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- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
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(54) Title: LUMINAIRE

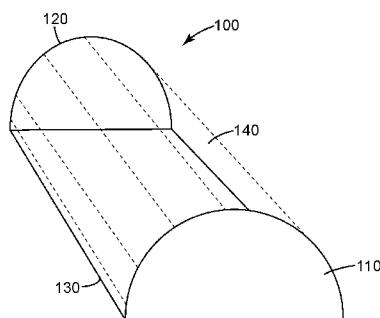


FIG. 1

(57) Abstract: Luminaires are described. In particular, luminaires that have reflectors and microstructured films are described. Some described hollow luminaires, including troffers, can hide electronics within their cavities when the luminaire is illuminated by light sources. Cylindrical luminaires are also described.



LUMINAIRE

Background

Luminaires are used for task-specific and general illumination purposes. Luminaires may be used in indoor areas where natural light is insufficient or for, as an example, in outdoor areas during the evening or night. Luminaires can provide general purpose illumination, decorative illumination, or a combination of general purpose and decorative illumination.

Summary

In one aspect, the present description relates to a luminaire. In particular, the luminaire has its greatest extent along a length direction and has a width direction perpendicular to the length direction. The luminaire includes a reflector disposed at at least one of the first and second ends of the luminaire along the length direction of the luminaire, a reflector disposed at the base of the luminaire and extending between the first and second ends of the luminaire and extending between third and fourth ends of the luminaire along the width direction of the luminaire, and a microstructured film disposed as a curved emission surface extending between the first and second ends of the luminaire and between the third and fourth ends of the luminaire.

In another aspect, the present disclosure relates to a cylindrical luminaire. The cylindrical luminaire includes a reflector disposed at the bottom of the luminaire, a top film disposed at the top of the luminaire, and a microstructured film disposed as a curved emission surface extending between the bottom and the top of the luminaire.

Brief Description of the Drawings

FIG. 1 is a top perspective view of a luminaire.

FIG. 2 is a top plan view of a luminaire.

FIG. 3 is a top perspective view of a luminaire.

FIG. 4 is a top perspective view of an exemplary edge-lit troffer showing the coordinate frame.

FIG. 5 is a plot of measured contrast versus azimuthal angle for certain edge-lit troffers.

Detailed Description

Luminaires, and in particular troffers, which refer to generally roughly rectangular downward-illuminating lights typically disposed within a ceiling or otherwise overhead, are

useful in many general illumination settings. Troffers may be placed recessed into a ceiling. Typically, troffers are outfitted with fluorescent tubes or light emitting diodes.

The configuration of troffers and other general luminaires typically do not permit for the placement of highly absorptive objects within the cavity of the luminaire. While it may be physically possible, the placement of such an object results in a very obvious dark spot where the object blocks the light.

It is advantageous to have a configuration where it is possible to place such an object within the cavity of the luminaire. For example, there may be driving electronics or wires that otherwise would require elaborate mounting and hiding mechanisms to keep from interfering with the optics of the luminaire. Wiring through the ceiling, if so mounted, may be complicated and make for difficult component replacement and repair.

Strong diffusers are typically used to hide light sources, and, by extension, dark spots caused by objects within a luminaire cavity. Surprisingly, excellent object hiding results are observed with the use of highly specular—not diffuse—reflectors within luminaire cavities. Specularity is discussed further herein.

FIG. 1 is a top perspective view of a luminaire. Luminaire **100** includes first reflector end **110**, second reflector end **120**, bottom reflector **130**, and top film **140**. Luminaire **100** may overall be any suitable size and be any suitable shape. Luminaire **100** may be hollow.

First reflector end **110** and second reflector end **120** may be the same shape or they may be different shapes. In some embodiments, the first reflector end and the second reflector end (either or both) have curved portions, straight portions, faceted portions, or any suitable shape. As shown in FIG. 1, first reflector end **110** and second reflector end **120** may be semicircular.

First reflector end **110** and second reflector end **120** each are or include reflective surfaces at least for the internal portions. The reflective surfaces may be or include any suitable reflector. In some embodiments, the reflector may be a silvered mirror. In some embodiments, the reflector may be spectrally neutral across visible wavelengths.

