(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
02 November 2023 (02.11.2023)

WIPO | PCT

(10) International Publication Number
WO 2023/209652 A1

(51) International Patent Classification:
G03B 17/04 (2021.01) *G03B 17/12* (2021.01) *G02B 15/14* (2006.01)

(21) International Application Number:
PCT/IB2023/054411

(22) International Filing Date:
28 April 2023 (28.04.2023)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

63/337,072	30 April 2022 (30.04.2022)	US
63/407,688	18 September 2022 (18.09.2022)	US
63/384,435	20 November 2022 (20.11.2022)	US
63/431,091	08 December 2022 (08.12.2022)	US

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO,

(54) Title: POP-OUT MOBILE CAMERAS AND COMPACT ACTUATORS

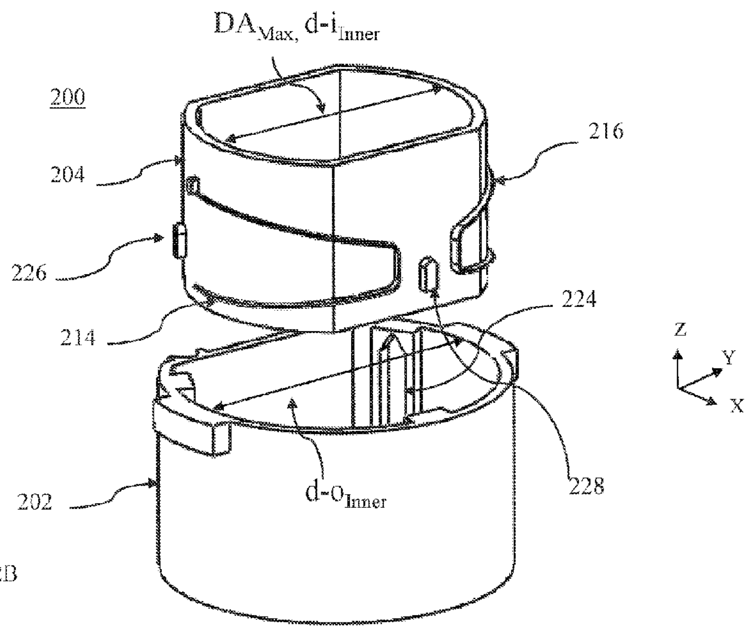

FIG. 2B

(57) Abstract: Pop-out cameras having pop-out lens modules that comprise an inner part, an outer part having an outer part diameter dO, a gap between the inner part and outer part having a maximum gap width WG-Max, a moving lens group fixedly coupled to the inner part, the moving lens group including a plurality of N lens elements and having an optical axis, wherein a maximum lens element diameter of all the moving lens elements is DAMax and actuators that include an open spring located in the gap, wherein the open spring is operative to move the inner part relative to the outer part in a first direction parallel to the optical axis to a pop-out state when no external forces are applied, wherein the inner part can move relative to the outer part in a second direction opposite to the first direction to a collapsed state under an external force, wherein do = DAMax + a penalty p, wherein 0.5mm< p <2.5mm, and wherein 3mm < DAMax < 15mm.

WO 2023/209652 A1

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RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

POP-OUT MOBILE CAMERAS AND COMPACT ACTUATORS

CROSS REFERENCE TO EXISTING APPLICATIONS

This application claims the benefit of priority from US Provisional Patent Applications Nos. 63/337,072 filed 30 April 2022, 63/384,435 filed 20 November 2022, and 63/431,091 filed 8 December 2022, all of which are incorporated herein by reference in their entirety.

FIELD

The presently disclosed subject matter is generally related to the field of digital cameras and in particular to pop-out compact cameras including compact pop-out actuators.

DEFINITIONS

In this application and for optical and other properties mentioned throughout the description and figures, the following symbols and abbreviations are used, all for terms known in the art:

Total track length (TTL): the maximal distance, measured along an axis parallel to the optical axis of a lens, between a point of the front surface S1 of a first lens element L1 and an image sensor, when the system is focused to an infinity object distance.

Back focal length (BFL): the minimal distance, measured along an axis parallel to the optical axis of a lens, between a point of the rear surface S2N of the last lens element LN and an image sensor, when the system is focused to an infinity object distance.

Effective focal length (EFL): in a lens (assembly of lens elements L1 to LN), the distance between a rear principal point P' and a rear focal point F' of the lens.

f-number (f/#): the ratio of the EFL to an entrance pupil diameter.

BACKGROUND

Multi-aperture digital cameras (or multi-cameras) are standard in present day mobile handheld electronic devices (or in short “mobile devices”, e.g. smartphones, tablets, etc.). A multi-camera often includes a Wide (or “Main”) camera, an Ultrawide camera and a Tele camera.

In the pursuit of achieving ever-higher image quality (IQ), there is a need for ever-larger image sensors (in Wide cameras) and ever-larger zoom factors (in Tele cameras). Pop-out cameras ("POCs") combine the benefits of large image sensors or large zoom factors with a slim thickness of a mobile device that includes the POC. Pop-out cameras are described for example in co-owned international patent application PCT/IB2020/058697.

FIG. 1A illustrates schematically a mobile device numbered **100** that includes a known POC **110** in a first state ("collapsed state") when the camera is not in use. In the collapsed state, POC **110** has a first TTL ("collapsed TTL" or "cTTL"). The cTTL is compatible with the height dimensions of modern mobile devices, i.e. POC **110** in its collapsed state does not exceed a height (or thickness) of mobile device **100**.

FIG. 1B illustrates schematically mobile device **100** with POC **110** in a second ("pop-out" or "P-O") state in which the POC is active (operational). In general, the POC is operational as a camera only in the pop-out state. In the P-O state, POC **110** has a "regular" P-O state TTL (referred to hereinafter as simply "TTL"). In the P-O state, POC **110** protrudes (or "pops out") from mobile device **100**. Typically, a mobile device has a thickness T of about 5-15mm. In the P-O state, the POC may protrude from (i.e. go beyond the T of the) mobile device **100** by about 1-10mm. In the P-O state, POC **110** may have a TTL of about 8-25mm, preferably about 10-20mm. The ratio cTTL/TTL may be in the range 0.5-0.95.

POC **110** may be a Wide camera with a Wide camera effective focal length EFL_W of about 8-20mm, a Wide camera field-of-view FOV_W of about 60-100 degrees (diagonal), a Wide camera sensor with a sensor diagonal SD of about 12-30mm, and a ratio $cTTL/SD < 0.8$. POC **110** may also be a Tele camera with a Tele camera EFL_T of about 10-30mm, a Tele camera FOV_T of about 20-50 degrees and a ratio $TTL/EFL < 1.1$. POC **110** may also be a Ultrawide (UW) camera with a UW camera EFL_{UW} of about 5mm-15mm and a UW camera FOV_{UW} of about 100-160 degrees.

FIGS. 1C-D show schematically in a cross-sectional view POC **110** in, respectively, a collapsed state and an extended state. Camera module **110** comprises a lens barrel **112**, a lens carrier (or simply "carrier") **114** configured to receive lens barrel **112**, and an image sensor **116**. Camera module **110** may further comprise a retractable cover window. **118**. Lens barrel **112** comprises an objective assembly. The objective assembly may hold coaxially a plurality (e.g. four to ten) lens elements **120** defining an optical axis **Z** of camera module **110**. Lens barrel **112** may be positioned coaxially inwardly to carrier **114**. Lens barrel **112** may be coupled to carrier **114** to allow axial displacement of lens barrel **112** relative to carrier **114**. Carrier **114** may not move axially relative to image sensor **116**, i.e. it may be fixed with respect to the Z axis.

Lens barrel **112** has a P-O (or “active”, “operative” or “operational”) state and a collapsed or “inactive” state. In the operative state, image sensor **116** is positioned in a focal plane or in an imaging plane of the objective assembly. The operative state of the lens barrel corresponds to a P-O (active) mode of camera module **110**.

Camera module **110** further includes a barrel P-O assembly **122** configured to controllably move lens barrel **112** from the collapsed state to the operative state and to bias (or push) lens barrel **112** in the operative state. P-O assembly **122** may be configured to cause lens barrel **112** to axially move relative to the carrier **114** from the collapsed state towards the operative state. P-O assembly **122** may be positioned in an interstice (space) between carrier **114** and lens barrel **112**. Such an interstice may be formed by cutting lens elements **120**, i.e. performing a D-cut as known in the art. P-O assembly **122** may be configured to create a P-O force capable of overcoming the weight of the lens barrel, when this weight resists the axial movement of lens barrel **112** from the collapsed state to the operative state. Retractable cover window **118** may be configured to controllably move axially between a retracted position and an extended position. In the retracted position, cover window **118** may be positioned to abut on the most distal surface (e.g. a rim) of the lens barrel **112** in the collapsed state. In the extended position, cover window **118** may be positioned to provide for an axial gap with the most distal surface of lens barrel **112** in the operative state.

The motion of the cover window **118** between the retracted and extended positions and the motion of lens barrel **112** between the collapsed and extended positions may be coordinated. The axial movement of cover window **118** may be driven by a cover window P-O assembly **124** operated by an actuator **126**. In the retracted position, cover window **118** may be configured to hold lens barrel **112** in the collapsed position. In the extended position, cover window **118** may be configured to provide for an axial gap with lens barrel **112** in the operative state. The axial gap may allow some axial movement of lens barrel **112** from the operative state, thereby allowing focusing (or autofocus “AF”). Cover window **118** may further be configured to cause lens barrel **112** to move from the operative state to the collapsed state when cover window **118** is operated to move from the extended position to the retracted position by window cover pop out assembly **124**. In other words, window cover **118** may push on lens barrel **112** and collapse lens barrel **112** in the collapsed state when moving from extended position to the retracted position upon operation of the window cover P-O assembly **124**. When cover window **118** is moved from the retracted position to the extended position, lens barrel

112 is released and a P-O force generated by P-O assembly **122** may drive lens barrel **112** towards the operative state.

FIG. 1E shows a known P-O lens module numbered **130** (also referred to as "optics frame") disclosed in FIG. 18E of PCT/IB2020/058697 in a top view. P-O lens module **130** may be used in a POC such as POC **110**. P-O lens module **130** includes an outer part **132**, an inner part **134**, a lens barrel (not shown) such as lens barrel **112**, a P-O assembly **140** and a P-O lens (not shown). P-O assembly **140** includes three springs **142, 144** and **146** and three pin-groove mechanisms **148, 150** and **152**. Together, pin-groove mechanisms **148, 150** and **152** form a kinematic coupling mechanism between outer part **132** and inner part **134**. When switching POC **110** from a P-O state to a collapsed state and vice versa, springs **142, 144** and **146** provide an actuation force of P-O assembly **140** and which moves inner part **134** relative to outer part **132** and the kinematic coupling mechanism provides a mechanical accuracy and repeatability of P-O assembly **140**.

Each of springs **142, 144** and **146** has a spring diameter "d_{Spring}". Inner part **134** has an outer diameter ("$d\text{-}i_{Outer}$") and an inner diameter ("$d\text{-}i_{Inner}$"), as shown. Outer part **132** has an inner radius ("$d\text{-}o_{Inner}$", not shown, see FIGS. 2A-B). We note that outer part **132** surrounds (or encircles) inner part **134**, so that $d\text{-}o_{Inner}$ of outer part **132** is equal to or larger than $d\text{-}i_{Outer}$. $d\text{-}i_{Inner}$ is limited by springs **142, 144** and **146** and it represents a maximum aperture diameter ("DA_{Max}", as marked) of a P-O lens included in POC **110**, i.e. $DA_{Max} = d\text{-}i_{Inner}$. The difference between $d\text{-}i_{Outer}$ and $d\text{-}i_{Inner}$ is referred to as "diameter penalty" or simply "penalty" or "p", wherein $d\text{-}i_{Outer} = DA_{Max} + p$. In P-O lens module **130**, p may be about $1mm < p < 7.5mm$.

For achieving a compact and still good performance POC that has some $d\text{-}i_{Outer}$, it is beneficial to minimize penalty p, as this maximizes DA_{Max}, which in turn maximizes the amount of light that can enter the POC and contribute to a POC signal. p is given by spring diameter d_{Spring} plus some air gap "g" of typically g=0.05mm-0.75mm, i.e. $p= d_{Spring}+g$. p is caused by incorporating springs **142, 144** and **146** between outer part **132** and the lens barrel. Springs **142, 144** and **146** are "closed" springs as known in the art. In the following we refer to the actuation provided by P-O lens module **130** as "spring actuation".

FIG. 1F shows a known example of a known closed spring **160** in perspective and top views. Its shape is referred to as "closed" spring, since in a top view it resembles a closed circle. Top views are views in a direction normal to the XY plane. Closed spring **160** has a spring diameter "d_{Spring}".

FIG. 1G shows another known P-O lens module numbered **170** in a top view. In lens module **170**, all entities and their markings have similar meanings to those in lens module **130**.

P-O lens module **170** may be used in a POC such as POC **110**. P-O lens module **170** includes an outer part **172**, an inner part **174**, a gap ("G") between inner part **172** and outer part **174**, an actuator **176** and a P-O lens (not shown). The width of G varies along the diameter of outer part **172** and inner part **174**, with maximum G width marked "$W_{G\text{-}Max}$". Actuator **176** is operational to move outer part **172** and an inner part **174** relative to each other along a P-O lens optical axis **178** for switching a POC including P-O lens module **170** from a P-O state to a collapsed state and vice versa. P-O lens optical axis **178** is oriented perpendicular to the x-y-axis as defined by the coordinate system shown. Actuator **176** includes two springs **180** and **182**. Springs **180** and **182** are "closed" springs. When switching the POC including P-O lens module **170** from a P-O state to a collapsed state and vice versa, springs **180** and **182** provide an actuation force of actuator **176**.

FIG. 1H shows schematically a known POC numbered **190** disclosed in FIGS. 18A-B of co-owned international patent application PCT/IB2022/052194 in collapsed state in a cross-sectional view. POC **190** includes a P-O assembly **122** which comprises at least one permanent magnet **192** fixed to lens barrel **112** and a ferromagnetic yoke **194** fixed to the carrier **114**. P-O assembly **122** represents a magnetic spring assembly. P-O assembly **122** provides magnetic forces applied on yoke **194** by permanent magnet **192** to produce a vertical biasing force on the lens barrel **112** in the manner of a spring. Therefore, in the following we refer to the actuation provided by P-O assembly **122** as "magnetic spring actuation". In a P-O state and in cooperation with a coil (not shown), yoke **194** and magnet **192** provide a force for performing focusing.

It would be beneficial to have (1) a POC using spring actuation including compact springs, i.e. springs that have a small spring diameter (or spring width) so that they cause only a small penalty p and (2) a POC using magnetic spring actuation have a magnetic spring that exercises a magnetic spring force which is defined not solely by a strength of the magnet and the yoke which are also operational for focusing. Such springs and their incorporation in POC are disclosed herein.

SUMMARY

In various exemplary embodiments there is disclosed a pop-out lens module, comprising: an inner part; an outer part having an outer part diameter d_O; a gap between the inner part and outer part having a maximum gap width $W_{G\text{-}Max}$; a moving lens group fixedly coupled to the inner part, the moving lens group including a plurality of N lens elements and

having an optical axis, wherein a maximum lens element diameter of all the moving lens elements is DA_{Max}; and an actuator that includes an open spring located in the gap, wherein the open spring is operative to move the inner part relative to the outer part in a first direction parallel to the optical axis to a pop-out state when no external forces are applied, wherein the inner part can move relative to the outer part in a second direction opposite to the first direction to a collapsed state under an external force, wherein $d_o = DA_{Max}$ + a penalty p, wherein p fulfills $0.5mm < p < 2.5mm$, and wherein $3mm < DA_{Max} < 15mm$.

In some examples, $0.5mm < p < 2mm$. In some examples, $0.5mm < p < 1.5mm$. In some examples, $0.5mm < p < 1mm$. In some examples, $5mm < DA < 12.5mm$. In some examples, $5mm < DA < 10mm$.

In some examples, the open spring has an open spring length L_{Spring}, and $L_{Spring} > W_{G-Max}$.

In some examples, the open spring is 1-folded. In some examples, the open spring is 7-folded. In some examples, the open spring is straight. In some examples, the open spring is curved. In some examples, the open spring is tapered. In some examples, the open spring is angled.

In some examples, the open spring has 2 - 6 serpentines. In some examples, the open spring has 2 - 4 windings.

In some examples, $1mm \leq L_{Spring} \leq 15mm$. In some examples, $4mm \leq L_{Spring} \leq 8mm$.

In some examples, the open spring has an open spring width W_{Spring}, and $0.1mm \leq W_{Spring} \leq 1mm$. In some examples, $0.15mm \leq W_{Sprin} \leq 0.5mm$.

In some examples, the open spring has an open spring height in a collapsed state $c\text{-}H_{Spring}$ and an open spring height in a pop-out state H_{Spring}, and the ratio $c\text{-}H_{Spring}/H_{Spring}$ fulfills $1/4 \leq c\text{-}H_{Spring}/H_{Spring} \leq 3/4$.

In some examples, the open spring has an open spring height in a collapsed state $c\text{-}H_{Spring}$ and an open spring height in a pop-out state H_{Spring}, wherein $1mm \leq c\text{-}H_{Spring} \leq 15mm$, and wherein $1mm \leq H_{Spring} \leq 20mm$. In some examples, $1mm \leq c\text{-}H_{Spring} \leq 10mm$ and $1mm \leq H_{Spring} \leq 15mm$. In some examples, $1mm \leq c\text{-}H_{Spring} \leq 8mm$ and $1mm \leq H_{Spring} \leq 12mm$.

In some examples, the pop-out lens module includes a kinematic coupling mechanism that provides mechanical accuracy and repeatability to the movement of the inner part relative to the outer part.

In some examples, the kinematic coupling mechanism includes one or more pin-groove mechanisms. In some examples, the kinematic coupling mechanism includes three pin-groove mechanisms.

In various exemplary embodiments there is provided a pop-out camera having an operative pop-out state and a collapsed state, comprising: an image sensor having an image sensor diagonal (SD); a lens including a plurality of N lens elements and comprising a moving lens group arranged along a lens optical axis and including M <N lens elements; a lens barrel containing the moving lens group; a carrier configured to receive the lens barrel, the lens barrel axially movable relative to the carrier; a magnetic spring assembly comprising at least two permanent magnets, a first permanent magnet being fixedly coupled to the lens barrel, a second permanent magnet, and a ferromagnetic yoke fixedly coupled to the carrier, wherein the magnetic spring assembly is configured to cause the lens barrel to move axially relative to the carrier along a first direction along the lens optical axis from the collapsed state towards an operative state, and wherein the image sensor is configured to image a field of view of the lens when the lens barrel is in the operative state.

In some examples, the second permanent magnet is fixedly coupled to the carrier, the first permanent magnet is divided into a top half and a bottom half, both the top half and the bottom half have a magnetization that is perpendicular to the first direction, and the magnetization of the bottom half is anti-parallel to the magnetization of the top half.

In some examples, the second permanent magnet has a magnetization perpendicular to the first direction. In some examples, a magnetization vector of the second permanent magnet is parallel to a magnetization vector of the bottom half of the first permanent magnet. In some examples, the first permanent magnet has a magnetization parallel to the first direction, and a magnetization vector points towards the image sensor.

