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(54) **Title:**
**CONTOUR FORM CONTROL**

(57) **Abstract:**
CONTOUR FORM CONTROL ABSTRACT This invention describes methods and apparatus for implementing a Convergence Process to Converge a Lens Design wherein a previous DMD Show may be modified for a subsequent Iteration. In preferred embodiments, an Iterative Loop may be initiated during a Convergence Process wherein one or more of various: techniques, modalities, and thickness correction methods may be implemented. Fig. 1

## CONTOUR FORM CONTROL

## ABSTRACT

This invention describes methods and apparatus for implementing a Convergence Process to Converge a Lens Design wherein a previous DMD Show may be modified for a subsequent Iteration. In preferred embodiments, an Iterative Loop may be initiated during a Convergence Process wherein one or more of various: techniques, modalities, and thickness correction methods may be implemented.

**Fig. 1**

# CONTOUR FORM CONTROL

## FIELD OF USE

The present invention describes methods and apparatus to control manufacture of an article via contour forming apparatus. More specifically, a contour forming apparatus may be controlled based upon a Convergence Process to manufacture a series of Contour Form Lenses until a Lens Design meets an Acceptance Criteria.

## SUMMARY OF THE INVENTION

Accordingly, one aspect of this invention provides for implementing a Convergence Process to create a contour form contact Lens that meets an Acceptance Criteria of a Lens Design. For example, a DMD Show may create a Lens that does not meet an Acceptance Criteria wherein a Convergence Process may be initiated for a subsequent Iteration. There may be a variety of one or more of a masking technique, a Convergence modality, and a thickness correction method used during a Convergence Process.

A masking technique may include one or more of a radial masking technique, a sector masking technique, a segment masking technique, and an area masking technique, wherein Blend Zones may be applied if necessary. A modality may include one or more of a one-sided Convergence modality and a two-sided Convergence modality. Accordingly, one or both of an apex-locking technique and a piston-shifting technique may be used when performing one or both of a one-sided Convergence Modality and a two-sided Convergence modality.

Furthermore, a thickness correction method may include one or more of a percentage thickness correction method, an arithmetic thickness correction method, and a secant thickness correction method. One of either of a uniform spatial gain method and a non-uniform spatial gain method may be applied when utilizing a thickness correction method. There may be multiple types of a non-uniform spatial gain method including a function-based non-uniform spatial gain method and a direct mapping non-uniform spatial gain method.

The present invention provides a method of controlling the manufacture of an ophthalmic device via a contour forming device, comprising:

(a) issuing an instruction to the contour forming device to make an ophthalmic device;

(b) making the ophthalmic device with the contour forming device based on the instruction;

(c) measuring the ophthalmic device;

(d) determining if the ophthalmic device conforms to an acceptance criteria of a lens design; and wherein

(e) following a determination that the ophthalmic device does not conform to the acceptance criteria, the method further comprises

(f) carrying out a convergence process to converge the ophthalmic device towards the lens design.

The convergence process may comprise (g) modifying the previous instruction to create a subsequent instruction capable of creating a subsequent ophthalmic device.

The method may further comprise (h) making a subsequent ophthalmic device with the contour forming device based on the subsequent instruction.

The method may further comprising repeating steps (g) and (h) until it is determined that the ophthalmic device conforms to the acceptance criteria of the lens design.

The contour forming device may comprise a digital micromirror device (DMD), and the or each instruction may be a DMD show instruction.

The convergence process may comprise a convergence masking technique.

The convergence masking technique may comprise defining a selected masking region, and selectively carrying out the convergence process within the selected masking region.

The convergence masking technique may comprise defining a selected masking region and selectively carrying out the convergence process outside of the selected masking region.

The selected masking region may comprise one or more of a radius, a sector, a segment, and an area.

The convergence masking technique may comprise one or more of a Blend Zone.

The Blend Zone may comprise one or more specified zones connecting said selected masking region to one or more of a non-masked region.

The convergence process may comprise a convergence modality.

The convergence modality may comprise modifying the previous instruction in regions of the measured ophthalmic device which are too thick compared with a target thickness and modifying the previous instruction in regions of the measured ophthalmic device which are too thin compared with a target thickness.

The convergence modality may comprise modifying the previous instruction only in regions of the measured ophthalmic device which are too thin compared to the target thickness.

Modifying the previous instruction may comprise increasing instruction in the regions of the measured ophthalmic device which are too thin compared to the target thickness.

The convergence modality may comprise modifying the previous instruction only in regions of the measured ophthalmic device which are too thick compared to the target thickness.

Modifying the previous instruction may comprise decreasing instruction in the regions of the measured ophthalmic device which are too thick compared to the target thickness.

The convergence modality may comprise a piston-shifting technique.

The piston-shifting technique may comprise performing a uniform shift of an equal amount, of one or more of a selected portion of a previous DMD Show instruction.

The convergence modality may comprise an apex-locking technique.

The apex-locking technique may comprise a locked $I_{CT}$ wherein said $I_{CT}$ is set to a specified value, that remains constant during a subsequent Iteration.

The convergence process may comprise a thickness correction method.

The thickness correction method may comprise one or more of a percentage method, an arithmetic method, and a secant method.

The thickness correction method may comprise a Filtering process of one or more of a data point.

The Filtering process may comprise one or more of defining, detecting, removing, and correcting errors in given data.

The thickness correction method may comprise a Surface Fitting process of one or more of said data point.

The Surface Fitting process may comprise constructing one or both of a surface and a mathematical function that has a best fit to a series of said data points by implementing one of either interpolation and smoothing.

The thickness correction method may comprise a uniform spatial gain method.

The uniform spatial gain method may provide for one or more of a same said thickness correction method to be applied across said Training Region wherein a gain magnitude factor is equal at each pixel location.

The thickness correction method may comprise a non-uniform spatial gain method.

The non-uniform spatial gain method may comprise one or more of same said thickness correction method applied across said Training Region wherein said gain magnitude factor may be different at each pixel location.

The non-uniform spatial gain method may comprise a function-based non-uniform spatial gain method.

The function-based non-uniform spatial gain method may comprise relating said gain magnitude factor to a radial location of said pixel.

The non-uniform spatial gain method may comprise a direct mapping non-uniform spatial gain method.

The direct mapping non-uniform spatial gain method may comprise leveraging corresponding data from a Training Region derived from one or more of said previous DMD Shows, said measured Lens, and said Lens Design wherein desired said gain magnitude factor may be calculated at each pixel location.

The present invention further provides an apparatus for modifying a digital micromirror device Show to create a Contour Form Ophthalmic Lens that Converges a Lens Design, the apparatus comprising:

a computer processor in digital communication with a Contour Forming device; and

a digital media storage device in communication with the computer processor and wherein stored on the digital media storage device is executable software code which is executable upon demand to implement the method described herein.

Optionally, stored on the digital media storage device is digital data descriptive of an inventory of data wherein said data comprise one or both of Lens Design data and DMD Show data.

## BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 illustrates methods steps that may be used to implement the present invention.

Fig. 2a illustrates an example of a radial masking technique that may be used to implement the present invention.

Fig. 2b illustrates an example of a sector masking technique that may be used to implement the present invention.

Fig. 2c illustrates an example of a segment masking technique that may be used to implement the present invention.

Fig. 2d illustrates an example of an area masking technique that may be used to implement the present invention.

Fig. 2e illustrates an example of Blend Zones that may be used to implement the present invention.

Fig. 3 illustrates a graphical representation in flat space of a two-sided Convergence modality that may be used to implement the present invention.

Fig. 4 illustrates a graphical representation in flat space of a one-sided Convergence modality utilizing a thickening ratchet procedure that may used to implement the present invention.

Fig. 5 illustrates a graphical representation in flat space of a one-sided Convergence modality utilizing a thinning ratchet procedure that may be used to implement the present invention.

Fig. 6 and Fig. 7 illustrate graphical representations in flat space of an apex locking technique that may be used to implement the present invention.

Fig. 8 illustrates a graphical representation in flat space of a piston-shifting technique that may be used to implement the present invention.

Fig. 9 illustrates a processor that may be used to implement the present invention.

## DETAILED DESCRIPTION OF INVENTION

The present invention provides for methods and apparatus for one or both of creating and modifying a DMD show to create a Lens that Converge a Lens Design. In the following sections detailed descriptions of embodiments of the invention will be given. The description of both preferred and alternative embodiments though thorough are exemplary embodiments only, and it is understood that to those skilled in the art that variations, modifications and alterations may be apparent. It is therefore to be understood that said exemplary embodiments do not limit the broadness of the aspects of the underlying invention. Method steps described herein are listed in a logical sequence in this discussion however this sequence no way limits the order in which they may be implemented unless specifically stated.

## GLOSSARY

In this description and claims directed to the presented invention, various terms may be used for which the following definitions will apply:

"Acceptance Criteria" as used herein, refers to one or both of specified parameter ranges and specified parameter values, such that if measured parameters of a fabricated Lens or Lens Precursor fall within a range or meet a value of one or both a Lens Design and a Desired Target File, the fabricated Product may be deemed acceptable.

"Blend Zone" as used herein means a contiguous area that blends one or both of a portion of a Lens to another adjoining portion of a Lens, and a portion of a DMD Show to another adjoining portion of a DMD Show. The blend zone is an area in which a property of a portion of a lens and a property of another adjoining portion of the lens are blended.

"Catalog Item" as used herein, refers to a file, feature, component, design, data or descriptor that may temporarily or permanently stored in , for example, libraries or databases, and may be recalled for use without having to recreate them.

"Contour Forming Device" as used herein, refers to equipment and methods for fabricating one or more of a Lens Precursor Form, a Lens Precursor, and a Lens wherein the device may involve, for example, the use of actinic radiation, Reactive Mixture, and DMD devices.

"Convergence" (also sometimes referred to herein as: "Convergence Process" or "Converge" with the same meaning as "Convergence Process") as used herein, refers to the process of modifying an instruction and using the modified instruction in an Iterative Loop. The iteration may be continued until subsequent fabricated Lens parameters satisfy one or both of a specified Acceptance Criteria and a Desired Target File. The instruction may be a DMD file or DMD files.

"Curved Space" as used herein, refers to a coordinate mapping space (e.g., Cartesian, polar, spherical, etc) where curvature of a design has not been removed.

"Custom Product" as used herein, refers to a Product including one or more parameters that may be available in other than incremental steps. Custom Product parameters allow for more precise sphere power, cylinder power, and cylinder axis (e.g., -3.125D/-0.47D x 18°) than Standard Product parameters, and may include base curves, diameters, and stabilization profiles, and thickness profiles based upon a particular use of a Product offered.

"Desired Target File" as used herein, "Desired Target File" or "Target File" refers to data that may represent one or more of a Lens Design, a Thickness Map, a Lens Precursor design, a Lens Precursor Form design, a Lens Precursor Feature design, and combinations of the above. A Desired Target File may be represented in either a hydrated or un-hydrated state, in Flat or Curved Space, in 2-dimensional or 3-dimensional space, and by methods including but not limited to, geometric drawings, power profile, shape, features, thicknesses etc. Desired Target Files may contain data on a regularly or irregularly spaced grid.

"Digital Core Break" as used herein, refers to a range of Product where select Lens Precursor Features or control parameters or other features may be identical and may remain constant within a specified Product range.

"DMD" as used herein, refers to a digital micromirror device that is a bistable spatial light modulator consisting of an array of movable micromirrors mounted over a CMOS SRAM. Each mirror may be independently controlled by loading data into the memory cell below the mirror to steer reflected light, spatially mapping a pixel of video data to a pixel on a display. The data electrostatically controls the mirror's tilt angle in a binary fashion, where the mirror states are either +X degrees ("on") or –X degrees ("off"). For example, with current devices, X may be either 10 degrees or 12 degrees (nominal); future devices may have different tilt angles. Light reflected by the "on" mirrors is passed through a projection Lens and onto a screen. Light reflected by the "off" mirrors creates a dark field, and defines the black-level floor for the image. Images are created by gray-scale modulation between "on" and "off" levels at a rate fast enough to be integrated by the observer. Each mirror may receive a number of instructions from one, none, or a plurality of DMD Shows. Select mirrors may be turned "on" during the Lens fabrication process. DMDs (digital micromirror device) may be found in DLP projection systems.

“DMD Control Software” as used herein, refers to software that organizes and utilizes DMD Files and DMD Shows that may enable fabrication of Lens Precursors, or Lens Precursor Features.

“DMD Show” as used herein “DMD Show” or “DMD File” refers to a collection of one or both of time based instructional data points and thickness based instructional data points that may be used to activate mirrors on a DMD, and enable a Lens or Lens Precursor or Lens Precursor Form or Lens Precursor Feature(s) to be fabricated. A DMD Show may have various formats, with (x,y,t), and (r, θ, t) being the most common where, for example “x” and “y” are Cartesian coordinate locations of DMD mirrors, “r” and “θ” are Polar coordinate locations of DMD mirrors, and “t” represents time instructions controlling DMD mirror states. DMD Shows may contain data on a regularly or irregularly spaced grid.

“Fabrication Process Conditions” as used herein, refers to settings, conditions, methods, equipment and processes used in fabrication of one or more of a Lens Precursor, a Lens Precursor Form, and a Lens.

“Filtering” as used herein, refers to the process including one or more of defining, detecting, removing, and correcting errors in given data, in order to minimize the impact of errors in input data on succeeding analyses.

“Flat Space” as used herein, refers to coordinate mapping space (e.g., Cartesian, polar, spherical, etc) where curvature of a design being considered has been removed.