In some embodiments, the reflector is a specular reflector, such as Enhanced Specular Reflector (“ESR”) (available from 3M Company, St. Paul, Minn). In some embodiments, such as for ESR, the reflector is a multilayer polymeric reflector. In some embodiments, the reflector is a semi-specular reflector or a diffuse reflector. Specularity refers to the degree of specular reflection for light incident on the reflector’s surface. Specular reflectors provide a single reflection angle for a single incidence angle, diffuse reflectors provide a broad or even Lambertian reflection pattern for a single incidence angle, and semi-specular reflectors provide a reflection characteristic somewhere in between. For example, semi-specular reflection may be

usefully characterized by its transport ratio, which may be given as the ratio of the difference of forward scattered light and back scattered light to the total light. Transport ratios of 0.7 or greater, as an example, may be useful to help transport light while providing enough scattering (albeit forward scattering) to hide defects and enhance uniformity. The proportion of the first and second reflector ends that includes reflective surfaces will depend on the desired application; however, in many cases, more than half of the internal surfaces of the reflector end will be reflective. Sometimes, the reflector has portions that are of different specularity, such as specular and diffuse portions, specular and semi-specular portions, semi-specular and diffuse portions, a gradient of specularity, or a combination of specular, semi-specular, and diffuse portions.

Bottom reflector **130** may be any suitable size and shape. In some embodiments, the bottom reflector joins first reflector end **110** and second reflector end **120** and is the same width as both the first and second reflector ends. Bottom reflector **130** may be formed from or made from the same monolithic piece of material or sheet as first reflector end **110** and second reflector end **120**. In some embodiments, bottom reflector **130** and the first and second reflector ends are laminated, adhered, or attached together. In some embodiments, bottom reflector **130** is or includes the same reflectors as the reflective surfaces of the first and second reflector end. Bottom reflector **130** may have any of the characteristics described in conjunction with the reflector ends.

Top film **140** may be chosen from many possible films and combinations of films. In some embodiments, top film **140** is not a film but a thicker sheet or some other at least partially transmissive element. Top film **140** may have any suitable thickness. In some embodiments, top film **140** is a microstructured film. Any suitable microstructured film, such as a one- or two-side microreplicated film or turning film may be used. The microstructures may be linear prisms (i.e., prisms arranged parallel and elongated along a single common direction), linear lenses (i.e., structures arranged parallel that have a cross section of lenses or arcs and are elongated along a single common direction), pyramids, cones, hexagonally closely packed cones, or any other suitable shape or combination of shapes. In some two-sided structured films, the structures on the top and bottom sides may be the same or different. In some embodiments, the top and bottom sides are registered to one another. In these two-sided films, the structures on the top and bottom may be arranged so that an elongation direction of the structures of each surface are arranged orthogonally to one another, or their elongation directions may form an angle therebetween of between 60 and 120 degrees. The bottom structures may be elongated parallel to the length of the luminaire or across it. With top and bottom structures, the bottom structures face toward bottom reflector **130** and the top structures face away from bottom reflector **130**. Microstructured

films may be formed through any suitable process, including UV cast-and-cure processes, embossing, and injection molding.

In some embodiments, top film **140** may be a prism film, such as Brightness Enhancing Film (BEF), available from 3M Company, St. Paul, Minn. In some embodiments, top film **140** may be a light redirecting film. In some embodiments, film **330** may be a transfective film. In some embodiments, top film **140** may be a reflective polarizer. In some embodiments, top film **140** may be a turning film. Top film **140** may be or include a collimating multilayer optical film, a partial mirror film, an absorber or color filter, a downconverter including phosphors, fluorescers, or quantum dots, a color shifting film, or a diffuser (with one or more of bulk or surface scattering). In some embodiments, top film **140** may include a non-woven component. In some embodiments, top film **140** may include transparent, translucent, clear, or hazy plastic or flexible glass. In some embodiments, top film **140** can have spatially varying optical properties. In some embodiments, top film **140** is a curved surface. In some embodiments, top film **140** is held in place—or shaped—by being held in compression. In some embodiments, top film **140** has a semi-cylindrical shape. In some embodiments, top film **140** acts as a curved emission surface.

