



US010295155B2

(12) **United States Patent**
Jurik et al.

(10) **Patent No.:** **US 10,295,155 B2**
(45) **Date of Patent:** **May 21, 2019**

(54) **HEAT PROTECTION AND HOMOGENIZING SYSTEM FOR A LUMINAIRE**

(71) Applicant: **Robe Lighting s.r.o.**, Roznov pod Radhostem (CZ)

(72) Inventors: **Pavel Jurik**, Prostedrni Becva (CZ); **Josef Valchar**, Prostedrni Becva (CZ)

(73) Assignee: **Robe Lighting s.r.o.**, Roznov pod Radhostem (CZ)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/179,491**

(22) Filed: **Nov. 2, 2018**

(65) **Prior Publication Data**

US 2019/0072259 A1 Mar. 7, 2019

Related U.S. Application Data

(63) Continuation of application No. 16/118,114, filed on Aug. 30, 2018.

(60) Provisional application No. 62/553,295, filed on Sep. 1, 2017.

(51) **Int. Cl.**

F21V 29/10 (2015.01)
F21V 14/04 (2006.01)
F21V 7/08 (2006.01)
F21S 10/00 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC **F21V 14/04** (2013.01); **F21S 10/007** (2013.01); **F21V 7/0066** (2013.01); **F21V 7/08** (2013.01); **F21V 21/15** (2013.01); **F21V 29/10** (2015.01)

(58) **Field of Classification Search**

CPC F21V 7/0066; F21V 7/08; F21V 14/04; F21V 21/15; F21V 29/10; F21S 10/007; H05B 33/08; H05B 37/02

See application file for complete search history.

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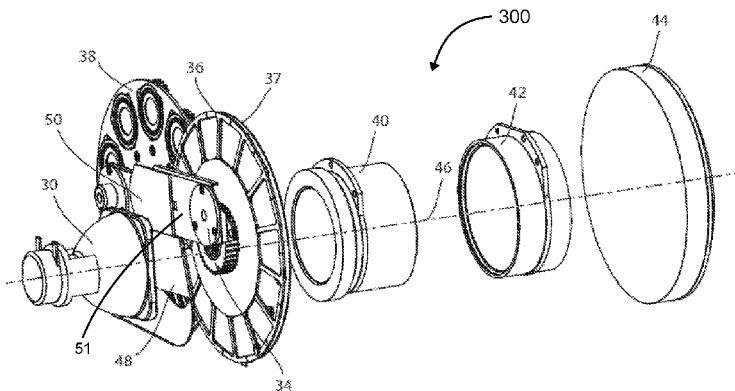
Primary Examiner — Jimmy T Vu

(74) *Attorney, Agent, or Firm* — Conley Rose, P.C.; Grant Rodolph; Brooks W Taylor

(57) **ABSTRACT**

An automated luminaire includes a light source, a compensation module, an optical device, and a controller. The light source has an ellipsoidal reflector and a fixedly mounted short arc discharge lamp and can move along its optical axis. The compensation module includes a diffuser. The optical device produces either a modified or unmodified light beam. If the light beam is modified, the controller either moves the light source to a first position or positions first and second portions of the diffuser in the light beam. If the light beam is unmodified and the light source is in the first position, the controller automatically moves the light source to a second

(Continued)



position. If the light beam is unmodified and the diffuser is in the light beam, the controller automatically removes the diffuser from the light beam.

10 Claims, 15 Drawing Sheets

- (51) **Int. Cl.**
F21V 7/00 (2006.01)
F21V 21/15 (2006.01)