“Fluent Lens Reactive Media” as used herein, means a Reactive Mixture that is flowable in either its native form, reacted form, or partially reacted form and may be formed upon further processing into a part of an ophthalmic Lens.

“Free-form” as used herein “free-formed” or “free-form”, (also sometimes referred to herein as: "contour formed" or "contour form" with the same meaning as "contour formed"), refers to a surface that is formed by crosslinking of a Reactive Mixture via exposure to actinic radiation on a voxel by voxel basis, with or without a fluent media layer, and is not shaped according to a cast mold, lathe, or laser ablation. Detailed description of Free-form methods and apparatus are disclosed in United States Patent Publication No. US2009/0053351 and in United States Patent Publication No. US2009/0051059.

"Iteration" as used herein, refers to the creation of a subsequent DMD File / DMD Show that is subsequently, used in the Convergence Process to satisfy Acceptance Criteria.

"Iterative Loop" as used herein, refers to one, or a series of process steps that may enable one or more of a Lens, a Lens Precursor, and a Lens Precursor Feature fabrication such that each time through a loop, one or more of a Lens, Lens Precursor, and a Lens Precursor Feature may be more conformal to a desired Lens Design, than its predecessor. A Convergence Process may contain one or more Iterative Loops wherein one or both of DMD Shows and Fabrication Process Conditions may be modified.

"Lens" as used herein, "Lens" or "lens" refers to any ophthalmic device that resides in or on the eye. These devices may provide optical correction or may be cosmetic. For example, the term Lens may refer to a contact Lens, intraocular Lens, overlay Lens, ocular insert, optical insert or other similar device through which vision is corrected or modified, or through which eye physiology is cosmetically enhanced (e.g., iris color) without impeding vision. The preferred Lenses may be soft contact Lenses and may be made from silicone elastomers or hydrogels, which include but are not limited to silicone hydrogels, and fluorohydrogels.

"Lens Design" as used herein, refers to form, function or both of a desired Lens, which if fabricated, may provide optical power correction, acceptable Lens fit (e.g., corneal coverage and movement), acceptable Lens rotation stability, etc. Lens Designs may be represented in either a hydrated or un-hydrated state, in Flat or Curved Space, in 2-dimensional or 3-dimensional space, and by a method including one or more of, geometric drawings, power profile, shape, features, thicknesses etc. Lens Designs may contain data on a regularly or irregularly spaced grid.

"Lens Precursor" as used herein, means a composite object consisting of a Lens Precursor Form and Fluent Lens Reactive Media in contact with a Lens Precursor Form that may be rotationally symmetrical or non-rotationally symmetrical. For example, Fluent Lens Reactive Media may be formed in the course of producing a Lens Precursor Form within a volume of Reactive Mixture. Separating a Lens Precursor Form and Fluent Lens Reactive Media from a volume of Reactive Mixture used to produce a Lens Precursor Form may generate a Lens Precursor. Additionally, a Lens Precursor may be converted to a different entity by either the removal of an amount of Fluent Lens Reactive Media or the conversion of an amount of Fluent Lens Reactive Media into non-fluent incorporated material.

"Lens Precursor Feature", also referred to as "feature", as used herein, refers to a non-fluent substructure of a Lens Precursor Form, and acts as an infrastructure for a Lens Precursor. Lens Precursor Features may be defined empirically or described mathematically by control parameters (height, width, length, shape, location, etc.,) may be are fabricated via DMD Show instructions. Examples of Lens Precursor Features may include one or more of the following: a Lens Edge feature, a Stabilization Zone feature, a Smart Floor Volumator feature, an Optic Zone feature, a Moat feature, a Drain Channel feature, etc. Lens Precursor Features may be fabricated using Actinic Radiation Voxels and may be incorporated into an ophthalmic Lens upon further processing.

"Lens Precursor Form" as used herein, refers to a non-fluent object, which may be consistent with being incorporated upon further processing into an ophthalmic Lens.

"Opthalmic device" or "Product" as used herein, refers to one or more of a Lens, a Lens Precursor, and a Lens Precursor Form and may include either "Standard Product" or "Custom Product".

"PV" (Peak to Valley) as used herein, refers to the difference between the highest point and the lowest point on a surface of one or more of a measured Lens Precursor, a measured Lens Precursor Form, and a measured Lens for one or both of a whole surface, and a specified region, (e.g., an optic zone), and may be part of an Acceptance Criteria.

"RMS" (Root Mean Square) as used herein, refers to the smoothness of one or more of a measured Lens Precursor, a measured Lens Precursor Form, and a measured Lens for one or both of a whole surface, and a specified region, (e.g., an optic zone), and may be part of an Acceptance Criteria.

"Standard Product" as used herein, refers to a Product with limited Product parameter availability, such as those offered in discrete steps. For example, sphere power parameters may only be available in 0.25D steps (e.g., -3.00D, 3.25D, -3.50D, etc.); cylinder power parameters may only be available in 0.50D steps (e.g, -0.75D, -1.25D, -1.75D, etc.); and cylinder axis parameters may only be available in 10° steps (e.g., 10°, 20°, 30°, etc.). Other Standard Product parameters and features offered in discrete steps include but are not limited to base curve radii, diameter, stabilization profiles and thickness profiles.

"Substrate" as used herein, refers to a physical entity upon which other entities may be placed or formed.

“Surface Fitting” as used herein, refers to the process of constructing a surface or mathematical function that has the best fit to a series of data points, possibly subject to constraints. Surface Fitting can involve either interpolation, where an exact fit to the data is required, or smoothing, in which a "smooth" function is constructed that approximately fits the data.

“Thickness Map” as used herein, refers to a 2-dimensional or 3-dimensional thickness profile representation of a desired Product, Lens Precursor Form, or Lens Precursor. Thickness Maps may either be in Flat or Curved Space coordinate space and may contain data on a regularly or irregularly spaced grid.

“Training Region” as used herein, refers to one or both of a whole Lens, and one or more portions of a Lens, that may be iterated upon during a Convergence Process.

“Voxel” as used herein, also referred to as “Actinic Radiation Voxel” is a volume element, representing a value on a regular or irregular grid in 3-dimensional space. A Voxel may be viewed as a three dimensional pixel, however, wherein a pixel represents 2D image data a Voxel includes a third dimension. In addition, wherein Voxels are frequently used in the visualization and analysis of medical and scientific data, in the present invention, a Voxel is used to define the boundaries of an amount of actinic radiation reaching a particular volume of Reactive Mixture, thereby controlling the rate of crosslinking or polymerization of that specific volume of Reactive Mixture. By way of example, Voxels are considered as existing in a single layer conformal to a 2-D mold surface wherein the Actinic Radiation may be directed normal to the 2-D surface and in a common axial dimension of each Voxel. As an example, specific volume of Reactive Mixture may be crosslinked or polymerized according to 768x768 Voxels.

A Lens may be fabricated based upon a desired Lens Design, via the use of DMD Shows. Furthermore, a fabricated Lens may not conform to an Acceptance Criteria of a Lens Design wherein an Iteration of a previous DMD Show may have to occur. For example, an Iteration of a previous DMD Show may enable closer Convergence of a desired Lens Design.

Referring now to Fig. 1, a flowchart illustrates method steps that may be followed to implement the present invention. At 101, in some embodiments, a Lens surface may be examined for surface anomalies (e.g., blobs, dirt, etc), that may be present on a Lens surface. At 102, upon determination that surface anomalies are present on a Lens surface, a Lens may be discarded and a new Lens remade for example, by utilizing the same settings of a previous DMD Show. At 103, upon determination that surface anomalies are not present on a Lens surface, a PV value may be determined. If a PV is not acceptable, at 104, parameters for a subsequent Iteration of a DMD Show may be created and a new Lens made. If a PV is acceptable, at 105, a determination may be made of whether a RMS is in a desired optic zone. If a RMS is not acceptable, at 104, parameters for a subsequent DMD Show may be created and a new Lens made. If a RMS is acceptable, at 106, a determination may be made of whether a measured Lens meets other thickness specifications (e.g., peripheral geometries). If other thickness specifications are not acceptable, at 104, parameters for a subsequent Iteration of a DMD Show may be created and an Iteration of a Lens made. If other thickness specifications are acceptable, at 107, a Lens may be released for post processing.

As discussed in the aforementioned method steps, there may be cases when a previous DMD Show creates a Lens that does not conform to an Acceptance Criteria of a Lens Design and a subsequent Iteration may be needed.

There may be a variety of one or more: techniques, modalities, and methods utilized during a Convergence Process. When performing a Convergence Process, a subsequent DMD Show instruction for a subsequent Iteration may be one or both of an altered previous DMD Show instruction, a combination of a previous show instruction and one or more of another DMD Show instruction, and a combination of two or more DMD Shows. For example, two or more portions from one or multiple DMD Shows may be combined together for a subsequent Iteration. Accordingly, an Iterative Loop of a Convergence Process may be continuously repeated until a Lens meets an Acceptance Criteria of a Lens Design.

In some aspects of the present invention, a masking technique may be implemented during a Convergence Process. In some embodiments, a masking technique may include one or more of a radial masking technique, a sector masking technique, a segment masking technique, and an area masking technique. In some related embodiments, one or more of a masking technique may be applied to either: one DMD Show, and two or more DMD Shows that may be used in a subsequent Iteration. Additionally, one or more of a masking technique may be applied to a Training Region of a Lens that may include one or both of a whole Lens, and one or more of a portion of a Lens.

Furthermore, performing a masking technique may be used to further Converge a Lens Design even if a measured Lens already meets a desired Acceptance Criteria. For example, a PV of a measured Lens may be acceptable, but performing a masking technique in a subsequent Iteration may cause Convergence of a Lens Design even more closely and therefore, enable better performance of a Lens such as improving vision with even more precision than it may have been without using a masking technique.

Referring now to Figs. 2a-2d, illustrate various examples of different masking techniques, in flat space. When implementing a masking technique a user may specify one or more of a boundary inside of which a DMD Show may be used, and outside of which a different DMD Show may be used.

Referring now to Fig. 2a, illustrates an example of a radial masking technique applied to a DMD Show. When using a radial masking technique for a subsequent Iteration, one or more portions of one or more DMD Shows, may be specified to occur within a certain radius 201. Additionally, one or more portions of one or more different DMD Shows may be specified to occur within one or both of one or more radii of a Lens Design, and an entire remaining portion of a Lens Design.

Referring now to Fig. 2b, illustrates an example of a sector masking technique applied to a DMD Show. When using a sector masking technique for a subsequent Iteration, one or more portions of one or more DMD Shows, may be specified to occur within a certain sector 202. Additionally, one or more portions, of one or more different DMD Shows may be specified to occur within one or both of one or more sectors of a Lens Design, and an entire remaining portion of a Lens Design.

Referring now to Fig. 2c, illustrates an example a segment masking technique applied to a DMD Show. When using a segment masking technique for a subsequent Iteration, one or more portions of one or more DMD Shows, may be specified to occur within a certain segment 203, 204. Additionally, one or more portions, of one or more different DMD Shows may be specified to occur within one or both of one or more segments of a Lens Design, and an entire remaining portion of a Lens Design.

Referring now to Fig. 2d, illustrates an example an area masking technique applied to a DMD Show. When using an area masking technique for a subsequent Iteration, one or more portions of one or more DMD Shows, may be specified to occur within a certain area 205. Additionally, one or more portions, of one or more different DMD Shows may be specified to occur within one or both of one or more areas of a Lens Design, and an entire remaining portion of a Lens Design.

One or more of a Blend Zone 206 may be specified when using a masking technique. For example, one or more of a Blend Zone 206 may be applied when implementing a masking technique and two or more portions 207, 208 taken from either one DMD Show or two or more DMD Shows, do not connect to one another when they are combined together in a subsequent DMD Show, as illustrated in Fig. 2e. A blend zone 206 exists between a portion 207 of the lens and an adjoining portion 208 of the lens. In each blend zone, a property of the portion 207 of the lens and a property of the adjoining portion 208 of the lens are blended.

In some additional aspects of the present invention, there may be different Convergence modalities implemented during a Convergence Process either, by one or both of a one-sided Convergence modality, and a two-sided Convergence modality. In some embodiments, a two-sided Convergence modality may be used when performing an Iteration of a previous DMD Show to Converge a Lens Design in a subsequent DMD Show. For example, a previous show may create parts of a Lens that may be either one or both of thicker than a Lens Design, and thinner than a Lens Design. When performing a two-sided Convergence modality, an Iteration for a subsequent DMD Show may occur by adjusting one or more of a parameter of both of an instruction that resulted in a Lens with both one or more thicker areas and one or more thinner areas, than called for in a Lens Design. Adjustments may occur at each pixel of a previous show for a subsequent show.

A one-sided Convergence modality may also be implemented to Converge a Lens Design in a subsequent DMD Show. When performing an Iteration of a previous DMD Show, a one-sided Convergence modality may be performed by utilizing either one or both of a thickening ratchet instruction, and a thinning ratchet instruction. For example, a previous DMD Show may create areas of a Lens that may be either one or both of thicker than a Lens Design, and thinner than a Lens Design. Iterations for a subsequent show instruction may occur by one of either adjusting one or more parameters of an instruction that needs to be decreased in value, and of an instruction that needs to be increased in value. Accordingly, adjustments may occur at each pixel of selected areas for a subsequent show instruction.

Referring now to Fig. 3, illustrates a graphical representation in flat space, of implementing a two-sided Convergence modality. In this example, the previous DMD instruction 301 created the measured Lens 303 with areas 306 of the Lens that were thinner than the target thickness 302, and areas 305 of the lens that were thicker than the target thickness 302 of the desired Lens Design.