FIG. 2 is a top plan view of a luminaire. Luminaire **200** includes light source **250** and driver **260**. Light source **250** includes one or more light emitting diodes (LEDs) or any other suitable light source. The LEDs are disposed to inject light into luminaire **200**. The light sources may emit light of any suitable wavelength and may include phosphors, quantum dots, or other downconverters to provide an appropriate color. In some embodiments, the light engine includes collimating optics to provide a light distribution with a full width half maximum (FWHM) of 40 degrees, of 30 degrees, of 20 degrees or even less. In some embodiments, the light engine may include a diffuser to provide increased uniformity. In some embodiments, the light sources of the light engine may cover 30% or more, 50% or more, or 70% or more of the end area of the reflector end. In some embodiments, the light engine is a strip of LEDs or OLEDs that are disposed within the luminaire. In some embodiments, light source **250** is disposed proximate to or on one of the reflector ends. In some embodiments, the luminaire may include more than one light source (or light source grouping): for example, on each reflector end. In some embodiments, light source **250** is external to the luminaire and disposed to inject light into the luminaire cavity.

Driver **260** is disposed within the cavity of luminaire **200**. In FIG. 2, driver **260** is disposed on the center of the bottom reflector (e.g., bottom reflector **130** in FIG. 1). Driver **260** is shown in dashed lines because when light source **250** emits light, driver **260** cannot be seen or

identified from a viewpoint external to the luminaire. The driver need not be placed in the center of the reflector, and the driver-hiding properties of the luminaire may vary as the driver becomes larger and larger. Driver **260** is represented as a rectangle but may take any shape or size and may include wires or other electronics as well. In some embodiments, being hidden means the driver is not viewable on-axis (directly under or over the bottom reflector. In some embodiments, being hidden means the driver is not viewable within 60 degrees azimuthal angle. In some embodiments, being hidden means the driver is not viewable at any angle.

FIG. 3 is a top perspective view of a luminaire. Luminaire **300** includes bottom reflector **310**, top film **320**, circumferential film **330**, light sources **350**, and driver **360**.

Bottom reflector **310** may be or include a reflector as described herein. Top film **320** may be or include a reflector or, in some embodiments, top film **320** may be or include a microstructured film or other film. The top film **320**, if a microstructured film, may have any or all of the characteristics as described in conjunction with top film **140** of FIG. 1. Similarly, circumferential film **330** is or includes a microstructured film that has any or all of those characteristics as well.

Light sources **350** are disposed on bottom reflector **310** and may be glued, adhered, or otherwise disposed. Light sources **350**, as described for light source **250**, may have any suitable spectral output and may have any suitable combination of features described in conjunction with FIG. 2.

Luminaire **300** may have any suitable form factor, shape, and size. For example, luminaire **300** may be a short cylinder as shown in FIG. 3, or it may have more extended dimensions (i.e., it may be a longer cylinder). The films may be adhered, laminated, or attached via any suitable process. In some embodiments, a housing or other structure may be placed around the luminaires described herein.

Examples

An edge-lit troffer was constructed as follows. The base of the troffer was rectangular with a width of 10 inches and a length of 36 inches. The end caps of the troffer were approximately semicircular with a height of 4.25 inches. The rectangular bottom of the troffer was covered with a sheet of reflective film, and the end caps were covered with Enhanced Specular Reflector (ESR) film (available from 3M Company, St. Paul MN). The troffer had two LEDs mounted on each endcap; these were XML LEDs (from Cree, Inc., Durham NC) driven at a power of 1 watt. An HID-PV m20/s electronics driver with dimensions 1.62 by 3.8 by 1.875 inches (available from Philips Lighting, Eindhoven, Netherlands) was placed at the center of the

rectangular base on top of the reflective film. The outer semi-cylindrical surface of the troffer was covered with an extraction film. The troffer is shown in FIG. 4.

Twelve combinations of extractor and reflector films were used to test their ability to hide the electronics driver from view. The combinations used are shown in Table 1. The extraction films were as follows:

- 2DRF was the film described in US2014/0104871 (Boyd et al.) with inverted cones having 67 degree apex angle, with hexagonal close-packing, 100% surface coverage, and refractive index of 1.5;
- XUT consisted of the film described in US pending application number 14/188687 (Bennett et. al.) having structures on both surfaces and oriented so that the structures on one side ran perpendicular to the structures on the other;
- TF was a conventional turning film having prisms with a 69 degree included angle, a pitch of 50 microns, made of a UV-curable acrylate on a PET substrate; and
- TF/2DRF was a two-film construction with 2DRF on the top and TF below, oriented so that TF faced the light source.