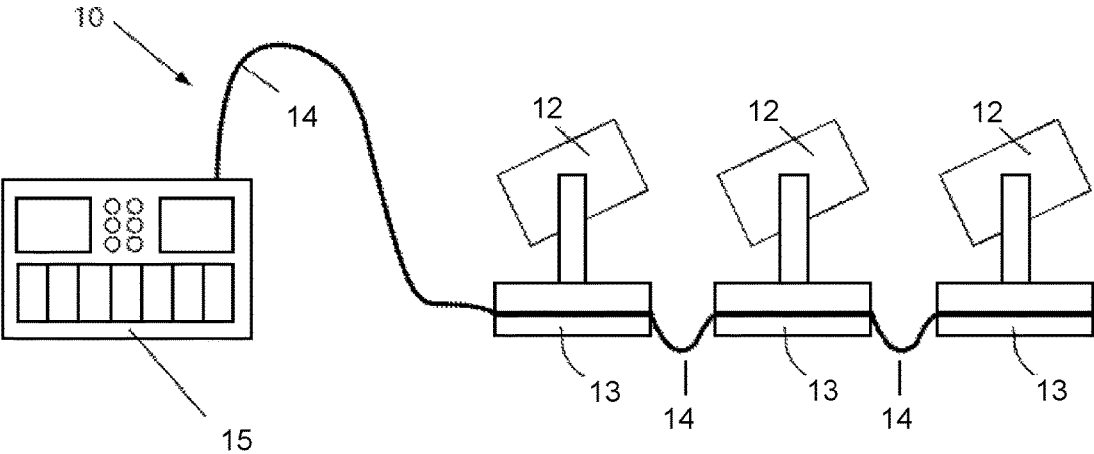


Figure 1

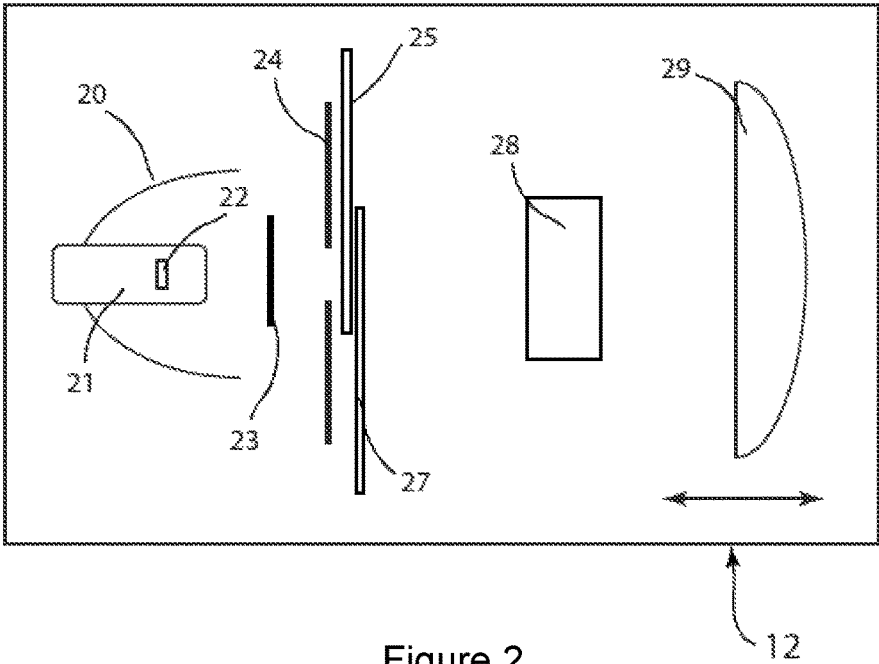


Figure 2

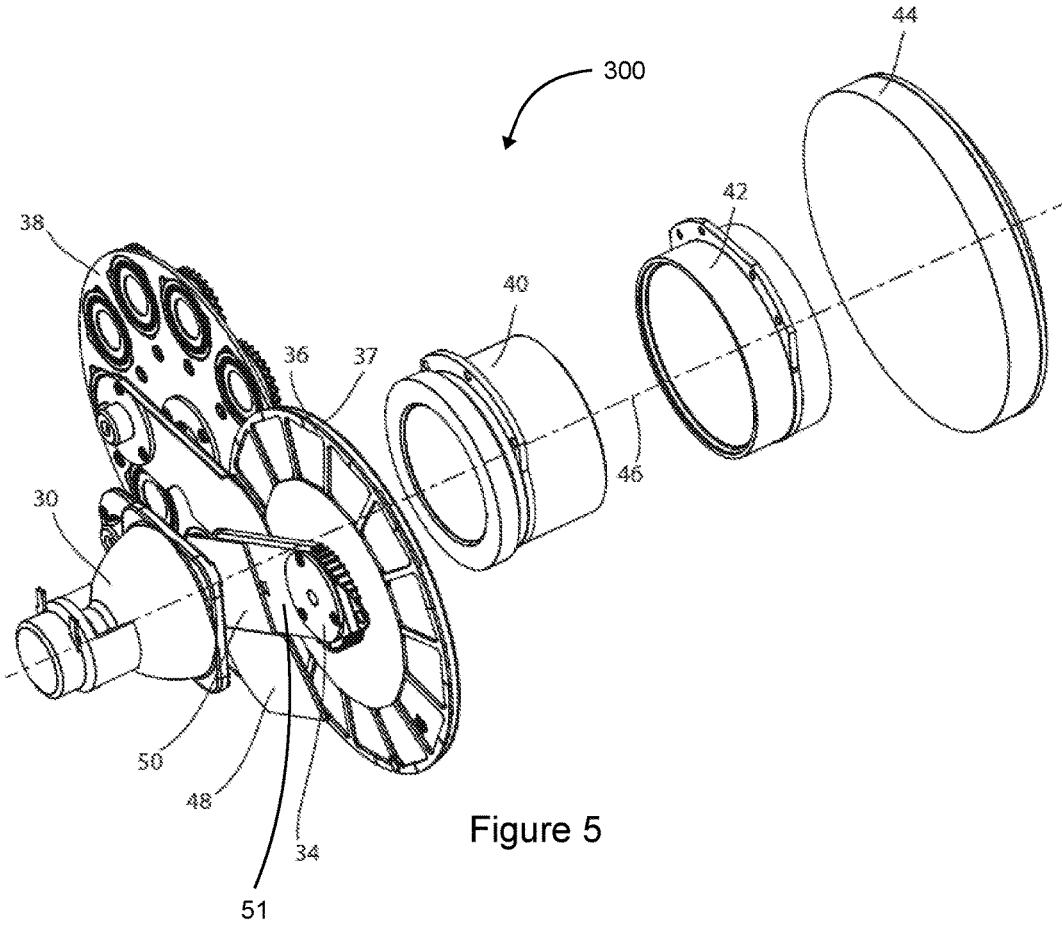


Figure 5

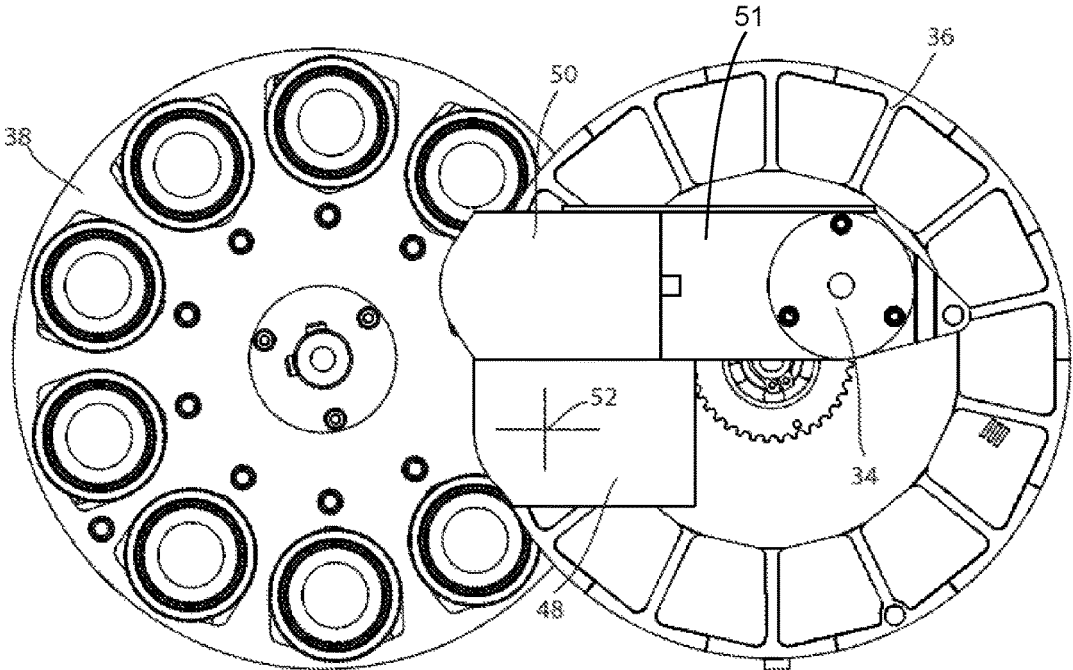


Figure 6

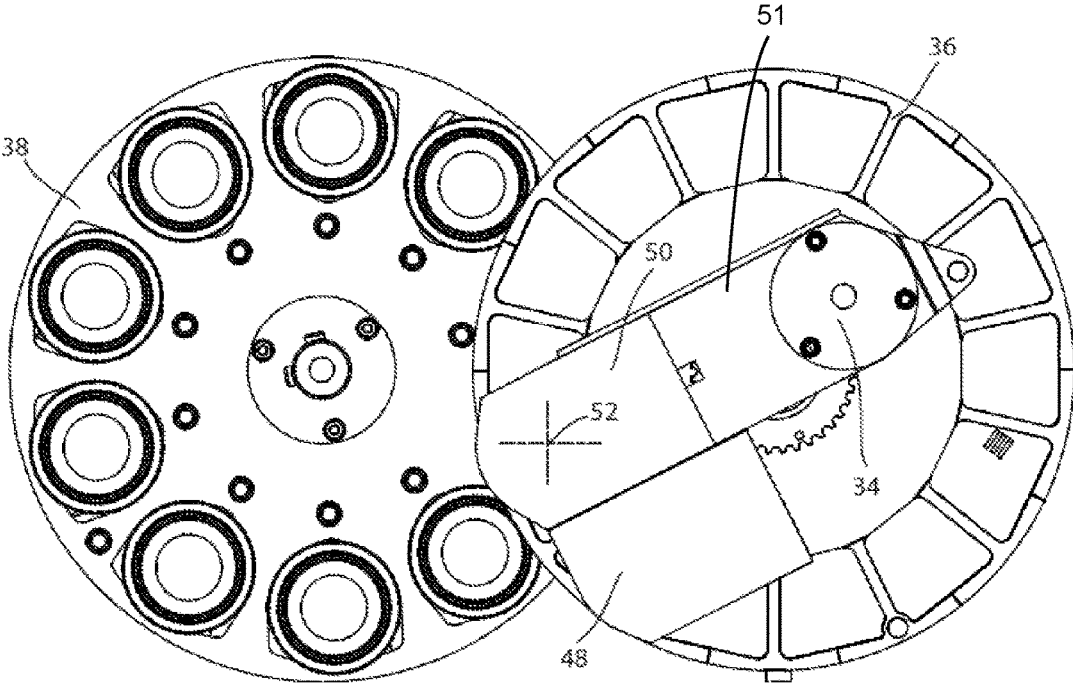


Figure 7

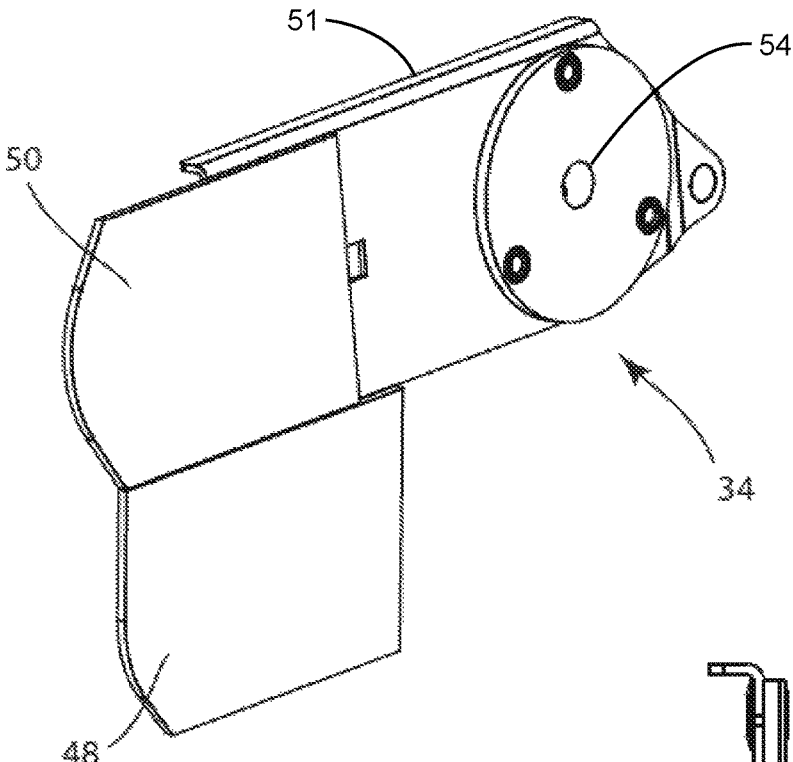


Figure 8

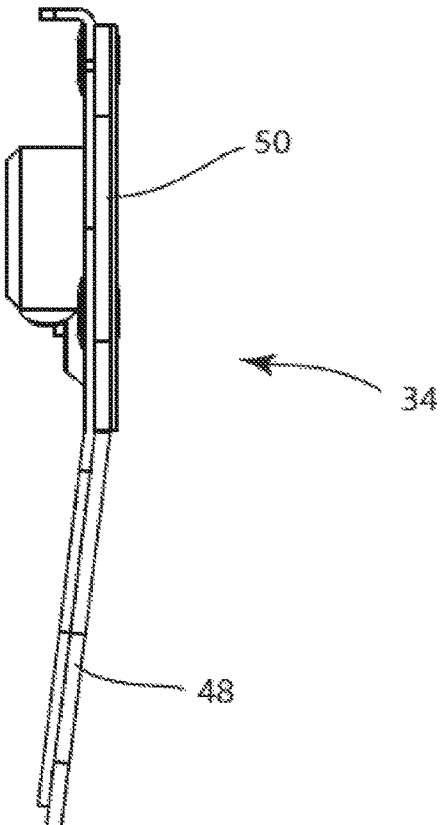


Figure 9

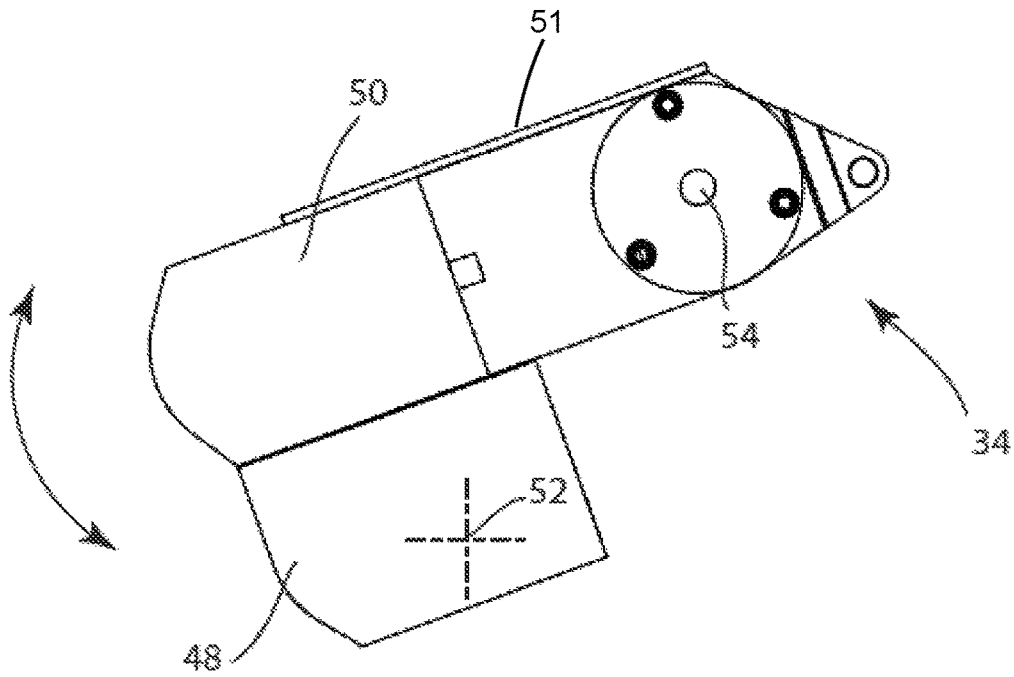


Figure 10

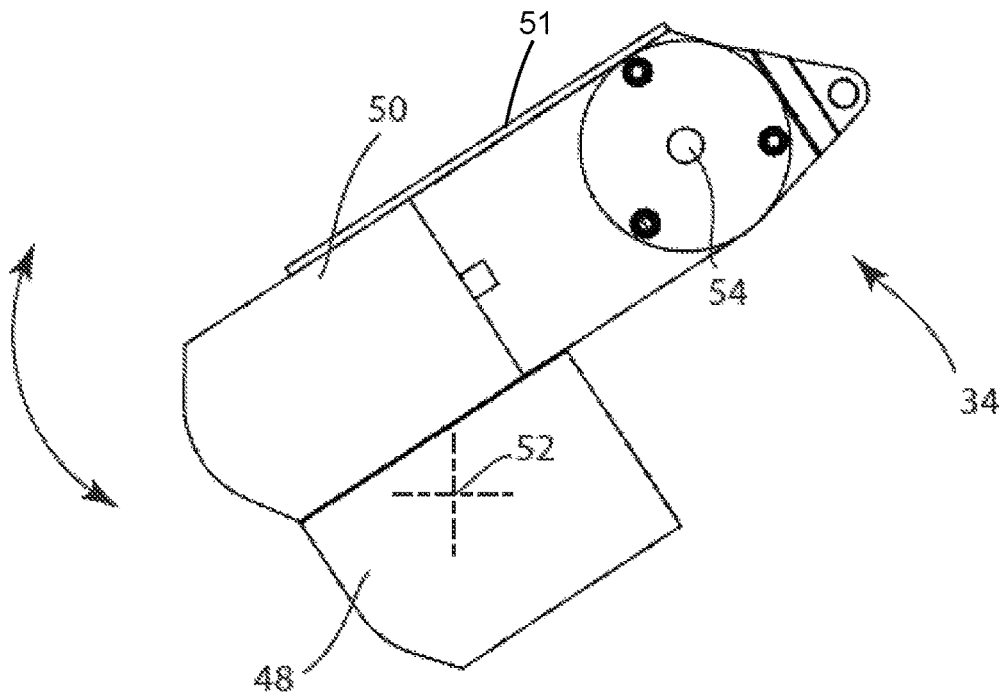


Figure 11

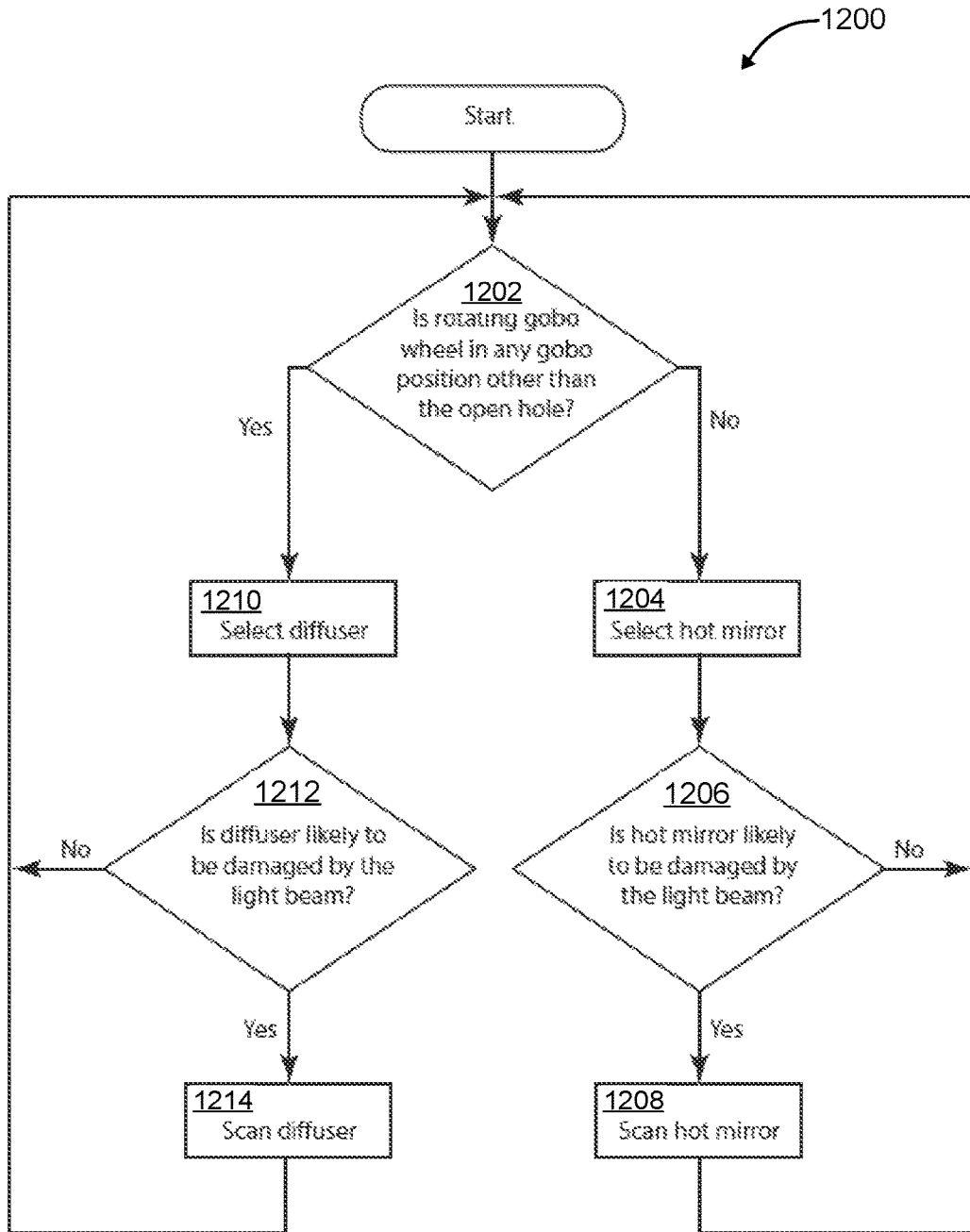


Figure 12

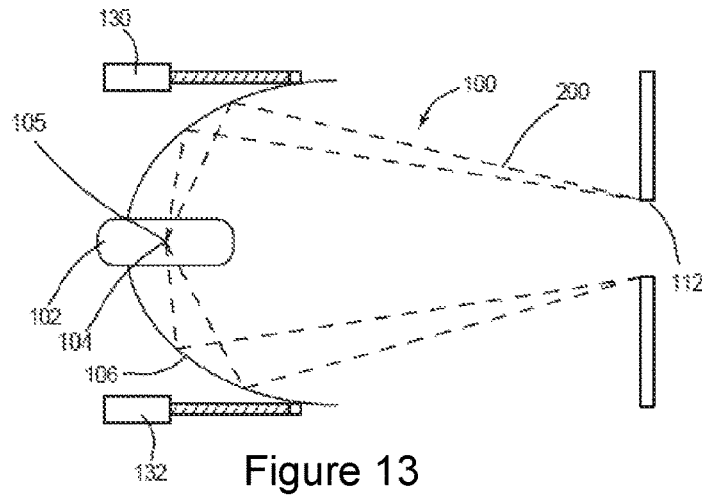


Figure 13

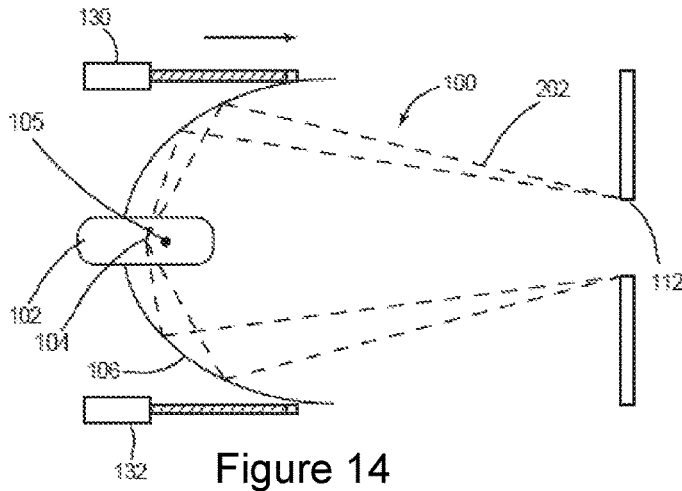


Figure 14

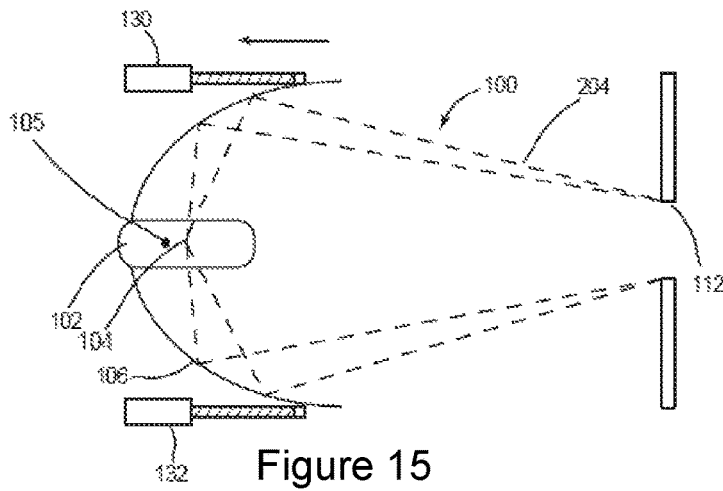


Figure 15

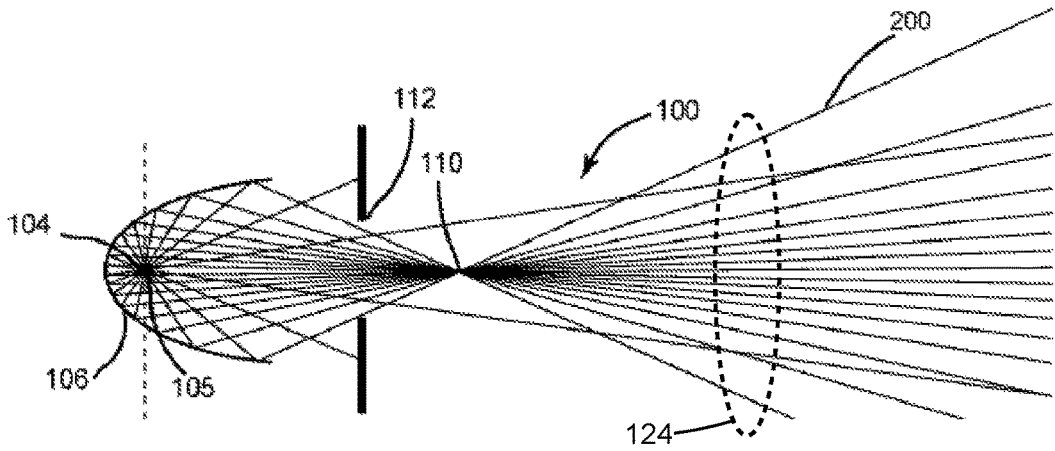


Figure 16

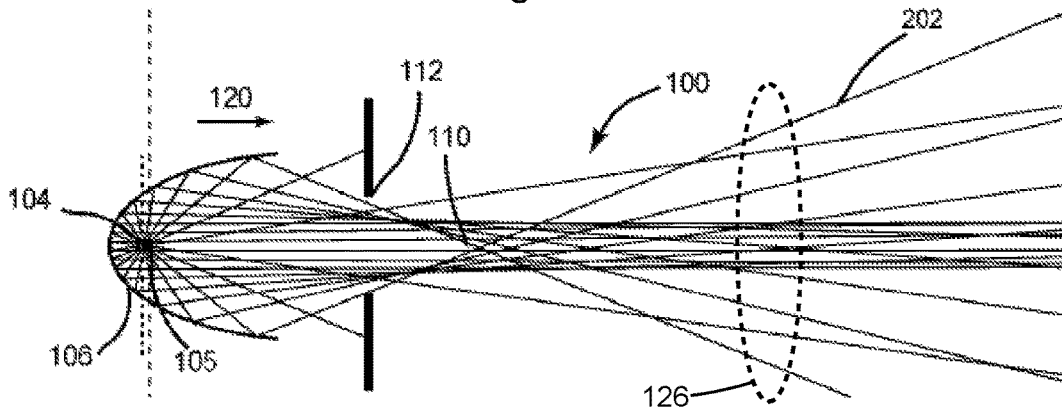


Figure 17

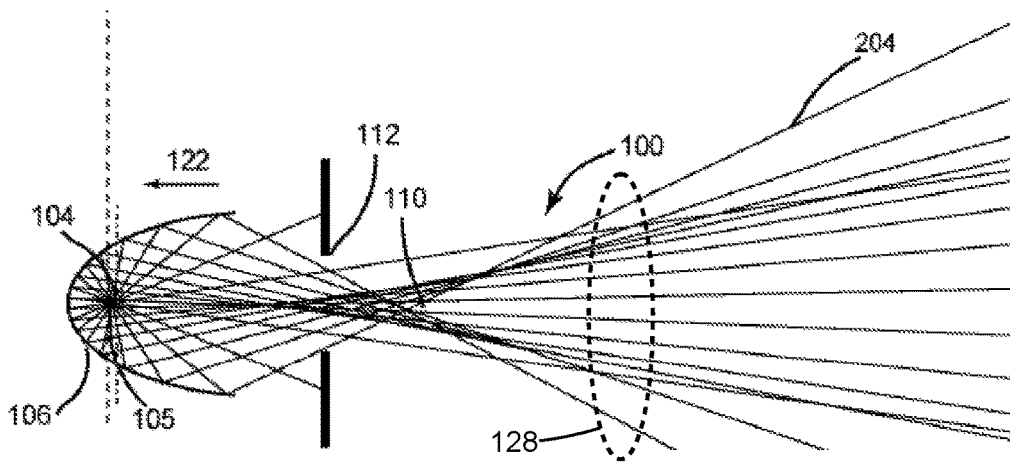


Figure 18

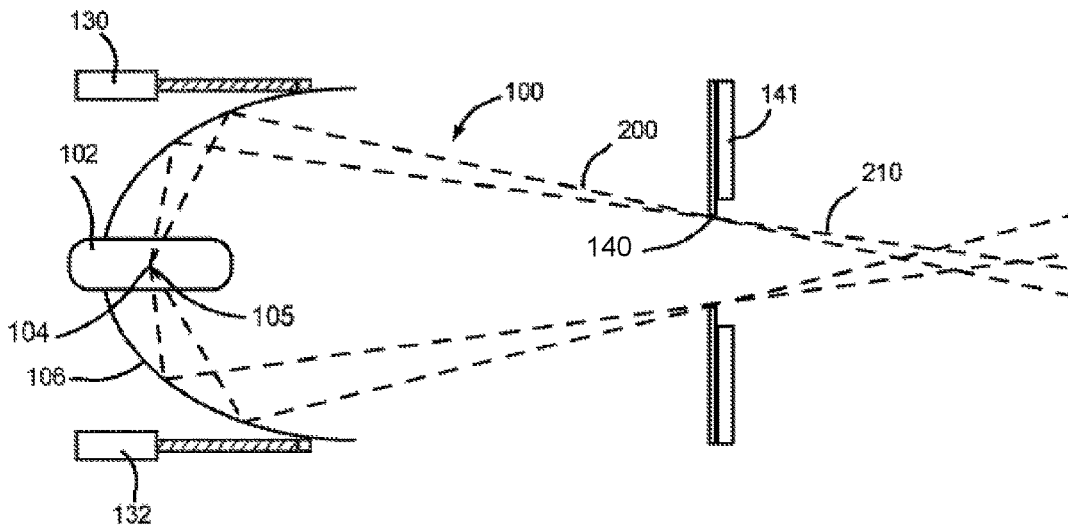


Figure 19

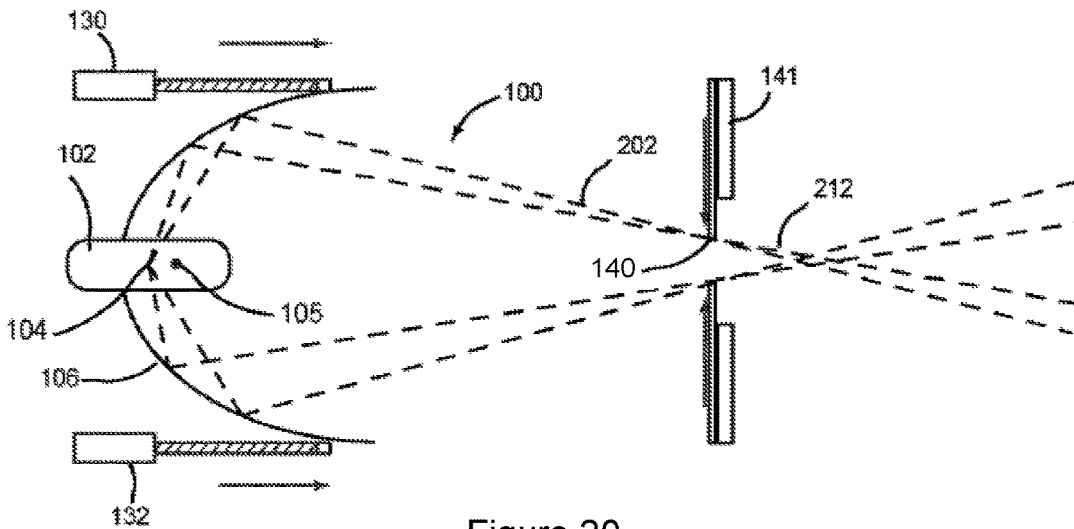


Figure 20

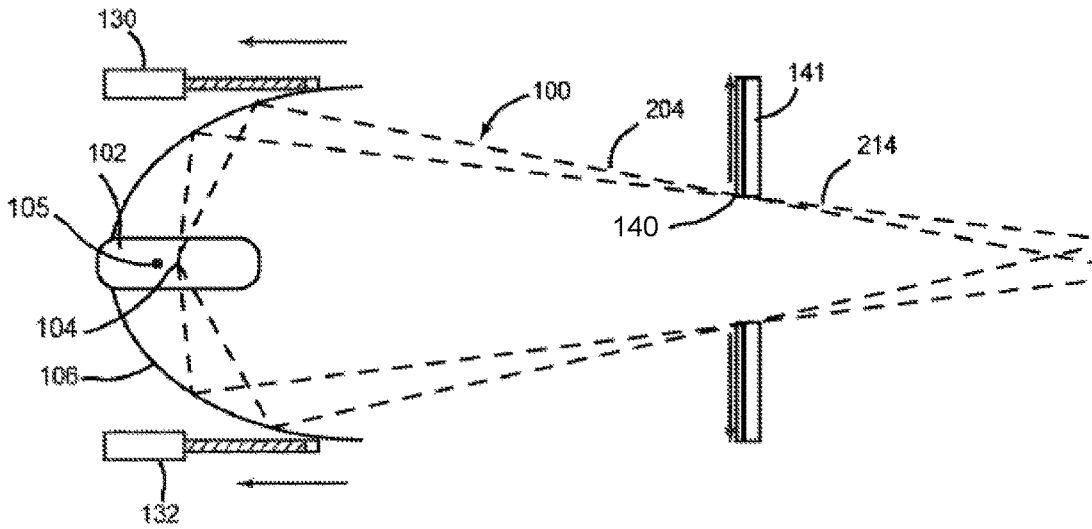


Figure 21

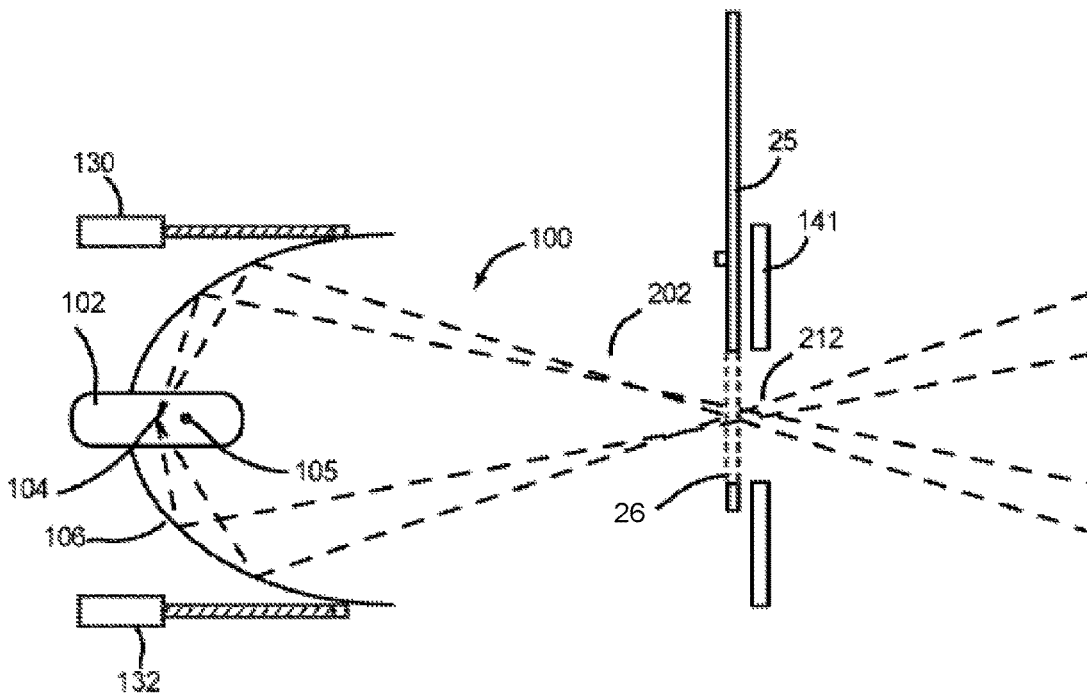


Figure 22

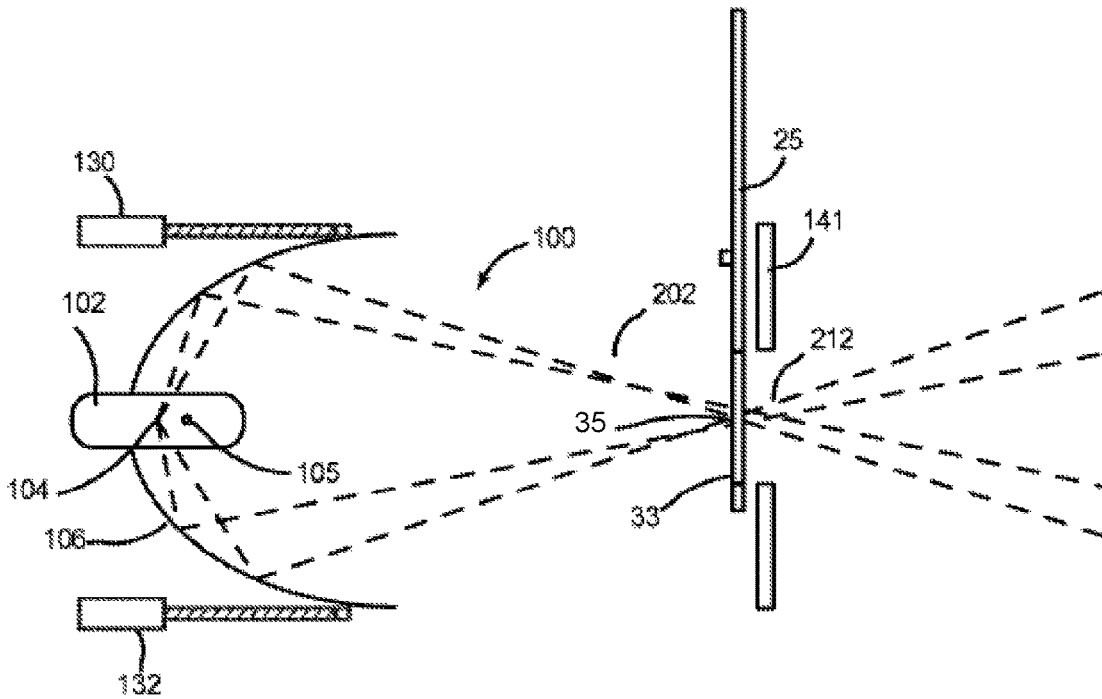


Figure 23

