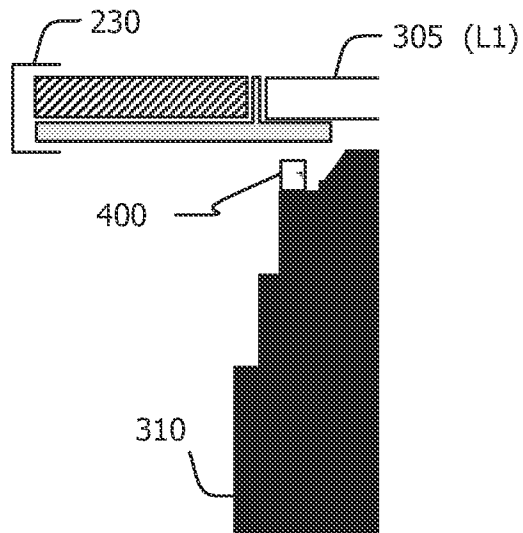


FIG. 4A

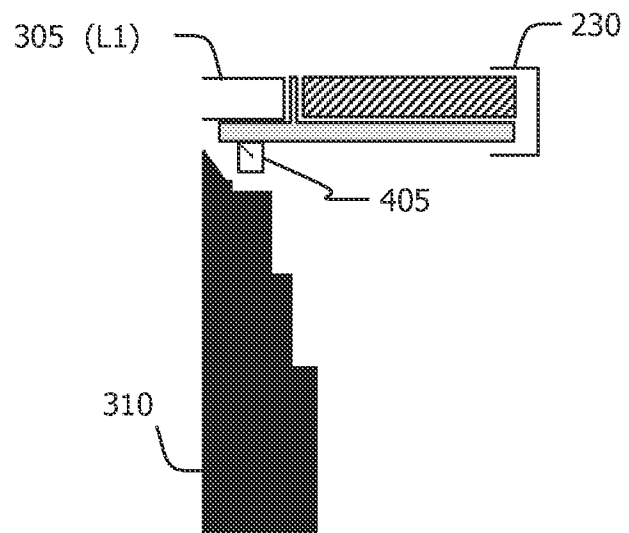


FIG. 4B

FIG. 5. ILLUSTRATIVE OPTO/MECHANICAL PROPERTIES FOR A 5-LENS CAMERA MODULE

	L1 305	L2 315	L3 320	L4 325	L5 330
MATERIAL	GLASS	GLASS OR PLASTIC	PLASTIC	PLASTIC	PLASTIC
SURFACE SHAPE	SPHERICAL SINGLET OR DOUBLET	ASPHERICAL	ASPHERICAL	ASPHERICAL	ASPHERICAL
CENTER THICKNESS/ CLEAR APERTURE DIAM. (MM)	> 0.20	> 0.30	> 0.14	> 0.25	> 0.15
EDGE THICKNESS (MM)	> 0.35	> 0.25	> 0.40	> 0.25	> 0.60
DECENTER SENSITIVITY (MICRONS)	± 10	± 2	± 2	± 2	± 5