The reflector films were as follows: EDR was Enhanced Diffuse Reflector film, ESR was Enhanced Specular Reflector film and LEF was Light Enhancement Film. All are available from 3M Company, St. Paul MN.

Table 1

Extraction film (Troffer upper film)	Reflector (Troffer lower film)
2DRF	EDR
XUT	EDR
TF	EDR
TF/2DRF	EDR
TF/2DRF	ESR
TF	ESR
2DRF	ESR
XUT	ESR
XUT	LEF
2DRF	LEF
TF	LEF
TF/2DRF	LEF

Three different people observed and rated the ability of the film combinations to hide the electronics driver from view. The XUT film was clearly superior in hiding power over the other extraction films.

A contrast analysis was done for the constructions with the XUT extraction film and each of the reflectors. Contrast was defined as $c = \frac{\Delta L}{\bar{L}}$, where $\bar{L}$ is average luminance and ΔL is difference in luminance from maximum to minimum. Luminance was measured using an FPM-520 light measurement system (from Westar Display Technologies, St. Charles MO) and a PR-705 spectroradiometer (from Photo Research, Inc., Chatsworth CA). The dark spot created by the electronic driver box was first identified visually. Minimum luminance was measured at the center of the dark spot area across a range of azimuths (the angle θ of FIG. 4); maximum luminance was measured at an adjacent region outside the dark spot at the same azimuths. Average luminance at each azimuth is the average of the maximum and minimum luminance values at that azimuth. FIG. 5 shows contrast of the dark spot behind the XUT film as a function of azimuth. The three curves correspond to the three different reflectors. Visual observations suggested that when XUT was used as the extraction film and for viewing positions with θ less than 60 degrees, observers were not able to identify an object with any of the extraction films EDR, ESR or LEF. For azimuths greater than 60 degrees with the XUT/LEF combination of extraction film and reflection film, observers were just able to identify an object beneath the XUT film. The threshold of visibility appeared therefore to be about $c = 0.25$. The combination of XUT as extraction film and ESR as reflector made the electronics driver fall below the threshold of visibility across the measured range of azimuth angles.

The following are exemplary embodiments according to the present disclosure:

Item 1. A luminaire having its greatest extent along a length direction and a width direction perpendicular to the length direction, comprising:

a reflector disposed at at least one of first and second ends of the luminaire along the length direction of the luminaire;

a reflector disposed at the base of the luminaire and extending between the first and second ends of the luminaire and extending between third and fourth ends of the luminaire along the width direction of the luminaire; and

a microstructured film disposed as a curved emission surface extending between the first and second ends of the luminaire and between the third and fourth ends of the luminaire.

Item 2. The luminaire of item 1, wherein the reflector is a specular reflector.

Item 3. The luminaire of item 1, wherein the microstructured film has top features facing away
5 from the reflector and bottom features facing toward the reflector.

Item 4. The luminaire of item 3, wherein the top features and the bottom features each extend
linearly in a top direction and a bottom direction, respectively, and the top direction and the
bottom direction form an angle therebetween of between 60 degrees and 120 degrees.

10 Item 5. The luminaire of item 4, wherein the top direction and the bottom direction are
orthogonal.

Item 6. The luminaire of item 3, wherein at least one of the top features and the bottom features
15 include linear lenses.

Item 7. The luminaire of item 3, wherein at least one of the top features and the bottom features
include prisms.

20 Item 8. The luminaire of item 3, wherein at least one of the top features and the bottom features
include pyramids.

Item 9. The luminaire of item 3, wherein at least one of the top features and the bottom features
include cones.

25 Item 10. The luminaire of item 9, wherein the cones are hexagonally closely packed cones.

Item 11. The luminaire of item 3, wherein each of the top features and the bottom features
include linear lenses.

30 Item 12. The luminaire of item 1, wherein the luminaire is hollow.

Item 13. The luminaire of item 1, further comprising at least one light source disposed at either
the first or second end.

