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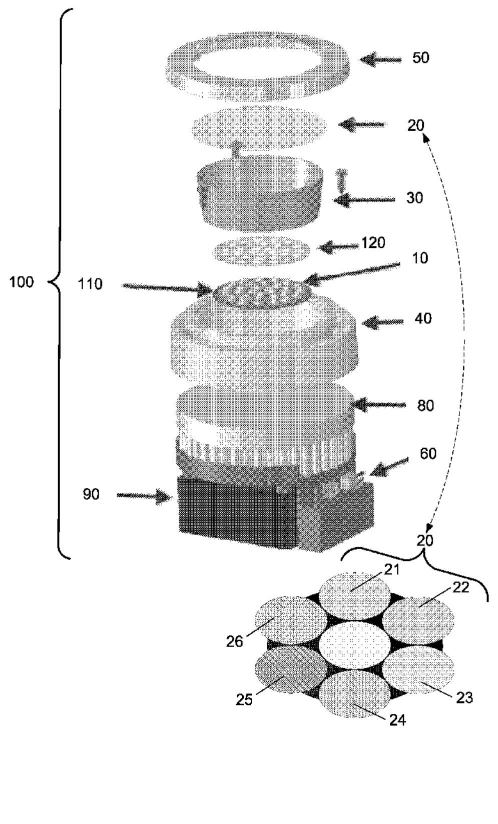
(54) Title: ELECTROMAGNETIC WAVELENGTH CONVERSION DEVICE

Fig. 1



(57) Abstract: Technologies are described for devices and methods to convert first wavelength electromagnetic waves to a second wavelength. The devices may comprise a light source to produce first electromagnetic waves of the first wavelength. The devices may comprise a reflector which may define an optical cavity around the light source and include a first and second end. The first end may be disposed around the light source. The reflector may reflect the first electromagnetic waves towards the second end. The devices may comprise a wavelength conversion component disposed at the second end which may absorb the first electromagnetic waves and emit second electromagnetic waves at the second wavelength. The devices may comprise a fixture housing disposed around the light source and the reflector. The devices may comprise a retaining component attachable to, and removable from, the fixture housing. The retaining component may secure the wavelength conversion component to the fixture housing.

WO 2016/022961 A1

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ELECTROMAGNETIC WAVELENGTH CONVERSION DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Provisional Application No. 62/034,853 filed August 8, 2014, the entirety of which is hereby incorporated by reference.

BACKGROUND

[0002] This application relates to systems and methods for generating electromagnetic waves with a specific frequency or wavelength and thereafter converting the generated electromagnetic waves to a different frequency or wavelength.

[0003] Electromagnetic waves may have electric amplitudes varying at a specific frequency or wavelength. Biological and non-biological applications may require electromagnetic waves with a specific wavelength and/or may require electromagnetic waves of different wavelengths at different times. Light-emitting diode (LED) lamps may emit light in narrow bands of electromagnetic wavelengths. LED lamps may be made with a semiconductor and emit light with a color characteristic of the energy bandgap of the semiconductor.

SUMMARY

[0004] In some examples devices to convert electromagnetic waves of a first wavelength to electromagnetic waves of a second wavelength are described. The devices may comprise a light source configured to produce first electromagnetic waves. The first electromagnetic waves may have the first wavelength. The devices may comprise a reflector. The reflector may define an optical cavity around the light source. The reflector may include a first end and a second end. The first end may be disposed around the light source. The reflector may be configured to reflect and direct the first electromagnetic waves towards the second end. The devices may comprise a wavelength conversion component disposed at the second end of the reflector. The wavelength conversion component may be configured to absorb the first electromagnetic waves and emit second electromagnetic waves upon the first electromagnetic waves being incident upon the wavelength conversion component. The second electromagnetic waves may have the second wavelength, different from the first wavelength. The devices may comprise a fixture housing disposed around the light source and the reflector. The devices may comprise a retaining component. The retaining component may be attachable to, and removable from, the fixture housing. The retaining component may be effective to secure the wavelength conversion component to the fixture housing at the second end of the reflector.

