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# (54) Title: ELECTROACTIVE POLYMER ACTUATOR LENTICULAR SYSTEM

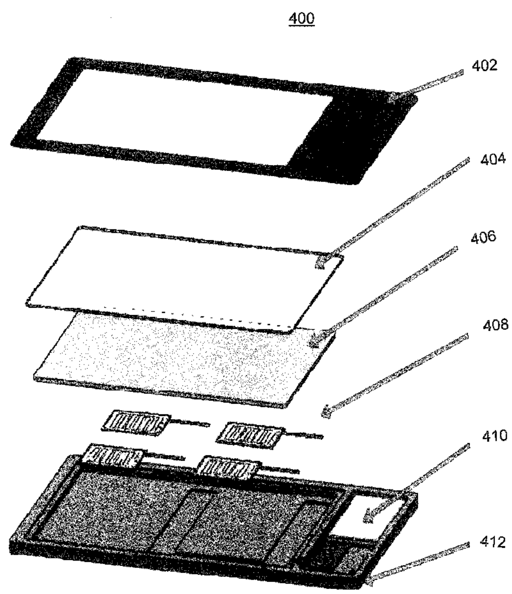



FIG. 4

**(57) Abstract**: The present invention provides an optical system comprising a lens element, a display unit displaced transversely from the lens element, at least one actuator coupled to at least one of the lens element or the display unit and capable of changing position of the lens element relative to the display unit in a lateral direction, and an electronic control system capable of driving the at least one actuator to move in a programmed manner to control positioning of the lens element relative to the display unit.

WO 2012/129357 A2

# ELECTROACTIVE POLYMER ACTUATOR LENTICULAR SYSTEM

## CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit, under 35 USC § 119(e), of United States provisional patent application number 61/466,129 filed March 22, 2011 entitled "ACTIVE LENTICULAR FOR LARGER SIZE USING BAR ACTUATOR", the entire disclosure of which is hereby incorporated by reference.

## FIELD OF THE INVENTION

The present invention relates in general to optical systems and more specifically to lenticular lens systems which enable the viewer to see two or more images in a display, such as an artwork, sequentially by changing the angle of the lenticular lens with respect to the viewer or by changing the position of the lens with respect to the display.

## BACKGROUND OF THE INVENTION

The kineograph, or flip book, was patented in 1897 by Linnet in GB189715668 as a means of advertising using animation of a linear sequence of images. These objects are oftentimes used as prizes, such as are found in breakfast cereal and CRACKER JACK boxes and as novelty or promotional items.

U.S. Published Patent Application No. 2010/0164329 relates the use of an electroactive polymer actuator to move a light source with respect to one or more reflectors to change the angle of the reflector (and the angle/intensity/focus of the output beam of light). A reflector can be between the light source and the user as well as behind the light source. The electroactive polymer actuator may be moved at different frequencies for different light effects. The frequency may be high enough that the user may not perceive the change in focus. Multiple actuators or phases of actuators may be used to direct the light in different directions.

U.S. Pat. No. 7,352,339, issued to Morgan et al., discloses sources of diffuse illumination for providing substantially uniform illumination to a surface. The diffuse illumination arises from varying the diffusion angle of light generated by a light emitting diode (LED) system. To vary the diffusion angle, a translucent member is placed between the LED system and the surface. Light emitted from the LED system across the translucent member can subsequently uniformly cover the surface. The translucent member can include a plurality of individual lenticular lenses. An electromagnetic actuator can be coupled to the LED-based light source and the translucent material and adapted to move the translucent material relative to the radiation generated by the LED-based light source.

## SUMMARY OF THE INVENTION

The present invention provides an optical system comprising a lens element, a display unit displaced transversely from the lens element, at least one actuator coupled to at least one of the lens element or the display unit and capable of changing the position of the lens element relative to the display unit in a lateral direction, and an electronic control system capable of driving the at least one actuator to move in a programmed manner to control positioning of the lens element relative to the display unit. The optical system of the present invention may find use in point-of-purchase displays or general illumination applications.

These and other advantages and benefits of the present invention will be apparent from the Detailed Description of the Invention herein below.

## BRIEF DESCRIPTION OF THE FIGURES

The present invention will now be described for purposes of illustration and not limitation in conjunction with the figures, wherein:

Figure 1 is a cutaway view of an electroactive polymer actuator system, according to one embodiment;

Figure 2 is a schematic diagram of one embodiment of an electroactive polymer actuator system to illustrate the principle of operation;

Figures 3A, 3B, and 3C illustrate three possible configurations, one/three/six bar actuator arrays, according to various embodiments;

Figure 4 provides an exploded view of one embodiment of the electroactive polymer actuator lenticular device of the present invention;

Figure 5 illustrates the prior art method of stacking a lenticular system;

Figure 6 shows the inventive method of stacking a lenticular system with a clearance between the display and the lens;

Figure 7 is a side view of the embodiment of the electroactive polymer actuator lenticular device of the present invention shown in Figure 4;

Figures 8A and 8B provide a schematic illustration of one embodiment of a lighting system useful in the present invention;

Figures 9A and 9B provide a schematic illustration of another embodiment of a lighting system useful in the present invention;

Figure 10 is a graph showing the steady, constant rate motion of a display with respect to a lens;

Figure 11 is a graph showing variable rate motion for rapid return to a starting position of a display with respect to a lens element;

Figure 12 shows the sequence of steps for assembly of an embodiment of optical system which comprises artwork as the display.

## DETAILED DESCRIPTION OF THE INVENTION

Before explaining the disclosed embodiments in detail, it should be noted that the disclosed embodiments are not limited in application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description. The disclosed embodiments may be implemented or incorporated in other embodiments, variations and modifications, and may be practiced or carried out in various ways. Further, unless otherwise indicated, the terms and expressions employed herein have been chosen for the purpose of describing the illustrative embodiments for the convenience of the reader and are not for the purpose of limitation thereof. Further, it should be understood that any one or more of the disclosed embodiments, expressions of embodiments, and examples can be combined with any one or more of the other disclosed embodiments, expressions of embodiments, and examples, without limitation. Thus, the combination of an element disclosed in one embodiment and an element disclosed in another embodiment is considered to be within the scope of the present disclosure and appended claims.

The present invention provides an optical system comprising a lens element, a display unit displaced transversely from the lens element, at least one actuator coupled to at least one of the lens element or the display unit and capable of changing position of the lens element relative to the display unit in a lateral direction, and an electronic control system capable of driving the at least one actuator to move in a programmed manner to control positioning of the lens element relative to the display unit. The optical system may further comprise one or more reflectors in some embodiments. The lens element may comprise one or more lenticular lenses or an array of lenses. The display may comprise two images or multiple images. The optical system may also be a lens stack which is illuminated by an array of LED light sources (or other light sources) as the display. Optionally, a second actuator capable of changing the transverse displacement between the lens element and the display unit may be included in some embodiments.