Item 14. The luminaire of item 13, wherein, when the at least one light source is illuminated, a 1.62 by 3.8 by 1.875 inch black object disposed on the center of the reflector is not visible.

5 Item 15. The luminaire of item 13, further comprising an electronics driver disposed on the center of the reflector, wherein when the at least one light source is illuminated, the electronics driver is not visible.

10 Item 16. The luminaire of item 1, wherein the microstructured film is held in a semi-cylindrical shape through compression.

Item 17. A cylindrical luminaire, comprising:

15 a reflector disposed at the bottom of the luminaire;
a top film disposed at the top of the luminaire;
a microstructured film disposed as a curved emission surface extending between the bottom and the top of the luminaire.

Item 18. The cylindrical luminaire of item 17, wherein the top film is a reflector.

20 Item 19. The cylindrical luminaire of item 17, wherein the top film is a microstructured film.

Item 20. The cylindrical luminaire of item 17, wherein the reflector is a specular reflector.

25 Descriptions for elements in figures should be understood to apply equally to corresponding elements in other figures, unless indicated otherwise. The present invention should not be considered limited to the particular examples and embodiments described above, as such embodiments are described in detail in order to facilitate explanation of various aspects of the invention. Rather, the present invention should be understood to cover all aspects of the invention, including various modifications, equivalent processes, and alternative devices falling
30 within the scope of the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. A luminaire having its greatest extent along a length direction and a width direction perpendicular to the length direction, comprising:

5 a reflector disposed at at least one of first and second ends of the luminaire along the length direction of the luminaire;

 a reflector disposed at the base of the luminaire and extending between the first and second ends of the luminaire and extending between third and fourth ends of the luminaire along the width direction of the luminaire; and

10 a microstructured film disposed as a curved emission surface extending between the first and second ends of the luminaire and between the third and fourth ends of the luminaire.

2. The luminaire of claim 1, wherein the reflector is a specular reflector.

3. The luminaire of claim 1, wherein the microstructured film has top features facing away from the reflector and bottom features facing toward the reflector.

4. The luminaire of claim 3, wherein the top features and the bottom features each extend linearly in a top direction and a bottom direction, respectively, and the top direction and the bottom direction form an angle therebetween of between 60 degrees and 120 degrees.

5. The luminaire of claim 4, wherein the top direction and the bottom direction are orthogonal.

6. The luminaire of claim 3, wherein at least one of the top features and the bottom features include linear lenses.

7. The luminaire of claim 3, wherein at least one of the top features and the bottom features include prisms.

8. The luminaire of claim 3, wherein at least one of the top features and the bottom features include pyramids.

9. The luminaire of claim 3, wherein at least one of the top features and the bottom features include cones.

10. The luminaire of claim 9, wherein the cones are hexagonally closely packed cones.

11. The luminaire of claim 3, wherein each of the top features and the bottom features include linear lenses.

12. The luminaire of claim 1, wherein the luminaire is hollow.

13. The luminaire of claim 1, further comprising at least one light source disposed at either the first or second end.

14. The luminaire of claim 13, wherein, when the at least one light source is illuminated, a 1.62 by 3.8 by 1.875 inch black object disposed on the center of the reflector is not visible.

15. The luminaire of claim 13, further comprising an electronics driver disposed on the center of the reflector, wherein when the at least one light source is illuminated, the electronics driver is not visible.

16. The luminaire of claim 1, wherein the microstructured film is held in a semi-cylindrical shape through compression.

17. A cylindrical luminaire, comprising:

a reflector disposed at the bottom of the luminaire;

a top film disposed at the top of the luminaire;