At 300, illustrates applying a two-sided Convergence modality to the subsequent DMD instruction 304. The subsequent DMD Show instruction 304 results in decreasing instruction in areas 307 of the previous DMD Show instruction 301 that created regions that were too thick on the measured Lens 303, in comparison to the target thickness value 302. In areas 307 the subsequent instruction is reduced compared to the previous instruction. Additionally, the subsequent DMD Show instruction results increasing instruction in areas 308 of the previous

DMD Show instruction 301 that created regions that were too thin on the measured Lens 303, in comparison to the target thickness value 302.

Referring now to Fig. 4, illustrates a graphical representation in flat space, of implementing a one-sided Convergence modality by utilizing a thickening ratchet instruction. In this example, the previous DMD instruction 401 created the measured Lens 403 with areas 406 of the Lens that were thicker than the target thickness and areas 407 of the Lens that were thinner than the target thickness 402 of the Lens Design.

At 400, illustrates applying a one-sided Convergence modality by utilizing a thickening ratchet instruction 405 in the subsequent DMD Show instruction 404. The subsequent DMD instruction 404 results in an increasing instruction only in areas 408 of the previous DMD Show instruction 401 that created regions 407 that were too thin on the measured Lens 403, in comparison to the target thickness value 402. Additionally, the subsequent DMD instruction 404 remains unchanged from the previous show instruction 401 that created regions 406 of the measured Lens 403 that were too thick, in comparison to the target thickness value 402. Therefore, for the subsequent Iteration, adjustments occur only to portions of the previous show that resulted in regions 407 that were too thin on the measured Lens 403 while other areas 409 remain unchanged in the subsequent DMD instruction 404. The previous instruction is to be used in regions 409 of the previous instruction that created regions 406 of the measured lens 403 that were too thick, in comparison to the target thickness value 402.

Referring now to Fig. 5, illustrates a graphical representation in flat space, of a one-sided Convergence technique by utilizing a thinning ratchet instruction. In this example, the previous DMD instruction 501 created the measured Lens 503 with areas that were both thicker 506 and thinner 507 than the target thickness 502 of the Lens Design.

At 500, illustrates applying a one-sided Convergence modality by utilizing a thinning ratchet instruction 505 in the subsequent DMD Show instruction 504. The subsequent DMD instruction 504 results in only decreasing instruction of the previous DMD Show instruction 501 that created regions 506 that were too thick on the measured Lens 503, in comparison to the target thickness 502. Additionally, the subsequent DMD instruction 504 remains unchanged from the previous show instruction 504 that created areas 507 of the measured Lens 503 that were too thin, as compared to the target thickness value 502. Therefore, for the subsequent Iteration, adjustments occur only to portions of the previous show that resulted in regions 506 that were too thick on the measured Lens 503 while other areas remain unchanged in the subsequent DMD instruction 504. At 509, the subsequent instruction is reduced compared to the previous instruction. At 508, the previous instruction is used.

In some further aspects of the present invention, various techniques including one or both of an Apex locking technique and a piston-shifting technique may be applied when implementing one or more the aforementioned Convergence modalities. When performing an apex-locking technique an instruction at an apex from a previous DMD Show may be adjusted up to a target thickness value. Furthermore, other selected areas of a previous instruction may be adjusted up uniformly by a same amount as an apex value and an apex may be locked so that it may be kept constant for other subsequent DMD Shows.

For example, when locking an apex control, instruction at an apex ($I_{CT}$) may be adjusted up to a target thickness apex value and kept the same; this measured distance between an $I_{CT}$ and a target thickness apex is a lock CT value. A lock CT value ($\Delta^{th}$), may be calculated by taking the difference between an $I_{CT}$ of a previous show and a target thickness apex value of that same show. Subsequently, $\Delta^{th}$ may be added to every point of an entire measured Lens surface, and may become a "modified" Lens thickness file for a subsequent DMD Show. Consequently, a subsequent DMD Show instruction may create a "modified" measured Lens and subsequently, be compared to a Lens Design.

Additionally, performing an apex locking technique may be used to further Converge a Lens Design even if a measured Lens already meets a desired Acceptance Criteria. For example, a PV of a measured Lens may be acceptable, but performing an apex locking technique in a subsequent Iteration may cause Convergence of a Lens Design even more closely and therefore, enable better performance of a Lens such as improving vision with even more precision than it may have been without using an apex locking technique.

Referring now to Fig. 6 and Fig. 7, Fig. 6, illustrates a graphical representation in flat space, of utilizing an apex locking technique when a Lens center thickness is too thin, and Fig. 7, illustrates a graphical representation in flat space, of utilizing an apex locking technique when a Lens center thickness is too thick. Additionally, both Fig. 6 and Fig. 7, are examples in flat space, of a comparison between a subsequent locked apex DMD instruction wherein the $I_{CT}$ remains the same as in the previous show instruction 601 and 701, and a subsequent non-locked apex DMD instruction 606 and 706, wherein the $I_{CT}$ may not remain the same as in the previous show instruction 601 and 701. The target thickness 602, 702, is shown in Figures 6 and 7 respectively. Referring now again to Fig. 6, in this example, the previous DMD instruction 601 created the measured Lens 603, where the $I_{CT}$ is thinner than the target thickness 602 apex value of the desired Lens Design. Referring now again to Fig. 7, in this example, the previous DMD instruction 701 created the measured Lens 703, where the $I_{CT}$ is thicker than the target thickness 702 apex value of the desired Lens Design.

Referring now again to both Fig. 6, at 605, and Fig. 7, at 705, the temporary adjusted measured Lens profile is created by comparing the difference between the $I_{CT}$ value of the measured Lens 603 and 703, and the target thickness apex value 602 and 702, and adjusting the subsequent instruction by $\Delta^{th}$. At 606 and at 706, the subsequent non-locked apex instruction is calculated by adding $\Delta^{th}$ to every point on the entire measured Lens 603 and 703, surface of a temporary adjusted measured Lens profile 605 and 705, plus any selected additional amount and thereby, adjusting a subsequent instruction by that total amount. At 604 and 704, the apex lock instruction is calculated by taking the difference of the non-locked apex instruction 606 and 706, and the $\Delta^{th}$, and subsequently, adding the difference to every point on the measured Lens 603 and 703, surface except to the $I_{CT}$. Accordingly, the $I_{CT}$ remains the same as in the previous DMD instruction 601 and 701, and is kept constant during subsequent Iterations when going through an Iterative Loop of a Convergence Process.

In some other additional aspects of the present invention, when performing a piston-shifting technique a uniform shift of a previous DMD Show instruction may be done to one or more selected portions of a previous instruction by a selected amount. Additionally, in some other embodiments, performing a piston shifting technique may be used to further Converge a Lens Design even if a measured Lens already meets a desired Acceptance Criteria. For example, a PV of a measured Lens may be acceptable, but performing a piston shifting technique in a subsequent Iteration may cause Convergence of a Lens Design even more closely and therefore, enable better performance of a Lens such as improving vision with even more precision than it may have been without using a piston shifting technique.

Referring now to Fig. 8, illustrates a graphical representation in flat space, of utilizing a piston-shifting technique. Additionally, at 800, is an example in flat space of a comparison between a subsequent piston shifted DMD instruction 805, wherein a uniform shift of one or more selected portions of the instruction of the previous show are adjusted by a same amount, and a subsequent non-piston shifted DMD instruction 804. In this example, the previous DMD instruction 801 created the measured Lens 803, with areas of the Lens that were both thicker and thinner than the target thickness 802 of the desired Lens Design. At 804, the subsequent non-piston-shifting instruction results by non-uniformly adjusting one or more of a selected portion of the previous DMD instruction 801 by one or more of various selected amounts. At 805, the subsequent piston-shift instruction results by uniformly shifting one or more of a selected portion of the previous DMD Show instruction 801 by a same selected amount.

Various thickness correction methods may be utilized in a Convergence Process to calculate a subsequent DMD Show instruction including one or more of an arithmetic thickness correction method, a percentage thickness correction method, and a secant thickness correction method. In cases where a Lens may not meet an Acceptance Criteria, a thickness correction method may be selected based upon observation made by someone skilled in the art.

Adjustments may be made at each pixel of a previous DMD Show using a selected thickness correction method to calculate a DMD Show instruction for a subsequent Iteration. Selected data points of a previous show may go through one or both of a Filtering process and a Surface Fitting process for a subsequent DMD Show prior to applying a thickness correction method. A DMD Show may be Iterated to affect certain or specific areas of a Lens. Accordingly, for example, subsequent Iterations of a previous DMD Show may result in one or more of changing a whole Lens, one or both of reducing certain apertures of a Lens and increasing certain apertures of a Lens (e.g., optic zone, peripheral zone), and changing select regions of a Lens.

Additionally, various gain magnitude factors may be applied to a calculation of a subsequent DMD Show instruction. Furthermore, a gain magnitude factor may be changed mid-stream during subsequent Iterations. For example, a gain factor of 200% applied to Iteration 3 may be dropped down to 150% at Iteration 5.

If a DMD Show creates a Lens that does not meet an Acceptance Criteria, an arithmetic thickness correction method may be used to calculate instructions for an Iterative DMD Show. Tables 1 to 4 illustrate a display of data generated by utilizing an arithmetic thickness correction method to calculate subsequent DMD Show instructions at different iterations and applying various gain magnitude factors. The illustrated data is generated by utilizing an arithmetic thickness correction method with application of various gain magnitude factors that may be used to implement the present invention.

For tables 1 to 4:

For each, any or all points in the data set, the location of the point is specified in cartesian coordinate space as ($X_{ij}$, $Y_{ij}$):

Instruction given in mm

For each, any or all points in Measured Lens data set, given at an (x,y) location:

Measured Lens Thicknesses given in mm

For each, any or all points in Target Thickness data set, given at an (x,y) location:

Target Thicknesses given in mm

Generically: Delta_Thickness = Target Thickness - Measured Lens Thickness

Scaled Delta Thickness Value = (DeltaT_* A)/100

Table 1

| | |
|---|---|
| Convergence Method | Arithmetic |
| Gain Factor (%) | 100 |

| Iteration # | # | Thickness Target (mm) | Instruction | Measured Lens | Delta Thickness | Gain Factor % | Scaled Delta Thickness |
|---|---|---|---|---|---|---|---|
| | | | Instruction_# | MLens_# | DeltaT_# | GF | CScaled_# |
| | | | | | | | |
| Initial Show | 0 | 0.0900 | 0.1250 | 0.0750 | 0.0150 | 100.000 | 0.0150 |
| Iteration I | 1 | 0.0900 | 0.1400 | 0.0850 | 0.0050 | 100.000 | 0.0050 |
| Iteration 2 | 2 | 0.0900 | 0.1450 | 0.0940 | -0.0040 | 100.000 | -0.0040 |
| Iteration 3 | 3 | 0.0900 | 0.1410 | 0.0910 | -0.0010 | 100.000 | -0.0010 |
| Iteration 4 | 4 | 0.0900 | 0.1400 | 0.0900 | 0.0000 | 100.000 | 0.0000 |

Table 2

| | |
|---|---|
| Convergence Method | Arithmetic |
| Gain Factor (%) | 200 |

| Iteration # | # | Thickness Target (mm) | Instruction | Measured Lens | Delta Thickness | Gain Factor % | Scaled Delta Thickness |
|---|---|---|---|---|---|---|---|
| | | | Instruction_# | MLens_# | DeltaT_# | GF | CScaled_# |
| | | | | | | | |
| Initial Show | 0 | 0.0900 | 0.1250 | 0.0750 | 0.0150 | 200.000 | 0.0300 |
| Iteration I | 1 | 0.0900 | 0.1550 | 0.0850 | 0.0050 | 200.000 | 0.0100 |
| Iteration 2 | 2 | 0.0900 | 0.1650 | 0.0940 | -0.0040 | 200.000 | -0.0080 |
| Iteration 3 | 3 | 0.0900 | 0.1570 | 0.0910 | -0.0010 | 200.000 | -0.0020 |
| Iteration 4 | 4 | 0.0900 | 0.1550 | 0.0900 | 0.0000 | 200.000 | 0.0000 |

Table 3

| | |
|---|---|
| Convergence Method | Arithmetic |
| Gain Factor (%) | 75 |

| Iteration # | # | Thickness Target (mm) | Instruction | Measured Lens | Delta Thickness | Gain Factor % | Scaled Delta Thickness |
|---|---|---|---|---|---|---|---|
| | | | Instruction_# | MLens_# | DeltaT_# | GF | CScaled_# |
| | | | | | | | |
| Initial Show | 0 | 0.0900 | 0.1250 | 0.0750 | 0.0150 | 75.000 | 0.0113 |
| Iteration I | 1 | 0.0900 | 0.1363 | 0.0850 | 0.0050 | 75.000 | 0.0037 |
| Iteration 2 | 2 | 0.0900 | 0.1400 | 0.0940 | -0.0040 | 75.000 | -0.0030 |
| Iteration 3 | 3 | 0.0900 | 0.1370 | 0.0910 | -0.0010 | 75.000 | -0.0008 |
| Iteration 4 | 4 | 0.0900 | 0.1363 | 0.0900 | 0.0000 | 75.000 | 0.0000 |

Table 4

| Convergence Method | Arithmetic |
|---|---|
| Gain Factor (%) | Various |

| Iteration # | # | Thickness Target (mm) | Instruction | Measured Lens | Delta Thickness | Gain Factor % | Scaled Delta Thickness |
|---|---|---|---|---|---|---|---|
| | | | Instruction_# | MLens_# | DeltaT_# | GF | CScaled_# |
| | | | | | | | |
| Initial Show | 0 | 0.0900 | 0.1250 | 0.0750 | 0.0150 | 100.000 | 0.0150 |
| Iteration I | 1 | 0.0900 | 0.1400 | 0.0850 | 0.0050 | 90.000 | 0.0045 |
| Iteration 2 | 2 | 0.0900 | 0.1445 | 0.0940 | -0.0040 | 200.000 | -0.0080 |
| Iteration 3 | 3 | 0.0900 | 0.1365 | 0.0910 | -0.0010 | 125.000 | -0.0013 |
| Iteration 4 | 4 | 0.0900 | 0.1353 | 0.0900 | 0.0000 | 75.000 | 0.0000 |

To calculate an Iteration value for a subsequent DMD Show instruction set using an arithmetic thickness correction method, a Delta thickness value may have to be calculated. For example, a Delta thickness value may be equal to a target thickness value of a target design minus a measured Lens thickness value created from a previous DMD Show. Subsequent to a calculation of a Delta thickness value, a Delta thickness value may be multiplied with an applicable gain magnitude factor amount selected and divided by 100, to determine a scaled Delta thickness value. A scaled Delta thickness value may be added to a value of a previous show instruction. Use of the aforementioned formula may occur at each pixel of a previous show to calculate a new value for each pixel for a subsequent DMD Show.