In some examples, the second permanent magnet is fixedly coupled to the carrier and has a magnetization parallel to the first direction, wherein a magnetization vector points away from the image sensor. In some examples, the magnetic spring assembly comprises three permanent magnets, and the third permanent magnet is fixedly coupled to the lens barrel. In some examples, the third permanent magnet has a magnetization parallel to the first direction, and a magnetization vector points towards the image sensor. In some examples, the second permanent magnet has a magnetization perpendicular to the first direction, and a magnetization vector points towards the lens barrel. In some examples, the second permanent magnet has a magnetization parallel to the first direction, and a magnetization vector points away from the image sensor.

In some examples, the pop-out camera has a total track length TTL in an active state and a collapsed total track length cTTL in an inactive state, and cTTL/TTL<0.9. In some examples, cTTL/TTL<0.8. In some examples, cTTL/TTL<0.75. In some examples, cTTL/TTL<0.7.

In some examples, the lens is formed by the moving lens group. In some examples, the lens is moved along the optical axis for focusing. In some examples, the lens is formed by the moving lens group fixedly coupled to the inner part and a non-moving lens group fixedly coupled to the outer part.

In some examples, the pop-out camera is a Wide camera including a Wide camera image sensor having a sensor diagonal SD in the range of 12-30mm, wherein the Wide camera has an effective focal length EFL in the range of 5-20mm, and wherein cTTL/SD < 0.8. In some examples, cTTL/SD < 0.75. In some examples, cTTL/SD < 0.7. In some examples, cTTL/SD < 0.65. In some examples, cTTL/SD < 0.6.

In some examples, the pop-out camera includes a retractable cover window that pushes on the inner part to bring the pop-out camera to the collapsed state.

In some examples, the pop-out camera is a Tele camera having an effective focal length EFL in the range of 10-30mm, and a ratio cTTL/EFL < 0.8. In some examples, cTTL/EFL < 0.75. In some examples, cTTL/EFL < 0.7. In some examples, cTTL/EFL < 0.65. In some examples, cTTL/EFL < 0.6.

In some examples, the pop-out camera is included in a mobile device. In some examples, the mobile device is a smartphone.

In some examples, the pop-out camera is included in a multi-camera together with at least one additional camera.

In some examples, the pop-out lens module is moved perpendicular to the optical axis for optical image stabilization.

In some examples, pop-out camera including an image sensor that is moved perpendicular to the optical axis for optical image stabilization.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting embodiments of the presently disclosed subject matter are described below with reference to figures attached hereto that are listed following this paragraph. Identical structures, elements or parts that appear in more than one figure may be labeled with the same numeral in the figures in which they appear. The drawings and descriptions are meant to illuminate and clarify examples disclosed herein, and should not be considered limiting in any way.

FIG. 1A shows exemplarily a known example of a mobile device including a pop-out camera in a collapsed state in a perspective view;

FIG. 1B shows exemplarily a known example of a mobile device including a pop-out camera in a pop-out or active state in a perspective view;

FIG. 1C shows schematically a known pop-out camera in a collapsed state in a cross-sectional view;

FIG. 1D shows schematically the known pop-out camera of FIG. 1C in an extended state;

FIG. 1E shows a known example of a pop-out lens module in a top view;

FIG. 1F shows a known example of a closed spring in perspective and top views;

FIG. 1G shows another known example of a pop-out lens module in a top view;

FIG. 1H shows another known example of a pop-out camera in a cross-sectional view;

FIG. 2A shows an example of a pop-out lens module disclosed herein in a top view;

FIG. 2B shows the example of a pop-out lens module of FIG. 2A in a perspective view;

FIG. 3A shows an example of a 1-folded curved open spring disclosed herein in a top view;

FIG. 3B shows the example of the 1-folded curved open spring of FIG. 3A in a perspective view;

FIG. 4A shows an example of a 1-folded curved and tapered open spring disclosed herein in a top view;

FIG. 4B shows the example of the 1-folded curved and tapered open spring of FIG. 4A in a pop-out state in a perspective view;

FIG. 4C shows the example of the 1-folded curved and tapered open spring of FIG. 4A in a collapsed state in a perspective view;

FIG. 5A shows an example of a 1-folded 2-serpentine curved and tapered open spring disclosed herein in a top view;

FIG. 5B shows the example of the 1-folded 2-serpentine curved and tapered open spring of FIG. 5A in a first perspective view;

FIG. 5C shows the example of the 1-folded 2-serpentine curved and tapered open spring of FIG. 5A in a second perspective view;

FIG. 6A shows an example of a 1-folded straight open spring disclosed herein in a top view;

FIG. 6B shows the example of the 1-folded straight open spring of FIG. 6A in a side view;

FIG. 6C shows the example of the 1-folded straight open spring of FIGS. 6A-B in a perspective view;

FIG. 7 shows an example of a 1-folded 4-serpentine curved open spring in a perspective view;

FIG. 8 shows an example of a 1-folded 3-windings curved open spring in a perspective view;

FIG. 9A shows schematically a pop-out camera including a pop-out assembly disclosed herein in a cross-sectional view in a collapsed state and in a cross-sectional view;

FIG. 9B shows schematically a pop-out camera including another pop-out assembly disclosed herein in a collapsed state and in a cross-sectional view;

FIG. 10A shows a pop-out assembly disclosed herein in a collapsed state and in a cross-sectional view;

FIG. 10B shows the pop-out assembly of FIG. 10A in a pop-out state and in a cross-sectional view;

FIG. 11A shows another pop-out assembly disclosed herein in a collapsed state and in a cross-sectional view;

FIG. 11B shows the another pop-out assembly of FIG. 11A in a pop-out state and in a cross-sectional view;

FIG. 12A shows yet another pop-out assembly disclosed herein in a collapsed state and in a cross-sectional view;

FIG. 12B shows the yet another pop-out assembly of FIG. 12A in a pop-out state and in a cross-sectional view;

FIG. 13A shows yet another pop-out assembly disclosed herein in a collapsed state and in a cross-sectional view;

FIG. 13B shows the yet another pop-out assembly of FIG. 13A in a pop-out state and in a cross-sectional view.

DETAILED DESCRIPTION

FIG. 2A shows a pop-out lens module numbered **200** disclosed herein in a top view. P-O lens module **200** is operational to be used in a pop-out camera such as POC **110**. P-O lens module **200** includes an outer part **202** separated by a gap G from an inner part **204**, an actuator **210** and a P-O lens (not shown). Actuator **210** is operational to move outer part **202** and inner part **204** relative to each other along a P-O lens optical axis **212** for switching the POC (and lens) from a P-O (operational) state to a collapsed state and vice versa. P-O lens optical axis **212** is oriented perpendicular to the X and Y axes (i.e. is along a Z-axis) the coordinate system shown. Actuator **210** includes two springs **214** and **216** and three pin-groove mechanisms **218, 220** and **222**. Together, mechanisms **218, 220** and **222** form a kinematic coupling mechanism between outer part **202** and inner part **204**. When switching the camera (and lens) from the P-O state to the collapsed state and vice versa, springs **214** and **216** provide an actuation force, and the kinematic coupling mechanism provides mechanical accuracy and repeatability for actuator **210**. Springs **214** and **216** are located within gap G between outer part **202** and inner part **204**. The width of gap G varies along the diameter of outer part **202** and inner part **204**, with a maximum G width marked "$W_{G\text{-}Max}$". $W_{G\text{-}Max}$ may be in the range of 0.25 - 5mm.

Each of springs **214** and **216** has a spring length "L_{Spring}" and a spring width "W_{Spring}". L_{Spring} may fulfill $1mm < L_{Spring} < 15mm$, or, beneficially, may fulfill $4mm < L_{Spring} < 8mm$. W_{Spring} may fulfill $0.1mm < W_{Spring} < 1mm$, or, beneficially, may fulfill $0.15mm < W_{Spring} < 0.5mm$. Outer part **202** has an inner diameter ("$d\text{-}o_{Inner}$") and inner part **204** has a maximum inner diameter ("$d\text{-}i_{Inner}$"). $D\text{-}i_{Inner}$ is limited by width W_{Spring} of springs **214** and **216** and it represents a maximum aperture diameter ("DA_{Max}", as marked) of the P-O lens included in P-O lens module **200**, i.e. $DA_{Max} = d\text{-}i_{Inner}$, as shown.

Note that the P-O lens (not shown here) may have a plurality N of lens elements, which in some examples may be divided into two or more lens groups, as disclosed for example in co-owned international patent applications PCT/IB2020/058697, PCT/IB2021/057311, PCT/IB2022/050575, PCT/IB2021/056358, PCT/IB2022/052194, PCT/IB2022/050594 and PCT/IB2022/056646.

$d\text{-}o_{Inner} = DA_{Max} + p$. In P-O lens module **200**, p may fulfill $0.25mm < p < 5mm$, preferably $0.25mm < p < 2.5mm$, or even $0.25mm < p < 1$ mm. As discussed, it is beneficial to minimize penalty p, as this maximizes DA_{Max}. The abovementioned p ranges in lens module **200** are much smaller than in the known art modules.

DA_{Max} refers only to lens elements of a moving lens group. A "moving lens group" is a lens group that moves together with inner part **204**, e.g. a lens group fixedly coupled to inner part **204**. In other words, a moving lens group is a lens group that moves relative to an image sensor included in a POC when the POC is switched between the P-O state and the collapsed state. DA_{Max} may be in the range $3mm < DA_{Max} < 15mm$. In some examples, $5mm < DA_{Max} < 12.5mm$ or $5mm < DA_{Max} < 10mm$. p is given by spring width W_{Spring} plus some air gap "a-g", i.e. $p = d_{Spring} + a\text{-}g$. a-g may be for example about 0.05-0.75mm. p is caused by incorporating springs **214** and **216** between outer part **202** and inner part **204**. Springs **214** and **216** may be for example springs **300**, **400**, **500**, **600**, **700** or **800**, see FIGS. 3-8. These springs are referred to as "open" springs, since in a top view their shape exhibits two open ends. An advantage of an open spring over a closed spring (as e.g. in FIG. 1F) is its relatively small spring width W_{Spring} when compared to the diameter d_{Spring} of the closed spring. Therefore, an open spring allows for a smaller penalty p when compared to a closed spring. Therefore, P-O lens module **200** as well as open springs **300**, **400**, **500**, **600**, **700**, and **800** disclosed herein are beneficial for use in a modern mobile device such as a smartphone.

In some embodiments, P-O lens module **200** is moved for optical image stabilization ("OIS") perpendicular to P-O lens optical axis **212**, i.e. in an x- direction and/or a y-direction,. The movement of P-O lens module **200** is relative to the image sensor. In other embodiments, the image sensor may be moved perpendicular to P-O lens optical axis **212** and relative to P-O lens module **200** for OIS.

FIG. 2B shows P-O lens module **200** of FIG. 2A in a perspective exploded view. Open springs **214** and **216** are visible. Groove **224** of pin-groove mechanism **220**, pin **226** of pin-groove mechanism **218** and pin **228** of pin-groove mechanism **220** are visible as well.

FIG. 3A shows a first example of an open spring numbered **300** disclosed herein in a top view. FIG. 3B shows open spring **300** of FIG. 3A in a perspective view. A working direction (parallel to the Z-axis) along which spring **300** exercises a force is indicated by arrow **302**. Spring **300** is shown in a collapsed state. Spring **300** is a “1-folded curved open spring”. L_{Spring} may fulfill $1mm < L_{Spring} < 15mm$, W_{Spring} may fulfill $0.1mm < W_{Spring} < 1mm$, and c-H_{Spring} may fulfill $1mm <$ c-$H_{Spring} < 15mm$. “Curved” refers to spring **300**’s shape in a top view, and “1-folded” refers to the number of foldings (here 1) of spring **300** in a direction perpendicular to its working direction.

An advantage of a 1-folded open spring is that it does not suffer from buckling, which is an undesired sudden change in a shape of a structural component under load.

Open spring **300** is operational to be used in a P-O lens module such as P-O lens module **200**. This is also the case for all other open spring examples disclosed herein, i.e. all springs **300**, **400**, **500**, **600**, **700** and **800** are operational to be used in such a P-O lens module. In a P-O module including open spring **300**, the working direction of open spring **300** is oriented parallel to an optical axis (such as optical axis **212**, see FIG. 2A) of a lens included in the P-O module. This is also the case for all other open spring examples disclosed herein, i.e. in a P-O module including open springs **300**, **400**, **500**, **600**, **700** or **800** respectively, the working direction of open springs **300**, **400**, **500**, **600**, **700** or **800** respectively is oriented parallel to the optical axis (e.g. **212**) of the lens.

FIG. 4A shows a second example of an open spring numbered **400** disclosed herein in a top view. FIG. 4B shows open spring **400** of FIG. 4A in a P-O state in two different perspective views. A height of spring **400** in the P-O state H_{Spring} may fulfill $2mm < H_{Spring} < 20mm$. A working direction along which spring **400** exercises a force is indicated by arrow **402**. FIG. 4C shows open spring **400** of FIGS. 4A-B in a collapsed state in two different perspective views. "c-H_{Spring}" may fulfill $1mm <$ c-$H_{Spring} < 15mm$. The ratio H_{Spring}/c-H_{Spring} may fulfill $1/4 < H_{Spring}$/c-$H_{Spring} < 3/4$. Spring **400** is a "1-folded curved and tapered open spring" and has a spring length "L_{Spring}" and a continuously changing spring width as indicated by a maximum spring width "$W1_{Spring}$" and by a minimum spring width "$W2_{Spring}$", as marked. "Tapered" refers to spring **400**'s continuously changing spring width as seen in a top view (FIG. 4A). An advantage of a tapered open spring such as spring **400** over a non-tapered open spring such as spring **300** is that the stress that acts on the open spring is distributed more homogeneously along L_{Spring}, allowing for a more efficient open spring. $W2_{Spring}$ may be larger than $W1_{Spring}/10$ and smaller than $W1_{Spring}/2$. $W1_{Spring}$ may be larger than 0.1mm and smaller than 2mm.

FIG. 5A shows a third example of an open spring numbered **500** disclosed herein in a top view. FIG. 5B shows open spring **500** of FIG. 5A in a first perspective view. FIG. 5C shows open spring **500** of FIGS. 5A-B in a second perspective view. A working direction along which spring **500** exercises a force is indicated by arrow **502**. Spring **500** is a "1-folded 2-serpentine curved and tapered open spring" and shown in a collapsed state. Spring **500** has a spring length "L_{Spring}", a collapsed spring height (c-H_{Spring}) and a continuously changing spring width as indicated by a maximum spring width "$W1_{Spring}$" and by a minimum spring width "$W2_{Spring}$", as marked. "2-serpentine" refers to spring **500**'s two foldings as seen in a top view (FIG. 5A). An advantage of a serpentine open spring such as spring **500** over a non-serpentine open spring such as spring **400** is that for a given L_{Spring}, H_{Spring} and $W2_{Spring}$, a more flexible spring is achieved, i.e. a spring which allows for larger P-O strokes (i.e. differences in the ratio of H_{Spring} and c-H_{Spring}). For example, a P-O stroke larger by 5%-50% compared to a previous open spring configuration such as e.g. spring **400** may be achieved.

FIG. 6A shows a fourth example of an open spring numbered **600** disclosed herein in a top view. Open spring **600** is shown in a P-O state. FIG. 6B shows open spring **600** of FIG. 6A in a side view. FIG. 6C shows open spring **600** of FIGS. 6A-B in a perspective view. A working direction along which spring **600** exercises a force is indicated by arrow **602**. Spring **600** is a "7-folded straight open spring". "7-folded" refers to spring **600**'s seven foldings as seen in a top view, "straight" refers to spring **600**'s straight shape as seen in a top view (FIG. 6A). L_{Spring} may be larger than 1mm and smaller than 15mm, W_{Spring} may be larger than 0.1mm and smaller than 1mm and H_{Spring} may be larger than 1mm and smaller than 20mm.

FIG. 7 shows a sixth example of an open spring numbered **700** disclosed herein in a perspective view. A working direction along which spring **700** exercises a force is indicated by arrow **702**. Spring **700** is a "1-folded 4-serpentine curved open spring". L_{Spring} may be larger than 1mm and smaller than 15mm and c-H_{Spring} may be larger than 1mm and smaller than 15mm.

FIG. 8 shows a seventh example of an open spring numbered **800** disclosed herein in a perspective view. A working direction along which spring **800** exercises a force is indicated by arrow **802**. Spring **800** is a "1-folded 3-windings curved open spring", as marked. "3-windings" refers to spring **800**'s number of windings with respect to an axis perpendicular to an axis along which spring **800**'s length L_{Spring} is measured. L_{Spring} may be larger than 1mm and smaller than 15mm and c-H_{Spring} may be larger than 1mm and smaller than 15mm. An advantage of open spring **800** is that it is relatively simple to manufacture.

FIG. 9A shows schematically a POC numbered **900** including a P-O assembly **902** disclosed herein in a cross-sectional view and in a collapsed state. P-O assembly **902** is configured to controllably move lens barrel **112** from the collapsed state to the operative state and to bias lens barrel **112** in the operative state. As known P-O assembly **122** (FIG. 1G), P-O assembly **902 c**omprises at least a first permanent magnet **192** fixed to lens barrel **112** and a ferromagnetic yoke **194** fixed to the carrier **114**. In addition, P-O assembly **902** comprises a second permanent magnet **904** fixed to lens barrel **112** and a third permanent magnet **906** fixed to coupled to carrier **114**. For axial movement of lens barrel **112**, second magnet **904** interacts with third magnet **906**. Both second magnet **904** and third magnet **906** do not interact with magnet **192** and yoke **194**. In other words, two independent forces are used to axially move lens barrel **112**, a first force generated by interaction of first magnet **192** and yoke **194** and a second force generated by interaction of second magnet **904** and third magnet **906.** P-O assembly **902** represents a first configuration of a "magnetic spring with repelling magnet" disclosed herein. In some examples and as shown in FIG. 9A, magnet **904** and magnet **906** are located at an opposite side of lens barrel **112** than magnet **192** and yoke **194**, "opposite side" referring here to a location, or an order, along the x-axis. In other examples and with reference to magnet **192** and yoke **194**, magnet **904** and magnet **906** may be located at a different side of lens barrel **112**, e.g. they may be located in front of or "behind" lens barrel **112**, "in front of" and "behind" referring here to a location, or an order, along the y-axis.

FIG. 9B shows schematically of POC numbered **910** including a P-O assembly **912** disclosed herein in a cross-sectional view and in a collapsed state. P-O assembly **912** is configured to controllably move lens barrel **112** from the collapsed state to the operative state and to bias lens barrel **112** in the operative state. P-O assembly **912** includes a second permanent magnet **914** that is fixedly coupled to carrier **114**. Magnet **914** is located at a same side of lens barrel **112** as first magnet **192** and yoke **194**. “Same side” refers here to a location, or an order, along the x-axis. For axial movement of lens barrel **112**, magnet **914** interacts with magnet **192**. In other words, two independent forces are used to axially move lens barrel **112**, a first force generated by interaction of magnet **192** and yoke **194** and a second force generated by interaction of magnet **192** and magnet **914.** P-O assembly **912** represents a second configuration of a “magnetic spring with repelling magnet” disclosed herein.

For both the first and the second configuration of a “magnetic spring with repelling magnet”, in a P-O state and in cooperation with a coil (not shown), yoke **194** and magnet **192** provide a force for performing focusing of POC **900** and POC **910** respectively. For focusing, lens barrel **112** is moved parallel to the z-axis, or, in other words, it is moved parallel to a lens optical axis of a lens (not shown) included in lens barrel **112**. In other examples for focusing, an image sensor included in the POC is moved parallel to the z-axis and relative to lens barrel **112**.