Lenticular lens systems enable the viewer to see sequentially two or more images printed in a display such as an artwork by changing the angle of the lenticular lens with respect to the viewer or by changing the position of the lens with respect to the display. In some embodiments, the display may comprise multiple images integrated to exhibit separately when viewed through different positions of the lenticular lens. With high quality artwork, multiple images may be arranged to enable the user to see the equivalent of a stop-action movie clip, similar to the effect seen in a kineograph or flip book. Electroactive polymer actuators may be used to change the position of the lens with respect to the artwork with high precision and speed. The motion of the actuator may be controlled with constant or variable rates to create different visual effects.

Examples of electroactive polymer devices and their applications are described, for example, in U.S. Pat. Nos. 7,394,282; 7,378,783; 7,368,862; 7,362,032; 7,320,457; 7,259,503; 7,233,097; 7,224,106; 7,211,937; 7,199,501; 7,166,953; 7,064,472; 7,062,055; 7,052,594; 7,049,732; 7,034,432; 6,940,221; 6,911,764; 6,891,317; 6,882,086; 6,876,135; 6,812,624; 6,809,462; 6,806,621; 6,781,284; 6,768,246; 6,707,236; 6,664,718; 6,628,040; 6,586,859; 6,583,533;

6,545,384; 6,543,110; 6,376,971; 6,343,129; 7,952,261; 7,911,761; 7,492,076; 7,761,981; 7,521,847; 7,608,989; 7,626,319; 7,915,789; 7,750,532; 7,436,099; 7,199,501; 7,521,840; 7,595,580; and 7,567,681, and in U.S. Patent Published Application Nos. 2009/0154053; 2008/0116764; 2007/0230222; 2007/0200457; 2010/0109486; and 2011/128239, and PCT Publication No. WO2010/054014, the entireties of which are incorporated herein by reference.

The present disclosure provides various embodiments of electroactive polymer actuator lenticular devices. Before launching into a description of various lenticular devices comprising an electroactive polymer actuator, the present disclosure briefly turns to Figure 1, which provides a cutaway view of an electroactive polymer actuator that may be integrally incorporated in the optical system of the present invention. Accordingly, one embodiment of an electroactive polymer actuator is now described with reference to the module **10**.

An electroactive polymer actuator slides an output plate **12** (e.g., sliding surface) relative to a fixed plate **14** (e.g., fixed surface) when energized by a high voltage. The plates **12**, **14** are separated by steel balls, and have features that constrain movement to the desired direction, limit travel, and withstand drop tests. For integration into an optical system, the top plate **12** may be attached to an inertial mass such the display unit of the optical system. In the embodiment illustrated in Figure 1, the top plate **12** of the module **10** comprises a sliding surface that mounts to an inertial mass or back of the optical system that can move bi-directionally as indicated by arrow **16**. Between the output plate **12** and the fixed plate **14**, the module **10** comprises at least one electrode **18**, optionally, at least one divider **11**, and at least one portion or bar **13** that attaches to the sliding surface, e.g., the top plate **12**. Frame and divider segments **15** attach to a fixed surface, e.g., the bottom plate **14**. The module **10** may comprise any number of bars **13** configured into arrays to amplify the motion of the sliding surface. The module **10** may be coupled to the drive electronics of an actuator controller circuit via a flex cable **19**.

Advantages of the electroactive polymer module **10** include providing smooth motion, consuming significantly less battery life, and suitability for customizable design and performance options. A flat, small, and lightweight form factor is particularly suitable for point-of-purchase displays and low profile lighting systems. The module **10** is representative of actuator modules developed by Artificial Muscle, Inc., of Sunnyvale, CA. In the present invention, an electronic control system is used to afford the smooth motion of the lens element. Such a control system is capable of driving the actuator to move in a programmed manner to control positioning of the lens element relative to the display unit. Suitable electronic control systems are disclosed, for example, in U.S. Published Patent Application Nos. 2009/0147340 and 2010/0033835, the entireties of which are incorporated herein by reference.

Still with reference to Figure 1, many of the design variables of the module **10**, (e.g., thickness, footprint) may be fixed by the needs of module integrators while other variables (e.g., number of dielectric layers, operating voltage) may be constrained by cost. Since actuator geometry – the allocation of footprint to rigid supporting structure versus active dielectric – does not impact cost much, it is a reasonable way to tailor performance of the module **10** to an application where the module **10** is integrated with an optical device.

Figure 2 is a schematic diagram of one embodiment of an actuator system **20** to illustrate the principle of operation. The actuator system **20** comprises a power source **22**, shown as a low voltage direct current (DC) battery, electrically coupled to an actuator module **21**. The actuator module **21** comprises a thin elastomeric dielectric **26** disposed (e.g., sandwiched) between two conductive electrodes **24A**, **24B**. In one embodiment, the conductive electrodes **24A**, **24B** are stretchable (e.g., conformable or compliant) and may be printed on the top and bottom portions of the elastomeric dielectric **26** using any suitable techniques, such as, for example screen printing. The actuator module **21** is activated by coupling the battery **22** to an actuator circuit **29** by closing a switch **28**. The actuator circuit **29** converts the low DC voltage $V_{Batt}$ into a high DC voltage $V_{in}$ suitable for driving the module **21**. The actuator circuit **29** may also comprise electronics components including microprocessors, memory, and signal generators, capable of generating specific patterns or waveforms or voltage drive signals to drive the motion of the actuator module **21**. When the high voltage $V_{in}$ is applied to the conductive electrodes **24A, 24B** the elastomeric dielectric **26** contracts in the vertical direction (V) and expands in the horizontal direction (H) under electrostatic pressure. The contraction and expansion of the elastomeric dielectric **26** can be harnessed as motion. The amount of motion or displacement is proportional to the input voltage $V_{in}$. The motion or displacement may be amplified by a suitable configuration of actuators as described below in connection with Figures 3A, 3B, and 3C.

Figures 3A, 3B, 3B illustrate three possible configurations, among others, of actuator arrays **30, 34, 36**, according to various embodiments. Various embodiments of actuator arrays may comprise any suitable number of bars depending on the application and physical spacing restrictions of the application. Additional bars provide additional displacement and therefore enhance the motion of the display that the user can appreciate substantially immediately. The actuator arrays **30, 34, 36** may be coupled to the drive electronics of an actuator controller circuit via a flex cable **38**.

Figure 3A illustrates one embodiment of a one bar actuator array **30**. The single bar actuator array **30** comprises a fixed plate **31**, an electrode **32**, and an elastomeric dielectric **33** coupled to the fixed plate **31**.