The formula for the arithmetic method are:

$\Delta^{th}$ value= $(Target\ Thickness - Measured\ Lens\ Thickness)$

Scaled $\Delta^{th}$ value= $\frac{(\Delta th\ \text{value} \times \text{Gain}\ Factor)}{100}$

Subsequent DMD Show Instruction= $Previous\ Instruction \dotplus Scaled\ \Delta th\ value$

Table 2 is an example of utilizing an arithmetic thickness correction method and applying a 200% gain magnitude factor to subsequent Iterations of the previous show, wherein the target thickness value of the Lens Design is .0900 mm and the measured Lens thickness is .0750 mm. In this example, the Delta thickness value is 0.0150 mm, which is calculated by subtracting the measured Lens thickness of 0.0750 mm from the target thickness value of 0.0900 mm. Furthermore, the scaled Delta thickness value is 0.0300 mm, which is calculated by multiplying the Delta thickness value of 0.0150 mm by the gain magnitude factor of 200%, and dividing that value by 100. Subsequently, the scaled Delta thickness value of 0.0300 mm is added to the previous show value of 0.1250 mm, giving the subsequent show instruction value of 0.1550 mm.

If a DMD Show creates a Lens that does not meet desired Acceptance Criteria a percentage thickness correction method may be used to calculate instructions for an Iterative DMD Show. Referring now to Tables 5 to 7 which illustrate a display of data generated by utilizing a percentage thickness correction method to calculate subsequent DMD Show instructions at different iterations and applying various gain magnitude factors. The illustrated data is generated by utilizing a percentage thickness correction method with application of various gain magnitude factors that may be used to implement the present invention.

Table 5

Convergence Method Percentage
Gain Factor (%) 100

| Iteration # | # | Thickness Target (mm) | Instruction | Measured Lens | Temporary Next Instruction Value | Gain Factor % | Delta_Instruction Next - Previous | Required Delta Instruction (based off GFression Level) |
|---|---|---|---|---|---|---|---|---|
| | | | Instruction_# | MLens_# | Temp_Instr_# | GF | Temp_Instr_#-Instruction_# | |
| | | | | | | | | |
| Initial Show | 0 | 0.090 | 0.125 | 0.075 | 0.150 | 100.000 | 0.025 | 0.025 |
| Iteration I | 1 | 0.090 | 0.150 | 0.085 | 0.159 | 100.000 | 0.009 | 0.009 |
| Iteration 2 | 2 | 0.090 | 0.159 | 0.094 | 0.152 | 100.000 | -0.007 | -0.007 |
| Iteration 3 | 3 | 0.090 | 0.152 | 0.091 | 0.150 | 100.000 | -0.002 | -0.002 |
| Iteration 4 | 4 | 0.090 | 0.150 | 0.090 | 0.150 | 100.000 | 0.000 | 0.000 |

Table 6

Convergence Method Percentage
Gain Factor (%) 200

| Iteration # | # | Thickness Target (mm | Instruction | Measured Lens | Temporary Next Instruction Value | Gain Factor % | Delta_Instruction Next - Previous) | Required Delta instruction (based off GFression Level) |
|---|---|---|---|---|---|---|---|---|
| | | | Instruction_# | MLens_# | Temp_Instr_# | GF | Temp_Instr_#-Instruction_# | |
| | | | | | | | | |
| Initial Show | 0 | 0.090 | 0.125 | 0.075 | 0.150 | 200.000 | 0.025 | 0.050 |
| Iteration I | 1 | 0.090 | 0.175 | 0.085 | 0.185 | 200.000 | 0.010 | 0.021 |
| Iteration 2 | 2 | 0.090 | 0.196 | 0.094 | 0.187 | 200.000 | -0.008 | -0.017 |
| Iteration 3 | 3 | 0.090 | 0.179 | 0.091 | 0.177 | 200.000 | -0.002 | -0.004 |
| Iteration 4 | 4 | 0.090 | 0.175 | 0.000 | 0.175 | 200.000 | 0.000 | 0.000 |

Table 7

Convergence Method Percentage
Gain Factor (%) 75

| Iteration # | # | Thickness Target (mm | Instruction | Measured Lens | Temporary Next Instruction Value | Gain Factor % | Delta_Instruction Next - Previous) | Required Delta Instruction (based off GFression Level) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Instruction_# | MLens_# | Temp_Instr_# | GF | Temp_Instr_#-Instruction_# | | |
| | | | | | | | | | |
| Initial Show | 0 | 0.090 | 0.125 | 0.075 | 0.150 | 75.000 | 0.025 | 0.019 | 0.144 |
| Iteration I | 1 | 0.090 | 0.144 | 0.085 | 0.152 | 75.000 | 0.008 | 0.006 | 0.150 |
| Iteration 2 | 2 | 0.090 | 0.150 | 0.094 | 0.144 | 75.000 | -0.006 | -0.005 | 0.145 |
| Iteration 3 | 3 | 0.090 | 0.145 | 0.091 | 0.144 | 75.000 | -0.002 | -0.001 | 0.144 |
| Iteration 4 | 4 | 0.090 | 0.144 | 0.090 | 0.144 | 75.000 | 0.000 | 0.000 | 0.144 |

For tables 5 to 7:

Initial_Instruction_0 (Start Show, does not have to be same as Target tile)
Generically:

Let PREV = Previous Instruction
Let GF = GFression Level
Let TARGET = Target Thickness
Let MEASURED = Measured Lens Thickness

Then: Next Instruction = PREV + (((PREV *x* GF) *x* (TARGET - MEASURED)) / (MEASURED x 100))
Instruction_1 = PREV_0 + (((PREV_0 *x* GF) *x* (TARGET - MEASURED_0)) / (MEASURED_0 x 100))

Instruction_2 = PREV_1 + (((PREV_1 x GF) x (TARGET - MEASURED_1)) /(MEASURED_1 x 100))

Instruction_3 = PREV_2 + (((PREV_2x GF) x (TARGET - MEASURED_2)) / (MEASURED_2 *x* 100))

Instruction_4 = PREV_3 + (((PREV_3 *X*GF) x (TARGET - MEASURED_3)) / (MEASURED_3 *X*100))

To calculate an Iteration value for a subsequent DMD Show instruction set utilizing a percentage thickness correction method, a Delta instruction value may have to be calculated. For example, a Delta instruction value may be equal to taking a previous show value and multiplying it by an applicable gain magnitude factor followed by, multiplying the resulting value by a target thickness value minus a measured Lens value. Furthermore, the preceding value is divided by a measured Lens value, followed by multiplying the resulting value by 100 and subsequently, adding the value to a previous show value. Use of the aforementioned formula may occur at each pixel of a previous show to calculate a new value for each pixel for a subsequent DMD Show. The formula for the percentage method is as follows:

$$\textit{Subsequent DMD Show Instruction} =$$

$$\left(\frac{((\textit{Previous Instruction} \times \textit{Gain Factor}) \times (\textit{Target Thickness} - \textit{Measured Lens Thickness})}{(\textit{Measured Lens Thickness} \times 100)}\right.$$

Table 6 is an example of utilizing a percentage thickness correction method calculation and applying a 200% gain magnitude factor to subsequent Iterations of an initial show, wherein the initial show is 0.125 mm, the target thickness is 0.090 mm, and the measured Lens thickness is .0750 mm. In this example, the subsequent DMD Show instruction is calculated by multiplying the initial show value of 0.125 mm by 200%, followed by multiplying this value by 0.015 mm, which is value of the difference of the target thickness value of 0.090 mm, and the measured Lens value of 0.075 mm, equaling the value of 0.00375 mm. Subsequently, the Delta instruction a value of 0.05 mm is calculated by dividing the value of 0.00375 mm by the measured Lens value of 0.075 mm. Furthermore, the previous show value of 0.125 mm is subsequently added to the Delta instruction value of 0.05 mm, resulting in the subsequent DMD Show instruction value of 0.175 mm.

An Iteration value for a subsequent DMD Show instruction set may be determined by utilizing a secant thickness correction method, which may be calculated by using a secant method algorithm. A secant method is a root-finding algorithm that uses a succession of roots of secant lines to better approximate a root of a function *f*, and is known to those skilled in the art.

Various spatial gain methods may be applied when using one or more of the aforementioned thickness correction methods. Spatial gain methods may include one or both of a uniform (linear) spatial gain method, and a non-uniform spatial gain method. Furthermore, a non-uniform spatial gain method may consist of two types including one or both of a function based non-uniform spatial gain method, and a direct mapping spatial gain method.

When applying a uniform (linear) spatial gain method, a same thickness correction method be applied across a designated Training Region wherein a gain magnitude factor is equal at each pixel location. For example, all pixels within an optic zone may be modified by the arithmetic method using a 100% gain magnitude factor. When applying a non-uniform spatial gain method, a same thickness correction method may be applied across a designated Training Region wherein a gain magnitude factor may be different at each pixel location. For example, pixels lying on a diameter of 4mm may have a gain magnitude factor of 200% whereas pixels lying a diameter of 2mm may have a gain magnitude factor of 150%.

When applying a function based non-uniform spatial gain method, a gain magnitude factor may be related to a radial location of a pixel. In some other related embodiments, when applying a direct mapping non-uniform spatial gain method, corresponding data may be leveraged from a Training Region of one or more previous DMD Shows, a measured Lens, and a Lens Design, to calculate a desired gain magnitude at each pixel location.

Referring now to Fig. 9, illustrates a controller 1100 that may be used to implement some aspects of the present invention. A processor unit 1101, which may include one or more processors, coupled to a communication device 1102 configured to communicate via a communication network. The communication device 1102 may be used to communicate, for example, with one or more controller apparatus or manufacturing equipment components.

A processor 1101 may also be used in communication with a storage device 1103. A storage device 1103 may comprise any appropriate information storage device, including combinations of magnetic storage devices (*e.g.*, magnetic tape and hard disk drives), optical storage devices, and/or semiconductor memory devices such as Random Access Memory (RAM) devices and Read Only Memory (ROM) devices.

A storage device 1103 may store an executable software program 1104 for controlling a processor 1101. A processor 1101 performs instructions of a software program 1104, and thereby operates in accordance with the present invention such as, for example, the aforementioned method steps. For example, a processor 1101 may receive information descriptive of a desired Lens Design. A storage device 1103 may also store ophthalmic related data in one or more databases 1105 and 1106. A database may include one or more of files containing DMD Show instruction data, customized Lens Design data, metrology data, defined Lens parameter data for specific Lens Designs.

Conclusion

The present invention, as described above and as further defined by the claims below, provides an apparatus for implementing a Convergence Process.

The following non-exhaustive list are aspects of the invention:

Aspect 1. An apparatus for modifying a DMD Show to create a Contour Form Ophthalmic Lens that Converges a Lens Design, the apparatus comprising:

a computer processor in digital communication with a Contour Forming device;

a digital media storage device in communication with the computer processor and storing executable software code which is executable upon demand and operative with the processor and the Contour Lens Forming device to:

store digital data descriptive of an inventory of data wherein said data comprise one or both of Lens Design data and DMD Show data;

receive a digital data input descriptive of said data;

create said DMD Show wherein a DMD Show instruction is based upon said Lens Design;

determine if said Lens conforms to an Acceptance Criteria of said Lens Design; and

create a subsequent DMD Show instruction wherein said subsequent DMD Show instruction comprises one or more of a Convergence masking technique.

Aspect 2. The apparatus of aspect 1 wherein said Convergence masking technique comprises one or more of said DMD Show covering one or more of a selected masking region.

Aspect 3. The apparatus of aspect 2 wherein said selected masking region comprises one or more of a radius, a sector, a segment, and an area.

Aspect 4. The apparatus of aspect 1 wherein one or more of said Convergence masking technique comprises one or more of a Blend Zone.

Aspect 5. The apparatus of aspect 4 wherein said Blend Zone comprises one or more specified zones connecting said selected masked region to one or more of a non-masked region.