In FIGS. 9A-B, 10A-B, 11A-B, 12A-B and 13A-B, a lens optical axis of a lens (not shown) is oriented parallel to the z-axis.

FIG. 10A shows a P-O assembly numbered **1000** disclosed herein in a cross-sectional view and in a collapsed state. P-O assembly **1000** represents a first example of a first configuration of a “magnetic spring with repelling magnet” (FIG. 9A). P-O assembly **1000** includes a lens barrel **1002**, a first permanent magnet **1012** fixedly coupled to lens barrel **1002,** a second permanent magnet **1016** fixedly coupled to lens barrel **1002**, a third permanent magnet **1018** fixedly coupled to a carrier (not shown) as well as a yoke **1006** fixedly coupled to a carrier (not shown). Interaction of first magnet **1012** with yoke **1006** creates a first force (“F1”) which is directed parallel to the z-axis and pointing upwards, as indicated by arrow **1014**. Interaction of second magnet **1016** with third magnet **1018** creates a second force (“F2”) which is directed parallel to the z-axis and pointing upwards, as indicated by arrow **1020**. In the collapsed state, both F1 and F2 are relatively large, as indicated by the relatively large size (or length) of arrow **1014** and arrow **1020**. In addition, P-O assembly **1000** includes a printed circuit board (PCB) **1004** and, fixedly coupled to PCB **1004**, a coil **1008** and a magnetic flux sensor (e.g. a Hall bar sensor) **1010**. PCB **1004** is fixedly coupled to a carrier (not shown). A magnetization (or “magnetic polarization” or “direction of the magnetic flux”) of the permanent magnets is indicated by arrows within the respective permanent magnet, and namely are as follows: A top half (with respect to the z-axis) **1012a** of magnet **1012** is magnetized parallel to the x-axis, with a magnetization vector pointing away from lens barrel **1002**. A bottom half (with respect to the z-axis) **1012b** of magnet **1012** is magnetized parallel to the x-axis, with a magnetization vector pointing towards lens barrel **1002**. Second magnet **1016** is magnetized parallel to the z-axis, with a magnetization vector pointing downwards, i.e. towards an image sensor (not shown) included in a POC including P-O assembly **1000**. Third magnet **1018** is magnetized parallel to the x-axis shown, with a magnetization vector pointing towards lens barrel **1002**.

FIG. 10B shows P-O assembly **1000** in the same view as FIG. 10A in a P-O state. In the P-O state, both F1 and F2 are relatively small, as indicated by the relatively small size of arrow **1014** and arrow **1020**. For F1, this is caused by the fact that first magnet **1012** and yoke **1006** are closer to an equilibrium position than in collapsed state. For F2, this is caused by the fact that second magnet **1016** and third magnet **1018** are farther away from each other than in the collapsed state.

FIG. 11A shows a P-O assembly numbered **1100** disclosed herein in a cross-sectional view and in a collapsed state. P-O assembly **1100** represents a second example of a first configuration of a “magnetic spring with repelling magnet” (FIG. 9A). Except differences in a second permanent magnet and in a third permanent magnet, P-O assembly **1100** is identical to P-O assembly **1000**. P-O assembly **1100** includes a second permanent magnet **1102** fixedly coupled to lens barrel **1002** and a third permanent magnet **1104** fixedly coupled to a carrier (not shown). Interaction of first magnet **1012** with yoke **1006** creates a first force (“F1”). Interaction of second magnet **1102** with third magnet **1104** creates a second force (“F2”) which is directed parallel to the z-axis and pointing upwards, as indicated by arrow **1106**. In the collapsed state, both F1 and F2 are relatively large, as indicated by the relatively large size of arrow **1014** and arrow **1106**. Second magnet **1102** is magnetized parallel to the z-axis, with a magnetization vector pointing downwards, i.e. towards an image sensor (not shown). Third magnet **1104** is magnetized parallel to the z-axis, with a magnetization vector pointing upwards, as shown.

FIG. 11B shows P-O assembly **1100** in the same view as FIG. 11A in a P-O state. In the P-O state, both F1 and F2 are relatively small, as indicated by the relatively small size of arrow **1014** and arrow **1106**. For F2, this is caused by the fact that second magnet **1102** and third magnet **1104** are farther away from each other than in the collapsed state.

FIG. 12A shows a P-O assembly numbered **1200** disclosed herein in a cross-sectional view and in a collapsed state. P-O assembly **1200** represents a first example of a second configuration of a “magnetic spring with repelling magnet” (FIG. 9B). In addition to components described above, P-O assembly **1200** includes a second permanent magnet **1202** fixedly coupled to a carrier (not shown). Interaction of second magnet **1202** with first magnet **1012** creates a second force ("F2") which is directed parallel to the z-axis and pointing upwards, as indicated by arrow **1204**. In the collapsed state, both F1 and F2 are relatively large, as indicated by the relatively large size of arrow **1014** and arrow **1204**. Second magnet **1202** is magnetized parallel to the x-axis, with a magnetization vector pointing towards lens barrel **1002**.

FIG. 12B shows P-O assembly **1200** in the same view as FIG. 12A in a P-O state. In the P-O state, both F1 and F2 are relatively small, as indicated by the relatively small size of arrow **1014** and arrow **1204**. For F2, this is caused by the fact that second magnet **1202** and first magnet **1012** are farther away from each other than in the collapsed state.

In a POC including one of P-O assembly **1000**, P-O assembly **1100**, or P-O assembly **1200**, yoke **1006**, coil **1008**, first magnet **1012** and (optionally) magnetic flux sensor **1010** may form a voice coil motor (VCM). The VCM may be operational to axially move lens barrel **1002** including a lens (not shown) parallel to the z-axis and relative to a carrier (not shown) for focusing.

FIG. 13A shows a P-O assembly numbered **1300** disclosed herein in a cross-sectional view and in a collapsed state. P-O assembly **1300** represents a second example of a second configuration of a "magnetic spring with repelling magnet" (FIG. 9B). In addition to components described above, P-O assembly **1200** includes a first permanent magnet **1302** which is fixedly coupled to lens barrel **1002** and a second permanent magnet **1304** which is fixedly coupled to a carrier (not shown).. Interaction of first magnet **1302** with yoke **1006** creates a first force ("F1") which is directed parallel to the z-axis and pointing upwards, as indicated by arrow **1306**. Interaction of first magnet **1302** with second magnet **1304** creates a second force ("F2") which is directed parallel to the z-axis and pointing upwards, as indicated by arrow **1308**. In the collapsed state, both F1 and F2 are relatively large, as indicated by the relatively large size of arrow **1306** and arrow **1308**. First magnet **1302** is magnetized parallel to the z-axis, with a magnetization vector pointing downwards, i.e. towards an image sensor (not shown). Second magnet **1304** is magnetized parallel to the z-axis, with a magnetization vector pointing upwards.

FIG. 13B shows P-O assembly **1300** in the same view as FIG. 13A in a P-O state. In the P-O state, both F1 and F2 are relatively small, as indicated by the relatively small size of arrow **1306** and arrow **1308**. For F1, this is caused by the fact that first magnet **1302** and yoke **1006** are closer to an equilibrium position than in collapsed state. For F2, this is caused by the fact that first magnet **1302** and second magnet **1304** are farther away from each other than in the collapsed state.

In a POC including P-O assembly **1300**, yoke **1006**, coil **1008**, first magnet **1302** and (optionally) magnetic flux sensor **1010** may form a VCM. The VCM may be operational to axially move lens barrel **1002** including a lens (not shown) parallel to the z-axis and relative to a carrier (not shown) for focusing.

All patents and patent applications mentioned in this specification are herein incorporated by reference into the specification in their entirety, to the same extent as if each individual patent or patent application was specifically and individually indicated to be incorporated by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present disclosure.

While this disclosure has been described in terms of certain examples and generally associated methods, alterations and permutations of the examples and methods will be apparent to those skilled in the art. The disclosure is to be understood as not limited by the specific examples described herein, but only by the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A pop-out lens module, comprising:

an inner part;

an outer part having an outer part diameter d_O;

a gap between the inner part and outer part having a maximum gap width $W_{G\text{-}Max}$;

a moving lens group fixedly coupled to the inner part, the moving lens group including a plurality of N lens elements and having an optical axis, wherein a maximum lens element diameter of all the moving lens elements is DA_{Max}; and

an actuator that includes an open spring located in the gap, wherein the open spring is operative to move the inner part relative to the outer part in a first direction parallel to the optical axis to an operative state when no external forces are applied, wherein the inner part can move relative to the outer part in a second direction opposite to the first direction to a collapsed state under an external force, wherein $d_O = DA_{Max}$ + a penalty p, wherein 0.5mm< p <2.5mm, and wherein 3mm< DA_{Max}<15mm.

2. The pop-out lens module of claim 1, wherein 0.5mm < p < 2mm.

3. The pop-out lens module of claim 1, wherein 0.5mm < p < 1.5mm.

4. The pop-out lens module of claim 1, wherein 0.5mm < p < 1mm.

5. The pop-out lens module of claim 1, wherein 5mm < DA < 12.5mm.

6. The pop-out lens module of claim 1, wherein 5mm < DA < 10mm.

7. The pop-out lens module of claim 1, wherein the open spring has an open spring length $L_{Spring} > W_{G\text{-}Max}$.

8. The pop-out lens module of claim 1, wherein the open spring is 1-folded.

9. The pop-out lens module of claim 1, wherein the open spring is 7-folded.

10. The pop-out lens module of claim 1, wherein the open spring is straight.

11. The pop-out lens module of claim 1, wherein the open spring is curved.

12. The pop-out lens module of claim 1, wherein the open spring is tapered.

13. The pop-out lens module of claim 1, wherein the open spring is angled.

14. The pop-out lens module of claim 1, wherein the open spring has 2 - 6 serpentines.

15. The pop-out lens module of claim 1, wherein the open spring has 2 - 4 windings.

16. The pop-out lens module of claim 7, wherein $1mm \leq L_{Spring} \leq 15mm$.

17. The pop-out lens module of claim 7, wherein $4mm \leq L_{Spring} \leq 8mm$.

18. The pop-out lens module of claim 1, wherein the open spring has an open spring width W_{Spring} and wherein $0.1mm \leq W_{Spring} \leq 1mm$.

19. The pop-out lens module of claim 18, wherein $0.15mm \leq W_{Sprin} \leq 0.5mm$.

20. The pop-out lens module of claim 1, wherein the open spring has an open spring height in a collapsed state $c\text{-}H_{Spring}$ and an open spring height in a pop-out state H_{Spring}, and wherein a ratio $c\text{-}H_{Spring}/H_{Spring}$ fulfills $1/4 \leq c\text{-}H_{Spring}/H_{Spring} \leq 3/4$.

21. The pop-out lens module of claim 20, wherein the open spring has an open spring height in a collapsed state $c\text{-}H_{Spring}$ and an open spring height in a pop-out state H_{Spring}, wherein $1mm \leq c\text{-}H_{Spring} \leq 15mm$ and wherein $1mm \leq H_{Spring} \leq 20mm$.

22. The pop-out lens module of claim 21, wherein $1mm \leq c\text{-}H_{Spring} \leq 10mm$ and wherein $1mm \leq H_{Spring} \leq 15mm$.

23. The pop-out lens module of claim 21, wherein $1mm \leq c\text{-}H_{Spring} \leq 8mm$ and wherein $1mm \leq H_{Spring} \leq 12mm$.

24. The pop-out lens module of claim 1, wherein the pop-out lens module includes a

kinematic coupling mechanism that provides mechanical accuracy and repeatability to the movement of the inner part relative to the outer part.

25. The pop-out lens module of claim 24, wherein the kinematic coupling mechanism includes one or more pin-groove mechanisms.

26. The pop-out lens module of claim 25, wherein the kinematic coupling mechanism includes three pin-groove mechanisms.

27. The pop-out lens module of any of the claims 1-26 included in a pop-out camera, wherein the pop-out camera has a total track length TTL in the operative state and a collapsed total track length cTTL in the collapsed state, and wherein cTTL/TTL < 0.9.

28. The pop-out lens module of claim 27, wherein cTTL/TTL < 0.8.

29. The pop-out lens module of claim 27, wherein cTTL/TTL < 0.75.

30. The pop-out lens module of claim 27, wherein cTTL/TTL < 0.7.

31. The pop-out lens module of claim 27, wherein the pop-out camera includes a retractable cover window and wherein the retractable cover window pushes on the inner part to bring the pop-out camera to the collapsed state.

32. The pop-out lens module of claim 27, wherein the pop-out camera includes a lens formed by the moving lens group.

33. The pop-out lens module of claim 32, wherein the lens is movable along the optical axis for focusing.

34. The pop-out lens module of claim 27, wherein the pop-out camera includes a lens, wherein the lens is formed by the moving lens group fixedly coupled to the inner part and by a non-moving lens group fixedly coupled to the outer part.

35. The pop-out lens module of claim 34, wherein the moving lens group is movable along the optical axis for focusing.

36. The pop-out lens module of claim 27, wherein the pop-out camera is a Wide camera including a Wide camera image sensor having a sensor diagonal SD in the range of 12-30mm, wherein the Wide camera has an effective focal length EFL in the range of 5-20mm, and wherein cTTL/SD < 0.8.

37. The pop-out lens module of claim 36, wherein cTTL/SD < 0.75.

38. The pop-out lens module of claim 36, wherein cTTL/SD < 0.7.

39. The pop-out lens module of claim 36, wherein cTTL/SD < 0.65.

40. The pop-out lens module of claim 36, wherein cTTL/SD < 0.6.

41. The pop-out lens module of claim 27, wherein the pop-out camera is a Tele camera having an effective focal length EFL in the range of 10-30mm, and wherein a ratio cTTL/EFL < 0.8.

42. The pop-out lens module of claim 41, wherein cTTL/EFL < 0.75.

43. The pop-out lens module of claim 41, wherein cTTL/EFL < 0.7.

44. The pop-out lens module of claim 41, wherein cTTL/EFL < 0.65.

45. The pop-out lens module of claim 41, wherein cTTL/EFL < 0.6.

46. The pop-out lens module of claim 27, wherein the pop-out camera is included in a mobile device.

47. The pop-out lens module of claim 46, wherein the mobile device is a smartphone.

48. The pop-out lens module of claim 27, wherein the pop-out camera is included in a multi-camera together with at least one additional camera.

49. The pop-out lens module of claim 46, wherein the pop-out lens module is moved

perpendicular to the optical axis for optical image stabilization.

50. The pop-out lens module of claim 46, wherein the pop-out camera includes an image sensor that is movable perpendicular to the optical axis for optical image stabilization.

51. A pop-out camera having an operative state and a collapsed state, the pop-out camera comprising:

an image sensor having an image sensor diagonal SD;

a lens including a plurality of N lens elements and comprising a moving lens group including $M \leq N$ lens elements, the moving lens group having a lens optical axis;

a lens barrel containing the moving lens group;

a carrier configured to receive the lens barrel, the lens barrel axially movable relative to the carrier; and

a magnetic spring assembly comprising a first permanent magnet fixedly coupled to the lens barrel, a second permanent magnet, and a ferromagnetic yoke being fixedly coupled to the carrier,

wherein the magnetic spring assembly is configured to cause the lens barrel to move axially relative to the carrier along a first direction along the lens optical axis from the collapsed state towards the operative state;

and wherein the image sensor is configured to image a field of view of the lens when the lens barrel is in the operative state.

52. The pop-out camera of claim 51, wherein the second permanent magnet is fixedly coupled to the carrier, wherein the first permanent magnet is divided into a top half and a bottom half, wherein both the top half and the bottom half have a magnetization that is perpendicular to the first direction, and wherein the magnetization of the bottom half is anti-parallel to the magnetization of the top half.

53. The pop-out camera of claim 51, wherein the second permanent magnet is fixedly coupled to the carrier, and wherein the second permanent magnet has a magnetization that is perpendicular to the first direction.

54. The pop-out camera of claim 51, wherein the second permanent magnet has a magnetization that is perpendicular to the first direction, and wherein a magnetization vector of the second permanent magnet is parallel to a magnetization vector of the bottom half of the first permanent magnet.

55. The pop-out camera of claim 51, wherein the second permanent magnet is fixedly coupled to the carrier, wherein the first permanent magnet has a magnetization that is parallel to the first direction, and wherein a respective magnetization vector points towards the image sensor.

56. The pop-out camera of claim 51, wherein the second permanent magnet is fixedly coupled to the carrier, wherein the second permanent magnet has a magnetization that is parallel to the first direction, and wherein a respective magnetization vector points away from the image sensor.

57. The pop-out camera of claim 51, wherein the magnetic spring assembly comprises a third permanent magnet that is fixedly coupled to the lens barrel.

58. The pop-out camera of claim 56, wherein the third permanent magnet has a magnetization that is parallel to the first direction, and wherein a respective magnetization vector points towards the image sensor.

59. The pop-out camera of claim 56, wherein the second permanent magnet has a magnetization which is perpendicular to the first direction, and wherein a magnetization vector points towards the lens barrel.

60. The pop-out camera of claim 56, wherein the second permanent magnet has a magnetization which is parallel to the first direction, and wherein a magnetization vector points away from the image sensor.

61. The pop-out camera of any of the claims 51-60, wherein the pop-out camera has a total track length TTL in the operative state and a collapsed total track length cTTL in the collapsed state, and wherein $cTTL/TTL < 0.9$.

62. The pop-out camera of claim 61, wherein $cTTL/TTL < 0.8$.

63. The pop-out camera of claim 61, wherein cTTL/TTL < 0.75.

64. The pop-out camera of claim 61, wherein cTTL/TTL < 0.7.

65. The pop-out camera of claim 61, wherein the pop-out camera includes a lens formed by the moving lens group.

66. The pop-out camera of claim 65, wherein the lens is movable along the optical axis for focusing.

67. The pop-out camera of claim 61, wherein the pop-out camera includes a lens, and wherein the lens is formed by the moving lens group fixedly coupled to the inner part and by a non-moving lens group fixedly coupled to the outer part.

68. The pop-out camera of claim 67, wherein the moving lens group is movable along the optical axis for focusing.

69. The pop-out camera of claim 51, wherein the pop-out camera is a Wide camera including a Wide camera image sensor having a sensor diagonal SD in the range of 12-30mm, wherein the Wide camera has an effective focal length EFL in the range of -20mm, and wherein cTTL/SD < 0.8.

70. The pop-out camera of claim 69, wherein cTTL/SD < 0.75.

71. The pop-out camera of claim 69, wherein cTTL/SD < 0.7.

72. The pop-out camera of claim 69, wherein cTTL/SD < 0.65.

73. The pop-out camera of claim 69, wherein cTTL/SD < 0.6.

74. The pop-out camera of claim 51, wherein the pop-out camera is a Tele camera having an effective focal length EFL in the range of 10-30mm, and wherein a ration between a collapsed total track length cTTL in the collapsed state and EFL fulfills cTTL/EFL < 0.8.

75. The pop-out camera of claim 74, wherein cTTL/EFL < 0.75.

76. The pop-out camera of claim 74, wherein cTTL/EFL < 0.7.

77. The pop-out camera of claim 74, wherein cTTL/EFL < 0.65.

78. The pop-out camera of claim 74, wherein cTTL/EFL < 0.6.

79. The pop-out camera of claim 51, wherein the pop-out camera is included in a mobile device.

80. The pop-out camera of claim 79, wherein the mobile device is a smartphone.

81. The pop-out camera of claim 79, wherein the pop-out camera is included in a multi-camera together with at least one additional camera.

82. The pop-out camera of claim 79, wherein the lens is moved perpendicular to the optical axis for optical image stabilization.