Figure 3B illustrates one embodiment of a three bar actuator array **34** comprising three bars **34A, 34B, 34C** coupled to a fixed frame **31**, where each bar is separated by a divider **37**. Each of the bars **34A-C** comprises an electrode **32** and an elastomeric dielectric **33**. The three bar array **34** amplifies the motion of the sliding surface in comparison to the single bar actuator array **30** of Figure 3A.

FIG. 3C illustrates one embodiment of a six bar actuator array **36** comprising six bars **36A, 36B, 36C, 36D, 36E, 36F** coupled to a fixed frame **31**, where each bar is separated by a divider **37**. Each of the bars **34A-F** comprises an electrode **32** and an elastomeric dielectric **33**. The six bar actuator array **36** amplifies the motion of the sliding surface in comparison to the single bar actuator array **30** of FIG. 3A and the three bar actuator array **34** of FIG. 3B.

Figure 4 illustrates an exploded view of one embodiment of the optical system of the present invention **400**. The system depicted in Figure 4 comprises a top cover **402**, which is fixed. A fixed lens element **404** and a movable display unit **406** are arranged below the top cover **402** and rest on actuators **408** which along with fixed battery and electronics **410** are located in main housing **412**. The lens element may be a lenticular lens and may comprise multiple lenses.

Figure 5 illustrates a prior art method of arranging the elements of an optical system **500**. Lens **502** is in contact with artwork **504** which contacts actuator **506** which contacts housing **508**. One problem encountered with the prior art method was friction between the lens and artwork along with the friction by-products such as jittery or jumpy motion and hysteresis. Because there was no need to move the artwork relative to the lens, the lens was always designed to be focused on the artwork when in full contact with each other.

As mentioned herein, moving displays cause friction problems; therefore, the present inventors positioned a clearance (gap) between the display unit and the lens to eliminate the friction. This embodiment of the optical system of the present invention **600** is illustrated in Figure 6, where lens element **602** is not in contact with display unit **604**, but is separated by a gap **610**. Electroactive polymer actuator **606** lies beneath display unit **604** and is in contact with housing **608**. In principle, the gap between the lens and the display unit may be any distance; however, it should be remembered that the gap will require a change in focal length of the lens element to ensure that it focuses on the display correctly. The gap may be created, for example, by stand-offs between the lens element **602** and the housing **608**. These standoffs may be separate piece parts as is known in the art. They may also be molded into either the lens element **602** or the housing **608**. Alternatively, the standoffs may comprise springs or telescoping sections which enable the adjustment of the gap.

Figure 7 provides a side view of the embodiment of the optical system of the present invention shown in Figure 4. The system depicted in Figure 7 comprises a top cover **702**, which is fixed. A fixed lens element **704** and a movable display unit **706** are arranged below the top cover **702** and rest on actuators **708** which along with fixed battery and electronics **710** are located in main housing **712**.

Electroactive polymer actuators have application in the lighting industry, in the context of both wall socket (120V/60 Hz power) driven/stationary lighting systems and battery-operated/mobile lighting systems. FIGS. 8A and 8B illustrate a schematic representation of an exemplary arrangement of such a lighting system **800**. Here, a single-phase, single frustum-type electroactive polymer actuator **802** is employed which includes a diaphragm **808** affixed to a frame **810**. The diaphragm may be weighted with a cap **842** having a selected mass to achieve the desired resonance frequency of the diaphragm. The diaphragm may also be pre-biased upwards by any suitable biasing means (not shown), e.g., a spring, to enhance performance of the actuator. Actuator **802** is in positional contact with or otherwise mechanically coupled by way of a stem or rod **822** to a light source **806**, which is any suitable light source depending on the application at hand. Upon application of a voltage to the actuator via lead lines **820** coupled to a power supply (not shown), diaphragm **808** relaxes and is moved in the z-axis along with rod **822** and light source **806** are also displaced in the same direction, as illustrated in FIG. 8B.

Positioned about the light source is a reflector assembly which includes one or more reflectors, e.g., mirrors, or lenses. Although any number of reflectors may be used, here, two reflectors are used—a primary reflector **812** positioned between actuator **802** and light source **806** and about the z-axis to create the primary reflecting surface, and a secondary reflector **814** positioned on the opposite side of the light source. This arrangement provides a reflector "ring", however, any other suitable arrangement of reflectors and the resulting construct may be employed with the present invention. In the illustrated embodiment, secondary reflector **814**, unlike primary reflector **812**, is mechanically coupled to light source **806**, and therefore exhibits no movement relative to light source **806** (i.e., secondary reflector is displaced together with the light source). In other embodiments, the light source and the secondary reflector may be stationary and the primary reflector movable relative thereto. The latter configuration is advantageous where the light source/secondary reflector combination is heavier than the primary reflector or where type of light source used is particularly sensitive to vibrational movement such as a filament type incandescent bulb.

In any case, primary reflector **812** is designed to do the bulk of the variable direction ray reflection. For example, at least half of the light emitted from light source **806** is designed to hit primary reflector **812** first and be reflected in the desired direction without the necessity of being diverted by secondary reflectors. Secondary reflector **814** is responsible for diverting rays emitted from light source **806** in the upper hemisphere back down to primary reflector **812** in a concentrated ray. Depending on the application, a tertiary reflector or reflectors (not shown), which are also stationary relative to the primary reflector, may be employed to assist in redirecting stray rays from the light source. In any case, the resulting reflected light ray is made up of substantially all available light provided by light source **806**.

By operating electroactive polymer actuator **802** between the high and low positions, as shown in FIGS. 8A and 8B, respectively, (or between any number of positions there between) at a frequency which is greater than that perceptible by the human eye, i.e., >25 Hz, light source **806** is moved relative to the primary reflector **812**. The variable focal length to the reflector ring creates the ability to change the overall focus of the emitted light. As illustrated, broader band light rays **816** are provided when the light source is in the "low" position and narrower band light rays **818** are provided when the light source is in the "high" position.

Any arrangement of actuators, light sources and reflectors/lenses may be employed in the subject systems where the relative motion between the light source(s) and reflector(s)/lens(es) is adjusted at a high rate of speed. As such, an alternative arrangement to the one illustrated in FIGS. 8A and 8B is one that couples the reflector assembly, or one or more reflectors/lenses thereof, to the electroactive polymer actuator to adjust its position relative to the light source(s). Alternatively, both the light source as well as the reflector assembly may be driven each by its own actuator to provide more control over the direction and diffusion of the light vector. Individual reflectors/lenses or groups of reflectors/lens may be driven or moved independently of each other to provide multi-faceted directionality to the light rays. Furthermore, any number of electroactive polymer diaphragms may be used to construct the subject actuators. For example, actuators having a stacked diaphragm configuration may be used to increase maximum displacement of a light source and/or reflector assembly.