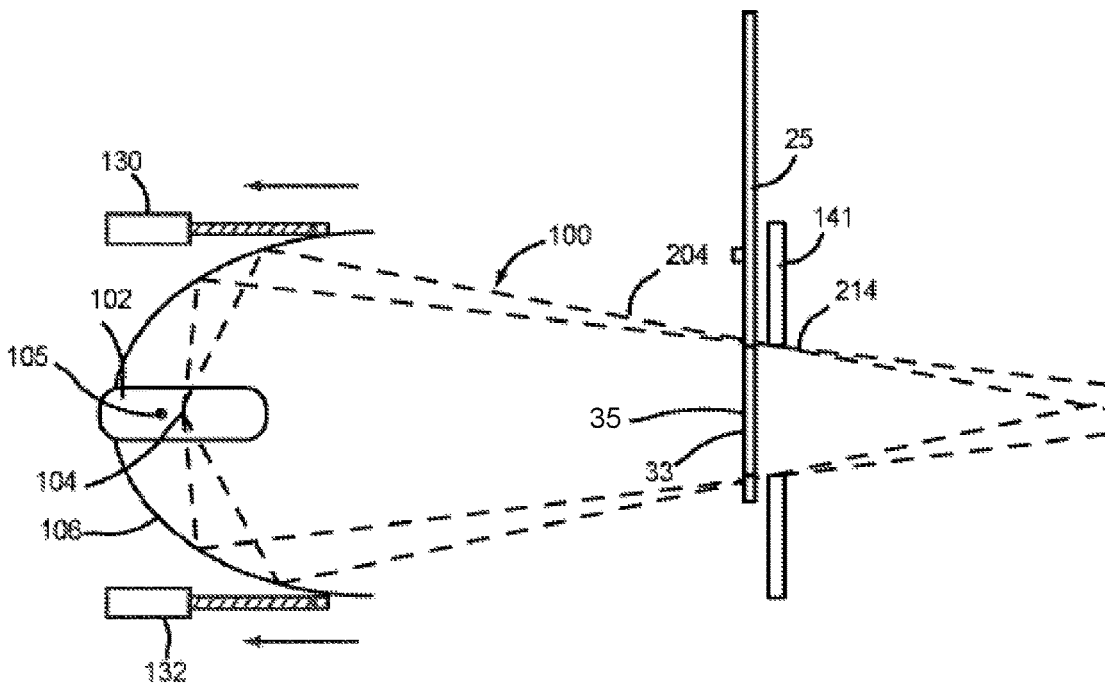


Figure 24

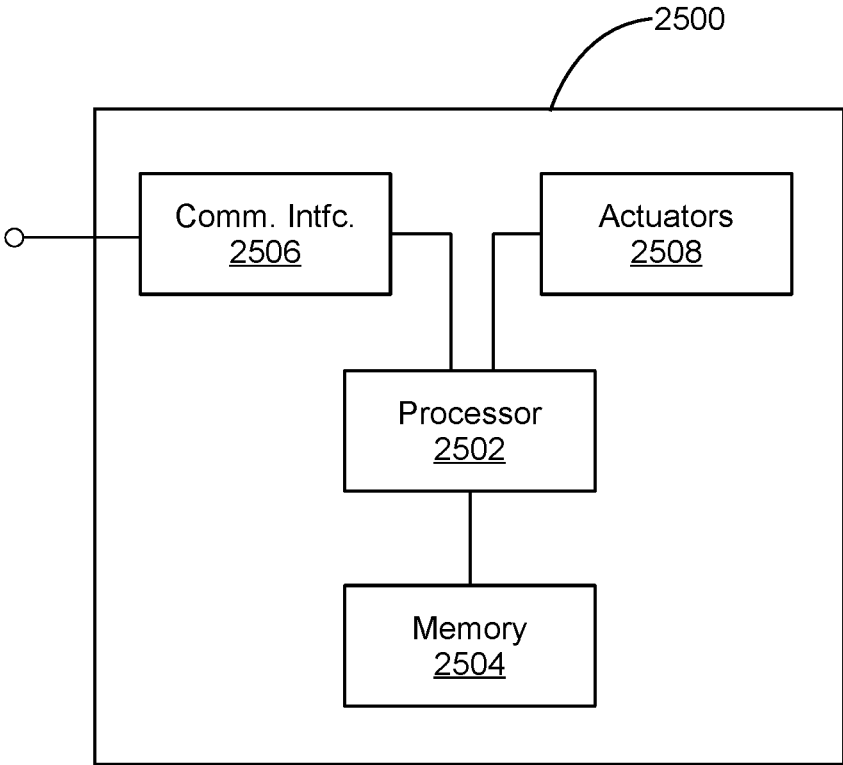


Figure 25

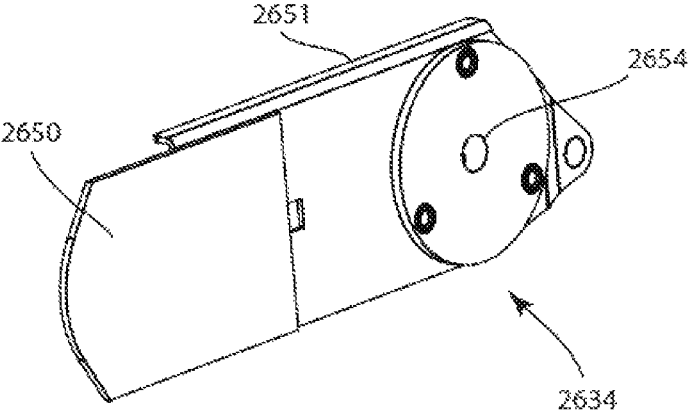


Figure 26

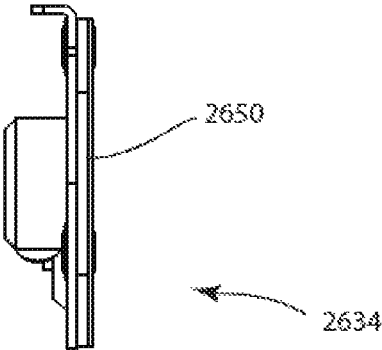


Figure 27

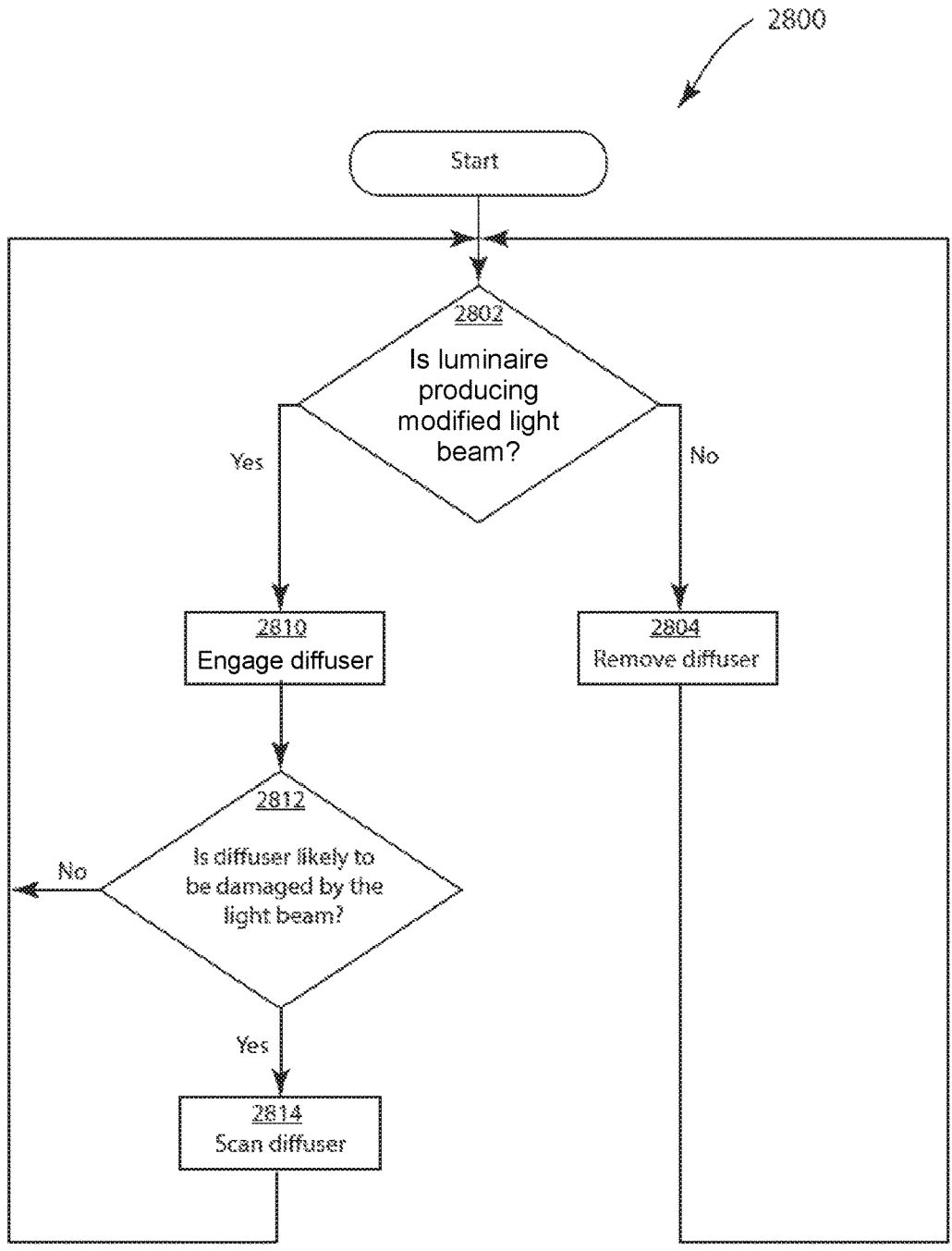


Figure 28

HEAT PROTECTION AND HOMOGENIZING SYSTEM FOR A LUMINAIRE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 16/118,114 filed Aug. 30, 2018 by Pavel Jurik, et al. entitled, "Heat Protection and Homogenizing System for a Luminaire", which claims priority to U.S. Provisional Application No. 62/553,295 filed Sep. 1, 2017 by Pavel Jurik, et al. entitled, "Heat Protection and Homogenizing System for a Luminaire", both of which are incorporated by reference herein as if reproduced in their entirety.

TECHNICAL FIELD

The disclosure generally relates to an automated luminaire, specifically to a heat protection and homogenization system in an automated luminaire.

BACKGROUND

Luminaires with automated and remotely controllable functionality are well known in the entertainment and architectural lighting markets. Such products are commonly used in theatres, television studios, concerts, theme