Aspect 6. An apparatus for modifying a DMD Show to create a Contour Form Ophthalmic Lens that Converges a Lens Design, the apparatus comprising:

a computer processor in digital communication with a Contour Forming device;

a digital media storage device in communication with the computer processor and storing executable software code which is executable upon demand and operative with the processor and the Contour Lens Forming device to:

store digital data descriptive of an inventory of data wherein said data comprise one or both of Lens Design data and DMD Show data;

receive a digital data input descriptive of said data;

create said DMD Show wherein a DMD Show instruction is based upon said Lens Design;

determine if said Lens conforms to an Acceptance Criteria of said Lens Design; and

create a subsequent DMD Show instruction wherein said subsequent DMD Show instruction comprises one or more of a Convergence modality.

Aspect 7. The apparatus of aspect 6 wherein said Convergence modality comprises a one-sided modality.

Aspect 8. The apparatus of aspect 7 wherein said one-sided modality comprises adjusting one or more parameters of one or more instructions of said previous DMD Show by either of decreasing a value of said instruction, and increasing said value of said instruction.

Aspect 9. The apparatus of aspect 7 wherein said one-sided modality comprises a thickening ratchet instruction.

Aspect 10. The apparatus of aspect 9 wherein said thickening ratchet instruction comprises an increased said value of said instruction in one or more portions of said previous DMD Show.

Aspect 11. The apparatus of aspect 7 wherein said one-sided modality comprises a thinning ratchet instruction.

Aspect 12. The apparatus of aspect 11 wherein said thinning ratchet instruction comprises a decreased said value of said instruction in one or more of said portion of said previous DMD Show.

Aspect 13. The apparatus of aspect 7 wherein said one-sided modality comprises a piston-shifting technique.

Aspect 14. The apparatus of aspect 13 wherein said piston-shifting technique comprises performing a uniform shift of an equal amount, of one or more of a selected portion of said previous DMD Show instruction.

Aspect 15. The apparatus of aspect 7 wherein said one-sided modality comprises an apex-locking technique.

Aspect 16. The apparatus of aspect 15 wherein said apex-locking technique comprises a locked $I_{CT}$ wherein said $I_{CT}$ is set to a specified value, that remains constant during said subsequent Iteration.

Aspect 17. The apparatus of aspect 6 wherein said Convergence modality comprises a two-sided modality.

Aspect 18. The apparatus of aspect 17 wherein said two-sided modality comprises adjusting one or more said parameters of one or more said instructions of said previous DMD Show by both of decreasing said value of said instruction, and increasing said value of said instruction.

Aspect 19. The apparatus of aspect 17 wherein said two-sided modality comprises a piston-shifting technique.

Aspect 20. The apparatus of aspect 19 wherein said piston-shifting technique comprises performing a uniform shift of an equal amount, of one or more of said selected portion of said previous DMD Show instruction.

Aspect 21. The apparatus of aspect 17 wherein said two-sided modality comprises an apex-locking technique.

Aspect 22. The apparatus of aspect 21 wherein said apex-locking technique comprises a locked $I_{CT}$ wherein said $I_{CT}$ is set to a specified value, that remains constant during said subsequent Iteration.

Aspect 23. An apparatus for modifying a DMD Show to create a Contour Form Ophthalmic Lens that Converges a Lens Design, the apparatus comprising:

a computer processor in digital communication with a Contour Lens Forming device;

a digital media storage device in communication with the computer processor and storing executable software code which is executable upon demand and operative with the processor and the Contour Lens Forming device to:

store digital data descriptive of an inventory of data wherein said data comprise one or both of Lens Design data and DMD Show data;

receive a digital data input descriptive of said data;

create said DMD Show wherein a DMD Show instruction is based upon said Lens Design;

determine if said Lens conforms to an Acceptance Criteria of said Lens Design; and

create a subsequent DMD Show instruction wherein said subsequent DMD Show instruction comprises one or more of a thickness correction method.

Aspect 24. The apparatus of aspect 23 wherein said thickness correction method comprises one or more of a percentage method, an arithmetic method, and a secant method.

Aspect 25. The apparatus of aspect 23 wherein said thickness correction method comprises a Filtering process of one or more of a data point.

Aspect 26. The apparatus of aspect 25 wherein said Filtering process comprises one or more of defining, detecting, removing, and correcting errors in given data.

Aspect 27. The apparatus of aspect 23 wherein said thickness correction method comprises a Surface Fitting process of one or more of said data point.

Aspect 28. The apparatus of aspect 27 wherein said Surface Fitting process comprises constructing one or both of a surface and a mathematical function that has a best fit to a series of said data points by implementing one of either interpolation and smoothing.

Aspect 29. The apparatus of aspect 23 wherein said thickness correction method comprises a uniform spatial gain method.

Aspect 30. The apparatus of aspect 29 wherein said uniform spatial gain method provides for one or more of a same said thickness correction method to be applied across said Training Region wherein a gain magnitude factor is equal at each pixel location.

Aspect 31. The apparatus of aspect 23 wherein said thickness correction method comprises a non-uniform spatial gain method.

Aspect 32. The apparatus of aspect 31 wherein said non-uniform spatial gain method comprises one or more of same said thickness correction method applied across said Training Region wherein said gain magnitude factor may be different at each pixel location.

Aspect 33. The apparatus of aspect 31 wherein said non-uniform spatial gain method comprises a function-based non-uniform spatial gain method.

Aspect 34. The apparatus of aspect 33 wherein said function-based non-uniform spatial gain method comprises relating said gain magnitude factor to a radial location of said pixel.

Aspect 35. The apparatus of aspect 31 wherein said non-uniform spatial gain method comprises a direct mapping non-uniform spatial gain method.

Aspect 36. The apparatus of aspect 35 wherein said direct mapping non-uniform spatial gain method comprises leveraging corresponding data from a Training Region derived from one or more of said previous DMD Shows, said measured Lens, and said Lens Design wherein desired said gain magnitude factor may be calculated at each pixel location.

## CLAIMS

What is claimed is:

1. A method of controlling the manufacture of an ophthalmic device via a contour forming device, comprising:

(a) issuing an instruction to the contour forming device to make an ophthalmic device;

(b) making the ophthalmic device with the contour forming device based on the instruction;

(c) measuring the ophthalmic device;

(d) determining if the ophthalmic device conforms to an acceptance criteria of a lens design; and wherein

(e) following a determination that the ophthalmic device does not conform to the acceptance criteria, the method further comprises

(f) carrying out a convergence process to converge the ophthalmic device towards the lens design.

2. The method according to claim 1, wherein the convergence process comprises (g) modifying the previous instruction to create a subsequent instruction capable of creating a subsequent ophthalmic device.

3. The method according to claim 2, further comprising (h) making a subsequent ophthalmic device with the contour forming device based on the subsequent instruction.

4. The method according to claim 3, further comprising repeating steps (g) and (h) until it is determined that the ophthalmic device conforms to the acceptance criteria of the lens design.

5. The method according to any of the preceding claims, wherein the contour forming device comprises a digital micromirror device (DMD), and wherein the or each instruction is a DMD show instruction.

6. The method according to any of the preceding claims, wherein the convergence process comprises a convergence masking technique.

7. The method of claim 6 wherein said convergence masking technique comprises defining a selected masking region, and selectively carrying out the convergence process within the selected masking region.

8. The method of claim 6, wherein said convergence masking technique comprises defining a selected masking region and selectively carrying out the convergence process outside of the selected masking region.

9. The method of claim 7 or 8 wherein said selected masking region comprises one or more of a radius, a sector, a segment, and an area.

10. The method of any of claims 6 to 9, wherein said Convergence masking technique comprises one or more of a Blend Zone.

11. The method of claim 10 wherein said Blend Zone comprises one or more specified zones connecting said selected masking region to one or more of a non-masked region.

12. The method according to any of the preceding claims, wherein the convergence process comprises a convergence modality.

13. The method according to claim 12, wherein the convergence modality comprises modifying the previous instruction in regions of the measured ophthalmic device which are too thick compared with a target thickness and modifying the previous instruction in regions of the measured ophthalmic device which are too thin compared with a target thickness.

14. The method according to claim 12, wherein the convergence modality comprises modifying the previous instruction only in regions of the measured ophthalmic device which are too thin compared to the target thickness.

15. The method according to claim 13 or 14, wherein modifying the previous instruction comprises increasing instruction in the regions of the measured ophthalmic device which are too thin compared to the target thickness.

16. The method according to claim 12, wherein the convergence modality comprises modifying the previous instruction only in regions of the measured ophthalmic device which are too thick compared to the target thickness.

17. The method according to claim 13 or 16, wherein modifying the previous instruction comprises decreasing instruction in the regions of the measured ophthalmic device which are too thick compared to the target thickness.

18. The method of any of claims 12 to 17, wherein the convergence modality comprises a piston-shifting technique.

19. The method of claim 18, wherein said piston-shifting technique comprises performing a uniform shift of an equal amount, of one or more of a selected portion of a previous DMD Show instruction.

20. The method of any of claims 12 to 17, wherein the convergence modality comprises an apex-locking technique.

21. The method of claim 20, wherein said apex-locking technique comprises a locked $I_{CT}$ wherein said $I_{CT}$ is set to a specified value, that remains constant during a subsequent Iteration.

22. The method of any of the preceding claims, wherein the convergence process comprises a thickness correction method.

23. The method of claim 22, wherein said thickness correction method comprises one or more of a percentage method, an arithmetic method, and a secant method.

24. The method of claim 22, wherein said thickness correction method comprises a Filtering process of one or more of a data point.

25. The method of claim 24, wherein said Filtering process comprises one or more of defining, detecting, removing, and correcting errors in given data.

26. The method of claim 22, wherein said thickness correction method comprises a Surface Fitting process of one or more of said data point.

27. The method of claim 26, wherein said Surface Fitting process comprises constructing one or both of a surface and a mathematical function that has a best fit to a series of said data points by implementing one of either interpolation and smoothing.

28. The method of claim 22, wherein said thickness correction method comprises a uniform spatial gain method.

29. The method of claim 28, wherein said uniform spatial gain method provides for one or more of a same said thickness correction method to be applied across said Training Region wherein a gain magnitude factor is equal at each pixel location.

30. The method of claim 22, wherein said thickness correction method comprises a non-uniform spatial gain method.

31. The method of claim 30, wherein said non-uniform spatial gain method comprises one or more of same said thickness correction method applied across said Training Region wherein said gain magnitude factor may be different at each pixel location.

32. The method of claim 30, wherein said non-uniform spatial gain method comprises a function-based non-uniform spatial gain method.

33. The method of claim 32, wherein said function-based non-uniform spatial gain method comprises relating said gain magnitude factor to a radial location of said pixel.

34. The method of claim 30, wherein said non-uniform spatial gain method comprises a direct mapping non-uniform spatial gain method.

35. The method of claim 34, wherein said direct mapping non-uniform spatial gain method comprises leveraging corresponding data from a Training Region derived from one or more of said previous DMD Shows, said measured Lens, and said Lens Design wherein desired said gain magnitude factor may be calculated at each pixel location.

36. An apparatus for modifying a digital micromirror device Show to create a Contour Form Ophthalmic Lens that Converges a Lens Design, the apparatus comprising:

a computer processor in digital communication with a Contour Forming device; and

a digital media storage device in communication with the computer processor and wherein stored on the digital media storage device is executable software code which is executable upon demand to implement the method of any of the preceding claims.

37. The apparatus of claim 36, wherein stored on the digital media storage device is digital data descriptive of an inventory of data wherein said data comprise one or both of Lens Design data and DMD Show data.