Still further, a multi-phase electroactive polymer actuator may be employed to provide a unique lighting pattern, e.g., a strobe effect, flashing, etc. For example, a single, variable-phase actuator, may be used to displace the light source and/or the reflector/lens assembly to change directionality of the light rays where the directionality depends on the "phase" in which the actuator is operated. Such a lighting system **930** is illustrated in FIGS. 9A and 9B, where selected portions of the multi-phase diaphragm **936** of actuator **932** having frame **934** may be activated to change the direction of the reflected rays. The diaphragm may have any number of phases to provide the desired effect. For example, FIGS. 9A and 9B show actuator **932** acting in a bi-lateral manner to provide left-directed rays **938** and right-directed rays **940**. A greater number of phases may be employed to produce a rotating light effect, such as those used on emergency vehicles, or a "wobble" pattern.

Those skilled in the art will appreciate than any number of lighting system architectures of the present invention may be employed. An aspect of the systems is achieve an efficient input voltage-to-diaphragm displacement ratio by providing or tuning the electroactive polymer actuators to operate at their natural frequency. Suitable power supplies for such applications are configured to generate high oscillating voltages from a direct current (DC) power source, such as a high voltage transistor array. Any increase in space requirements of the power supply are offset by the reduced requirement for bulky chemical energy storage, i.e., batteries, as the power supply is lighter than most batteries, making the overall system lighter and more efficient.

As for light sources, any type may be employed with the subject systems, depending on the desired lighting effect. For example, for directed light, light-emitting diodes (LEDs) may be employed, whereas conventional incandescent lights may be used to produce diffuse light. Short arc high intensity discharge light sources are the closest to point light sources and are therefore easily usable in the high efficiency light systems of the present invention.

The present invention provides in some embodiments, a lighting or illumination system using the lens stack with an array of LED light sources (or other light sources) as the display. The light sources may emit the same or different colors. In some embodiments, the display may include a layer of phosphors placed between the LED light sources and the lens stack. The phosphor layer may be excited by light from the LEDs and emit light of a different color. The phosphor layer may comprise a single chemical composition or may have regions of different chemical compositions which may emit different colors. By moving the lens array either laterally or transversely with respect to the LED light source array, the light perceived by the user can change in intensity, focus, and beam direction.

Where the array of LEDs contains multiple colors of LED light sources or excites an array of multiple compositions of phosphors, the relative intensities of the different colors of light emitted may be varied by moving the lens array laterally with respect to the LED array so the user will perceive different mixtures of colored light. The actuator(s) may be moved at different frequencies or with variable rates to provide complex patterns of colors, intensity, focus, and other lighting effects such as a stroboscopic effect. The actuator(s) may also be moved to a specific position for a constant color, intensity, and focus. A reflector or array of reflectors may be included in the stack for more capability in changing intensity, focus, and beam direction, particularly where the optical system includes an additional actuator which can change the displacement between any combination of the lens array, the reflector, and the LED array. In some embodiments, individual reflectors may be interspersed between and among the LEDs in an LED array. In other embodiments, reflectors may be situated above the LEDs beneath the lens element.

As illustrated in Figures 10 and 11, electroactive polymer actuators permit the system to have different motion regimens. Figure 10 shows an example of a motion with the constant rate in both directions of movement. Figure 11 shows an example of a motion with a variable rate, here a snap back action. The motion regimen depicted in Figure 11 is particularly advantageous for lenticular systems where the forward motion of the actuator enables the viewer to see a series of images similar to a video clip. The snap-back motion of the actuator enables a rapid return to the first image to reset the series of images without the viewer having to see the series of images in reverse. Those skilled in the art will appreciate there are many other potential motion regimens that could be given based on application requirements including a regimen where the actuator is moved and held at a set position to hold a fixed position of the lens element relative to the display. The motion regimen should preferably be matched with the artwork to create the proper intended visual effect.

Figures 12A, 12B and 12C illustrate the steps of assembling an optical system which has an artwork as the display in this embodiment. Figure 12A depicts the artwork laminated to the moving plate (shown as 406 in Figure 4). Figure 12B shows the lens element placed over the artwork while leaving a gap to prevent friction and jittery motion. Figure 12C shows attachment of the top cover which may be secured by fasteners, such as screws.

The foregoing examples of the present invention are offered for the purpose of illustration and not limitation. It will be apparent to those skilled in the art that the embodiments described herein may be modified or revised in various ways without departing from the spirit and scope of the invention. The scope of the invention is to be measured by the appended claims.

**WHAT IS CLAIMED IS:**

1. An optical system comprising:

a lens element;

a display unit displaced transversely from the lens element, said display unit containing a display;

at least one actuator coupled to at least one of the lens element or the display unit and capable of changing position of the lens element relative to the display unit in a lateral direction; and

an electronic control system capable of driving the at least one actuator to move in a programmed manner to control positioning of the lens element relative to the display unit.

2. The optical system according to Claim 1 further comprising at least one reflector.

3. The optical system according to one of Claims 1 and 2 further comprising at least a second actuator capable of changing the transverse displacement between the lens element and the display unit.

4. The optical system according to any one of Claims 1 to 3, wherein the lens element comprises multiple lenses.

5. The optical system according to any one of Claims 1 to 4, wherein the lens element comprises a lenticular lens.

6. The optical system according to Claim 5, wherein the display comprises multiple images integrated to exhibit separately when viewed through different positions of the lenticular lens.

7. The optical system according to any one of Claims 1 to 6, wherein the display comprises an array of light sources.

8. The optical system according to Claim 7, wherein the light sources emit light of different colors.

9. The optical system according to one of Claims 7 and 8, wherein the display comprises an array of light emitting diode (LED) light sources.

10. The optical system according to Claim 9, wherein the array excites a phosphor layer to emit light of a color different from the color of the light emitting diode (LED) light sources.

11. The optical system according to Claim 10, wherein the phosphor layer comprises regions with different phosphor compositions to emit different colors when excited by the light emitting diode (LED) light sources.

12. The optical system according to any one of Claims 1 to 11, wherein motion of the at least one actuator is programmed to cycle between positions of the lens element relative to the display unit at one selected from the group consisting of a constant rate, a variable rate, and a combination thereof.

13. The optical system according to any one of Claims 1 to 12, wherein motion of the at least one actuator is programmed to set a fixed position of the lens element relative to the display unit.

14. The optical system according to any one of Claims 6 to 13, wherein motion of the at least one actuator enables a user to view a sequence of images.

15. The optical system according to any one of Claims 7 to 13, wherein motion of the at least one actuator provides illumination comprising a mixture of

different colors of the light sources based on the relative position of the array of light sources and the lens element.

16. The optical system according to any one of Claims 1 to 15, wherein the at least one actuator comprises an electroactive polymer actuator.