parks, night clubs and other venues. Such a luminaire may provide control over the direction the luminaire is pointing and thus the position of the light beam on the stage or in the studio. This directional control may be provided via control of the luminaire's orientation in two orthogonal axes of rotation usually referred to as pan and tilt. Some products provide control over other parameters such as the intensity, color, focus, beam size, beam shape and beam pattern. The beam pattern may be provided by a stencil or slide called a gobo which may be a steel, aluminum or etched glass pattern.

SUMMARY

In one embodiment, an automated luminaire includes a light source, a compensation module, an optical device, and a controller. The light source produces a first light beam and includes an ellipsoidal reflector and a short arc discharge lamp mounted with the arc near a first focus of the ellipsoidal reflector. The light source has an optical axis and can move along its optical axis. The compensation module receives the first light beam, produces a second light beam, and includes a diffuser. The optical device receives the second light beam and produces either a modified light beam or an unmodified light beam. The controller determines whether the optical device is producing the modified beam or the unmodified light beam. If the optical device is producing the modified light beam, the controller (i) automatically moves the light source to a first selected position along the optical axis or (ii) automatically alternately position first and second portions of the diffuser in the first light beam. If the optical device is producing the unmodified light beam and light source is in the first selected position, the controller automatically moves the light source to a second selected position along the optical axis. If the optical device is producing the unmodified light beam and the diffuser is positioned in the first light beam, the controller automatically removes the diffuser from the first light beam.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of this disclosure, reference is now made to the following brief description,

taken in conjunction with the accompanying drawings in which like reference numerals indicate like features.