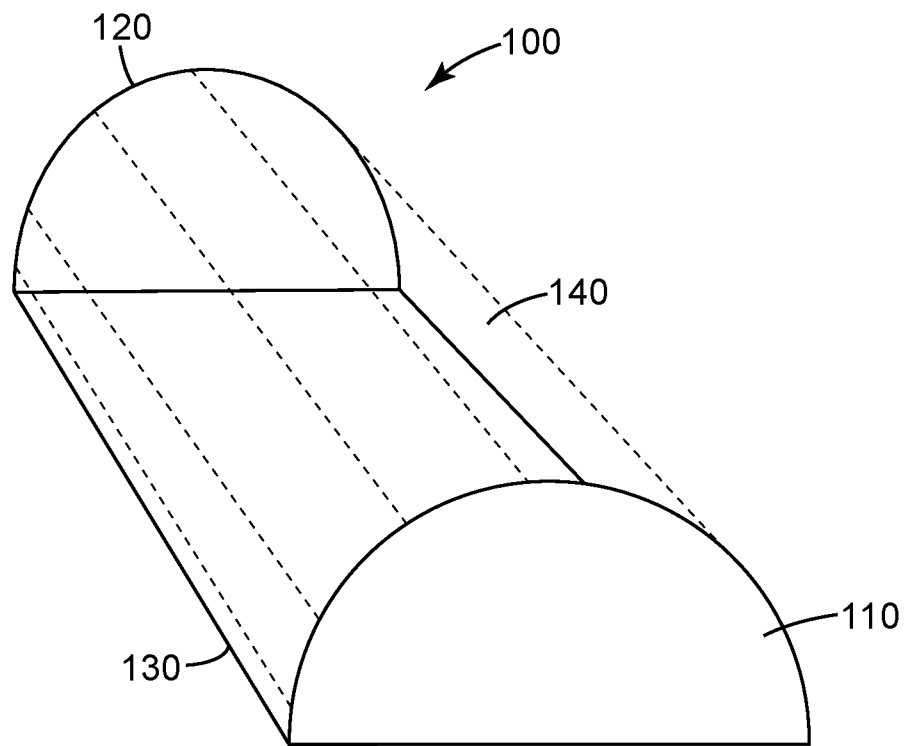
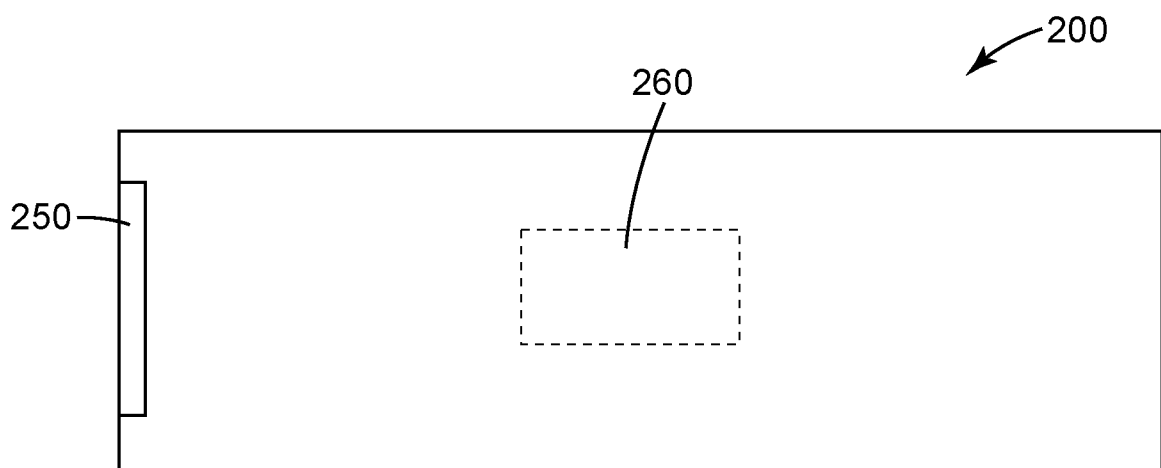
a microstructured film disposed as a curved emission surface extending between the bottom and the top of the luminaire.