17. The optical system according to any one of Claims 3 to 15, wherein the second actuator comprises an electroactive polymer actuator.

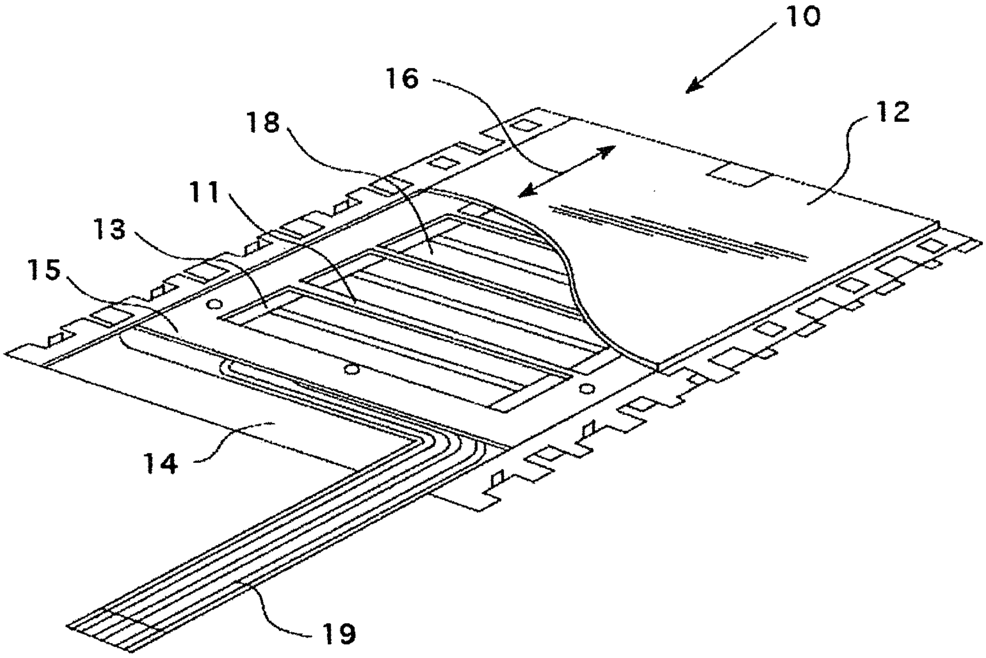



FIG. 1

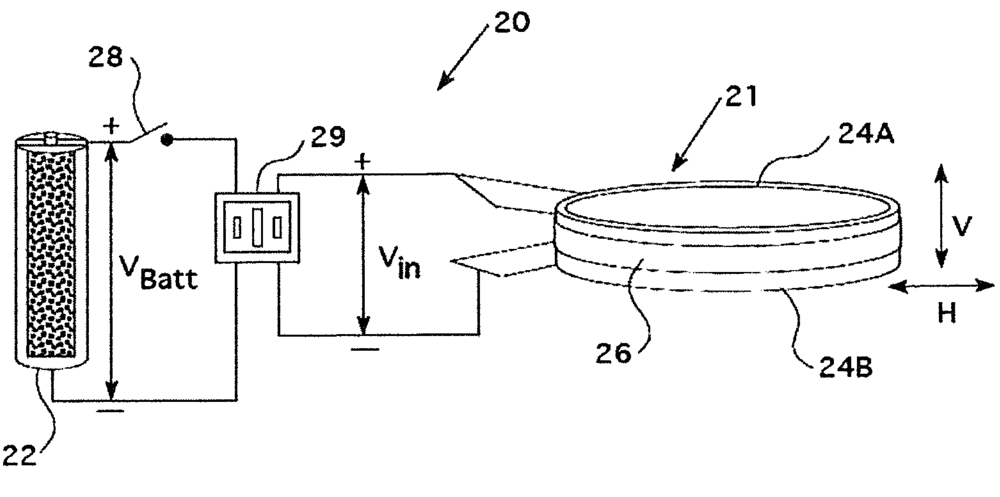



FIG. 2

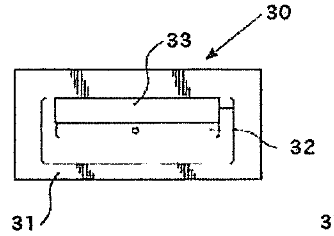



FIG. 3A

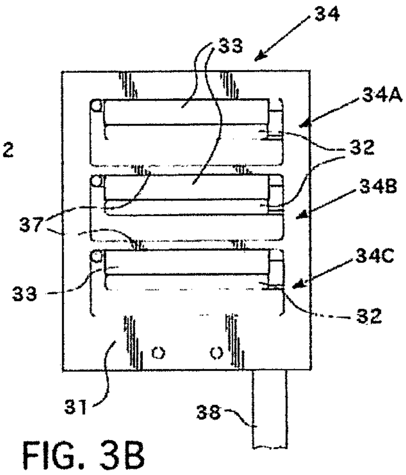



FIG. 3B

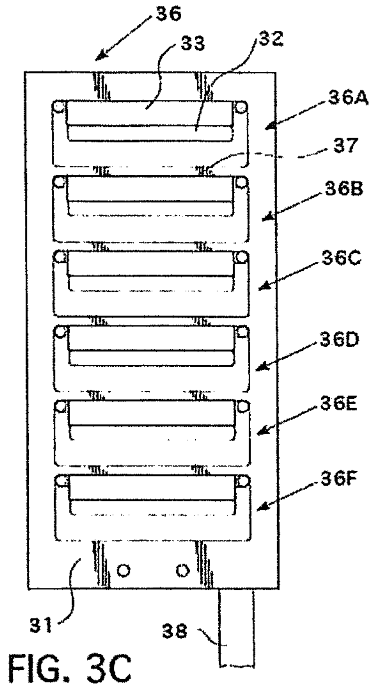



FIG. 3C

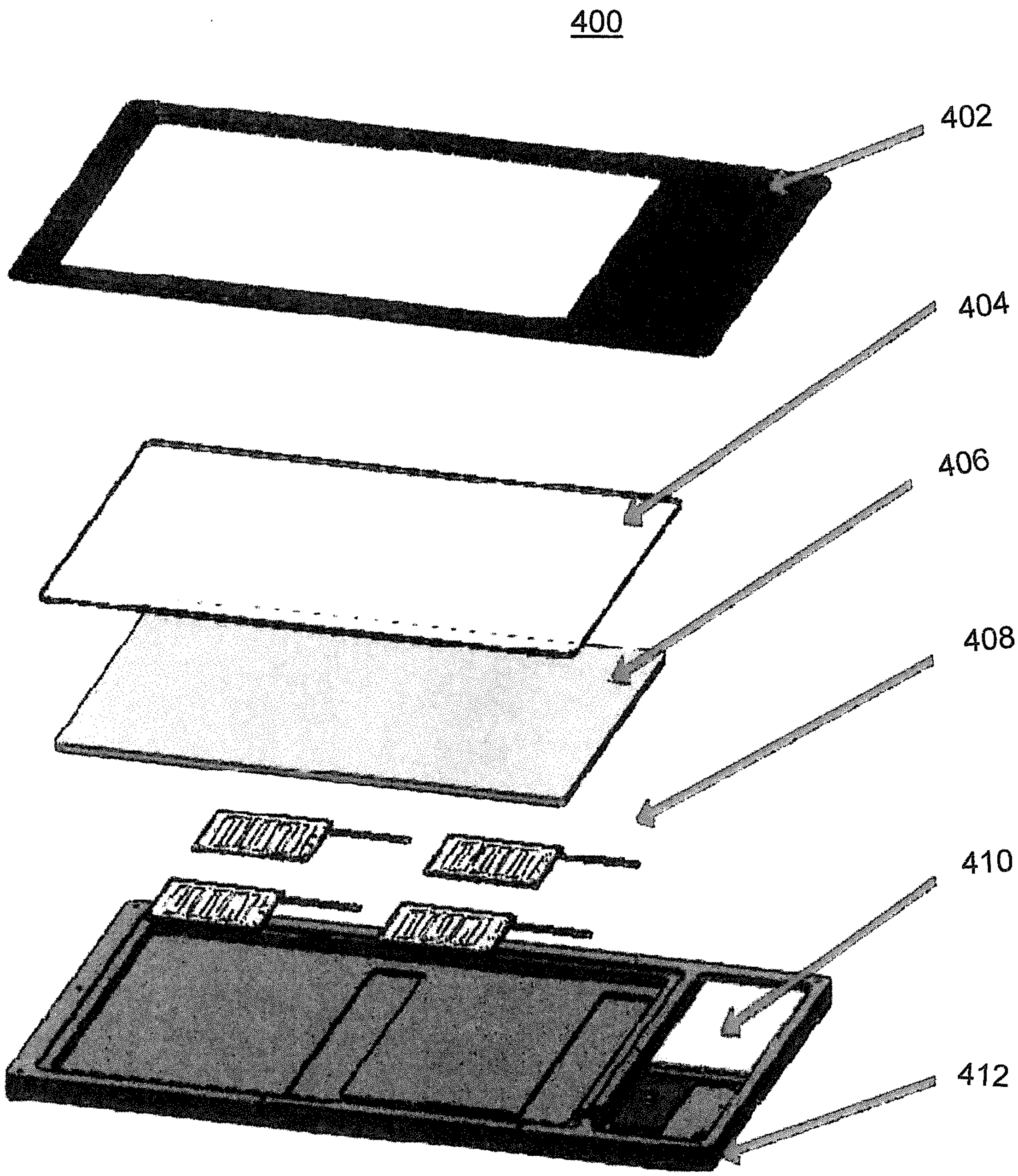



FIG. 4

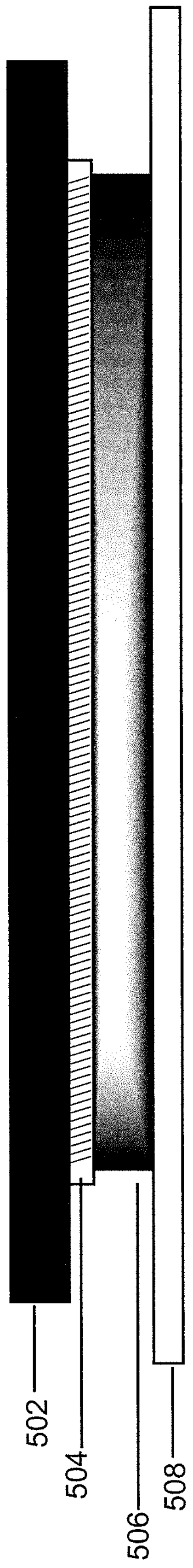



FIG. 5 ( Prior Art)