83. The pop-out camera of claim 79, wherein the image sensor is moved perpendicular to the optical axis for optical image stabilization.

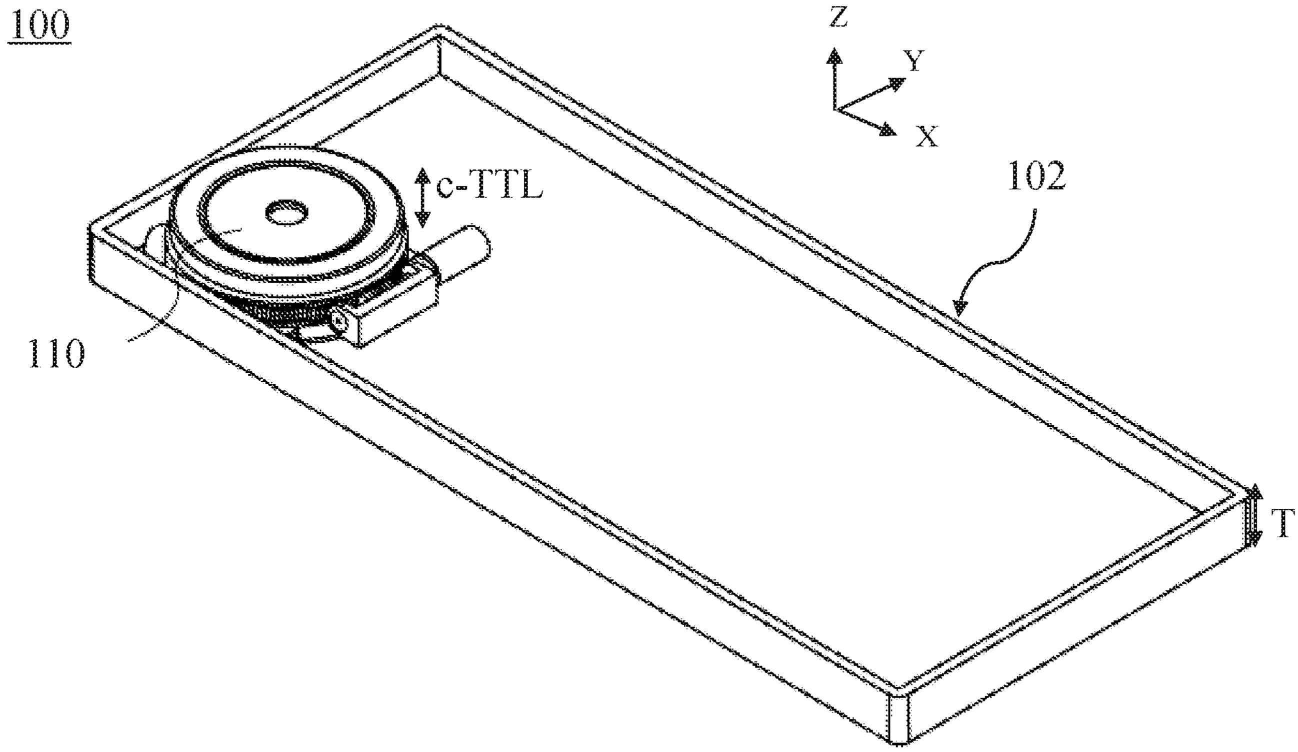


FIG. 1A KNOWN ART

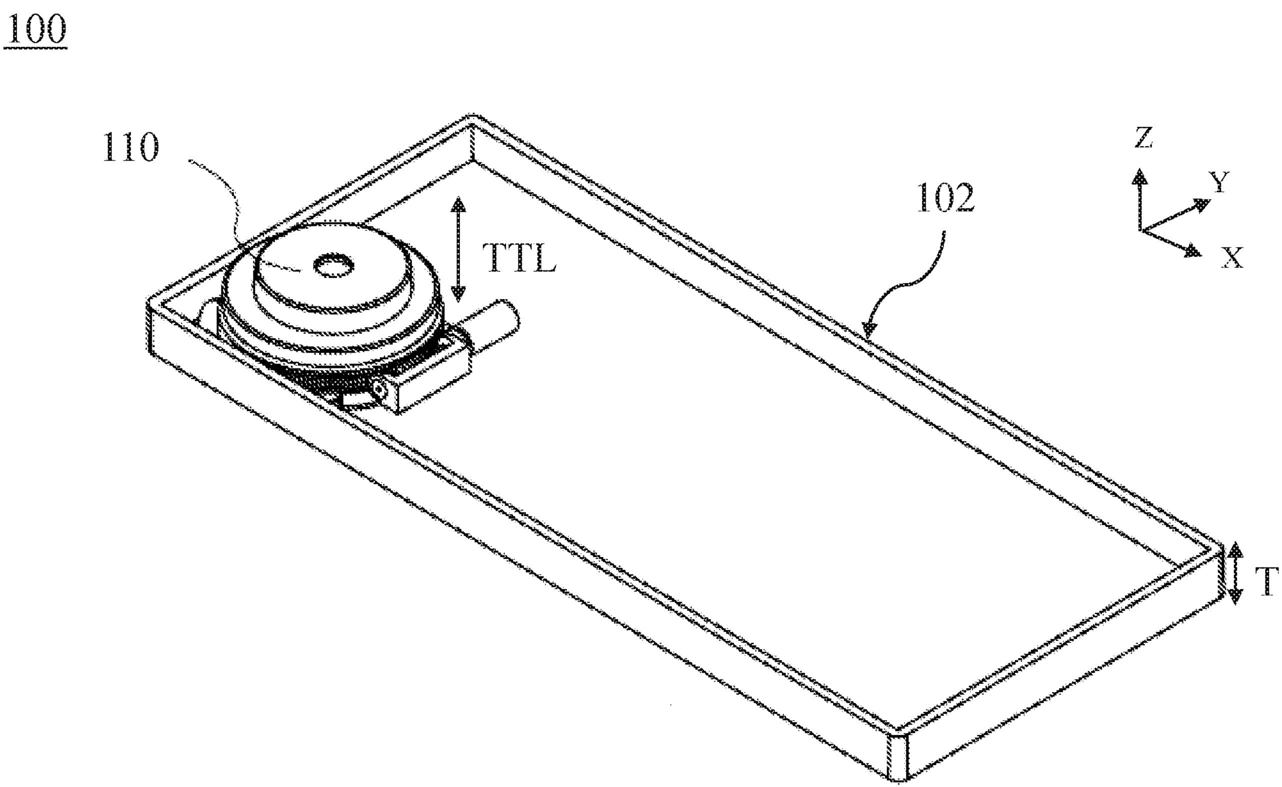


FIG. 1B KNOWN ART

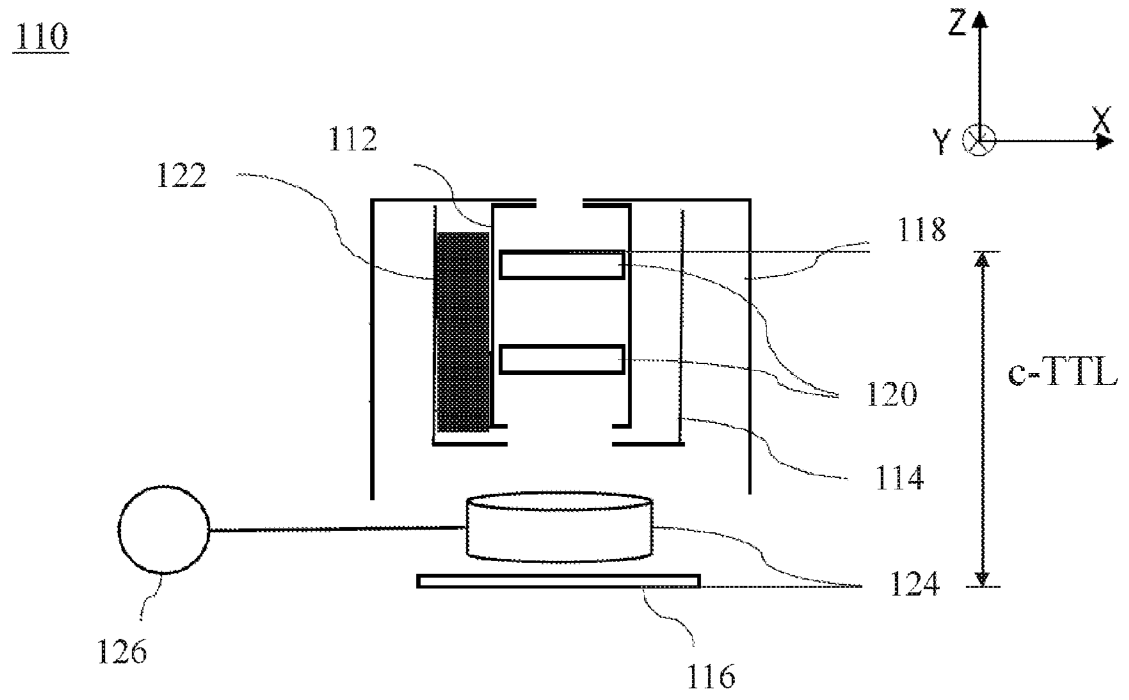


FIG. 1C KNOWN ART

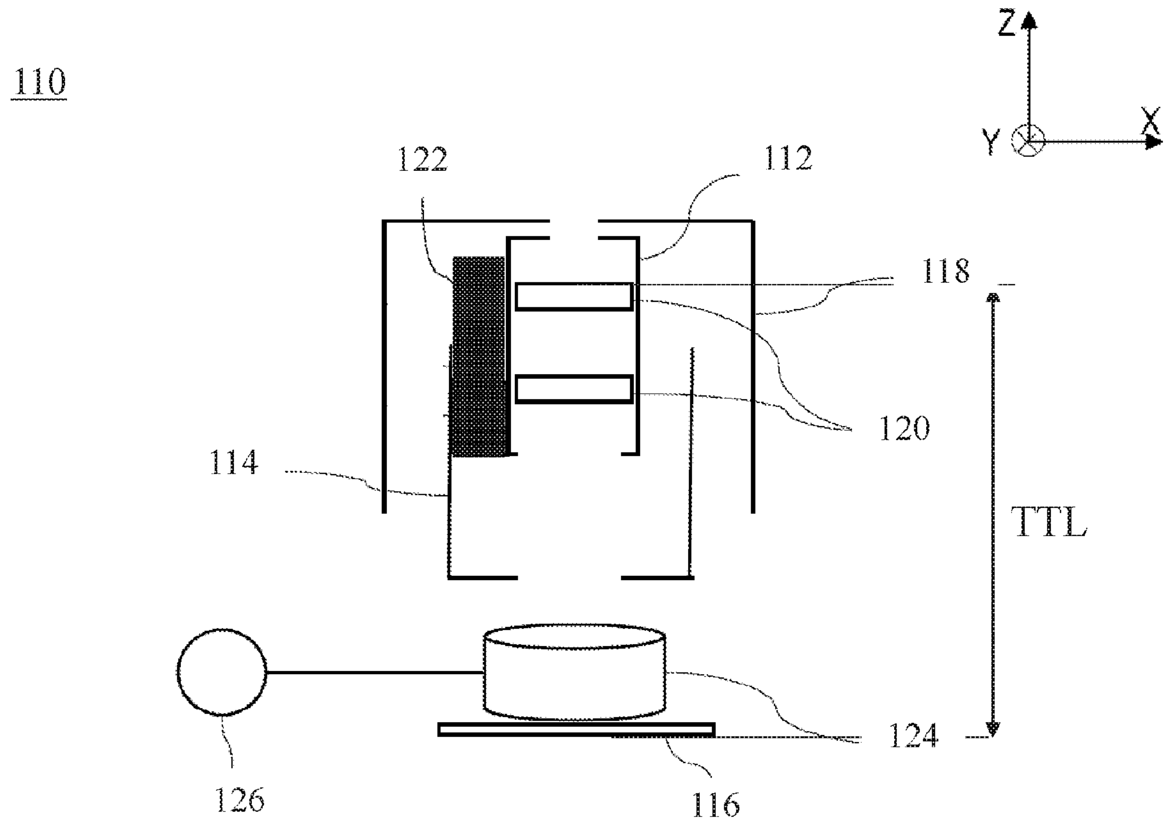


FIG. 1D KNOWN ART

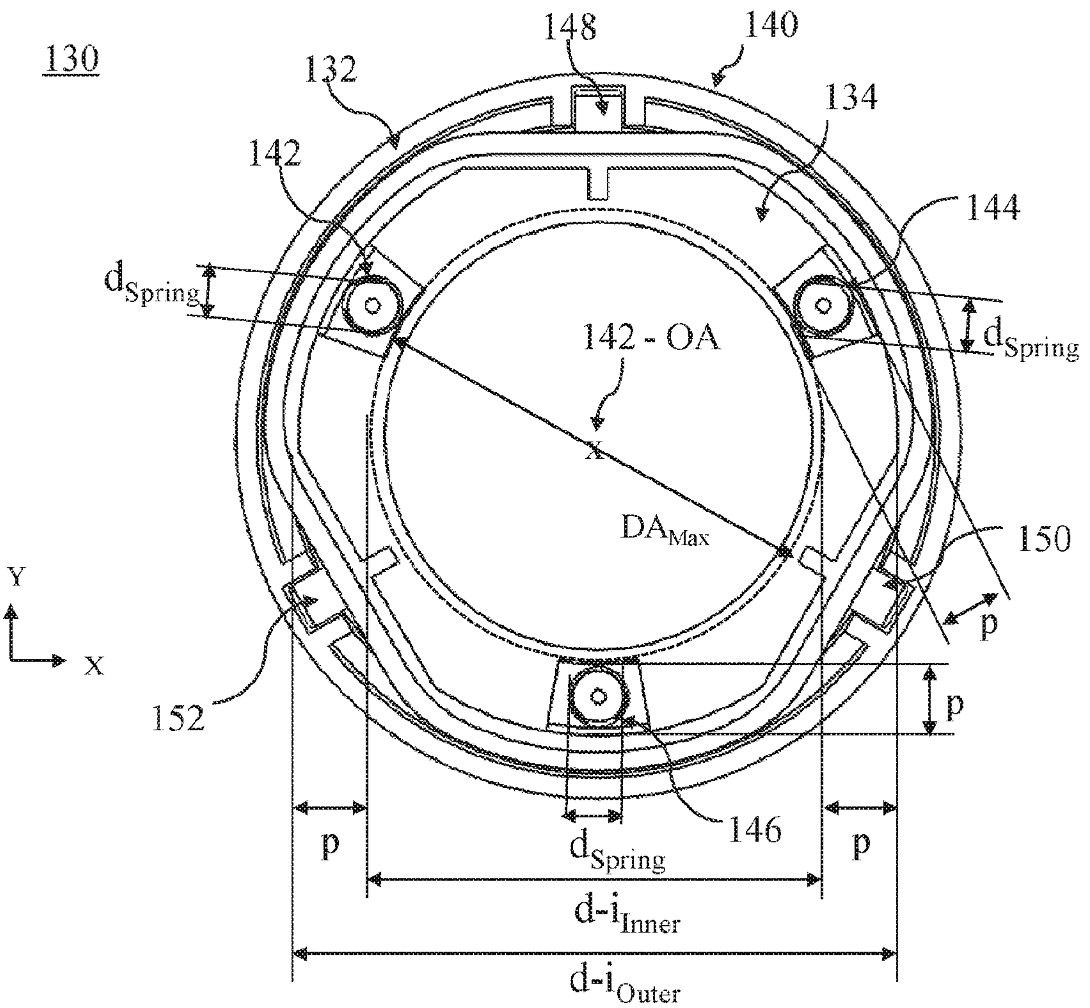


FIG. 1E KNOWN ART

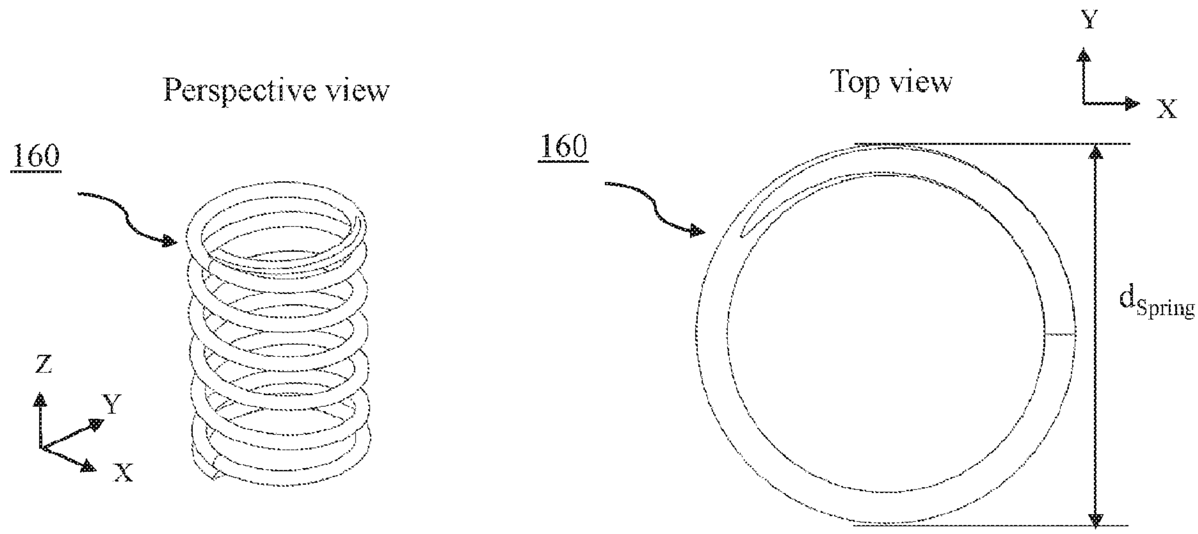


FIG. 1F KNOWN ART

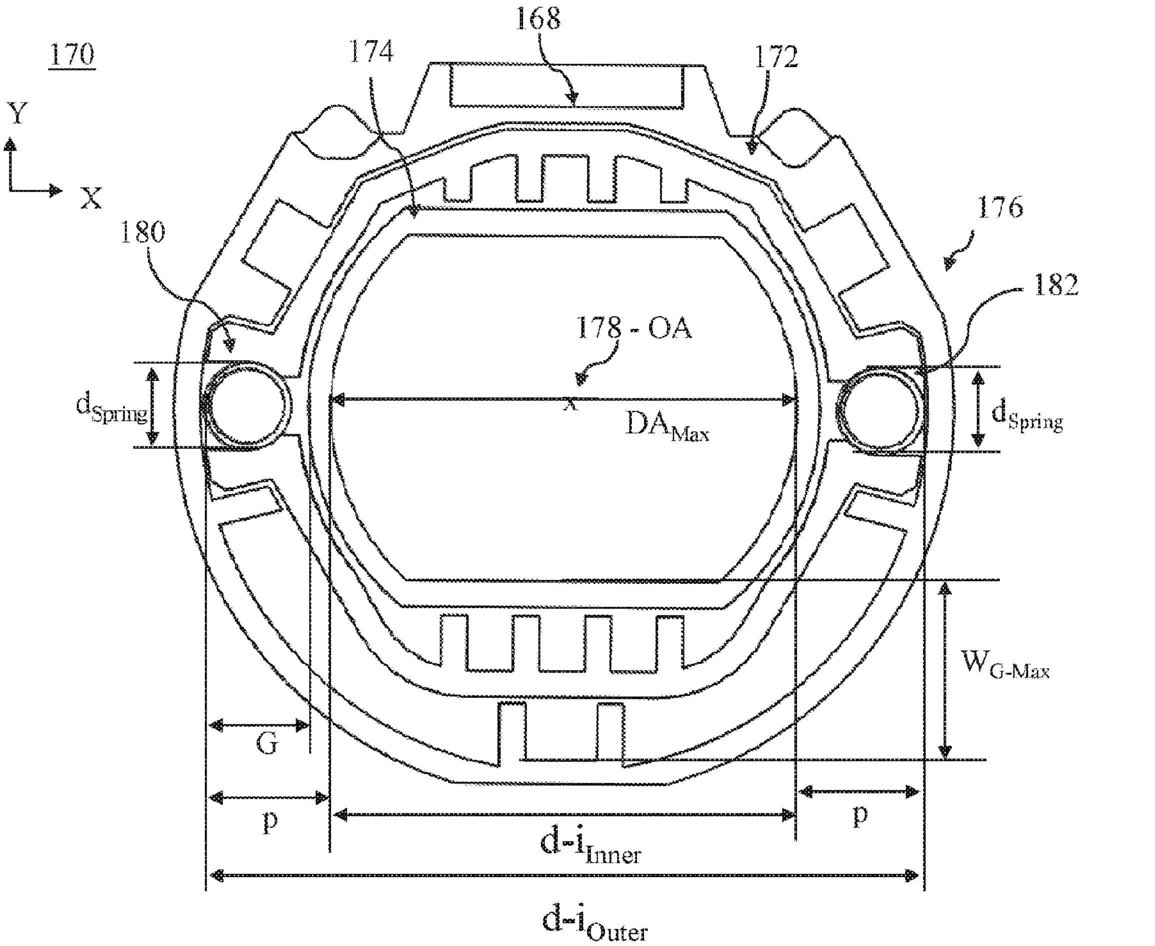


FIG. 1G KNOWN ART

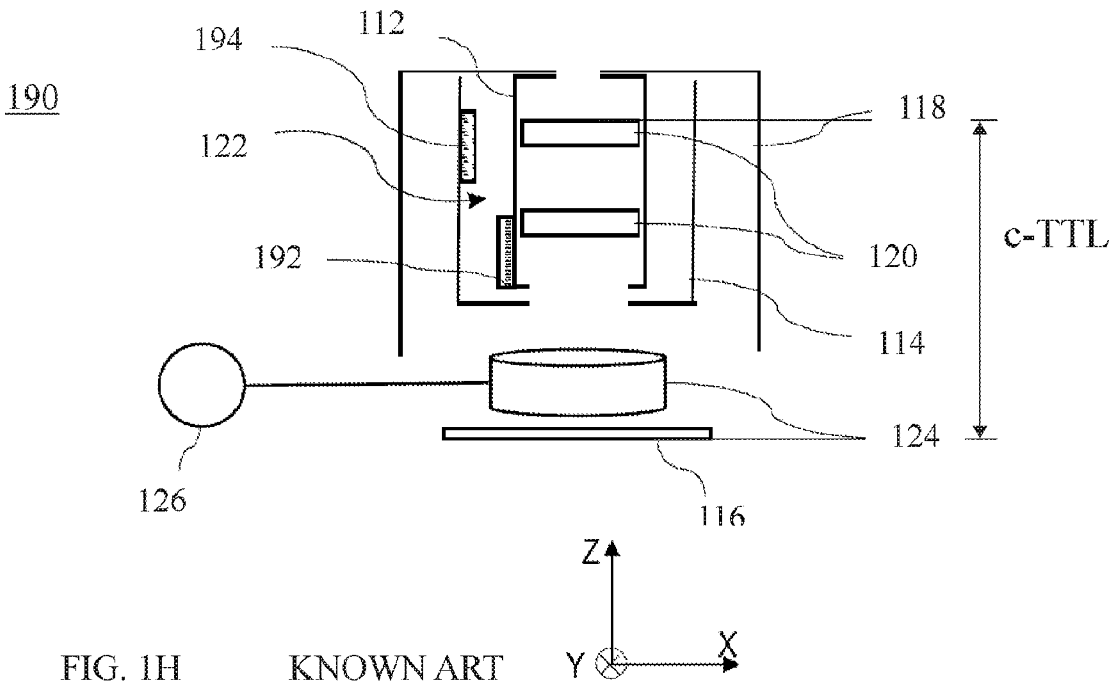


FIG. 1H KNOWN ART

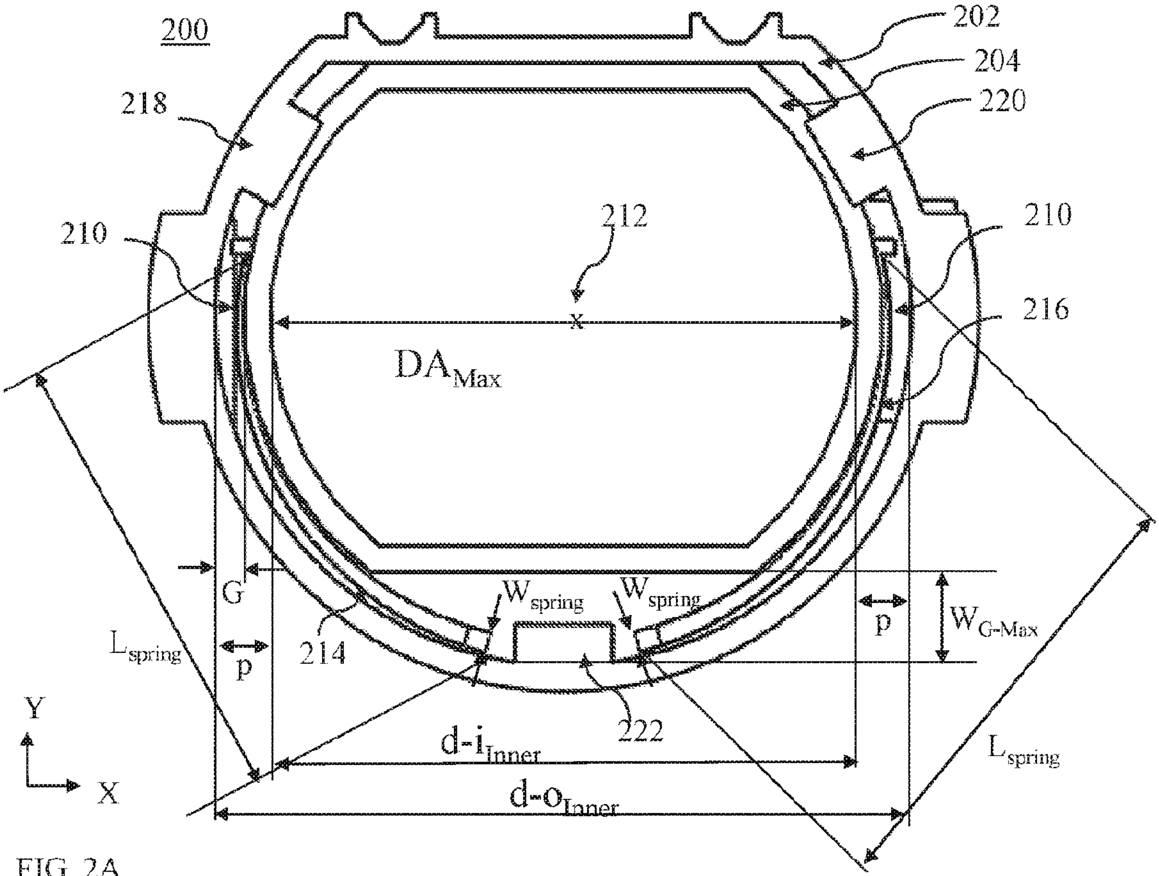
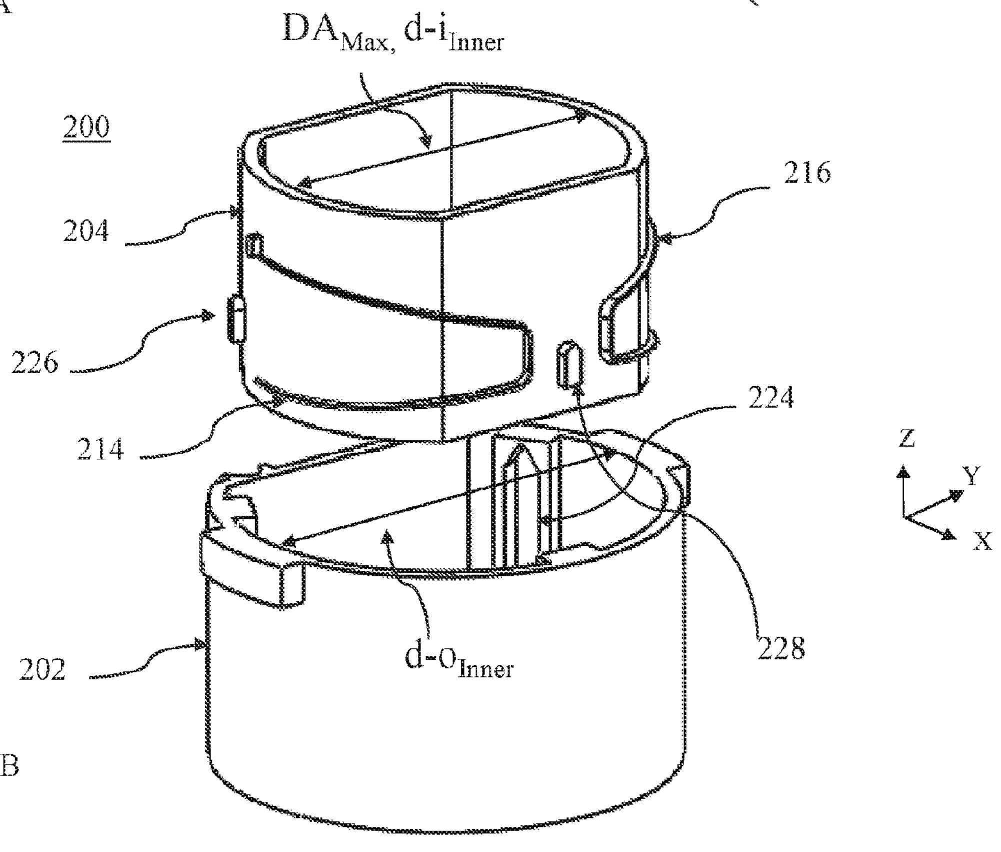

200
202
204
218
220
210
212
210
216
DA_{Max}
G
W_{spring}
W_{spring}
p
$W_{G\text{-}Max}$
L_{spring}
214
p
222
Y
X
$d\text{-}i_{Inner}$
$d\text{-}o_{Inner}$
L_{spring}

FIG. 2A


DA_{Max}, $d\text{-}i_{Inner}$
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224
Z
Y
X
228
202
$d\text{-}o_{Inner}$