18. The cylindrical luminaire of claim 17, wherein the top film is a reflector.

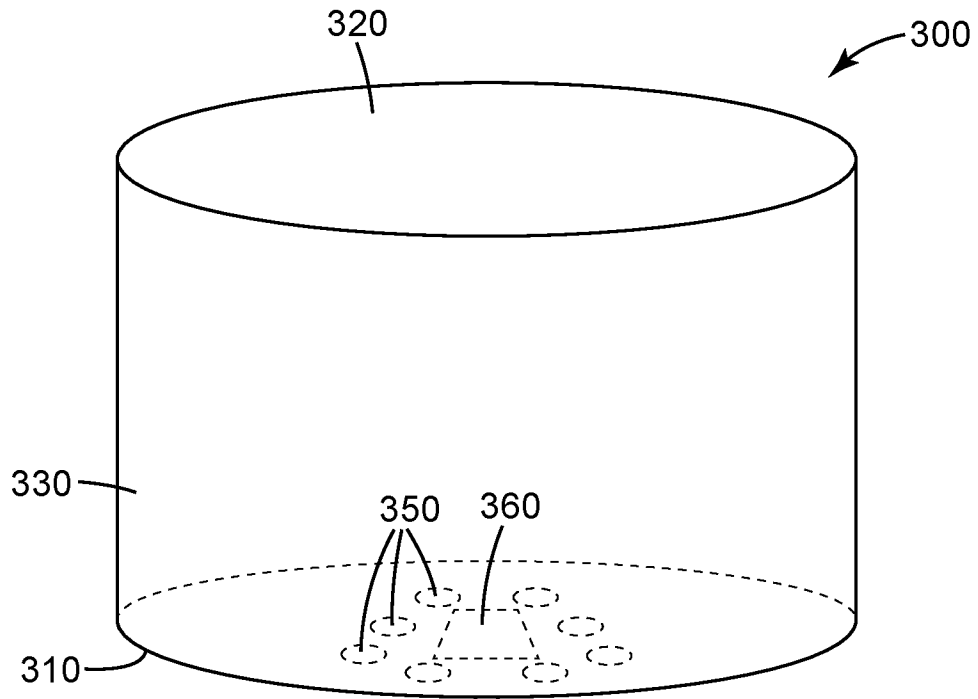
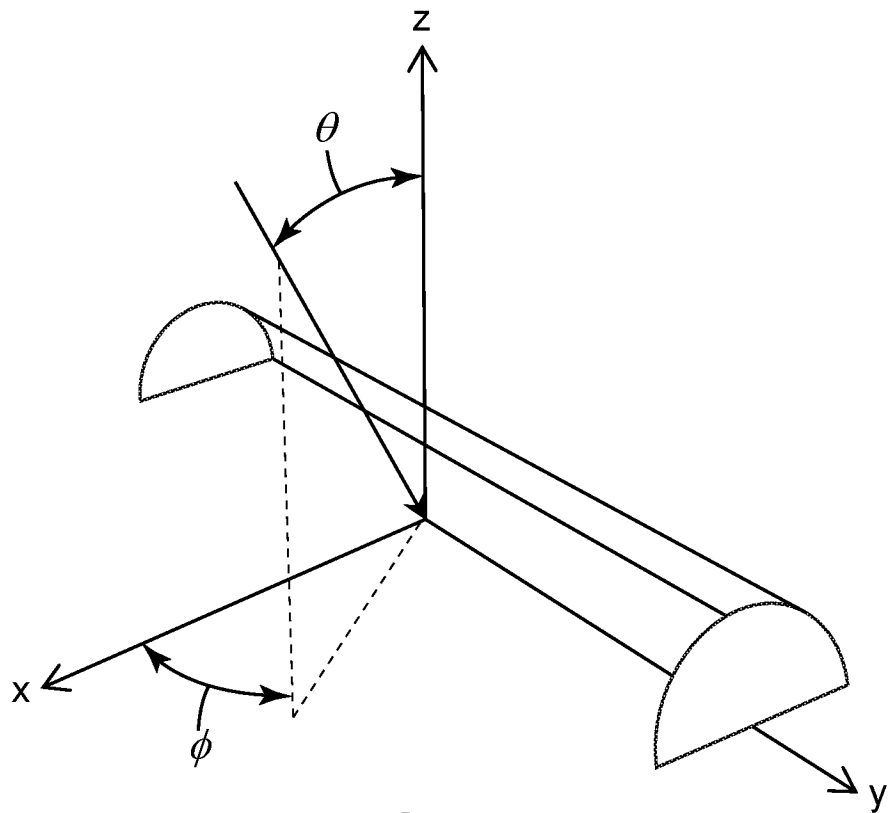
19. The cylindrical luminaire of claim 17, wherein the top film is a microstructured film.