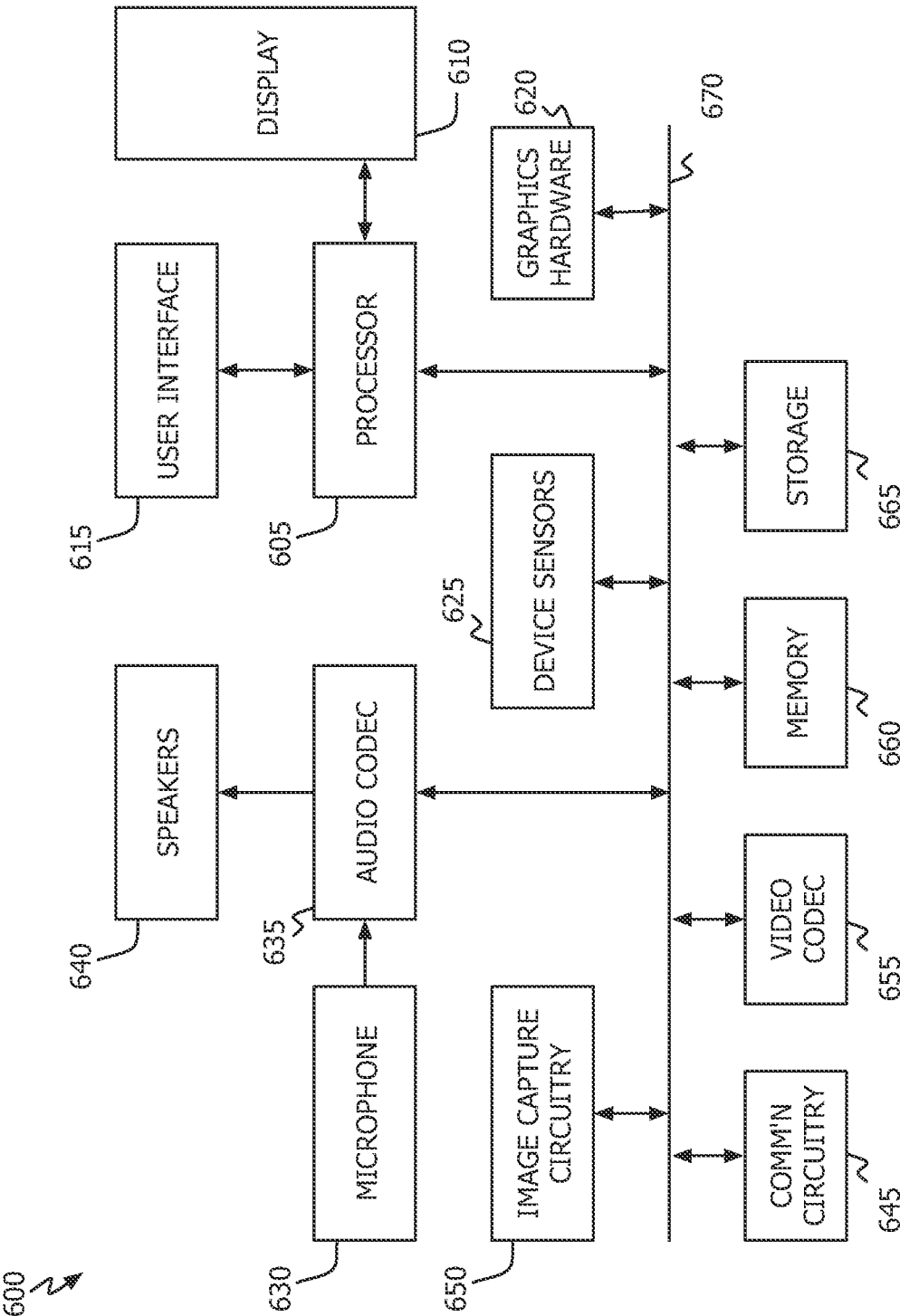


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/054665

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04N5/225 G02B7/10
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)

H04N G02B G03B

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/057068 A1 (ICHIKAWA KEISUKE [JP] ET AL) 8 March 2012 (2012-03-08)	1-5, 9-14, 16-18
Y	figures 1A-1C, 15, 18 -----	6-8, 15
X	US 2008/266674 A1 (HUANG CHUN-HUNG [TW]) 30 October 2008 (2008-10-30)	1-5, 9-14, 16-18
A	figures 10, 11 -----	6-8, 15
X	US 5 699 200 A (UNO TETSUYA [JP] ET AL) 16 December 1997 (1997-12-16)	1-5, 9-14, 16-18
A	column 14, line 63 - column 15, line 24; figures 1-3 ----- -/-	6-8, 15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

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

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"&" document member of the same patent family

Date of the actual completion of the international search

19 November 2013

Date of mailing of the international search report

27/11/2013

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/054665

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/177238 A1 (SAITO MASASHI [JP]) 15 July 2010 (2010-07-15) paragraph [0065]; figure 2a -----	6-8,15
A	US 2008/203508 A1 (CHO JUNG-HYUN [KR] ET AL) 28 August 2008 (2008-08-28) paragraph [0060]; figure 3 -----	3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/054665

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012057068 A1	08-03-2012	JP 2012058406 A US 2012057068 A1	22-03-2012 08-03-2012
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