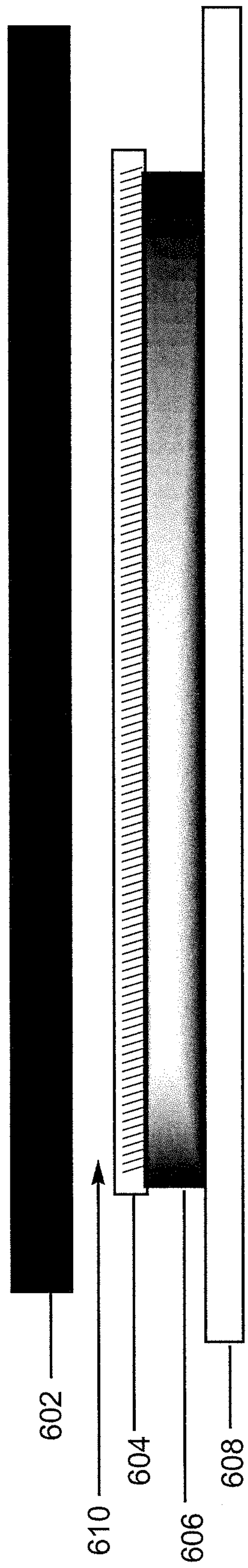



FIG. 6

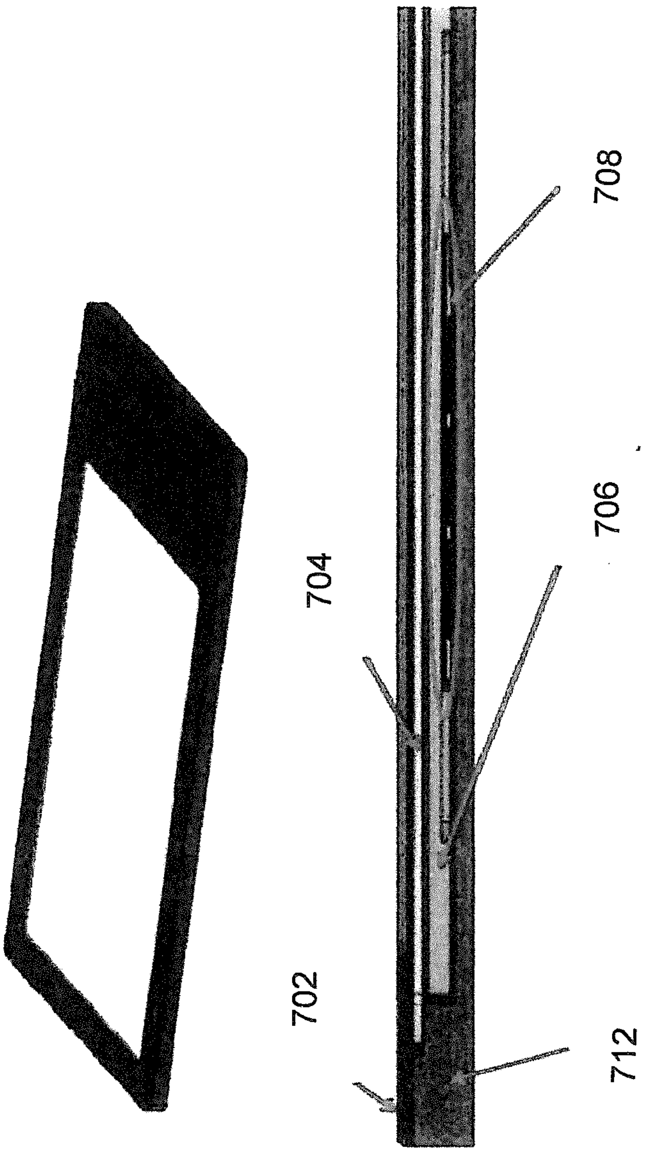



FIG. 7

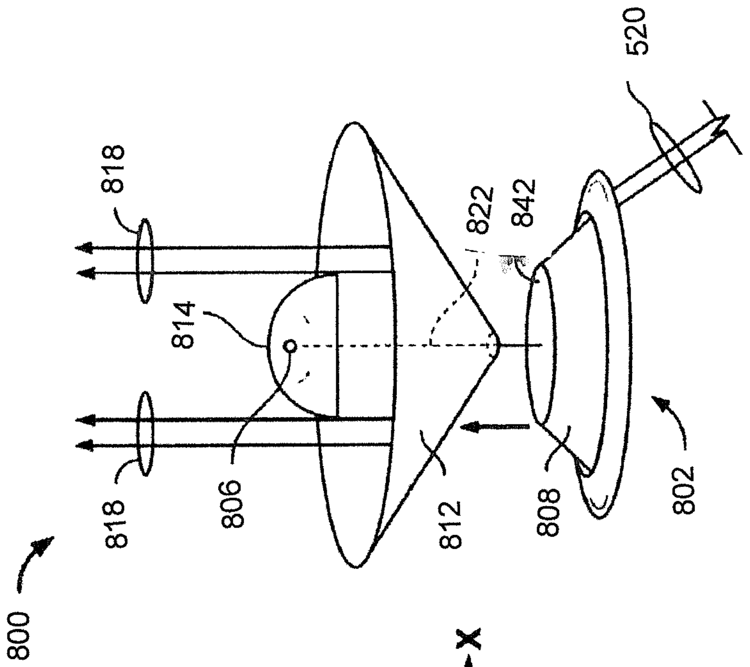