FIG. 2B

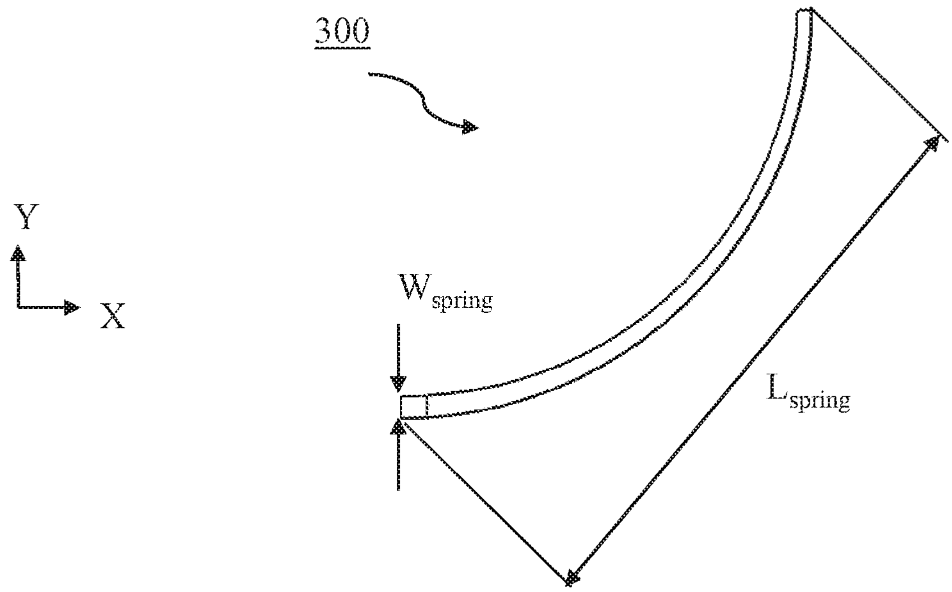


FIG. 3A

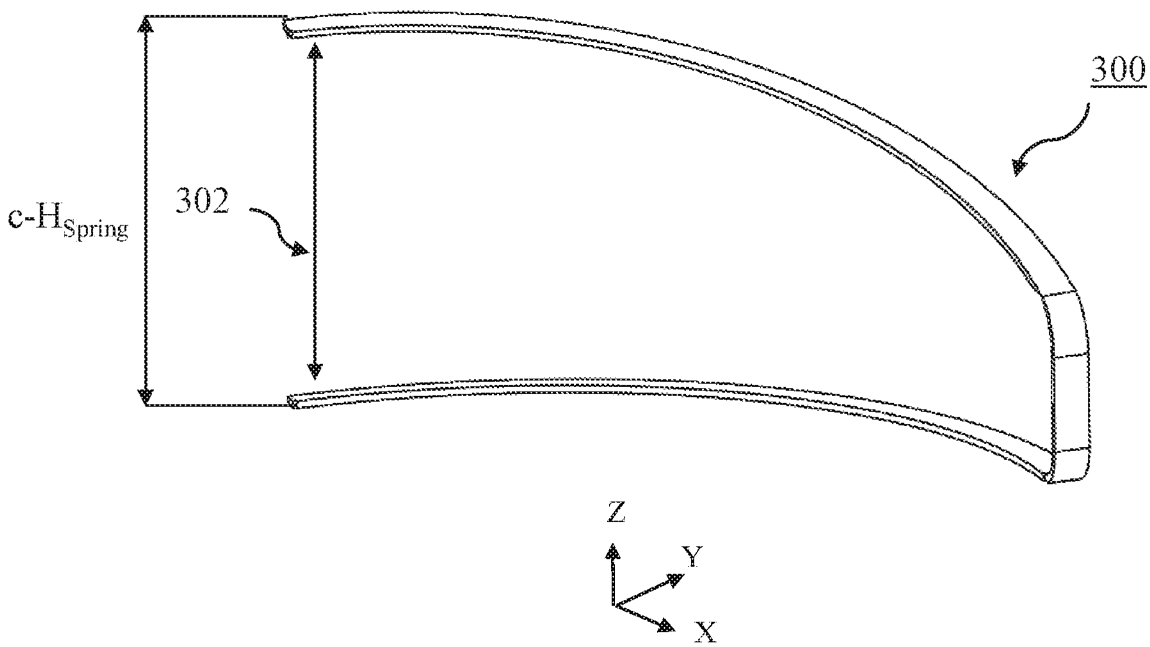


FIG. 3B

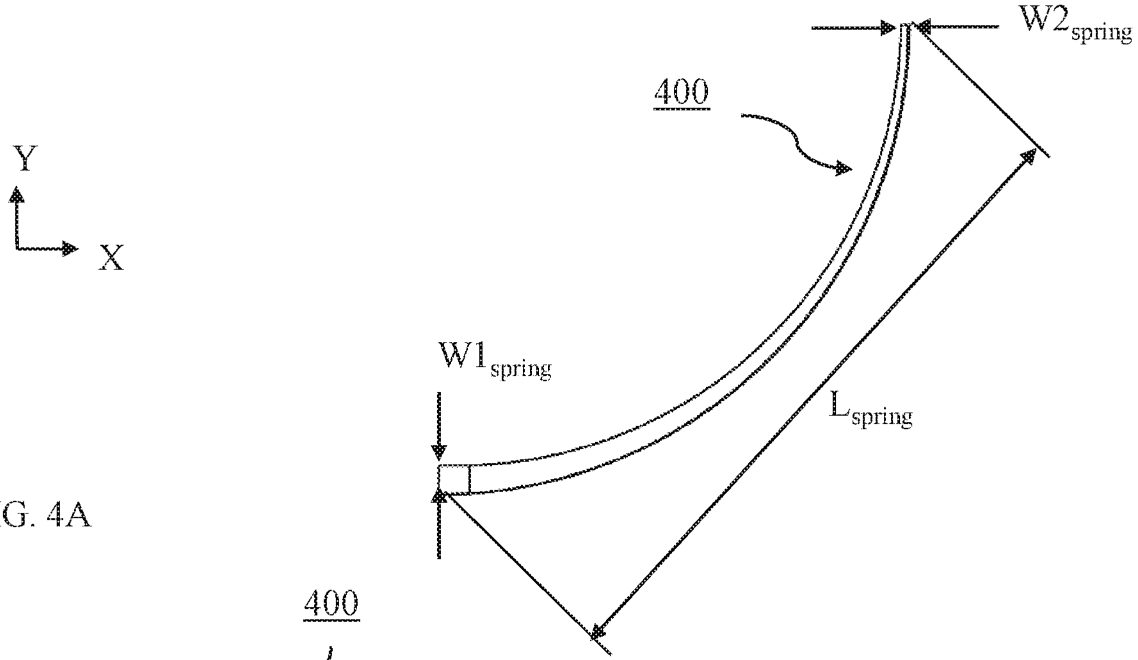


FIG. 4A

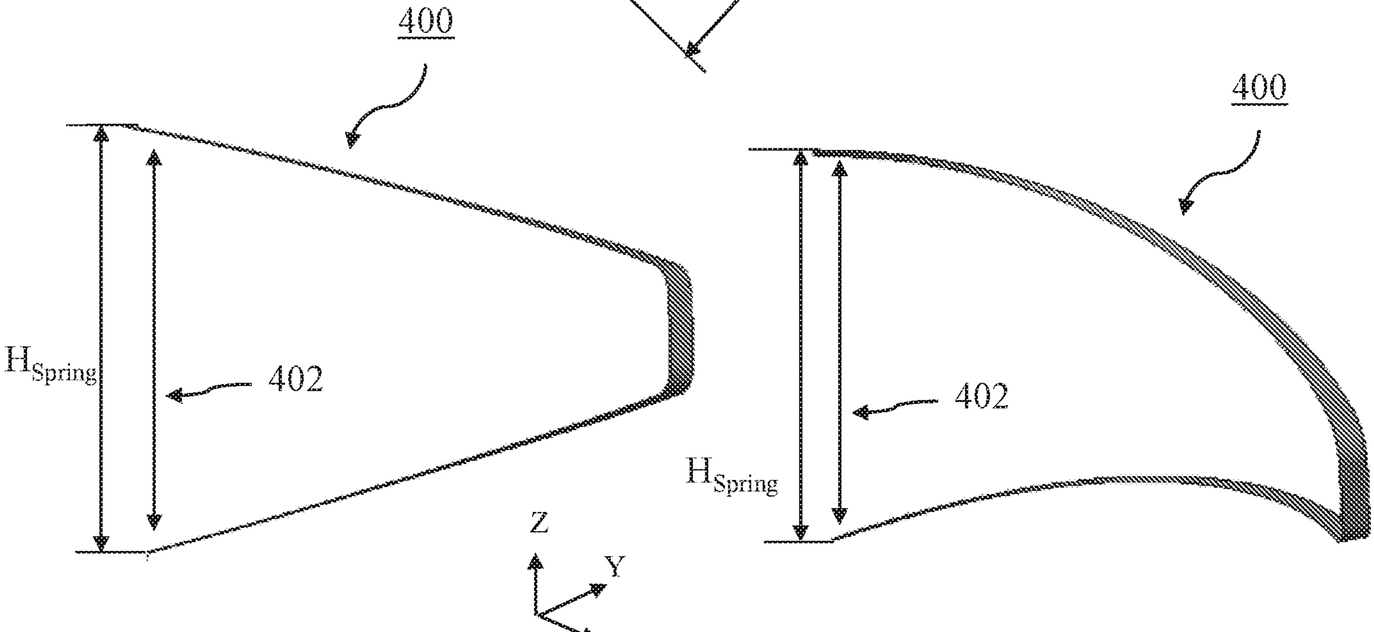


FIG. 4B

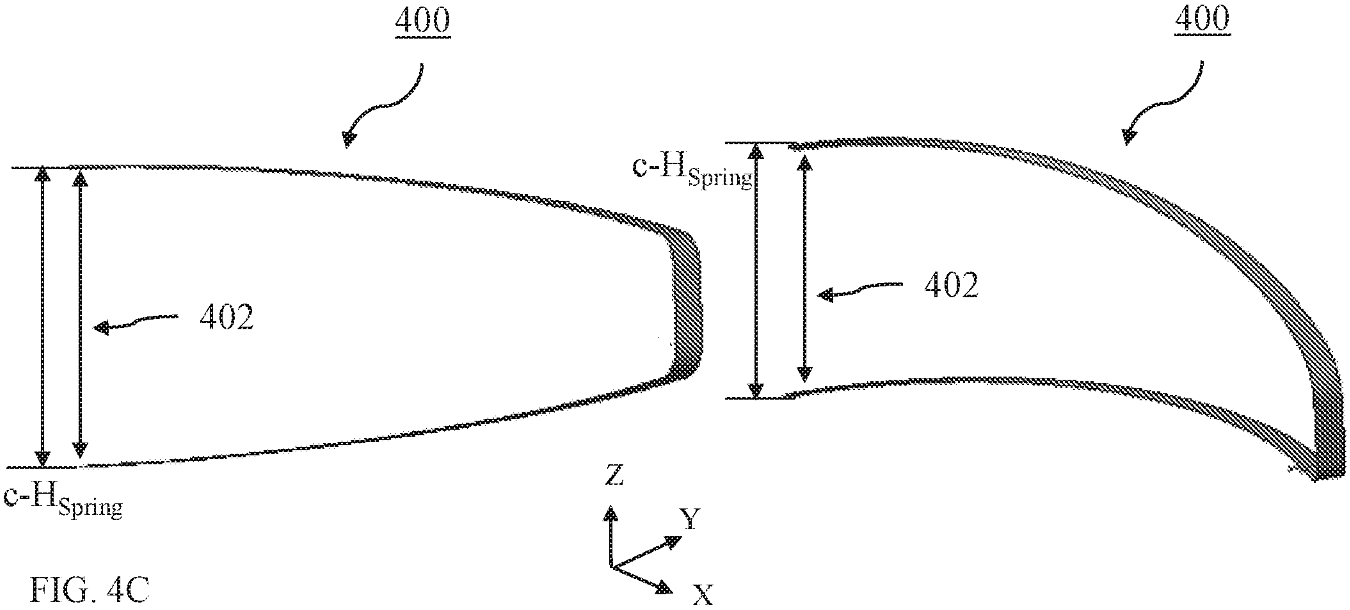


FIG. 4C

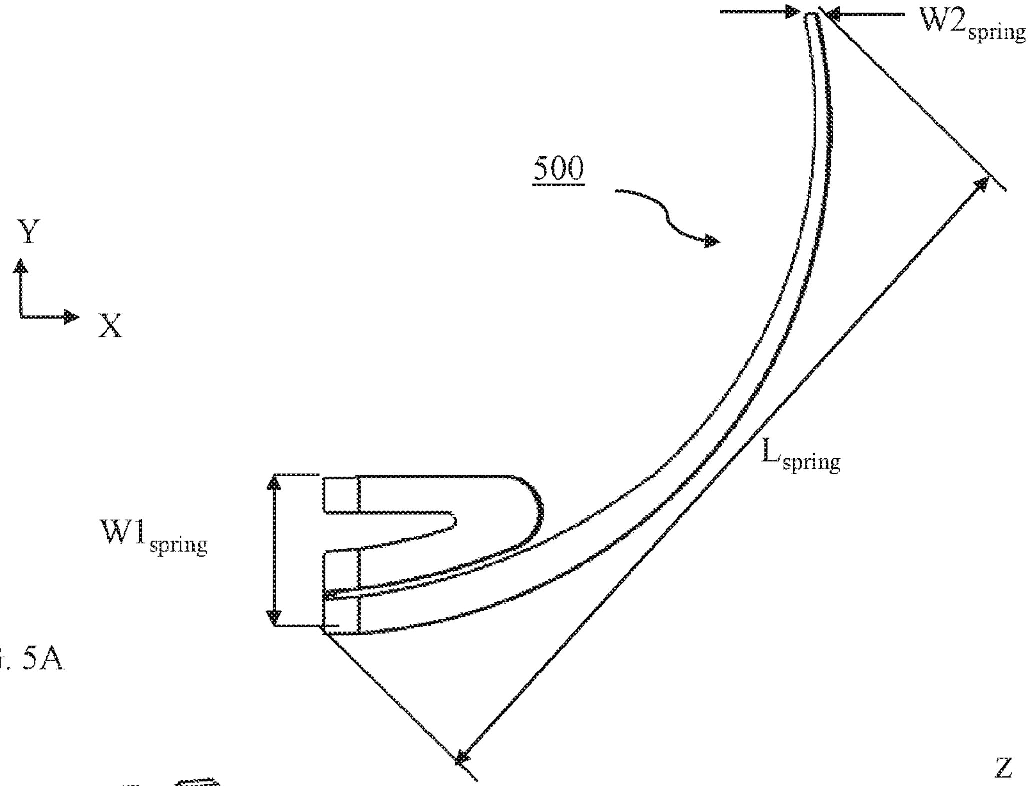


FIG. 5A

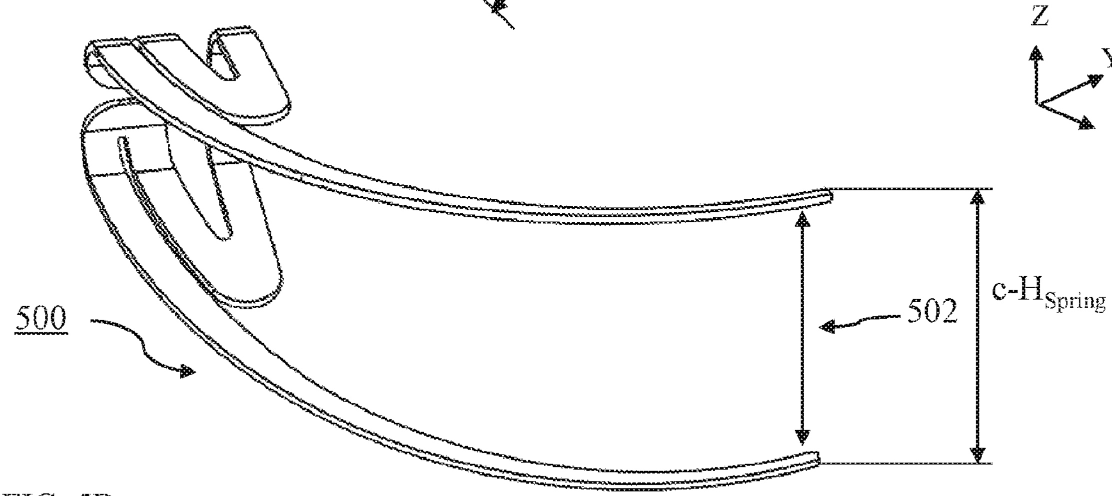


FIG. 5B

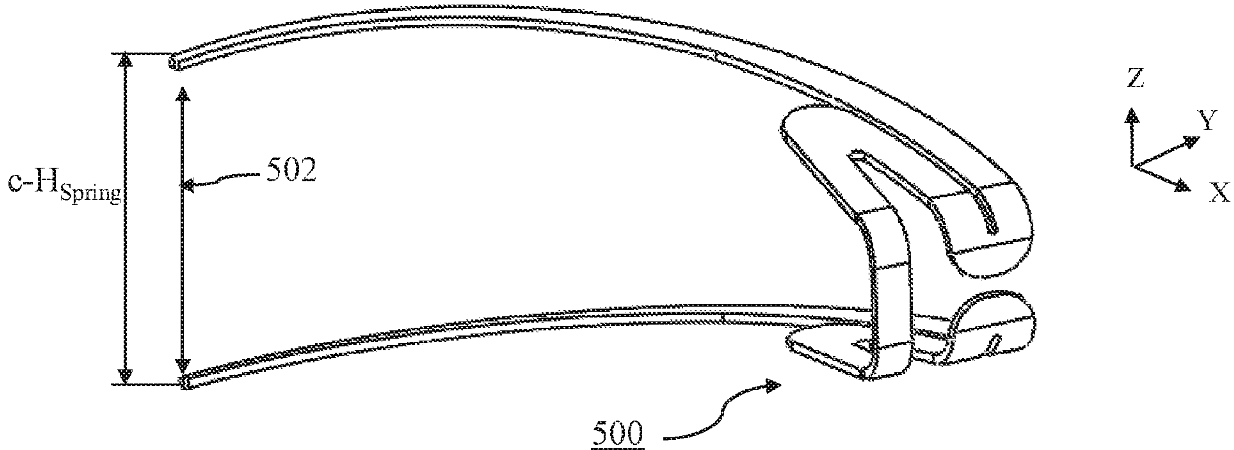


FIG. 5C

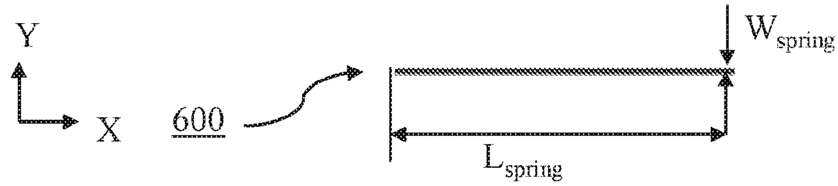


FIG. 6A