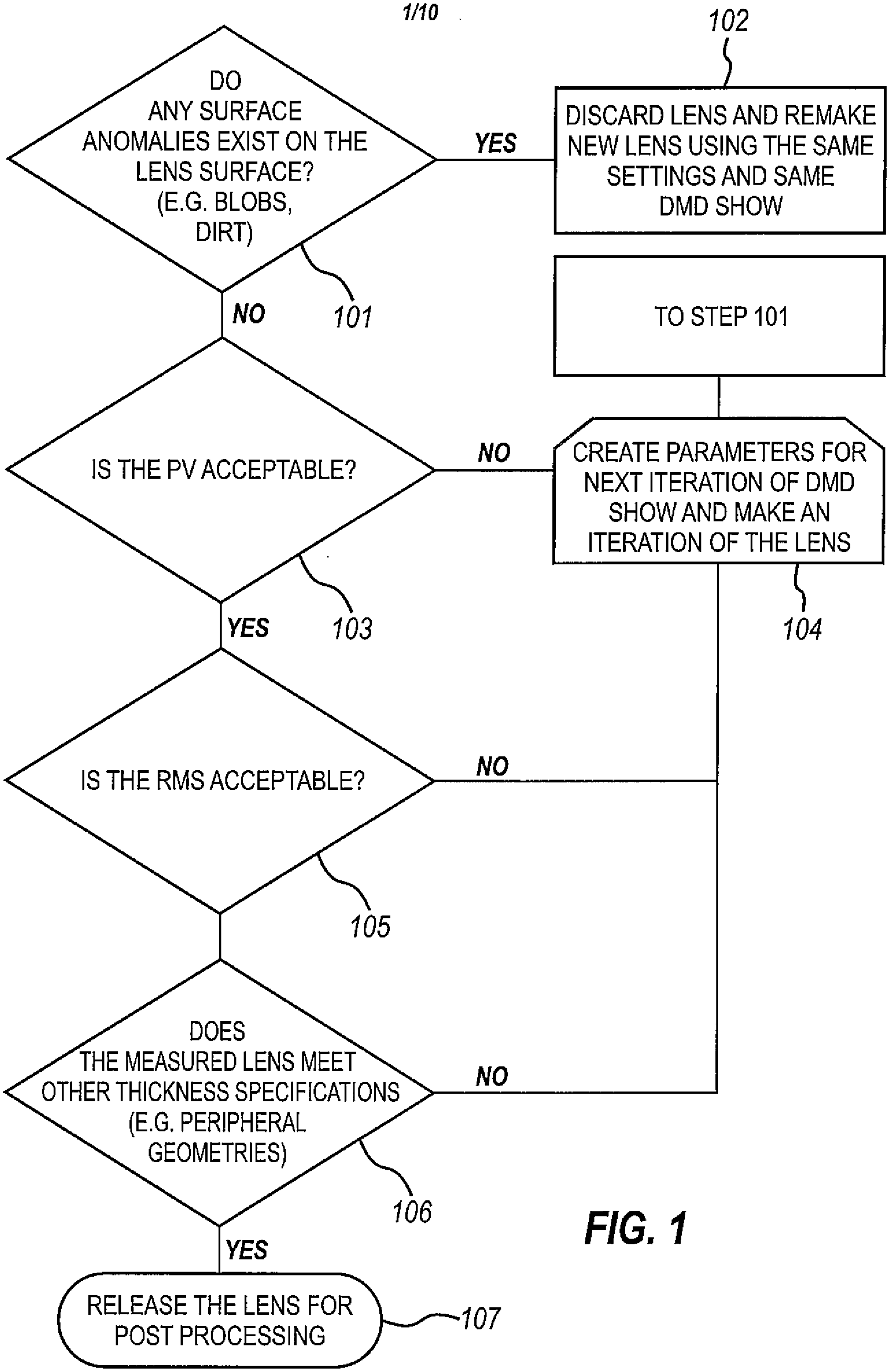

DO ANY SURFACE ANOMALIES EXIST ON THE LENS SURFACE? (E.G. BLOBS, DIRT)
YES
DISCARD LENS AND REMAKE NEW LENS USING THE SAME SETTINGS AND SAME DMD SHOW
102
101
NO
TO STEP 101
IS THE PV ACCEPTABLE?
NO
CREATE PARAMETERS FOR NEXT ITERATION OF DMD SHOW AND MAKE AN ITERATION OF THE LENS
103
YES
104
IS THE RMS ACCEPTABLE?
NO
105
DOES THE MEASURED LENS MEET OTHER THICKNESS SPECIFICATIONS (E.G. PERIPHERAL GEOMETRIES)
NO
106
YES
RELEASE THE LENS FOR POST PROCESSING
107