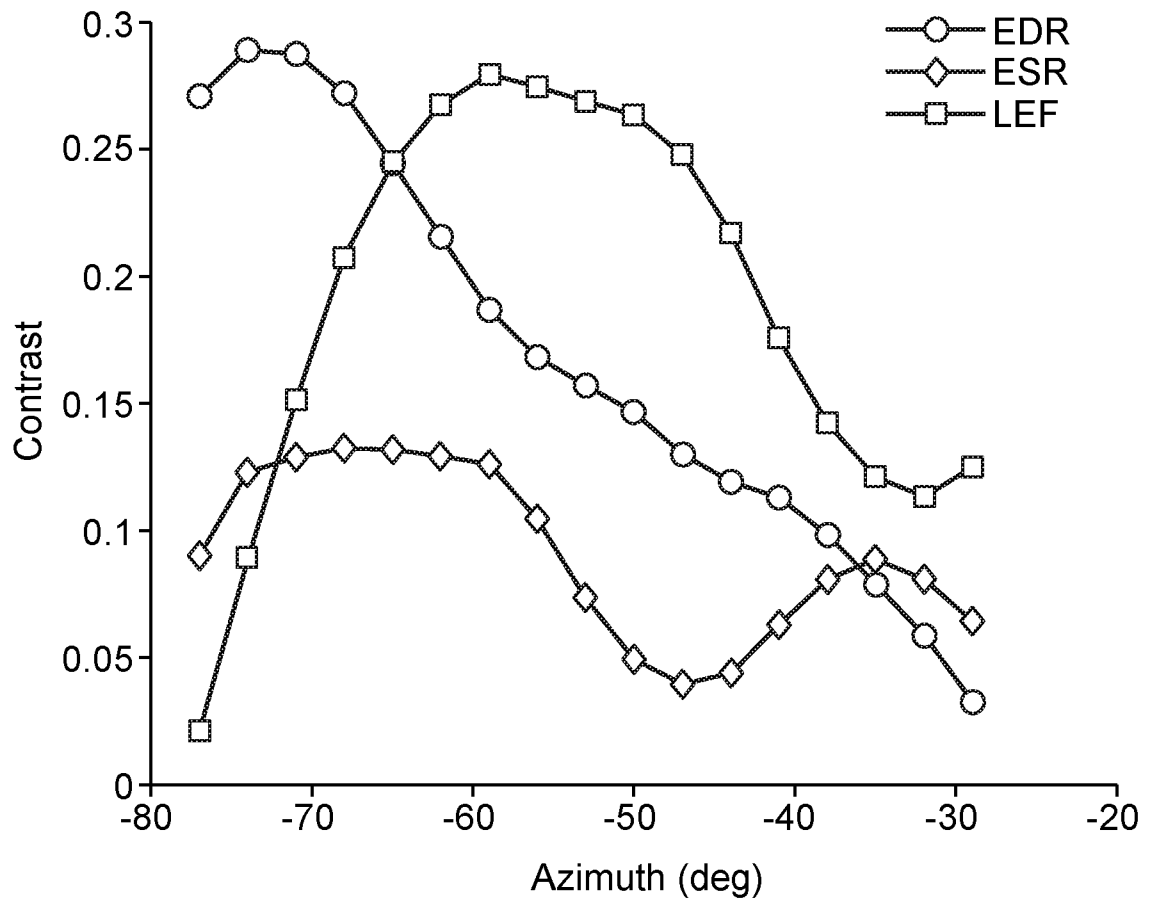
20. The cylindrical luminaire of claim 17, wherein the reflector is a specular reflector.

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**FIG. 1****FIG. 2**

2/3

**FIG. 3****FIG. 4**

**FIG. 5**

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/030703

A. CLASSIFICATION OF SUBJECT MATTER

INV. F21V5/00 F21V7/00 F21V13/04
ADD. F21V7/22 F21Y115/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F21V F21Y

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/207610 A1 (KONINKL PHILIPS NV [NL]) 31 December 2014 (2014-12-31) page 8, line 20 - page 12, line 2 figures 1,2 -----	1-3,7, 12-16
X	US 2012/300471 A1 (HOWE LESLIE [US]) 29 November 2012 (2012-11-29) paragraph [0154] - paragraph [0157] figures 10A, 10B -----	1-20
X	US 5 481 637 A (WHITEHEAD LORNE A [CA]) 2 January 1996 (1996-01-02) column 4, line 62 - column 5, line 24 column 6, line 1 - line 15 figures 8,11 -----	17-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

14 July 2016

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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