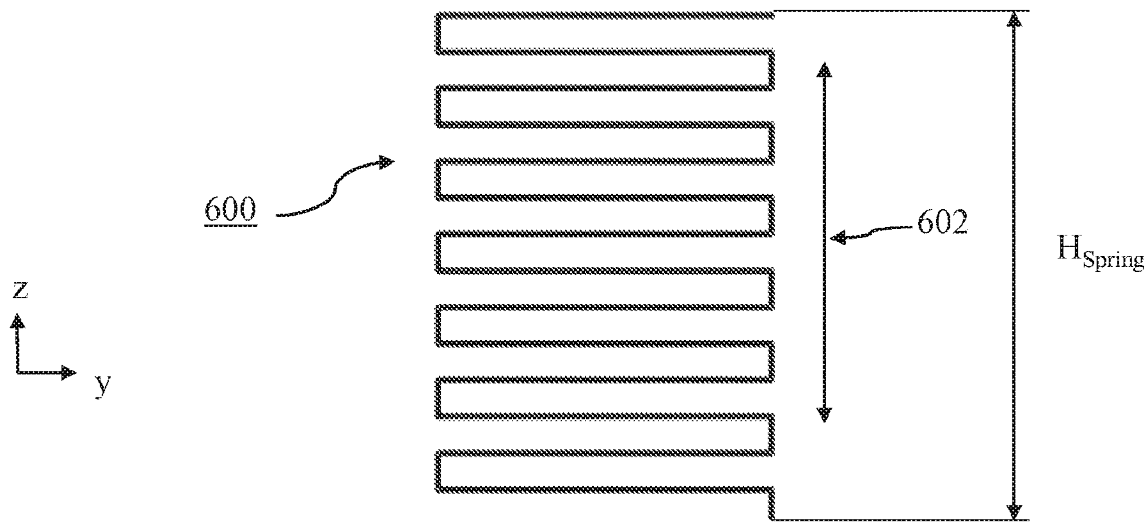


FIG. 6B

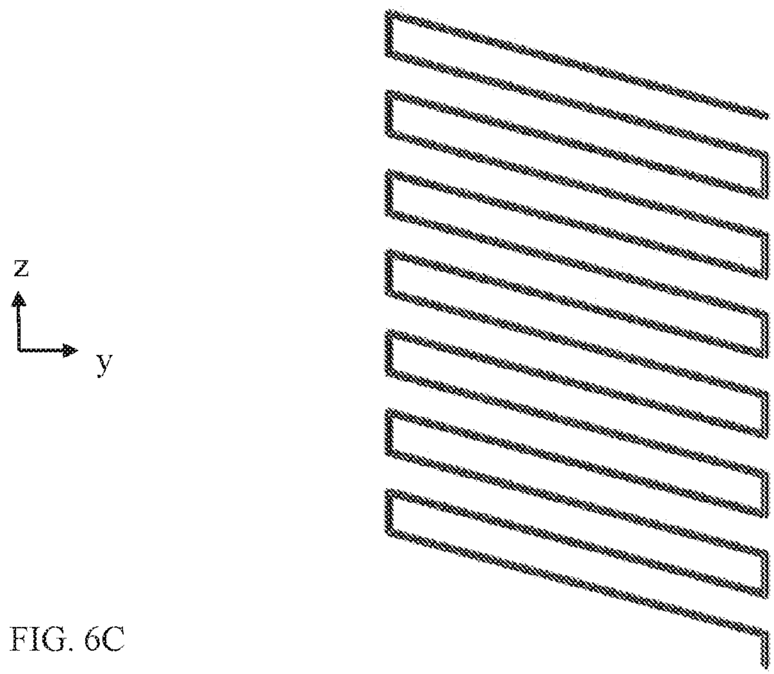


FIG. 6C

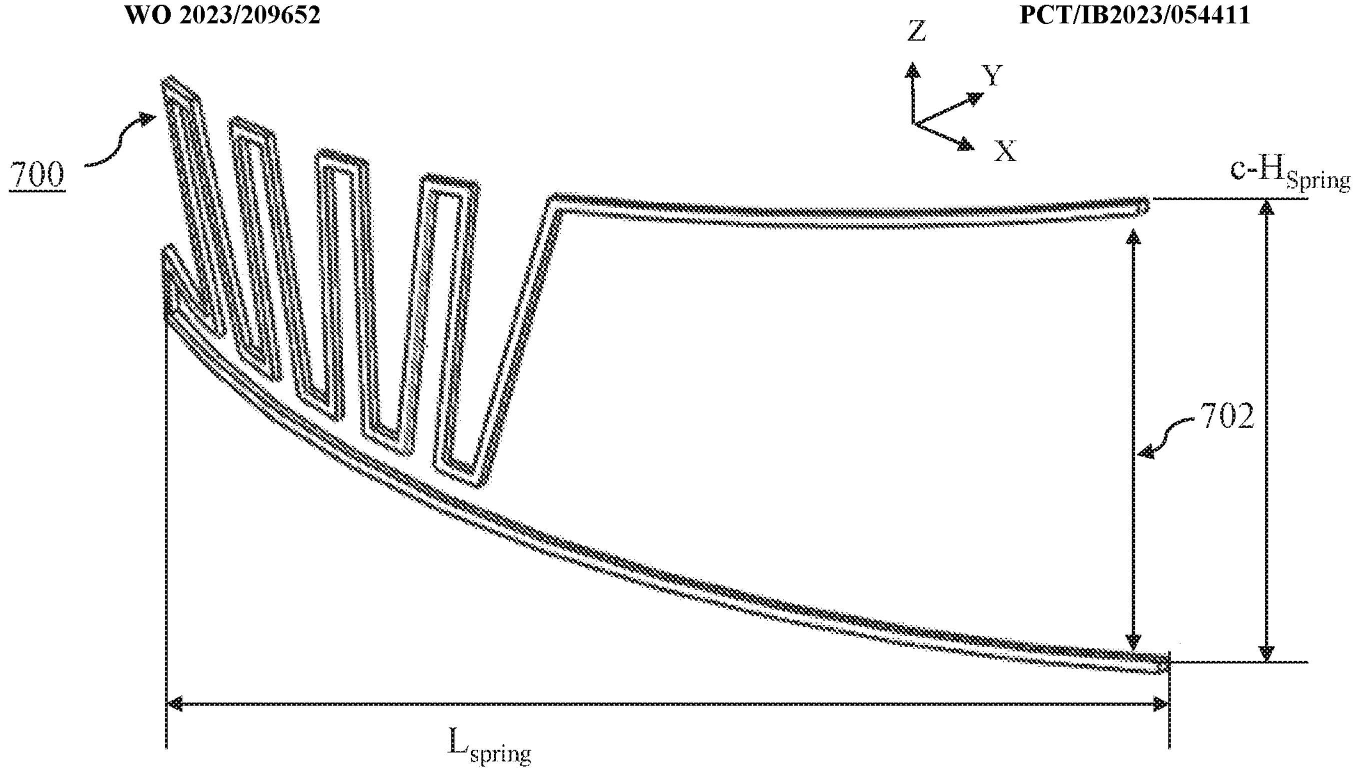


FIG. 7

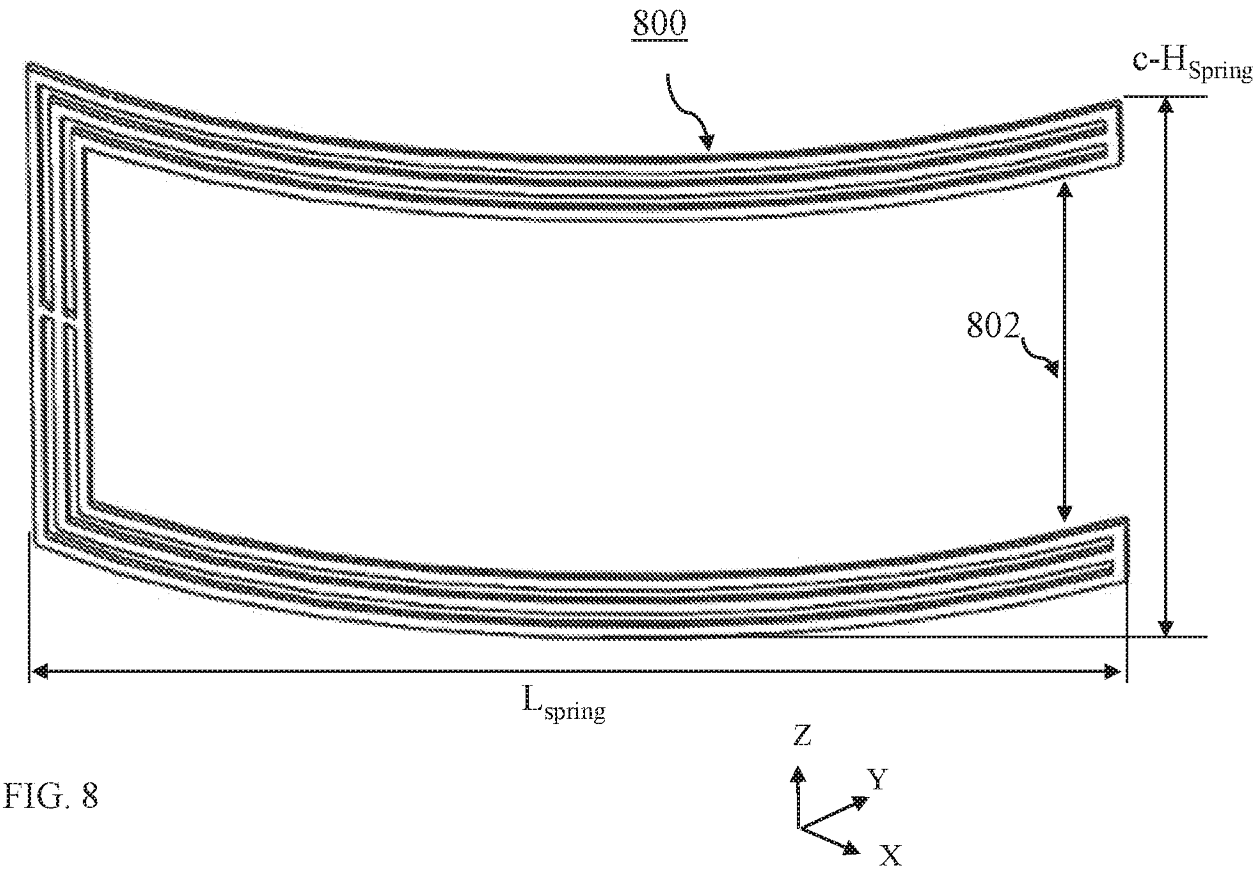


FIG. 8

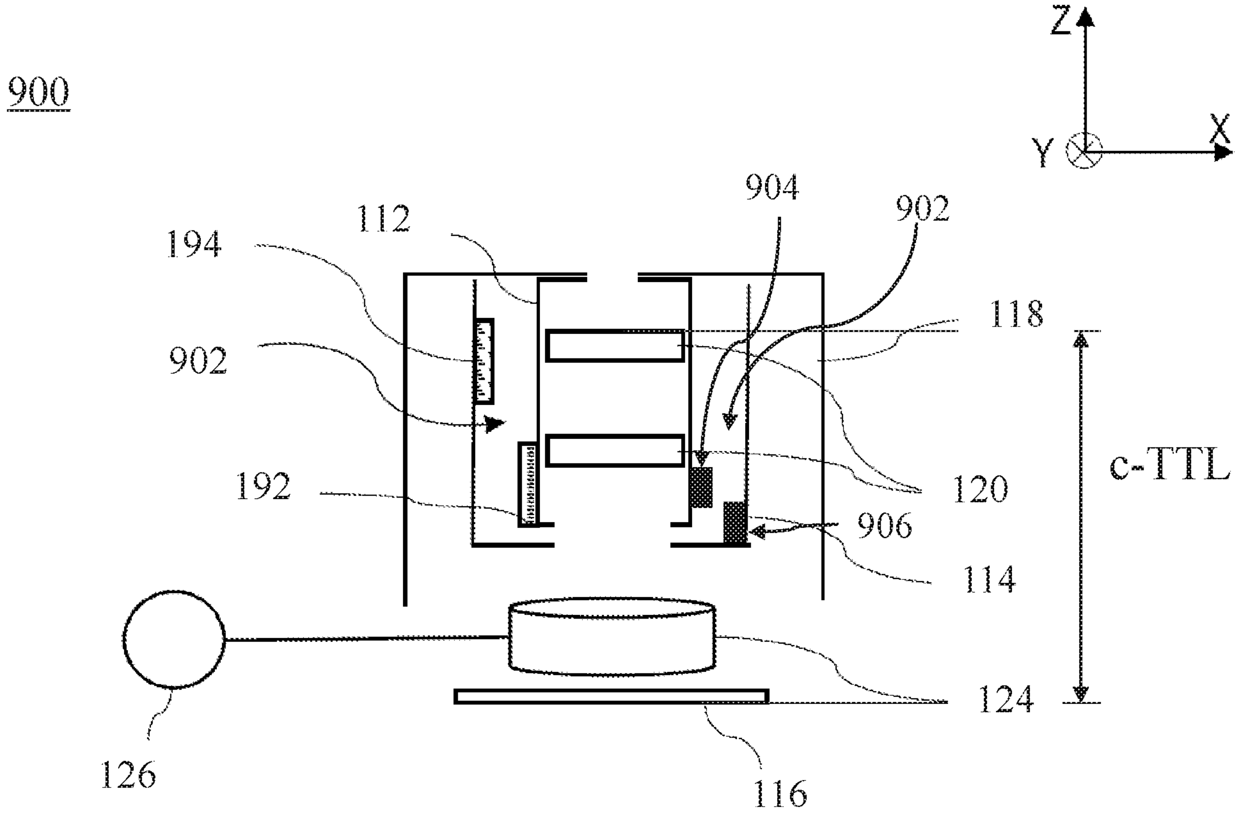
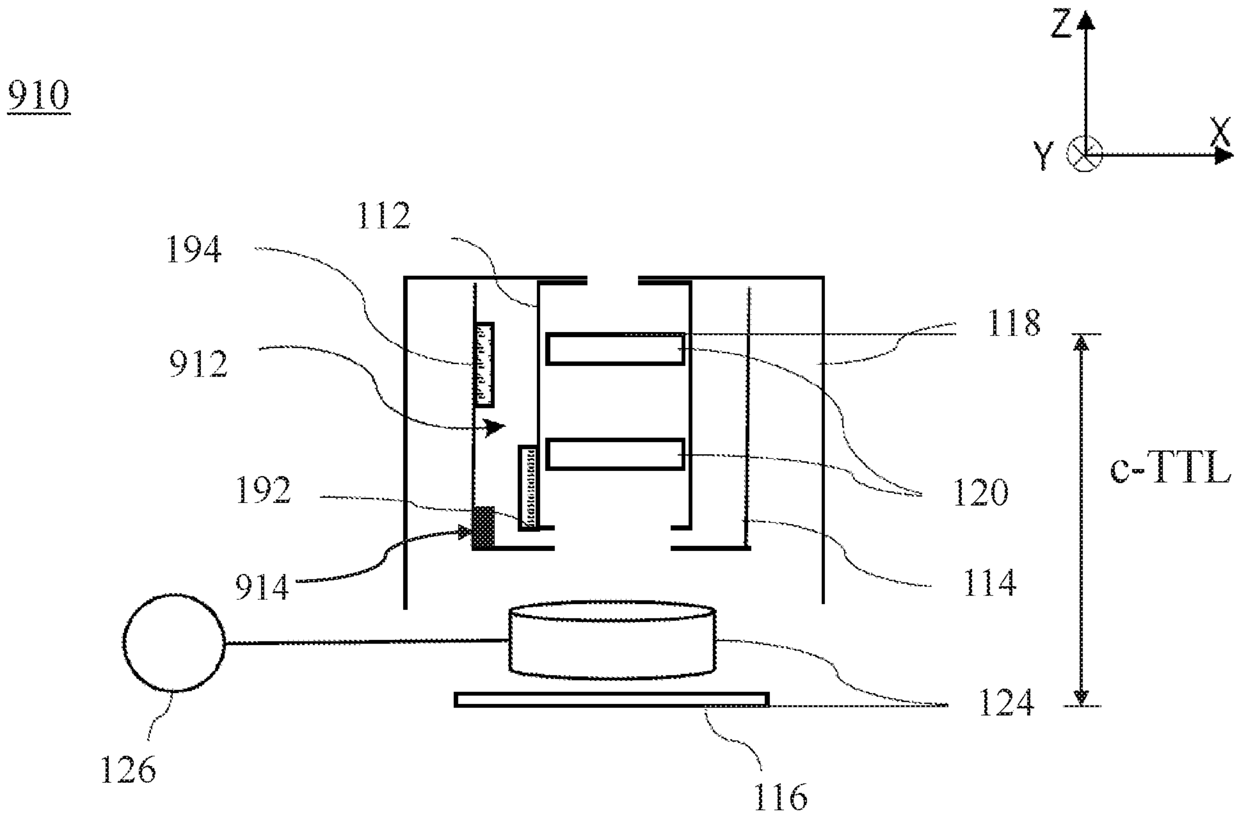

900
Z
Y
X
904
902
112
194
118
902
c-TTL
120
192
906
114
124
126
116

FIG. 9A


910
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118
912
c-TTL
120
192
914
114
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126
116