FIG. 1 illustrates a multiparameter automated luminaire system;

5 FIG. 2 illustrates an automated luminaire;

FIG. 3 presents a schematic side view of an optical system according to the disclosure;

10 FIG. 4 presents a schematic isometric view of the optical system of FIG. 3 with the compensation module in a first configuration;

FIG. 5 illustrates an isometric view of the optical system of FIG. 3 with the compensation module in a second configuration;

15 FIG. 6 shows a cross-sectional view of the optical system of FIG. 3 with the compensation module in the first configuration;

FIG. 7 shows a cross-sectional view of the optical system of FIG. 3 with the compensation module in the second configuration;

20 FIG. 8 presents an isometric view of the compensation module of the optical system of FIG. 3;

FIG. 9 presents a side view of the compensation module of the optical system of FIG. 3;

25 FIG. 10 presents a view of the compensation module in a first position of the first configuration;

FIG. 11 presents a view of the compensation module in a second position of the first configuration;

30 FIG. 12 presents a flow chart of a process of controlling a heat protection and homogenization system according to the disclosure;

FIG. 13 illustrates a remotely actuated reflector according to the disclosure, with the reflector in a first position;

35 FIG. 14 illustrates the remotely actuated reflector of FIG. 13, with the reflector in a second position;

FIG. 15 illustrates the remotely actuated reflector of FIG. 13, with the reflector in a third position;

40 FIG. 16 presents a ray trace diagram of the optical system of FIG. 13;

FIG. 17 presents a ray trace diagram of the optical system of FIG. 14;

45 FIG. 18 presents a ray trace diagram of the optical system of FIG. 15;

FIG. 19 illustrates an optical system according to the disclosure with a reflector and a variable iris in a first configuration;

FIG. 20 illustrates the optical system of FIG. 19 with the reflector and the variable iris in a second configuration;

50 FIG. 21 illustrates the optical system of FIG. 19 with the reflector and the variable iris in a third configuration;

FIG. 22 shows an optical system according to the disclosure with a reflector and a gobo wheel in a first configuration;

55 FIG. 23 shows the optical system of FIG. 22 with the reflector and the gobo wheel in a second configuration;

FIG. 24 shows the optical system of FIG. 22 with the reflector and the gobo wheel in a third configuration;

60 FIG. 25 presents a block diagram of a control system for an automated luminaire according to the disclosure;

FIG. 26 presents an isometric view of a second embodiment of a compensation module according to the disclosure;

FIG. 27 presents a side view of the compensation module of FIG. 26; and

65 FIG. 28 presents a flow chart of a second process of controlling a heat protection and homogenization system according to the disclosure.

Preferred embodiments are illustrated in the figures, like numerals being used to refer to like and corresponding parts of the various drawings.

Disclosed herein is an automated luminaire (or fixture), specifically the design and operation of a heat protection and homogenization system for use within an automated luminaire utilizing a light source with an intense hotspot such that the luminaire is capable of producing a narrow light beam in a first mode, and, in a second mode, capable of producing a wide, even, wash beam or projecting gobos without damaging the gobos or compromising the narrow beam performance of the first mode.

The optical systems of automated luminaires may be designed such that a very narrow output beam is produced, so that the units may be used with long throws or for almost parallel light laser like effects. Such optics may be called 'Beam' optics. In fixtures with a large light source, such a narrow beam may be formed using a large output lens with a large separation between the lens and the luminaire's gobos. In other such fixtures, an output lens with a short focal length may be positioned closer to the gobos.

Having a large separation with a large lens can cause the luminaire to be large and unwieldy and may make automation of the fixture's pan and tilt movement more difficult. In some systems, a preferred solution is a closer and smaller lens with a short focal length. In other systems a Fresnel lens may be used as a front lens, providing the same focal length with a lighter, molded glass lens having multiple circumferential facets. Fresnel lenses can provide a good match to the focal length of an equivalent plano-convex lens, however the image projected by a Fresnel lens may be soft edged and fuzzy and not provide as sharp an image as may be desired when projecting gobos or patterns.

FIG. 1 illustrates a multiparameter automated luminaire system 10. The luminaire system 10 includes a plurality of multiparameter automated luminaires 12 which each contains an on-board light source (not shown), light modulation devices, electric motors coupled to mechanical drive systems, and control electronics (not shown). In addition to being connected to mains power either directly or through a power distribution system (not shown), the luminaires 12 are connected in series or in parallel via a data link 14 to one or more control desks 15. The luminaire system 10 may be controlled by an operator using the control desk 15. Control of an individual automated luminaire 12 is typically effected by electromechanical devices within the luminaire 12 and electronic circuitry 13 including firmware and software within the control desk 15 and/or the luminaire 12. The luminaire 12 and the electronic circuitry 13 may also be referred to collectively as a fixture. In many of the figures herein, important parts like electromechanical components such as motors and electronic circuitry including software and firmware and some hardware are not shown in order to simplify the drawings. Persons of skill in the art will recognize where these parts have been omitted.

FIG. 2 illustrates an automated luminaire 12. A lamp 21 includes a light source 22 which emits light. The light is reflected and controlled by a reflector 20 through one or more of a static hot mirror 23, aperture or imaging gate 24, and optical devices 25 and 27. The optical devices 25 and 27 may include one or more of dichroic color filters, effects glass and other optical devices. The optical devices 25 and 27 may be imaging components and may include gobos, rotating gobos, irises, and/or framing shutters. A final output beam may be transmitted through focusing lens 28 and

output lens 29. Output lens 29 may be a short focal length glass lens or equivalent Fresnel lens as described above. The optical devices 25 and 27, focusing lens 28, and/or output lens 29 may be moved along the optical axis of the automated luminaire 12 to provide focus and/or beam angle adjustment for the imaging components. Static hot mirror 23 may protect the optical devices 25 and 27 from high infrared energy in the light beam, and typically comprises a glass plate with a thin film dichroic coating designed to reflect long wavelength infra-red light radiation, thus allowing only the shorter wavelength, visible light to remain in the light beam. However, in such designs, the static hot mirror 23 is always in position, modifying the light beam.

Some lamps 21 have extremely small light sources 22. Such light sources may have a very short arc gap, on the order of 1 millimeter (mm), between two electrodes as the light-producing means. Such lamps are well-suited for producing a very narrow beam, as their source etendue is low. Furthermore, the size of the lenses and optical devices to collimate the light from such a small source can be substantially reduced. However, the short arc and small light source coupled with a short focal length, and thus large light beam angles, of the reflector can result in a light beam with large amounts of energy concentrated in the central region, known as a hotspot. This intense central energy region is not ideal for producing a large even wash of light, and can damage or destroy elements of optical devices 25 and 27. In particular, glass gobos and projection patterns may be damaged by such an intense central hotspot. The light energy may damage the surface coatings and materials of the gobos.

Optical systems according to the present disclosure are capable of producing a narrow light beam in a first mode, and also, in a second mode, of producing a wide wash beam or of projecting gobos without damaging the gobos.

FIG. 3 presents a schematic side view of an optical system 300 according to the disclosure. The optical system 300 includes a light source 32 within reflector 30 (the combination of light source 32 and reflector 30 may also be referred to as a light source). Light source 32 may be a short arc discharge lamp with arc length of approximately 1 mm, and reflector 30 may be positioned near a first focus of an ellipsoidal glass reflector. The combination of a short arc light source and an ellipsoidal reflector produces a light beam towards a second focus of the ellipsoidal reflector. Such a beam typically has a very high energy beam center, or hotspot. The beam also produces a poor wide beam pattern when trying to use the luminaire as a wash light.

In the optical system 300, the light beam emitted by the light source 32 and reflector 30 passes through a heat protection and homogenization system (compensation module) 34 and the resulting compensated light beam passes through optical devices color system 36, static gobo system 37, and rotating gobo system 38. In other embodiments, one or more of systems 36, 37, and 38 may be omitted. The light beam then continues through lenses 40, 42, and 44, which may each individually or collectively be moveable along optical axis 46 so as to alter one or more of the focus, beam angle, and/or zoom of the light beam produced by the optical system 300.

Optical elements such as static gobo system 37 and rotating gobo system 38 may contain gobos or patterns that can be damaged by an intense hotspot. Such gobos may have a glass substrate with layers of aluminum, thin film coatings or other means for creating an image layer on the glass. The energy gradient from a light beam with an intense hotspot may damage these coatings, or crack or melt the glass. Similarly, devices such as irises or framing shutters may be

damaged by the hotspot. The compensation module 34 provides protection for optical elements by introducing either a diffuser or hot mirror into the light beam, when such protection is required. The compensation module 34 also provides for the removal of both diffuser and hot mirror from the beam when no optical element protection is required and an unmodified light beam is desired.

The compensation module 34 protects optical elements that are sensitive to a beam hotspot by automatically introducing a diffuser into the light path whenever a gobo or other heat sensitive element is inserted into the light beam. This diffuser may also be automatically removed from the light beam when all hotspot sensitive or heat sensitive devices are removed from the light beam, and may be replaced with a hot mirror. In some circumstances, an operator may manually control the compensation module 34 so that the diffuser is across the light beam when it is desired to produce a wide, smooth light beam for use as a wash light. In such circumstances, lenses 40, 42, and 44 may be adjusted to produce a wide beam angle or zoom, and the resultant beam will be smooth and flat with no intense bright central hotspot. In other circumstances, the operator may manually control the compensation module 34 so that the hot mirror is across the light beam when it is desired to produce a very tight, narrow beam of light. In such circumstances the central hotspot is useful to the optics and it is desirable to remove all homogenization or diffusion such that the light beam is as narrow and sharp as possible. In still other circumstances, the operator may manually control the compensation module 34 so that neither the diffuser nor the hot mirror is across the light beam.

FIG. 4 presents a schematic isometric view of the optical system 300 of FIG. 3 with the compensation module 34 in a first configuration. The compensation module 34 includes an arm 51 to which are mounted hot mirror 48 and diffuser 50. The hot mirror 48 and the diffuser 50 may be referred to as compensation elements. Hot mirror 48, which is positioned in the light beam in FIG. 4, is a filter that may be fabricated as one or more thin film coatings on glass, which reflects infra-red and other long wavelength energy, while allowing visible light to pass through. Diffuser 50, which is positioned out of the light beam in FIG. 4, is a homogenizing filter. The diffuser 50 may be manufactured as a frosted glass, lenticular glass, bead lens or filter, particulate frost filter, microlens array, or other kind of homogenizing filter. The diffuser 50 acts to spread out or dissipate any central hotspot in the light beam, providing a flatter, more diffuse beam that will not damage optical devices 36, or gobos mounted on the static gobo system 37 and the rotating gobo system 38, and will produce a smoother wash light beam.

FIG. 5 presents a schematic isometric view of the optical system 300 of FIG. 3 with the compensation module 34 in a second configuration. In this figure the arm 51 has been rotated so that the diffuser 50 is in the optical path and the hot mirror 48, is removed from the optical path. The compensation module 34 may be rapidly rotated from a first position where the hot mirror 48 is in the optical path to a second position where the diffuser 50 is in the optical path. The means for this movement may be as shown in the figures using the pivoted arm 51 driven through gears and a stepper motor (not shown). In other embodiments, movement of the compensation elements may be through other mechanical means such as linear actuators, lead screw, rack and pinion drive, direct drive motors, servo motors, solenoids or other mechanical actuators. In some embodiments, the hot mirror 48 and the diffuser 50 may be moved by separate arms or

other actuators, permitting either or both to be inserted or removed from the light beam, as desired.

FIGS. 6 and 7 shows cross-sectional views of the optical system 300 of FIG. 3 with the compensation module 34 in the first and second configurations, respectively. In FIG. 6, the hot mirror 48 is in the optical path, as shown by the optical axis marker 52. In FIG. 7, the arm 51 has been rotated so that diffuser 50 is in the optical path, again as shown by the optical axis marker 52.

FIG. 8 presents an isometric view of the compensation module 34 of the optical system 300 of FIG. 3. FIG. 9 presents a side view of the compensation module 34 of the optical system 300 of FIG. 3. In this embodiment, the hot mirror 48 is mounted at an angle to the optical axis 46, which lies parallel to an axis of rotation 54 of the arm 51. By angling hot mirror 48, the infra-red and other long wavelength energy reflected by hot mirror 48 is not sent back directly into the lamp, potentially overheating it. Instead, that energy is deflected to one side, away from the light source 32.

The diffuser 50 may be constructed of a single substrate as shown in FIGS. 8 and 9, or may comprise two or more layers. In some embodiments, the diffuser 50 may be a single substrate with a hot mirror coating on one of its surfaces so as to also act as a hot mirror as well as a diffuser. In other embodiments, the diffuser 50 may comprise two or more substrates, of which at least a first substrate is a diffuser or homogenizer and at least a second substrate is a hot mirror.