800
818
818
806
814
812
822
842
808
802
520

FIG. 8B

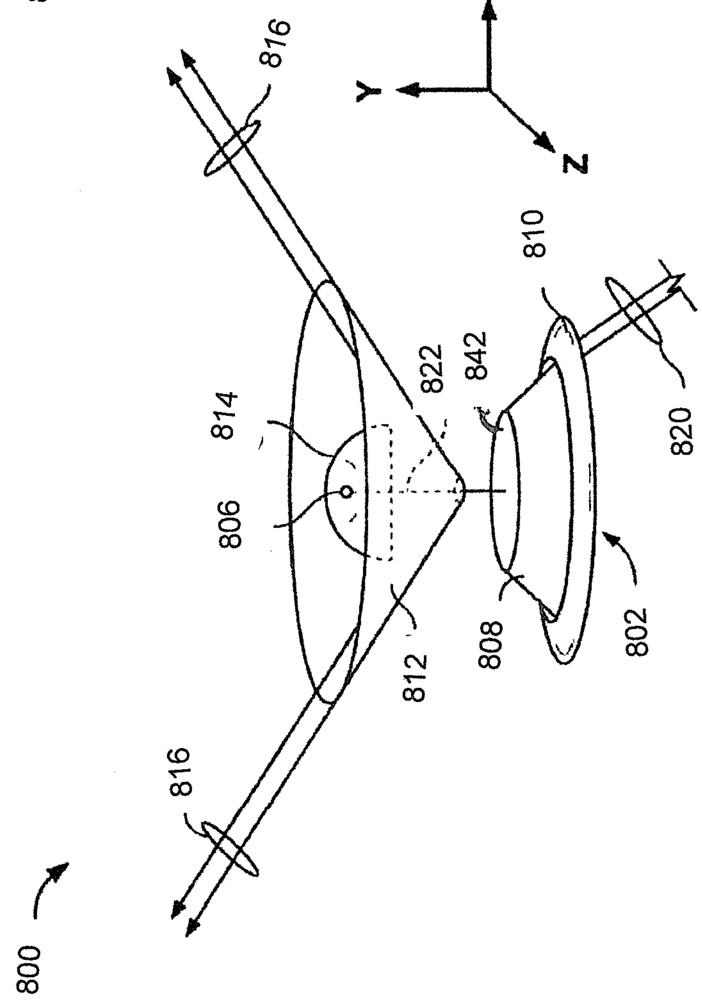
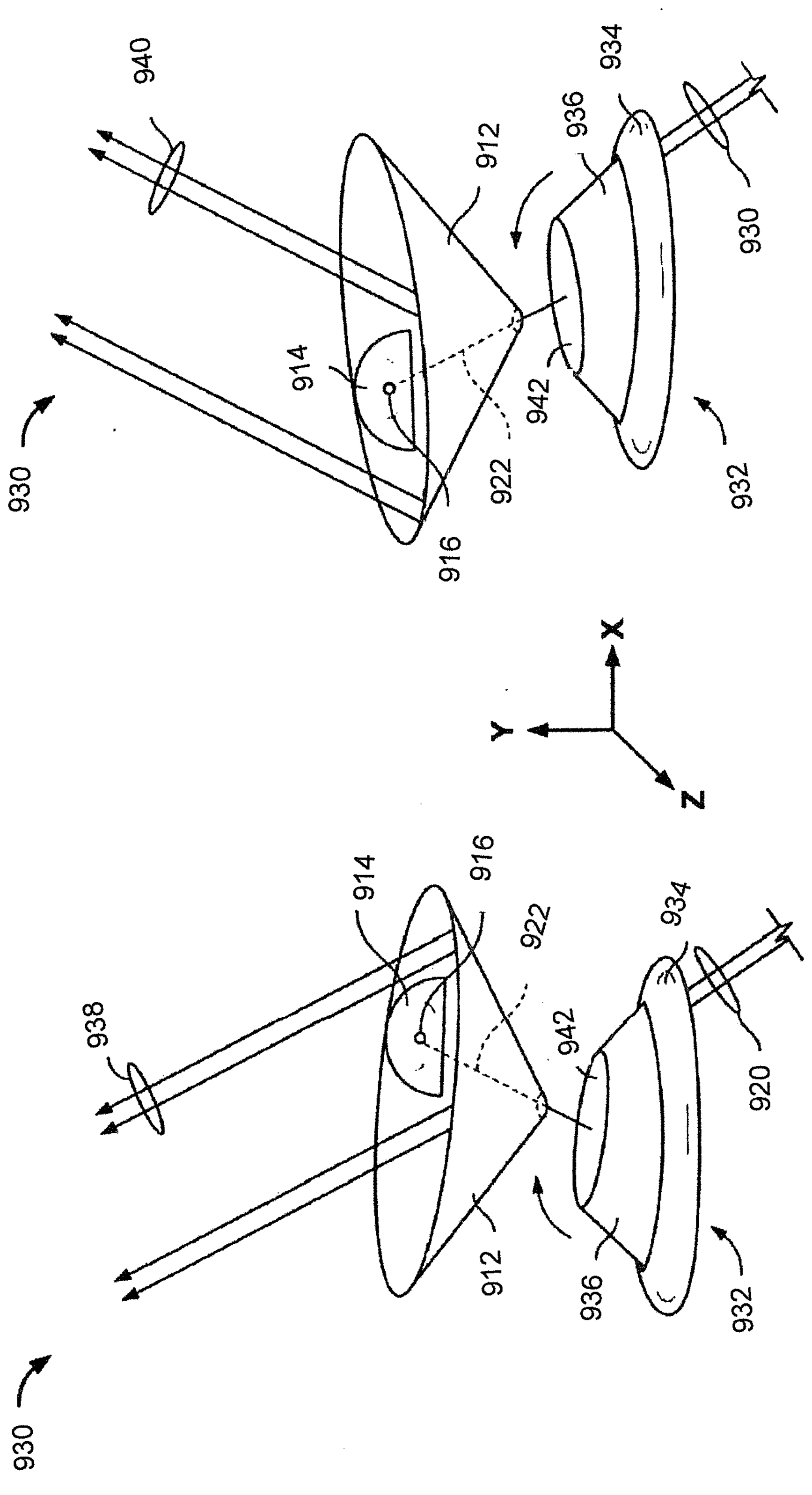