FIG. 9B

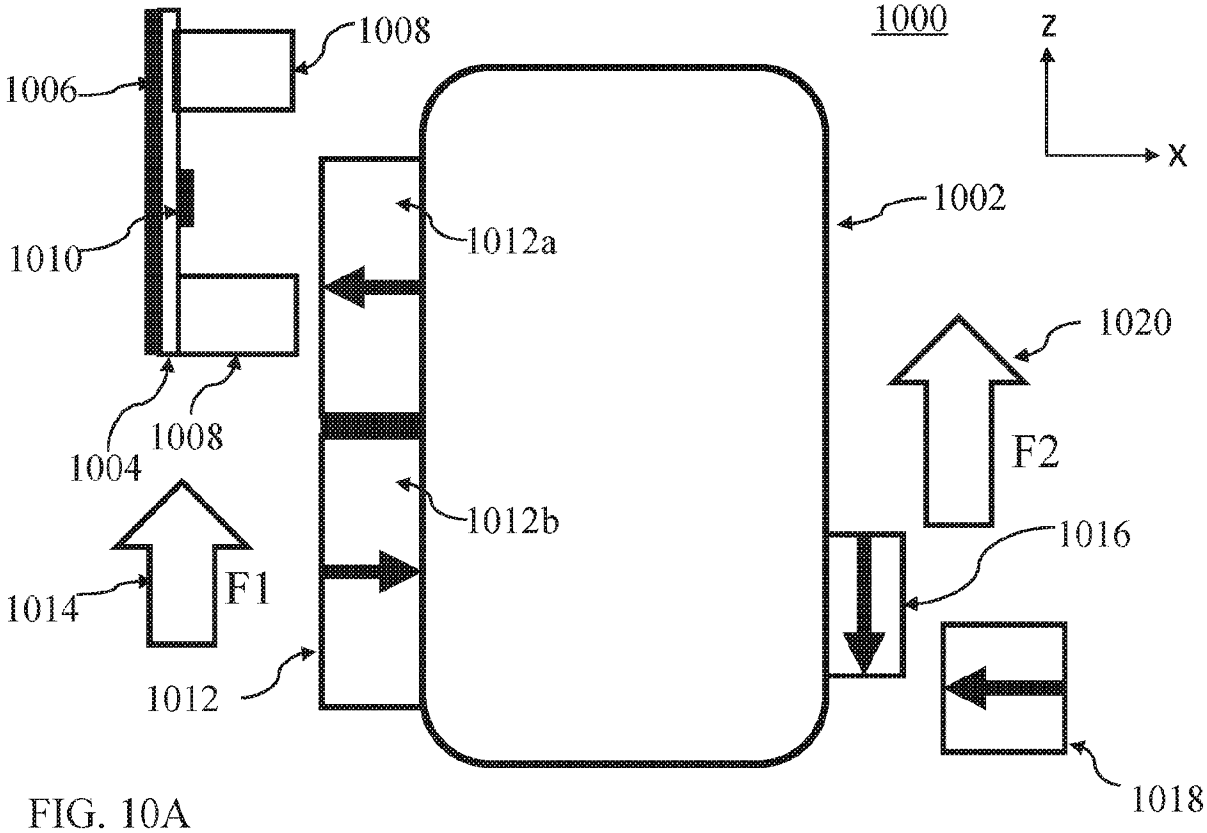

FIG. 10A

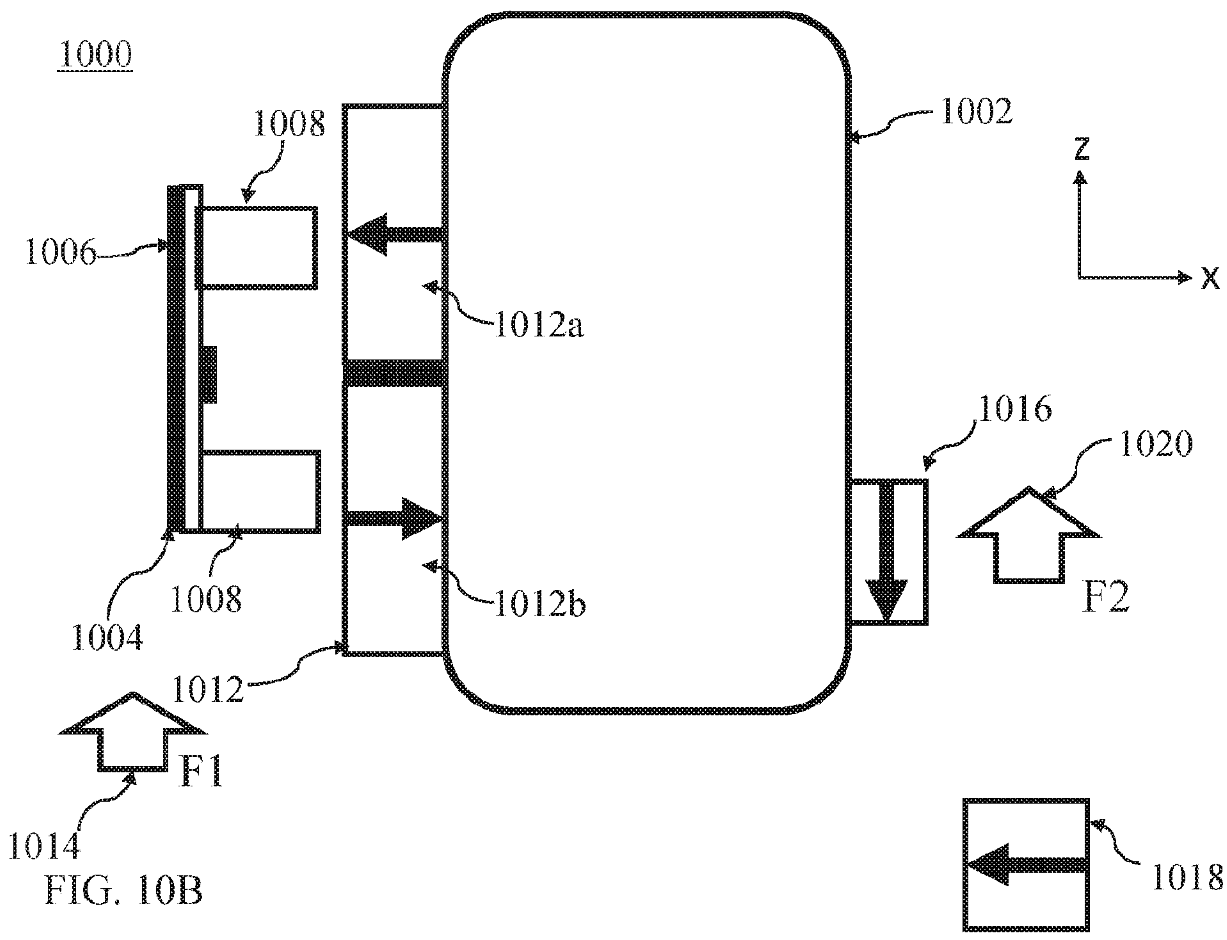

FIG. 10B

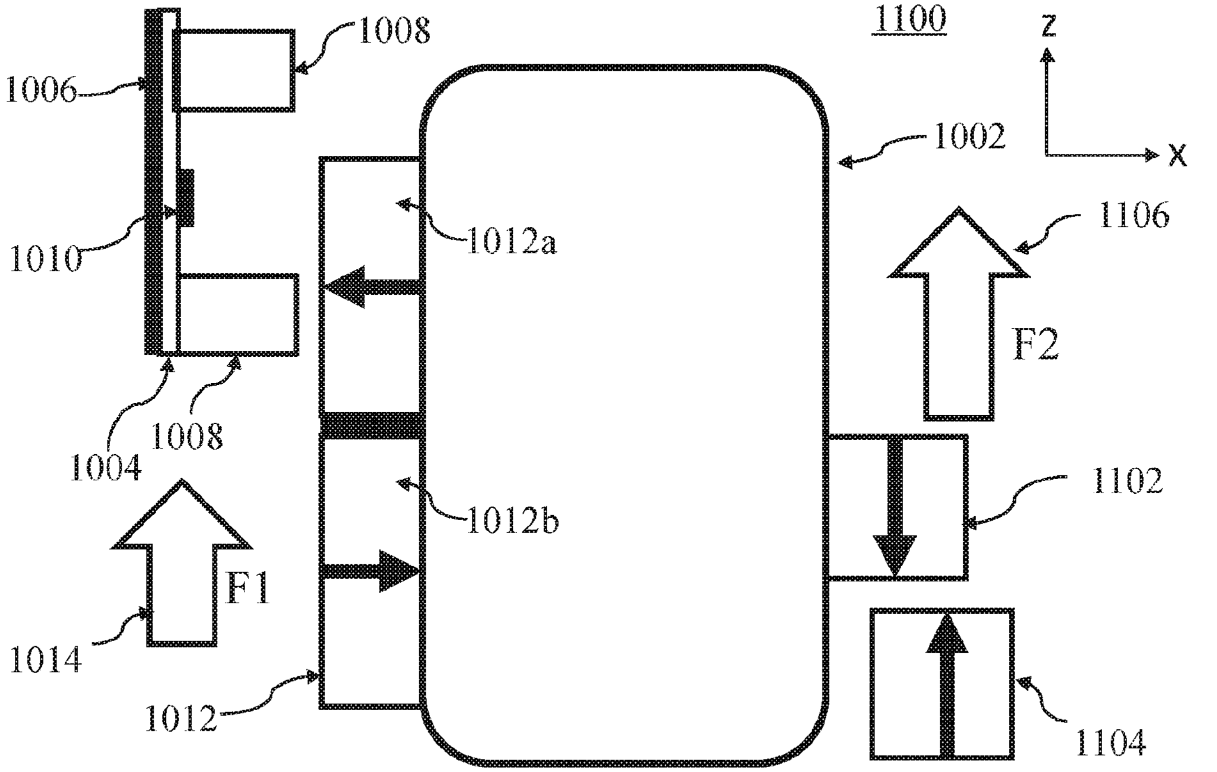

FIG. 11A

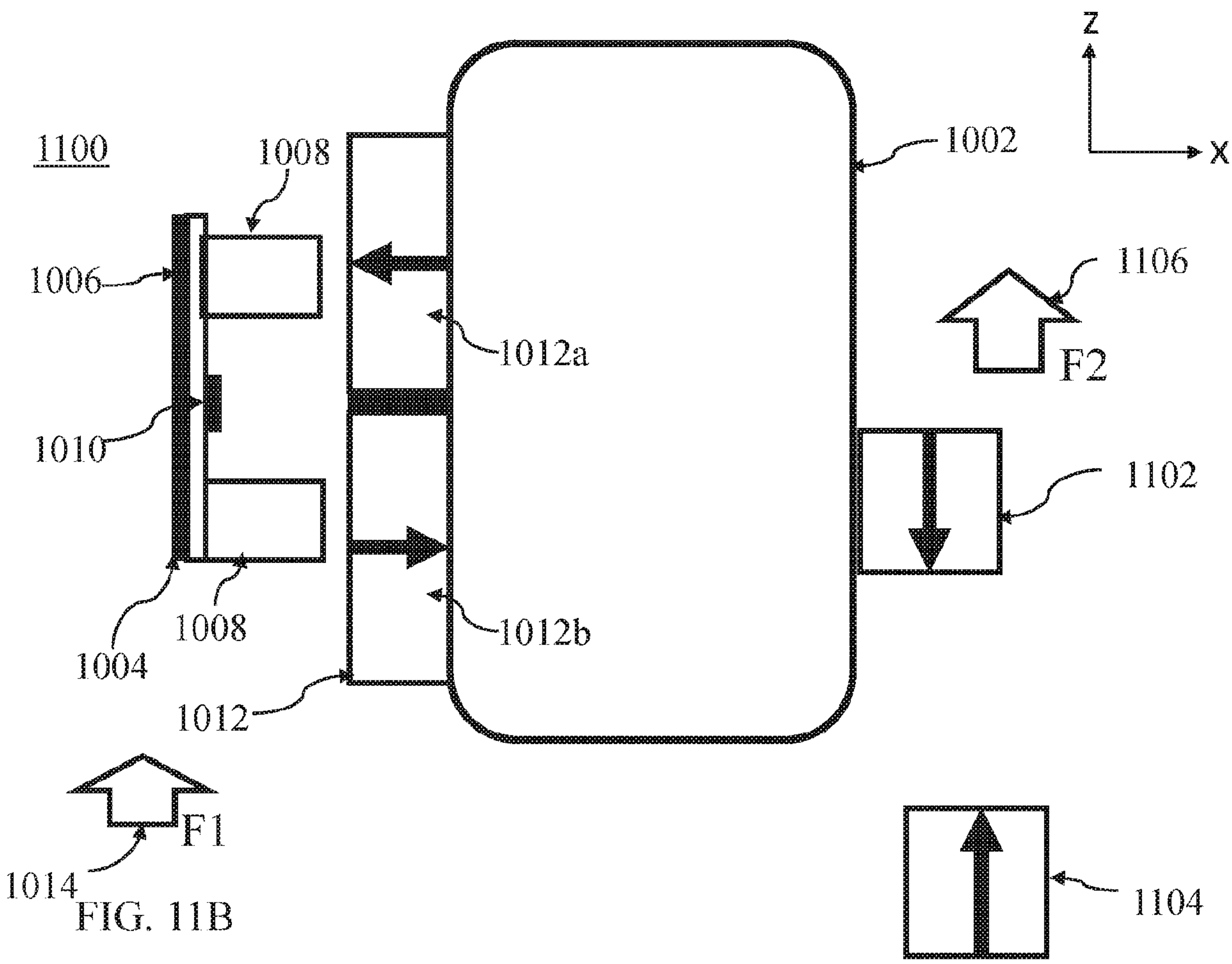

FIG. 11B

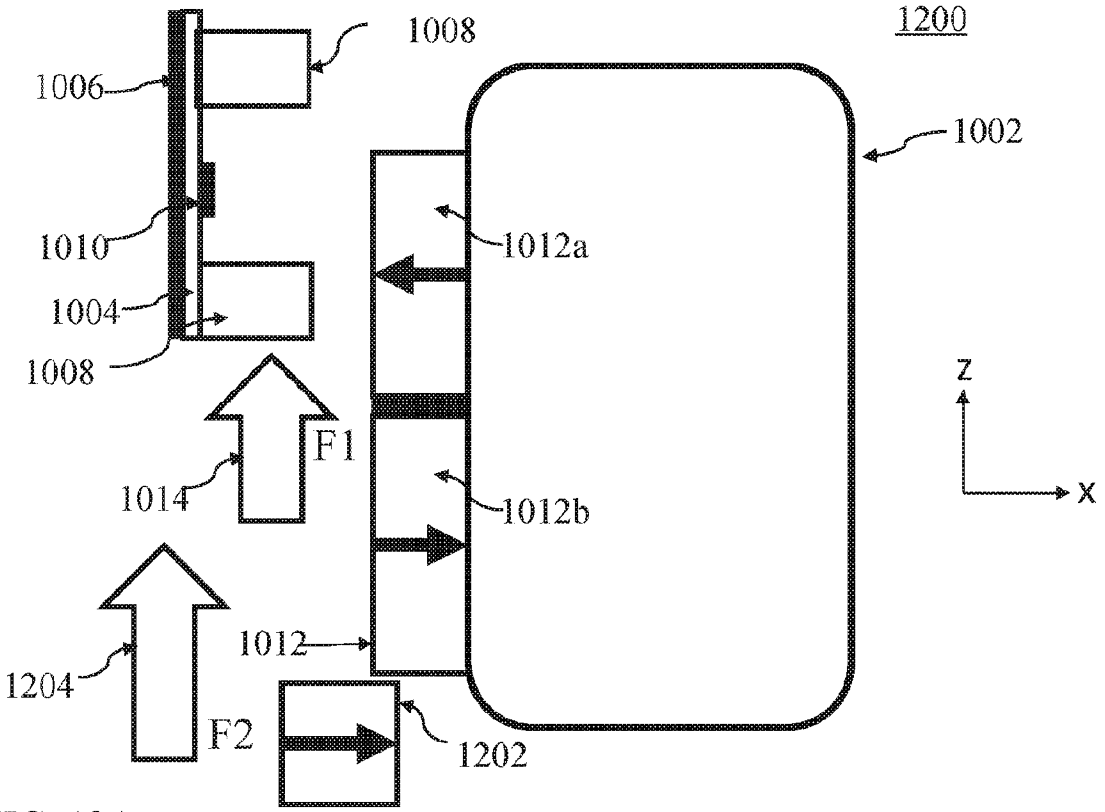

FIG. 12A

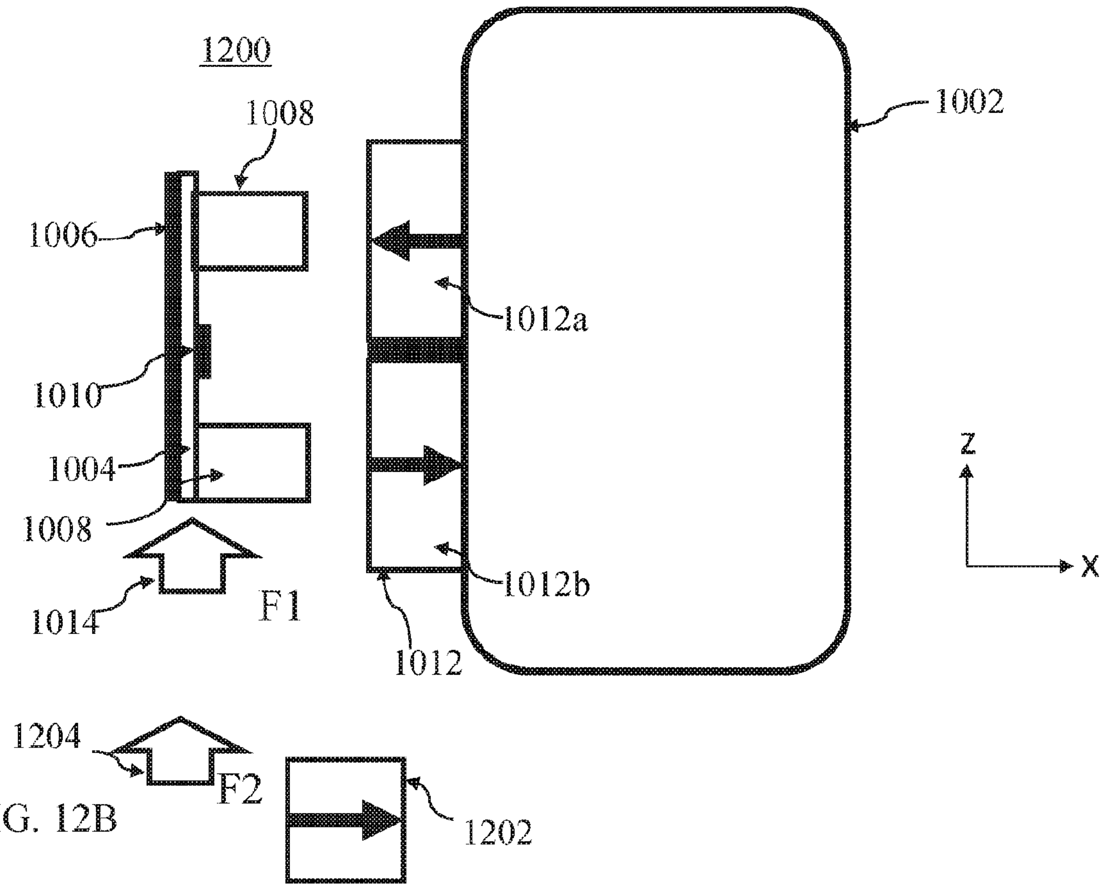

FIG. 12B

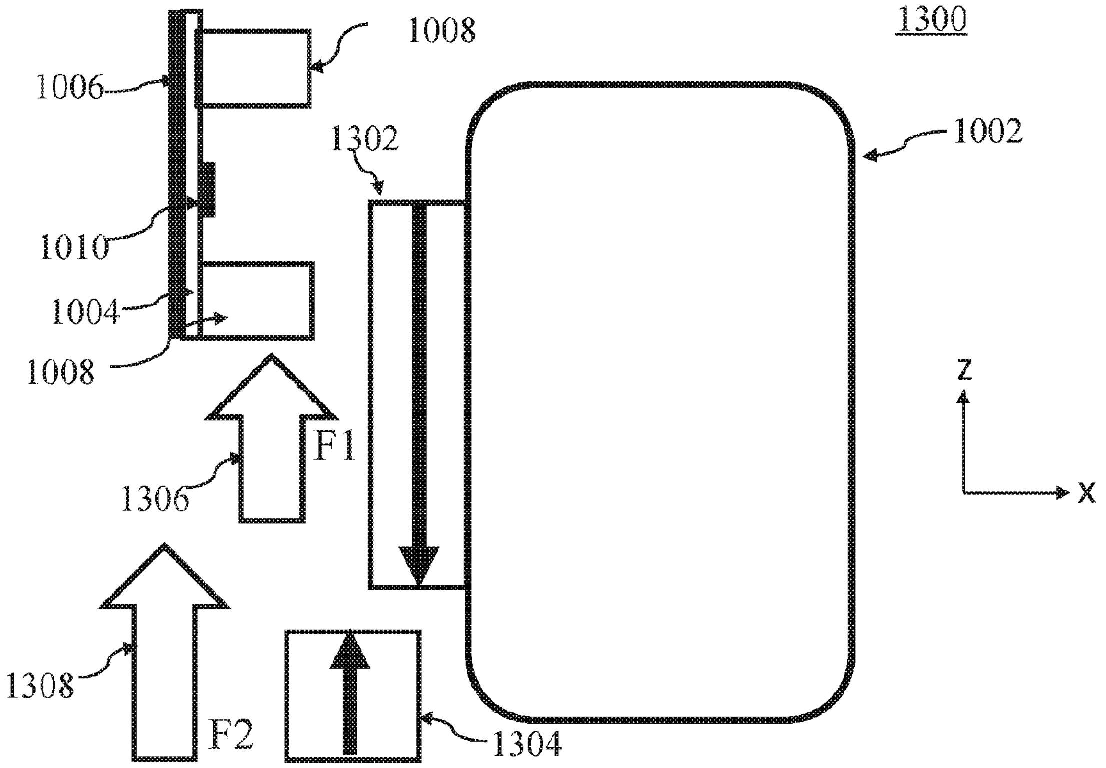

FIG. 13A

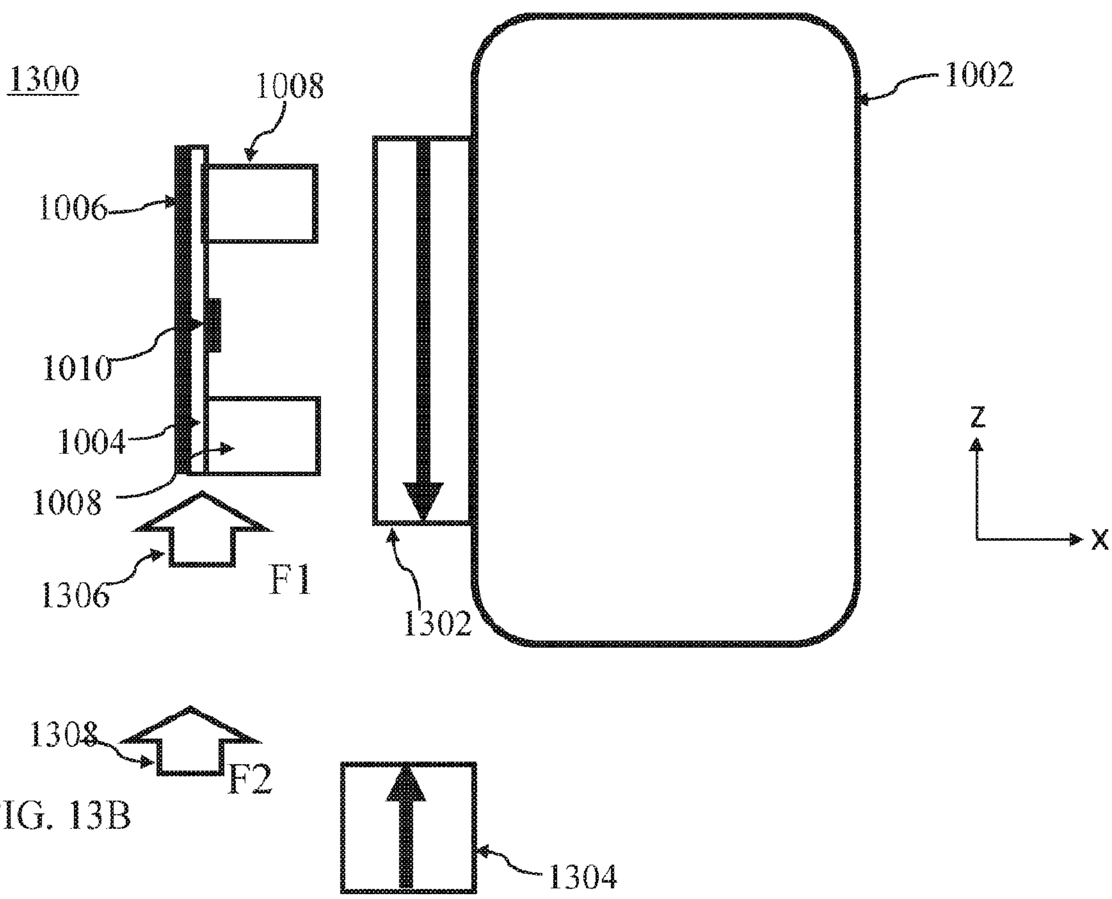

FIG. 13B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB23/54411

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. G03B 17/04; G02B 15/14; G03B 17/12 (2023.01)

ADD.

CPC - INV. G03B 17/04; G02B 13/0015; G02B 13/009; G02B 15/14; G03B 17/12

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)
See Search History document

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

Electronic database consulted during the international search (name of database and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2022/0004085 A1 (COREPHOTONICS LTD.) 06 January 2022; figures 4A-4B , 6A-6B, 16A-18F; table 10; paragraphs [0011, 0022, 0029, 0100, 0103, 0119, 0121-0125, 0132, 0136-0137 0163-0165]	1-50
Y	US 2009/0147340 A1 (LIPTON, M. ET AL.) 11 June 2009; figures 14A-14B; paragraphs [0063, 0066-0068].	1-50
Y	US 6,445,514 B1 (OHNSTEIN, T. ET AL.) 03 September 2002; figures 5, Column 5 line 18-column 6, line 64	9, 14, 27/9, 27/14, 28/27/9, 28/27/14, 29/27/9, 29/27/14, 30/27/9, 30/27/14, 31/27/9, 31/27/14, 32/27/9, 32/27/14, 33/32/27/9, 33/32/27/14, 34/27/9, 34/27/14, 35/34/27/9, 35/34/27/14, 36/27/9, 36/27/14, 37/36/27/9, 37/36/27/14, 38/36/27/9, 38/36/27/14, 39/36/27/9, 39/36/27/14, 40/36/27/9, 40/36/27/14, 41/27/9, 41/27/14, 42/41/27/9, 42/41/27/14, 43/41/27/9, 43/41/27/14, 44/41/27/9, 44/41/27/14,

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 August 2023 (25.08.2023)	SEP 27 2023

Name and mailing address of the ISA/	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Shane Thomas Telephone No. PCT Helpdesk: 571-272-4300

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
		45/41/27/9, 45/41/27/214, 46/27/9, 46/27/14, 47/46/27/9, 47/46/27/14, 48/27/9, 48/27/14, 49/46/27/9, 49/46/27/14, 50/46/27/9, 50/46/27/14
Y	US 2019/0187486 A1 (COREPHOTONICS LTD.) 20 June 2019; figures 5; paragraphs [0035]	16-19, 27/16-27/19, 28/27/16-28/27/19, 29/27/1-29/27/19, 30/27/16-30/27/19, 31/27/16-31/27/19, 32/27/16-32/27/19, 33/32/27/16-33/32/27/19, 34/27/16-34/27/19, 35/34/27/16-35/34/27/19, 36/27/16-36/27/19, 37/36/27/16-37/36/27/19, 38/36/27/16-38/36/27/19, 39/36/27/16-39/36/27/19, 40/36/27/16-40/36/27/19, 41/27/16-41/27/19, 42/41/27/16-42/41/27/19, 43/41/27/16-43/41/27/19, 44/41/27/16-44/41/27/19, 45/41/27/16-45/41/27/19, 46/27/16-46/27/19, 47/46/27/16-47/46/27/19, 48/27/16-48/27/19, 49/46/27/16-49/46/27/19, 50/46/27/16-50/46/27/19

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
-***-Please See Supplemental Page-***-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-50