In a further embodiment, the compensation module 34 may continually oscillate between two positions on either or both of the hot mirror 48 or the diffuser 50 while they are positioned in the beam. In some circumstances the compensation elements themselves could be sensitive to the damaging effects of the hotspot it is being used to mitigate. In such circumstances, the compensation elements may be continually moved back and forth across the light beam, exposing different portions of the active compensation element to the hotspot and spreading the heat energy over a larger area of the compensation element. FIGS. 10 and 11 illustrate this technique.

FIG. 10 presents a view of the compensation module 34 in a first position of the first configuration. A first portion of the hot mirror 48 is on the optical axis 46, as shown by the marker 52. FIG. 11 presents a view of the compensation module 34 in a second position of the first configuration. In FIG. 11, compensation module 34 has been rotated and a second portion of the hot mirror 48 is on the optical axis 46, as shown by the optical axis marker 52. In a preferred embodiment, this oscillation is modulated at rates of approximately 0.5 hertz (Hz) in a sinusoidal pattern, when position is graphed against time. In other embodiments, other movement rates, oscillation frequencies, or position wave patterns may be employed.

The diffuser 50 may be similarly protected by oscillating the arm 51. In other embodiments, color wheels could be modulated in a similar manner. However in such an embodiment, the color filters on the color wheel would have to be large enough to allow for a sufficient range of oscillation motion. The range of motion necessary, in the case of a color wheel may be different for different colors.

FIG. 12 presents a flow chart 1200 of a process of controlling a heat protection and homogenization system according to the disclosure. The flow chart 1200 describes logic for protecting heat sensitive optical elements of an automated luminaire. The process described by the flow chart 1200 may be performed by the control system described below with reference to FIG. 25.

When the automated luminaire is on, the system monitors whether the luminaire is producing a modified light beam, for example, by placing a heat sensitive optical element in the light beam (step 1202). If the system determines that the luminaire is not producing a modified light beam (or if the beam is modified by an optical element that is not heat sensitive), then the hot mirror 48 is selected to engage the light beam. (step 1204). The system then monitors the operation of the luminaire to determine whether the status of the luminaire may cause risk of damage to the hot mirror 48 (step 1206). If so, the hot mirror 48 is scanned or oscillated as described with reference to FIGS. 10 and 11 (step 1208) and the system returns to step 1202 to look for a change in light beam modification status. In determining a risk of damage to the hot mirror 48, the system may consider, how long the hot mirror 48 has been engaged, how long it is expected to be engaged given preprogrammed lighting instructions, fixture temperature, ambient temperature, and/or other factors. In other embodiments, the logic can dictate that whenever the luminaire optical elements are repositioned to produce an unmodified light beam, the hot mirror 48 is selected to engage the light beam and, if needed, is scanned.

If the system determines that the luminaire is producing a modified light beam (step 1202), then the diffuser 50 is selected to engage the light beam (step 1210). The system then monitors the operation of the luminaire to determine whether the status of the luminaire may cause risk of damage to the diffuser 50 (step 1212). If so, the diffuser 50 is scanned as described with reference to FIGS. 10 and 11 (step 1214). In determining a risk of damage, the system may consider, how long the diffuser 50 has been engaged, how long it is expected to be engaged given preprogrammed lighting instructions, fixture temperature, ambient temperature, and/or other factors. In other embodiments, the logic can dictate that whenever the luminaire optical elements are repositioned to produce a modified light beam, the diffuser 50 is selected to engage the light beam and, if needed, is scanned.

FIG. 13 illustrates a remotely actuated reflector optical system 100 according to the disclosure, with an ellipsoidal reflector 106 in a first position. The optical system 100 includes a light source 102 having an emission point 104, the ellipsoidal reflector 106 configured to reflect light emitted by the light source 102, and motors 130 and 132 configured to move the ellipsoidal reflector 106 along its optical axis relative to the light source 102. Other shaped reflectors are contemplated for other embodiments. In FIG. 13 the ellipsoidal reflector 106 is positioned relative to the light source 102 with the emission point 104 of light source 102 at the first focal point 105 of the ellipsoidal reflector 106. In this first position, emitted light beam 200 is directed through aperture 112 with a slightly peaky beam distribution.

FIG. 14 illustrates the remotely actuated reflector optical system 100 of FIG. 13, with the ellipsoidal reflector 106 in a second position. Motors 130 and 132 have been activated to move the ellipsoidal reflector 106 forward to position the emission point 104 of light source 102 behind the first focal point 105. In this second position, emitted light beam 202 is directed through aperture 112 with a peakier distribution and increased hotspot.

FIG. 15 illustrates the remotely actuated reflector optical system 100 of FIG. 13, with the ellipsoidal reflector 106 in a third position. Motors 130 and 132 have been activated to move the ellipsoidal reflector 106 rearwards to position the emission point 104 of light source 102 in front of the first focal point 105. In this third position, emitted light beam 204 is directed through aperture 112 with a flatter distribution and reduced hotspot.

In other embodiments more or fewer than two motors may be used to control the position of the ellipsoidal reflector 106. In still other embodiments, stepper motors, servo motors, linear actuators, or other suitable mechanical actuators may be used to move the ellipsoidal reflector 106. The movement of the ellipsoidal reflector 106 in the preferred embodiment is continuous, providing multiple positions between an extreme forward position and an extreme rearward position. In other embodiments, the movement may be more stepwise with two or more positions selectable by an operator through the automated lighting system in which the luminaire is a part.

FIG. 16 presents a ray trace diagram of the optical system 100 of FIG. 13, with the ellipsoidal reflector 106 in the first position. The emission point 104 of the light source 102 (for clarity, illustrated in FIGS. 16-18 as an idealized point source) is positioned at the first focal point 105 of the ellipsoidal reflector 106. Light is collected by the ellipsoidal reflector 106 and directed through the aperture 112 towards a second focal point 110. The light beam 200 then continues towards further downstream optical elements (not shown) or towards a light target.

The light beam 200 may be directed through a series of optical devices such as a rotating gobo wheel containing multiple patterns or gobos, a static gobo wheel containing multiple patterns or gobos, an iris, color mixing systems utilizing subtractive color mixing flags, color wheels, framing shutters, graphic wheels, animation wheels, frost and diffusion filters, and beam shapers. The light beam 200 may then pass through an objective lens system, which may provide variable beam angle or zoom functionality, as well as the ability to focus on various components of the optical system before emerging as the required light beam.

The light beam 200 of light has a distribution 124. With the light source and ellipsoidal reflector 106 in the configuration shown in FIG. 16, the output light distribution 124 is produced with more light in the center than around the edges, and the intensity reduces gradually from the center to the edges of the beam. The shape of this light distribution may follow a bell curve shape and may be referred to as having a 'hotspot'. An operator may control the intensity of this hotspot and the flatness of the field by manually moving the light source of a prior art optical system along the optical axis to position its emission point in front of or behind the first focal point of the reflector during lamp installation.

Optical systems according to the disclosure provide remote control of the position of the reflector relative to the light source. As a result, field flatness becomes a dynamic operational control that an operator may use during a performance to dynamically adjust the beam to a desired profile at any moment. In one embodiment, the position of the light source is fixed and the ellipsoidal reflector may be moved backwards and forwards relative to that light source along its optical axis.

FIG. 17 presents a ray trace diagram of the optical system 100 of FIG. 13, with the ellipsoidal reflector 106 in the second position. The ellipsoidal reflector 106 has been moved forward along the optical axis as shown by arrow 120 and the emission point 104 is positioned further back than the first focal point 105 of the ellipsoidal reflector 106. Light beams still pass through aperture 112, however they are not directed through the second focal point 110 of the ellipsoidal reflector 106. Instead they are directed generally towards a point further along the optical axis than the second focal point 110. In this second position of the ellipsoidal reflector 106, the distribution 126 of the light beam 202 is less flat and the central hotspot is more pronounced than in the light

beam 200 shown in FIG. 16. Such a beam distribution may be advantageous for producing aerial beam effects.

FIG. 18 presents a ray trace diagram of the optical system 100 of FIG. 13, with the ellipsoidal reflector 106 in the third position. The ellipsoidal reflector 106 has been moved rearward along the optical axis, as shown by arrow 122, and the emission point 104 is positioned further forward than the first focal point 105 of the ellipsoidal reflector 106. Light beams still pass through aperture 112, however they are now directed generally towards a point closer along the optical axis than the first focal point 105. In this third position of the ellipsoidal reflector 106, the distribution 128 of the light beam 204 is flatter and the central hotspot is less pronounced, that is, the center of light beam 204 has a lower intensity than the center of light beam 200, shown in FIG. 16. Such a flat beam, with a reduced intensity hotspot, may be advantageous for projecting gobos, where a flat field may be desirable. As discussed above, a pronounced central hotspot may damage optical devices such as gobos, dichroic filters, prisms and other heat sensitive items. When such optical devices are in use, the flat field position of the reflector may be used to avoid heat-related damage. In some embodiments according to the disclosure, a control system automatically moves the reflector to the flat field position when an optical device that could be damaged by the hotspot is inserted into the beam.

FIGS. 19, 20, and 21 illustrate an optical system 100 according to the disclosure where a position of the ellipsoidal reflector 106 may be based on an opening or closing of a variable iris 140 to provide a desired amount or characteristic of light through the iris 140. FIG. 19 illustrates an optical system 100 according to the disclosure with a ellipsoidal reflector 106 and an iris 140 in a first configuration. The iris 140 is mounted to a bulkhead 141. The ellipsoidal reflector 106 is positioned with the emission point 104 of the light source 102 at the first focal point 105 of the ellipsoidal reflector 106. In this configuration, light beam 202 is directed through the iris 140 with a slightly peaky distribution 210.

FIG. 20 illustrates the optical system 100 of FIG. 19 with the ellipsoidal reflector 106 and variable iris 140 in a second configuration. The iris 140 has been stopped down to a smaller size, producing a modified beam with a smaller diameter. If the configuration of light source 102 and ellipsoidal reflector 106 were left unchanged from the first configuration, then a large amount of light from the light source 102 and ellipsoidal reflector 106 would impact on the iris 140 and not pass through the smaller central aperture. However, as shown in FIG. 20, motors 130 and 132 are activated in a first direction and ellipsoidal reflector 106 is moved forwards. In this configuration of the ellipsoidal reflector 106, the emission point 104 of the light source 102 is positioned behind the first focal point 105 of the ellipsoidal reflector 106. In this second configuration, light is directed in a narrower beam with more light passing through the center of the beam (an increased hotspot 212) and an increased amount of light passes through the iris 140.

FIG. 21 illustrates the optical system 100 of FIG. 19 with the ellipsoidal reflector 106 and the variable iris 140 in a third configuration. The iris 140 has been opened up to a larger size. If the configuration of light source 102 and ellipsoidal reflector 106 were left unchanged from the first configuration, then the outside edge of the aperture in the iris 140 would be illuminated at a low level. However, motors 130 and 132 are activated in a second direction and ellipsoidal reflector 106 is moved rearwards so that the emission point 104 of the light source 102 is positioned in front of the

first focal point 105 of the ellipsoidal reflector 106. In this third configuration, light is directed in a wider, flatter beam with light distributed (214) across the whole aperture in the iris 140, and an increased amount of light passes through the outside edge of the aperture in the iris 140.

The iris 140 provides a variable aperture. In other embodiments, a variable aperture may be provided by a gobo wheel having gobos with apertures of differing diameters.