X
Y
Z
800
816
816
806
814
812
822
842
808
810
802
820

FIG. 8A


930
940
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922
942
936
934
930
932
X
Y
Z
930
938
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916
922
942
934
912
936
932
920

FIG. 9B

FIG. 9A

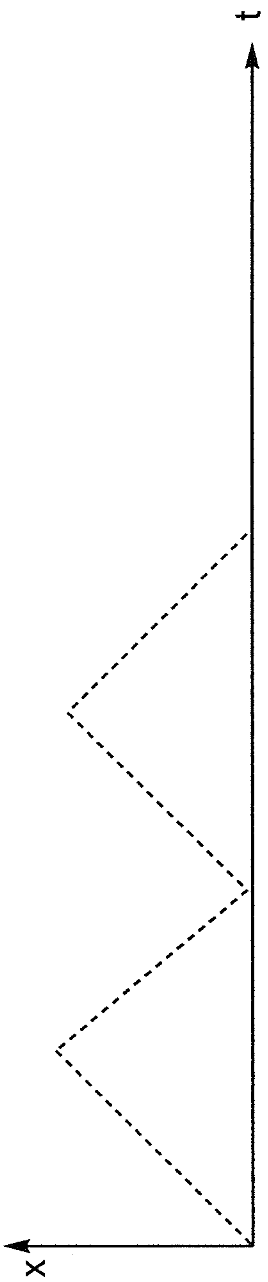


FIG. 10

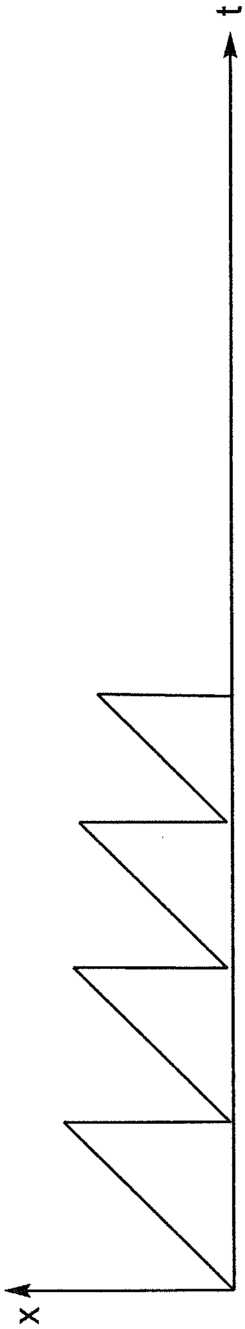


FIG. 11

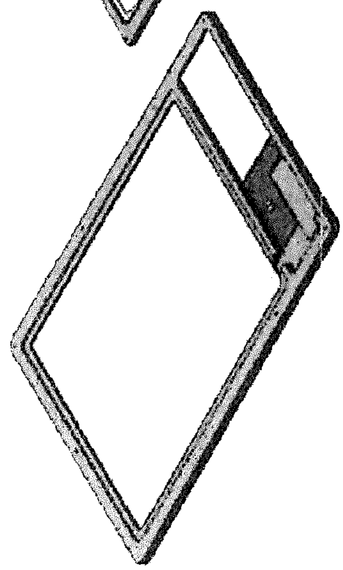

FIG. 12A

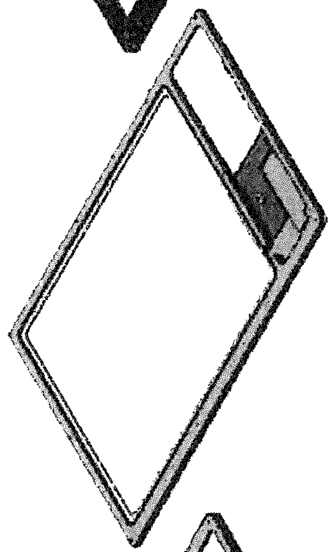

FIG. 12B

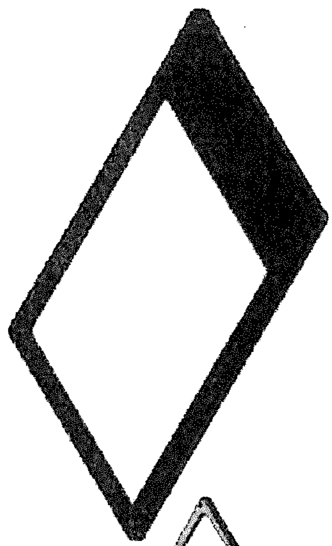

FIG. 12C