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

-***-Continued From Box No. III: Observations where unity of invention is lacking-***-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claims 1-50 are directed towards a group of lens elements.
Group II: Claims 51-83 are directed towards a camera mechanism.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I include at least an inner part; an outer part having an outer part diameter d_o; a gap between the inner part and outer part having a maximum gap width W_G-Max; a moving lens group fixedly coupled to the inner part, the moving lens group including a plurality of N lens elements and having an optical axis, wherein a maximum lens element diameter of all the moving lens elements is DA_Max; and an actuator that includes an open spring located in the gap, wherein the open spring is operative to move the inner part relative to the outer part in a first direction parallel to the optical axis to an operative state when no external forces are applied, wherein the inner part can move relative to the outer part in a second direction opposite to the first direction to a collapsed state under an external force, wherein d_o= DA_Max + a penalty p, wherein 0.5mm < p < 2.5mm, and wherein 3mm < DA_Max < 15mm which are not present in Group II.

The special technical features of Group II include at least a pop-out camera having an operative state and a collapsed state, the pop-out camera comprising: an image sensor having an image sensor diagonal SD; a lens including a plurality of N lens elements and comprising a moving lens group including M :S N lens elements, the moving lens group having a lens optical axis; a lens barrel containing the moving lens group; a carrier configured to receive the lens barrel, the lens barrel axially movable relative to the carrier; and a magnetic spring assembly comprising a first permanent magnet fixedly coupled to the lens barrel, a second permanent magnet, and a ferromagnetic yoke being fixedly coupled to the carrier, wherein the magnetic spring assembly is configured to cause the lens barrel to move axially relative to the carrier along a first direction along the lens optical axis from the collapsed state towards the operative state; and wherein the image sensor is configured to image a field of view of the lens when the lens barrel is in the operative state, which are not present in Group I.

The common technical features shared by Groups I and II are pop-out lens module having a moving lens group.

However, these common features are previously disclosed by US 2017/0064166 A1 to Xiaomi Inc. (hereinafter "XIAOMI"). XIAOMI discloses pop-out lens module having a moving lens group (a camera and lens pop up assembly includes multiple lenses; abstract; para [0038]).

Since the common technical features are previously disclosed by the XIAOMI reference, these common features are not special and so Groups I and II lack unity.