FIG. 1

FIG. 2a

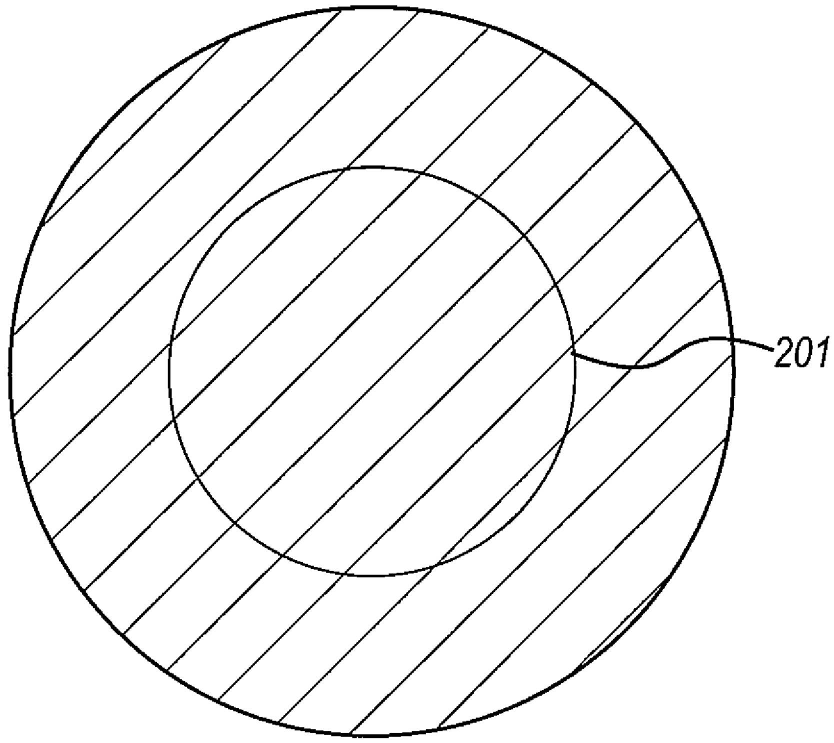



FIG. 2b

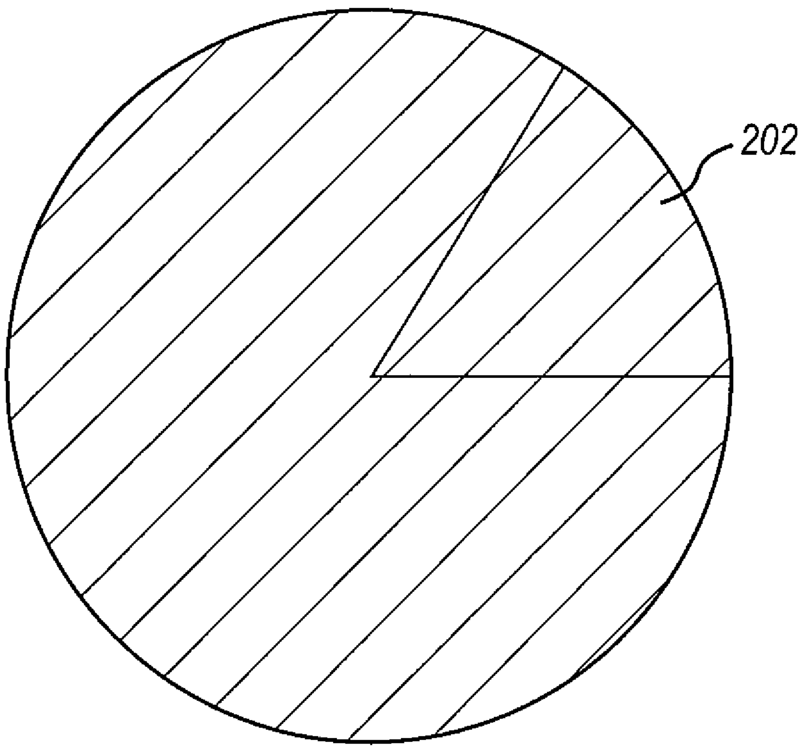


FIG. 2c

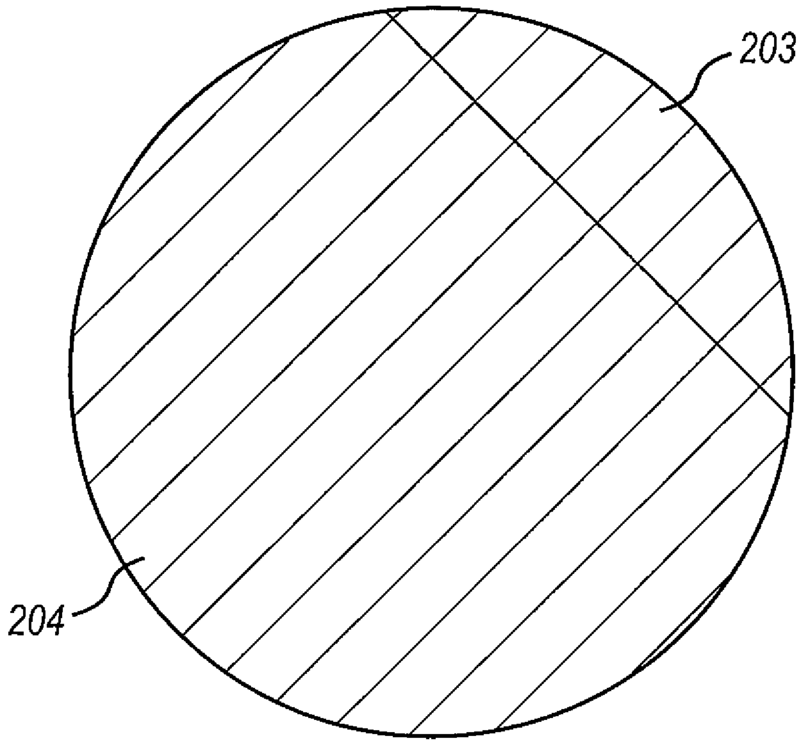



FIG. 2d

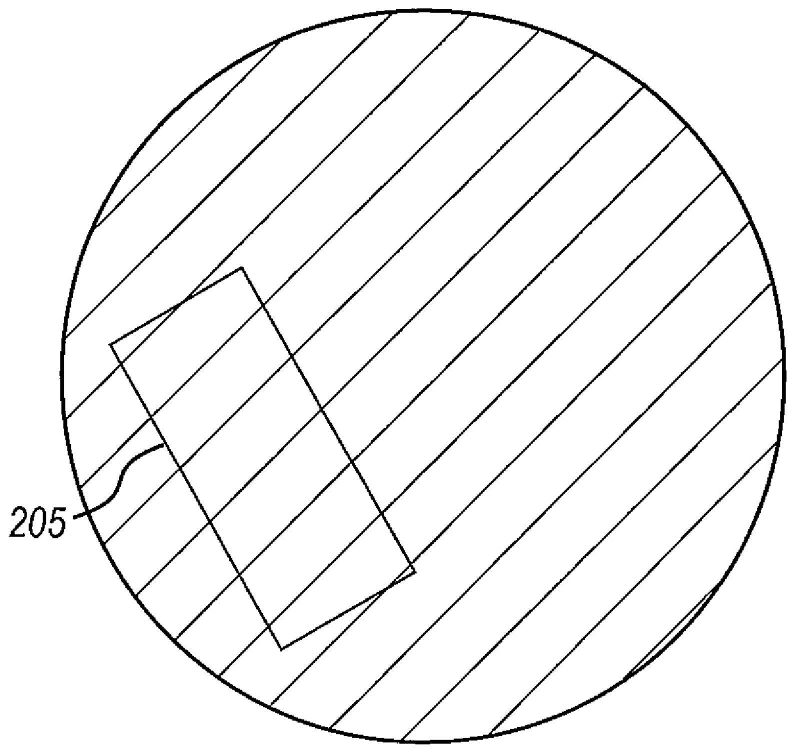


FIG. 2e

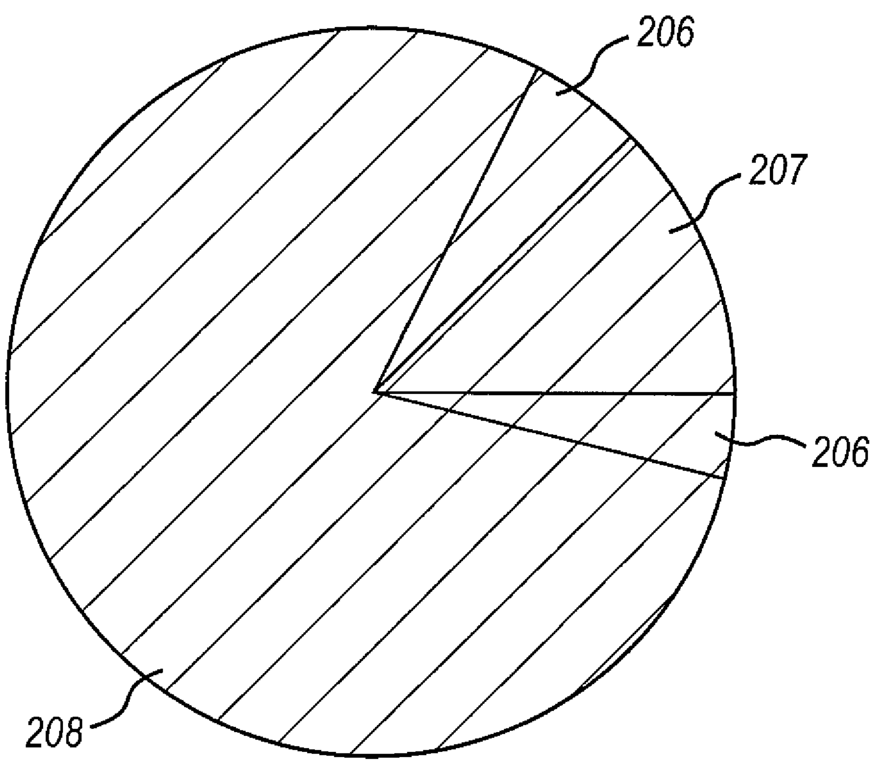

206
207
206
208

FIG. 9

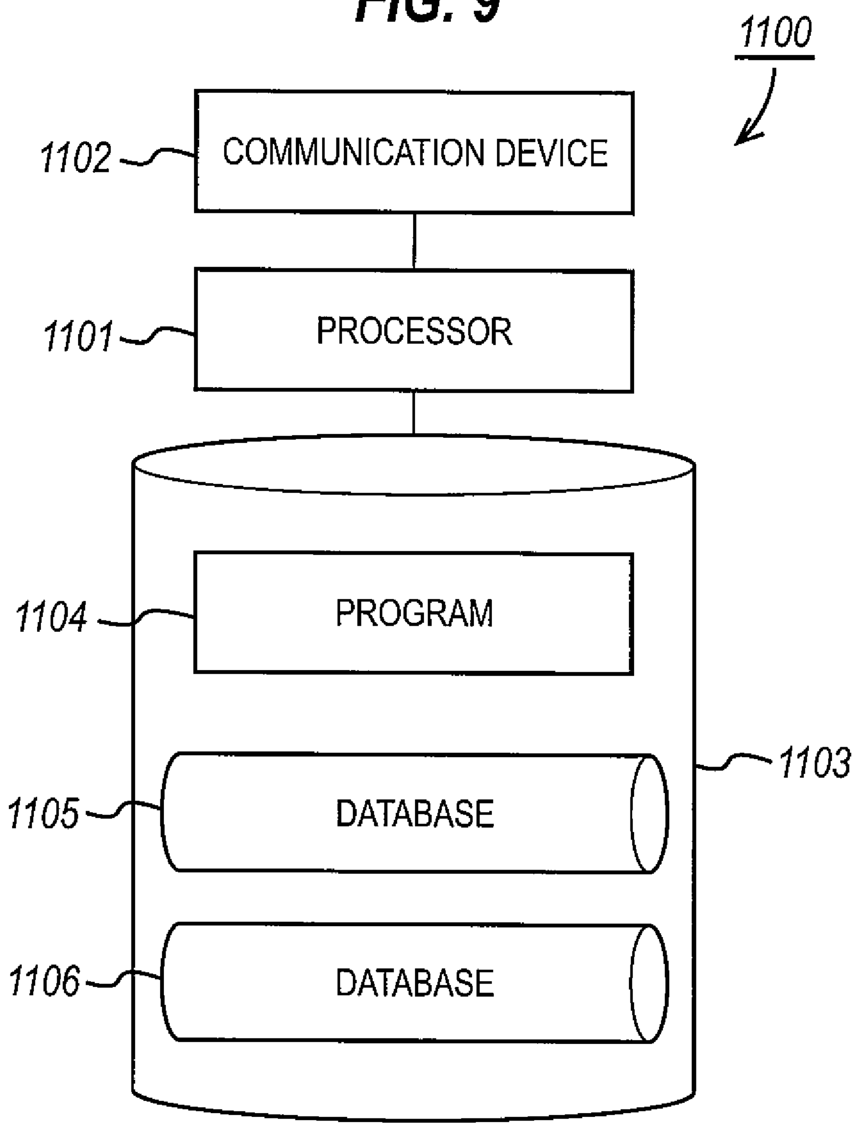

1100
COMMUNICATION DEVICE
1102
PROCESSOR
1101
PROGRAM
1104
DATABASE
1105
DATABASE
1106
1103

FIG. 3

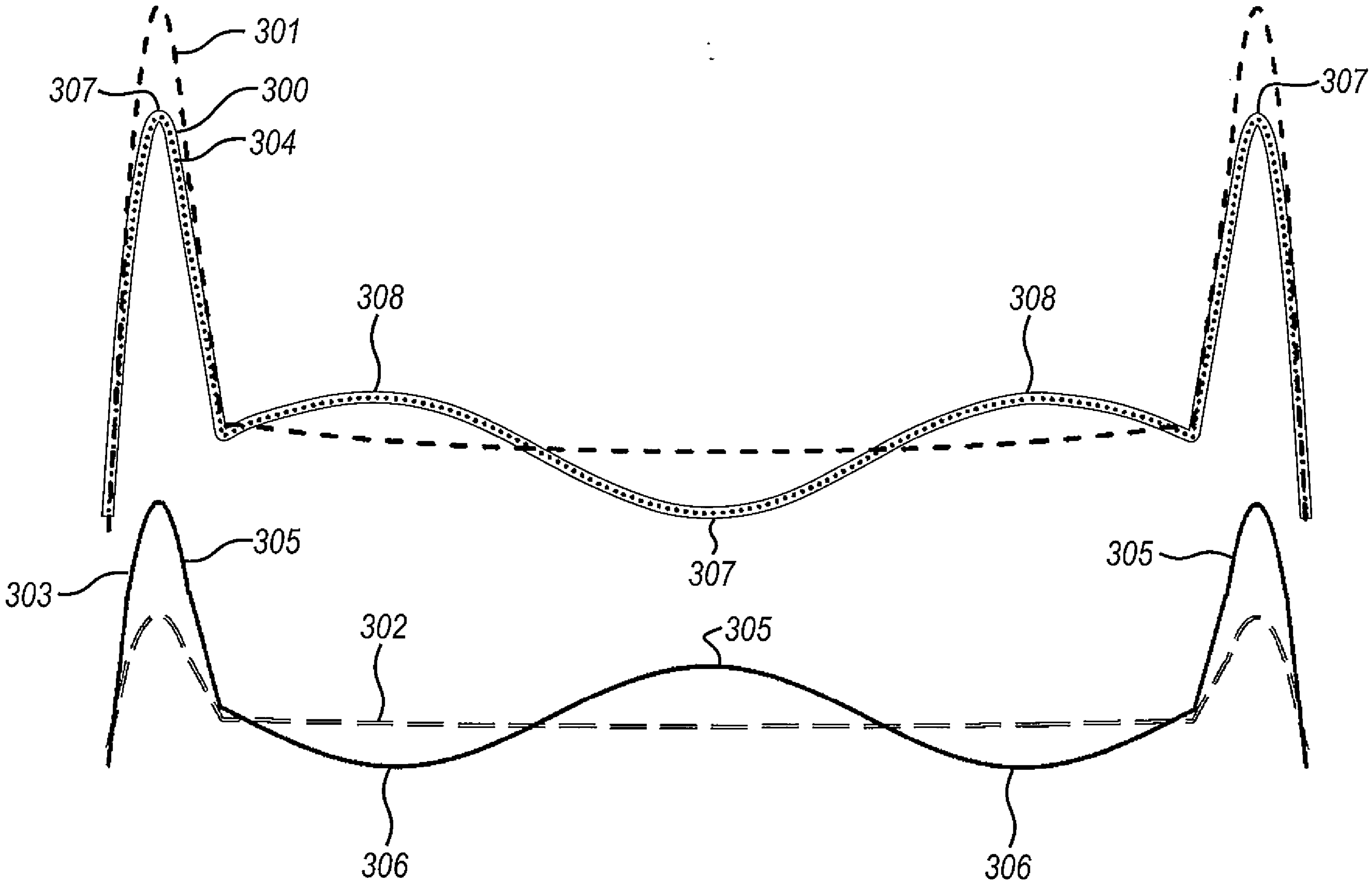


FIG. 4

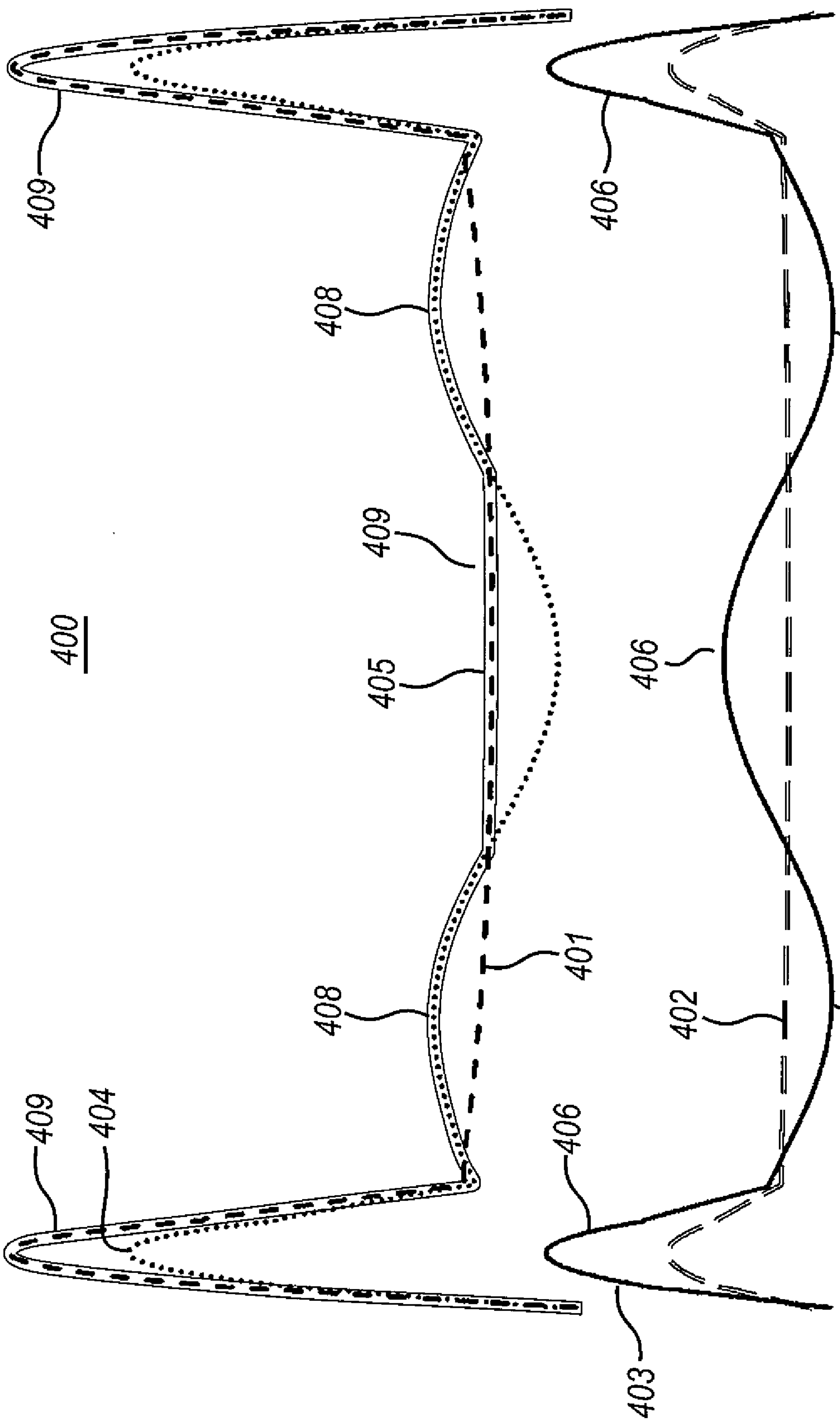
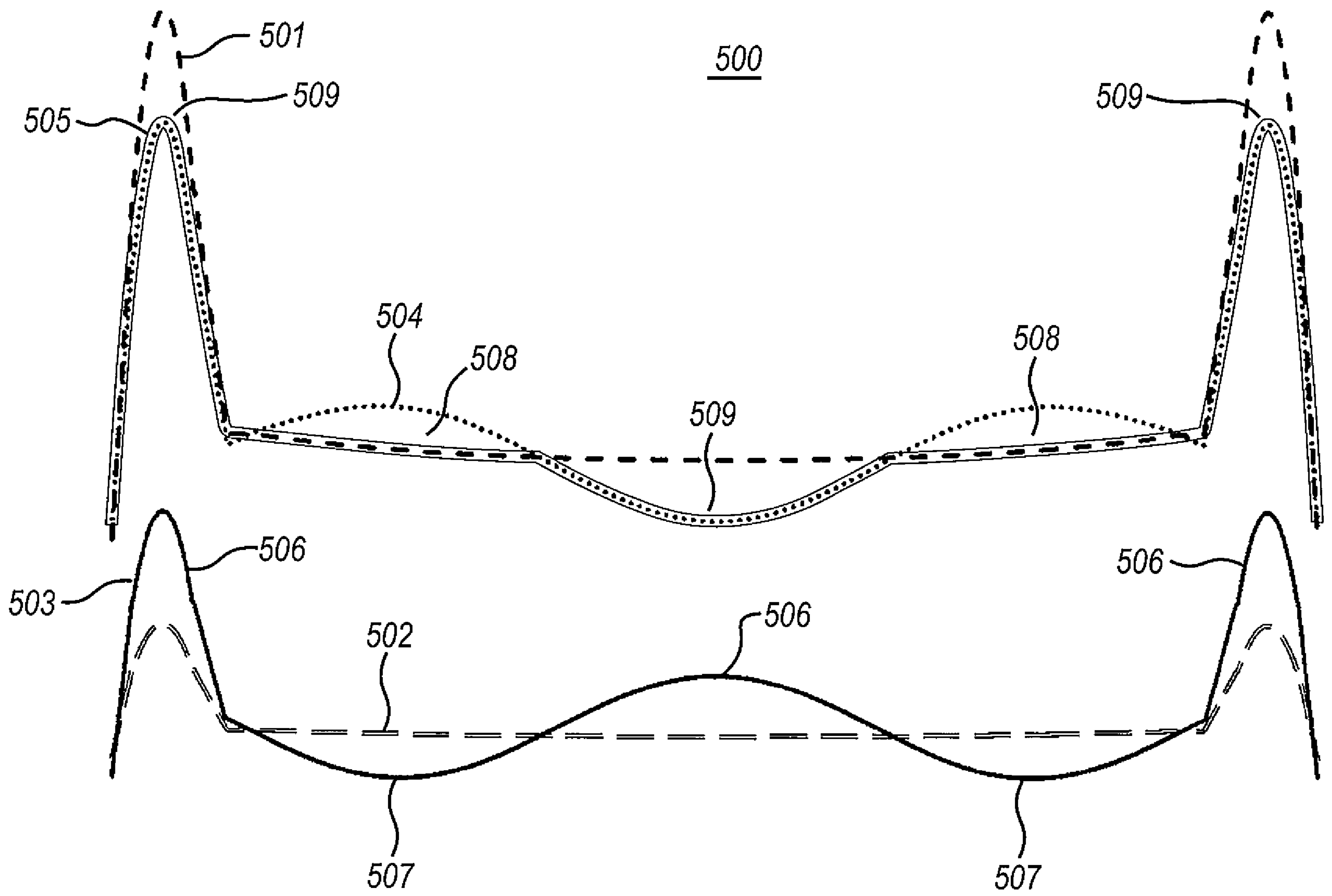
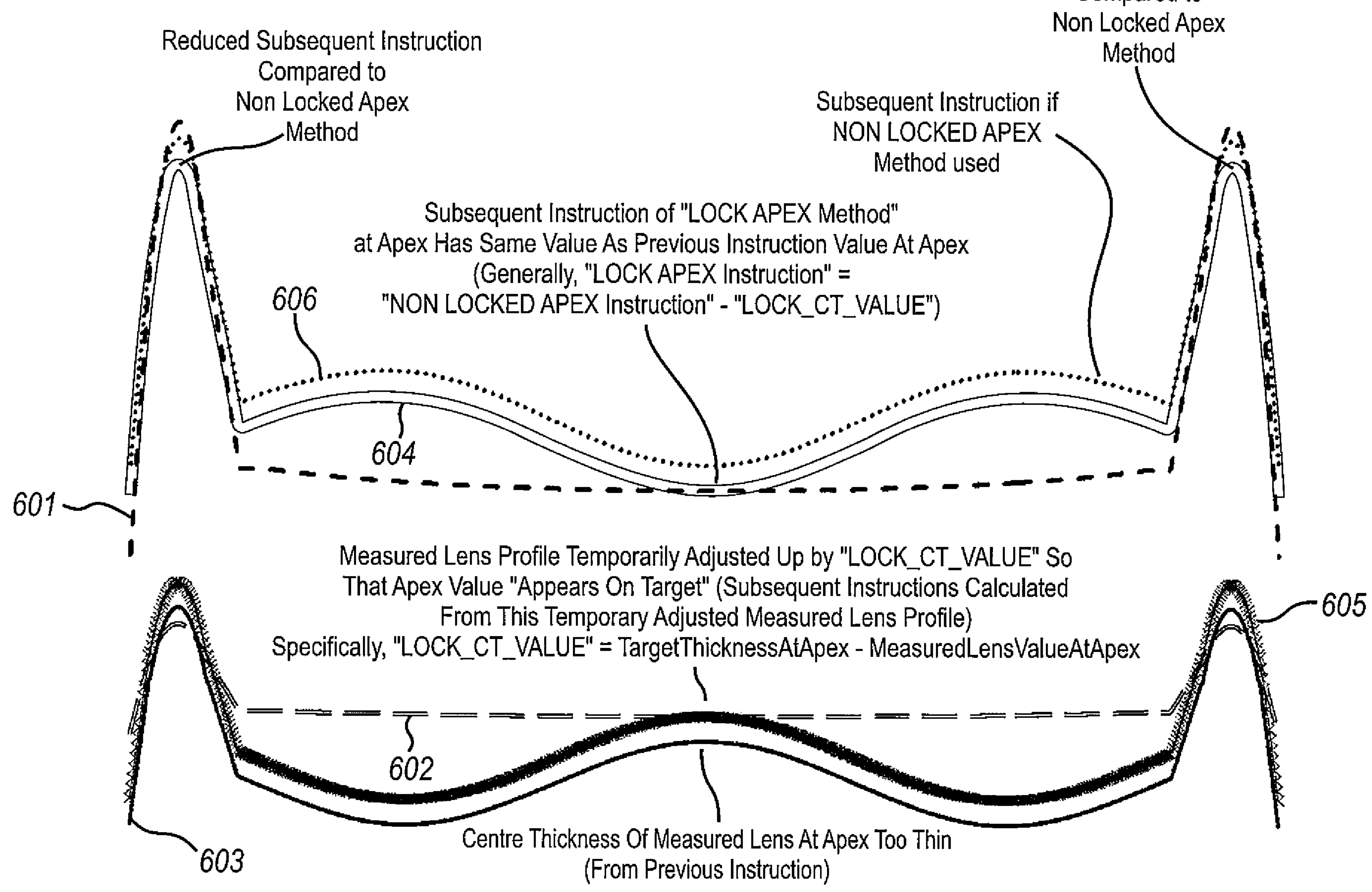