In a further embodiment, the movement of motors 130 and 132 may be coupled to a motor actuating the iris 140. In such an embodiment, as the iris 140 is opened and closed and its aperture size changes, the position of ellipsoidal reflector 106 is correspondingly adjusted to optimally position the ellipsoidal reflector 106 relative to the light source 102 so that a maximal light output is directed through the aperture in the iris 140. For example, as an operator reduces a size of the iris 140 aperture, motors 130 and 132 may be simultaneously actuated to move the ellipsoidal reflector 106 forwards, directing more light through the smaller aperture. Conversely, as an operator increases a size of the iris 140 aperture, motors 130 and 132 may be simultaneously actuated to move the ellipsoidal reflector 106 rearwards, to better fill the larger aperture.

The coupling of the movement of the iris 140 and the ellipsoidal reflector 106 may be any kind of coupling understood in the art. In some embodiments, the coupling could be a mechanical coupling, where a single motor or motors drives the movement of both the iris 140 and the ellipsoidal reflector 106 through linkages or gearing. In other embodiments, separate motors may be used to actuate the iris 140 and the ellipsoidal reflector 106, and the separate motors are coupled electrically and fed with a common electrical signal. In still other embodiments, separate motors actuate the ellipsoidal reflector 106 and the iris 140, firmware or software controls the motors independently, and the motors are coupled via a motor control system.

FIGS. 22, 23, and 24 show an optical system 100 according to the disclosure where a position of the ellipsoidal reflector 106 may be based on the insertion and removal of a gobo or other heat sensitive optical device into the light beam, to avoid damaging the gobo or optical device. FIG. 22 shows an optical system 100 according to the disclosure with a ellipsoidal reflector 106 and a gobo wheel 25 in a first configuration. The optical system 100 is shown in a peaked position where the light source 102 is positioned with its emission point 104 behind the first focal point 105 of the ellipsoidal reflector 106. Light beam 200 is directed through an open aperture 26 of gobo wheel 25 and is thus an unmodified beam. Light beam 200 has a peaked beam distribution with a hotspot at 212. As the open aperture 26 is in the beam there is no heat sensitive optical device into the light beam 200 and an operator may safely utilize the high output of the peaked beam.

FIG. 23 shows the optical system 100 with the ellipsoidal reflector 106 and the gobo wheel 25 in a second configuration. The gobo wheel 25 has been rotated to position a gobo 33 in the light beam 202, producing a modified beam. As the position of the ellipsoidal reflector 106 remains unchanged from the position shown in FIG. 22, the peaked light distribution of the light beam 202 with the pronounced hotspot 212 could damage the gobo 33 by local overheating at its center point 35.

FIG. 24 shows the optical system 100 with the ellipsoidal reflector 106 and the gobo wheel 25 in a third configuration that may reduce or prevent such damage. Motors 130 and 132 have been activated to move ellipsoidal reflector 106 rearwards so that the emission point 104 of the light source

102 is positioned in front of the first focal point **105** of the ellipsoidal reflector **106**. In this position, light is directed in a wider, flatter beam with light distributed (**214**) across the whole of gobo **33**, reducing both the beam's hotspot and overheating at center point **35**.

In some embodiments, such movement of the ellipsoidal reflector **106** to the flat field position shown in FIG. **24** occurs automatically by, for example, motor control firmware recognizing that the gobo wheel **25** has been rotated to position gobo **33** across the beam. In such embodiments, the ellipsoidal reflector **106** may automatically return to the forward, peaked position shown in FIGS. **22** and **23** when the gobo wheel **25** is rotated back to the open aperture position and the gobo **33** is removed from the beam. In other embodiments, such control of the movement of the ellipsoidal reflector **106** to protect heat sensitive optical devices may be performed manually by an operator or by software in a remote control desk. An operator may also choose to override such protection and position the ellipsoidal reflector **106** manually.

In further embodiments, automatic movement of the ellipsoidal reflector **106** to the flat field position shown in FIG. **24** may be used to protect other thermally sensitive optical devices, such as dichroic filters, irises, graphic wheels, automation wheels, prisms, lenses, or other devices.

In some embodiments, automatic movement of the ellipsoidal reflector **106** to the flat field position shown in FIG. **24** may be used to protect the hot mirror **48** or diffuser **50** of the heat protection and compensation module **34**. A preset specified position for the ellipsoidal reflector **106** may be preprogrammed into the system of the automated luminaire and the ellipsoidal reflector **106** moved automatically to the preset position when the hot mirror **48** or diffuser **50** is moved into the beam. In some such embodiments, the preset position may be overwritten by an operator or by software in a remote control desk. A system according to the disclosure may provide separate, individual preset positions for the hot mirror **48** and the diffuser **50**.

In some embodiments, an operator is able to program whether the system automatically moves to the preset position of ellipsoidal reflector **106** or oscillates the hot mirror **48** or diffuser **50**, as described with reference to FIGS. **10** and **11**. In such embodiments, the flow chart of FIG. **12** may be modified to permit the additional protection modes described herein.

In still other embodiments, the system may dictate that whenever the gobo wheel is moved into a non-open gobo position, a preset selection of diffuser **50**, ellipsoidal reflector **106** position, or combination of diffuser **50** and ellipsoidal reflector **106** position is automatically employed to protect the engaged gobo. A preset position for the ellipsoidal reflector **106** used alone may be different than a preset position for the combination of reflector position and homogenizer. For an individual gobo, or for a particular use of a gobo, an operator may specify whether the diffuser **50**, a ellipsoidal reflector **106** position, or a combination of diffuser **50** and ellipsoidal reflector **106** position is automatically engaged.

FIG. **25** presents a block diagram of a control system (or controller) **2500** for an automated luminaire according to the disclosure. The control system **2500** includes a processor **2502** coupled to a memory **2504**. The processor **2502** is implemented by hardware and software. The processor **2502** may be implemented as one or more CPU chips, cores (e.g., as a multi-core processor), field-programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), and digital signal processors (DSPs). The processor **2502** is

further electrically coupled to and in communication with a communication interface **2506** and one or more actuators **2508**.

The control system **2500** is suitable for implementing processes, motor control, and other functionality as disclosed herein. Such processes, motor control, and other functionality may be implemented as instructions stored in the memory **2504** and executed by the processor **2502**.

The memory **2504** comprises one or more disks, tape drives, and/or solid-state drives and may be used as an over-flow data storage device, to store programs when such programs are selected for execution, and to store instructions and data that are read during program execution. The memory **2504** may be volatile and/or non-volatile and may be read-only memory (ROM), random access memory (RAM), ternary content-addressable memory (TCAM), and/or static random-access memory (SRAM).

FIG. **26** presents an isometric view of a second embodiment of a compensation module **2634** according to the disclosure. FIG. **27** presents a side view of the compensation module **2634** of FIG. **26**. In this embodiment, a diffuser **2650** is mounted to an arm **2651** that has an axis of rotation **2654**. The diffuser **2650** may be constructed of a single substrate as shown in FIGS. **26** and **27**, or may comprise two or more layers. In some embodiments, the diffuser **2650** may be a single substrate with a hot mirror coating on one of its surfaces so as to also act as a hot mirror as well as a diffuser. In other embodiments, the diffuser **2650** may comprise two or more substrates, of which at least a first substrate is a diffuser or homogenizer and at least a second substrate is a hot mirror.

It will be understood that, in some embodiments, the compensation module **2634** is used in the optical system **300** in place of the compensation module **34**. It will be understood that the technique of oscillating the diffuser **2650** between first and second positions in the beam (as described with reference to FIGS. **10** and **11**) may be used to reduce the effect of the heat energy of the beam on the diffuser **2650**.

FIG. **28** presents a flow chart **2800** of a second process of controlling a heat protection and homogenization system according to the disclosure. The flow chart **2800** describes logic for protecting heat sensitive optical elements of an automated luminaire. The process described by the flow chart **2800** may be performed by the control system described below with reference to FIG. **25**.

When the automated luminaire is on, the system monitors whether the luminaire is producing a modified light beam, for example, by placing a heat sensitive optical element in the light beam (step **2802**). If the system determines that the luminaire is not producing a modified light beam (or if the beam is modified by an optical element that is not heat sensitive) the diffuser **2650** is removed from the light beam. (step **2804**).

If the system determines that the luminaire is producing a modified light beam (step **2802**), then the diffuser **2650** is positioned in the light beam (step **2810**). The system then monitors the operation of the luminaire to determine whether the status of the luminaire may cause risk of damage to the diffuser **2650** (step **2812**). If so, the diffuser **2650** is scanned as described with reference to FIGS. **10** and **11** (step **2814**). In determining a risk of damage, the system may consider, how long the diffuser **2650** has been engaged, how long it is expected to be engaged given preprogrammed lighting instructions, fixture temperature, ambient temperature, and/or other factors. In other embodiments, the logic can dictate that whenever the luminaire optical elements are

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repositioned to produce a modified light beam, the diffuser 2650 is selected to engage the light beam and, if needed, is scanned.

While the disclosure has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised which do not depart from the scope of the disclosure herein. The disclosure has been described in detail, it should be understood that various changes, substitutions and alterations can be made hereto without departing from the spirit and scope of the disclosure.

What is claimed is:

1. An automated luminaire, comprising:
 - a light source configured to produce a first light beam, the light source comprising an ellipsoidal reflector and a short arc discharge lamp fixedly mounted with the arc positioned near a first focus of the ellipsoidal reflector, the light source having an optical axis and being configured to move along the optical axis;
 - a compensation module optically coupled to the light source, the compensation module comprising a diffuser, the compensation module being configured to receive the first light beam and to produce a second light beam;
 - an optical device optically coupled to the compensation module and configured to receive the second light beam and to produce one of a modified light beam and an unmodified light beam; and
 - a controller configured to:
 - determine whether the optical device is producing the modified light beam or the unmodified light beam; and
 - in response to determining that the optical device is producing the modified light beam, (i) automatically move the light source to a first selected position along the optical axis or (ii) automatically alternately position first and second portions of the diffuser in the first light beam; and
 - in response to determining that the optical device is producing the unmodified light beam:
 - determine whether the light source is in the first selected position and, in response to so determining, automatically move the light source to a second selected position along the optical axis; and

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determine whether the diffuser is positioned in the first light beam and, in response to so determining, automatically remove the diffuser from the first light beam.

2. The automated luminaire of claim 1, wherein the compensation module further comprises an arm mechanically coupled to the diffuser and the controller is configured to rotate the arm to alternately position first and second portions of the diffuser in the first light beam.
3. The automated luminaire of claim 1, wherein the compensation module further comprises a hot mirror and the controller is configured to automatically alternately position first and second portions of a selected one of the diffuser or the hot mirror in the first light beam in response to determining that the optical device is producing the modified light beam.
4. The automated luminaire of claim 3, wherein the hot mirror is configured to reflect infrared light away from the light source.
5. The automated luminaire of claim 3, wherein the controller is further configured to position the hot mirror in the first light beam in response to determining that the optical device is producing the unmodified light beam.
6. The automated luminaire of claim 1, wherein the optical device comprises one of a gobo and a variable aperture.
7. The automated luminaire of claim 6, wherein the optical device comprises a variable aperture and the first selected position is based on a size of the variable aperture.
8. The automated luminaire of claim 7, wherein the controller is further configured to move the variable aperture to a desired size and to determine the first selected position based on an amount of light passing through the variable aperture.
9. The automated luminaire of claim 1, wherein an intensity in a center of the second light beam received by the optical device is lower in the first selected position than in the second selected position.
10. The automated luminaire of claim 1, wherein the controller is further configured to determine whether the diffuser is positioned in the first light beam and, in response to so determining, move the light source to the first selected position along the optical axis.

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