FIG. 5

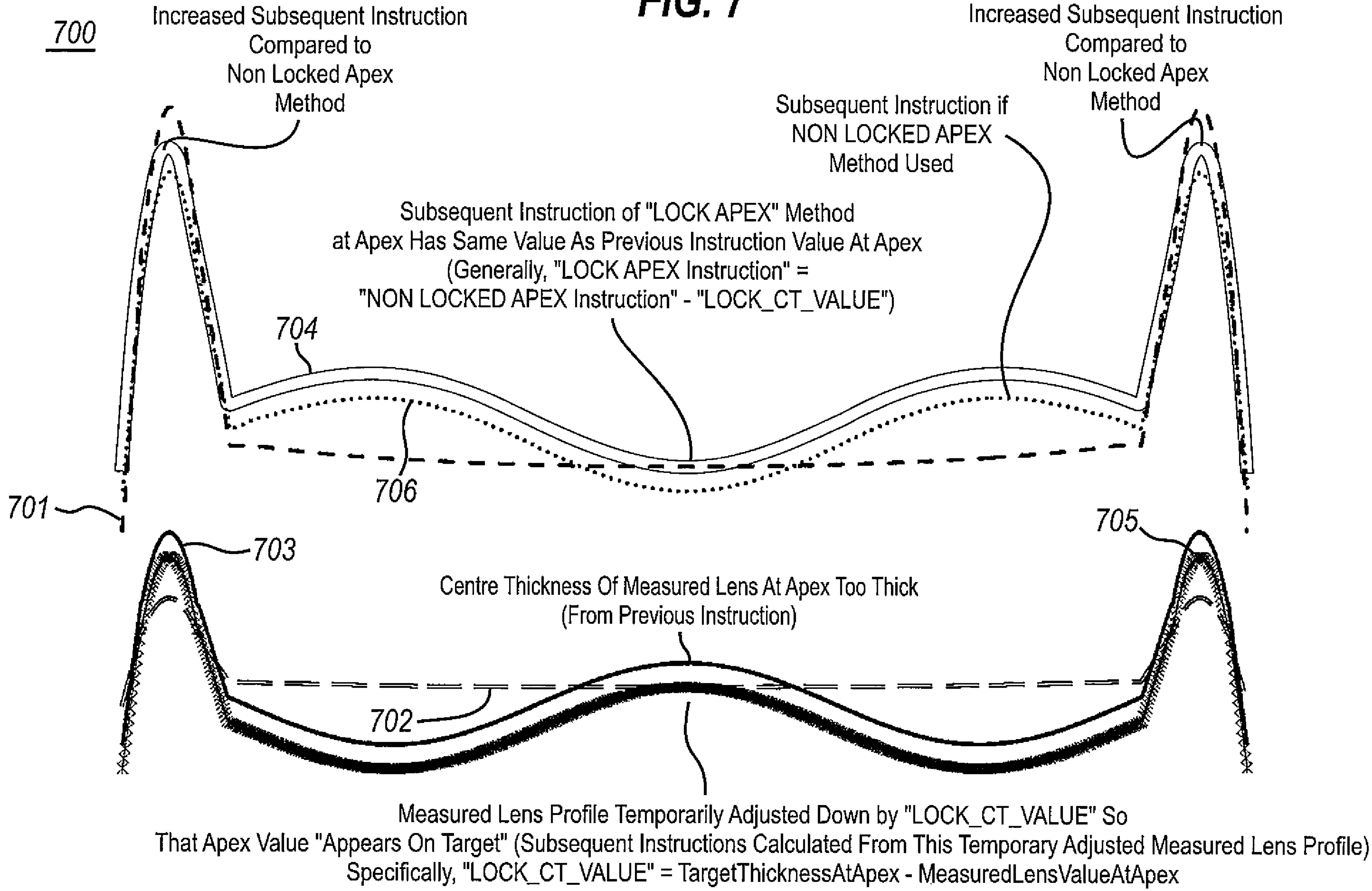


600

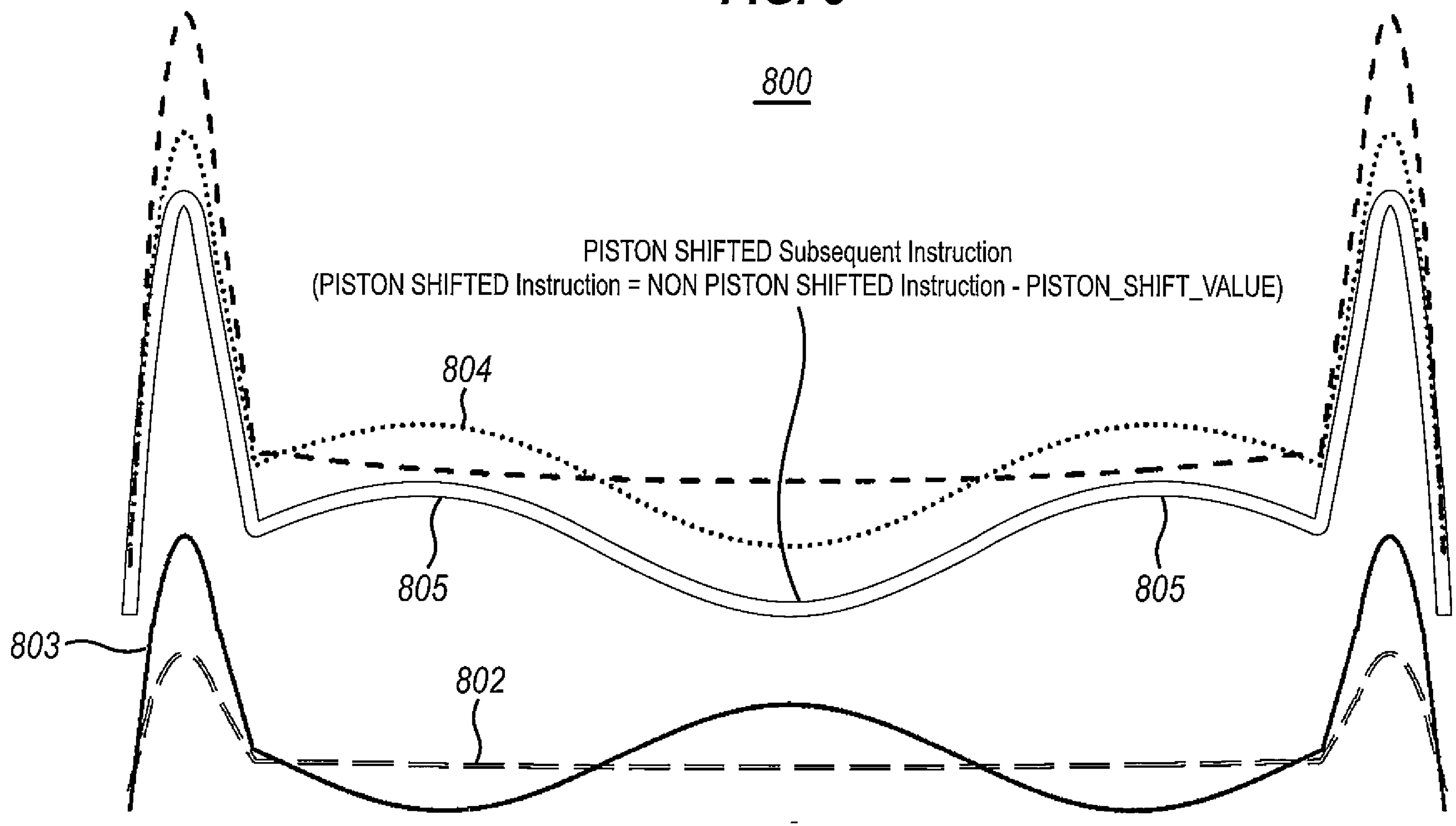
**FIG. 6**


Reduced Subsequent Instruction Compared to Non Locked Apex Method
Reduced Subsequent Instruction Compared to Non Locked Apex Method
Subsequent Instruction if NON LOCKED APEX Method used
Subsequent Instruction of "LOCK APEX Method" at Apex Has Same Value As Previous Instruction Value At Apex (Generally, "LOCK APEX Instruction" = "NON LOCKED APEX Instruction" - "LOCK_CT_VALUE")
606
604
601
Measured Lens Profile Temporarily Adjusted Up by "LOCK_CT_VALUE" So That Apex Value "Appears On Target" (Subsequent Instructions Calculated From This Temporary Adjusted Measured Lens Profile)
Specifically, "LOCK_CT_VALUE" = TargetThicknessAtApex - MeasuredLensValueAtApex
605
602
603
Centre Thickness Of Measured Lens At Apex Too Thin (From Previous Instruction)

# FIG. 7


700
Increased Subsequent Instruction Compared to Non Locked Apex Method
Increased Subsequent Instruction Compared to Non Locked Apex Method
Subsequent Instruction if NON LOCKED APEX Method Used
Subsequent Instruction of "LOCK APEX" Method at Apex Has Same Value As Previous Instruction Value At Apex (Generally, "LOCK APEX Instruction" = "NON LOCKED APEX Instruction" - "LOCK_CT_VALUE")
704
706
701
703
705
Centre Thickness Of Measured Lens At Apex Too Thick (From Previous Instruction)
702
Measured Lens Profile Temporarily Adjusted Down by "LOCK_CT_VALUE" So That Apex Value "Appears On Target" (Subsequent Instructions Calculated From This Temporary Adjusted Measured Lens Profile) Specifically, "LOCK_CT_VALUE" = TargetThicknessAtApex - MeasuredLensValueAtApex

# FIG. 8


800
PISTON SHIFTED Subsequent Instruction
(PISTON SHIFTED Instruction = NON PISTON SHIFTED Instruction - PISTON_SHIFT_VALUE)
804
805
805
803
802