[0005] In some examples, methods for converting wavelengths of electromagnetic waves are described. The methods may comprise securing a first wavelength conversion component to a fixture with a retaining component are described. The methods may comprise directing first electromagnetic waves from a light source towards the first wavelength conversion component The first electromagnetic waves may have a first wavelength. The methods may comprise causing second electromagnetic waves to be emitted from the first wavelength conversion component. The first wavelength conversion component may be effective to absorb the first electromagnetic waves and emit the second electromagnetic waves upon the first electromagnetic waves being incident upon the first wavelength conversion component. The second electromagnetic waves may have a second wavelength. The second wavelength may be different from the first wavelength. The methods may comprise removing the retaining component from the fixture. The methods may comprise removing the first wavelength conversion component from the fixture. The methods may further comprise securing a second wavelength conversion component to the fixture with the retaining component. The method may comprise directing third electromagnetic waves from the light source towards the second wavelength conversion component. The methods may comprise causing fourth electromagnetic waves to be emitted from the second wavelength conversion component. The second wavelength conversion component may be effective to absorb the third electromagnetic waves and emit the fourth electromagnetic waves upon the third electromagnetic waves being incident upon the second wavelength conversion component. The fourth electromagnetic waves may have a third wavelength. The third wavelength may be different from the first wavelength and the second wavelength.

[0006] In some examples, lighting fixtures for electromagnetic wavelength conversion are described. The lighting fixtures may comprise a light source. The light source may be configured to produce first electromagnetic waves. The first electromagnetic waves may have a first wavelength. The lighting fixtures may comprise a circuit board. The light source may be mounted on a first side of the circuit board. The lighting fixtures may comprise a heat sink. A first side of the heat sink may be mounted on a second side of the circuit board. The second side of the circuit board may be opposite the first side of the circuit board. The lighting fixture may comprise an active thermal management device. The active thermal management device may be mounted to a second side of the heat sink. The second side of the heat sink may be opposite the first side of the heat sink. The lighting fixture may comprise a reflector. The reflector may define an optical cavity around the light source. The reflector may include a first end and a second end. The first end may be disposed around the light source. The reflector may be configured to reflect and direct the first electromagnetic waves towards the second end. The lighting fixtures may comprise a fixture housing around the light source, the reflector, the circuit board, the heat sink, and the active thermal management device. An opening in the fixture housing may be at the second end of the reflector. The lighting fixture may comprise a retaining component. The retaining component may be attachable to, and removable from, the fixture housing. The retaining component may be effective to secure a wavelength conversion component to the opening of the fixture housing at the second side of the reflector. The wavelength conversion component may be configured to absorb the first electromagnetic waves and emit second electromagnetic waves upon the first electromagnetic waves being incident upon the wavelength conversion component. The second electromagnetic waves may have the second wavelength. The second wavelength may be different from the first wavelength.

[0007] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE FIGURES

[0008] The foregoing and other features of this disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings, in which:

Fig. 1 is a side perspective blow up view of components of a device that can be utilized to implement electromagnetic wavelength conversion;

Fig. 2 is a schematic illustrating an example of a wavelength conversion component converting electromagnetic waves from a light source;

Fig. 3 is a schematic illustrating an example of removal and replacement of a wavelength conversion component;

Fig. 4 is a schematic illustrating an example of multiple removals and replacements of different wavelength conversion components;

Fig. 5 is a schematic illustrating an example of removal of a wavelength conversion component; and

Fig. 6 is a schematic illustrating an example of a wavelength conversion component arranged to convert electromagnetic waves from an independent light source;

all arranged according to at least some embodiments described herein.

DETAILED DESCRIPTION

[0009] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0010] It will be understood that any compound, material or substance which is expressly or implicitly disclosed in the specification and/or recited in a claim as belonging to a group or structurally, compositionally and/or functionally related compounds, materials or substances, includes individual representatives of the group and all combinations thereof.

[0011] Fig. 1 is a side perspective blow up view of components of a device 100 that can be utilized to implement electromagnetic wavelength conversion, arranged in accordance with at least some embodiments presented herein. As discussed in more detail below, the electromagnetic waves generated by a light source may be converted to specific electromagnetic wavelengths.

[0012] Device 100 may include a light source 10, a circuit board 110, reflective material 120, a reflector 30, a wavelength conversion component 20, a fixture housing 40, a retaining component 50, drive electronics 60, a heat sink 80, and an active thermal management device 90. Light source 10 may be mounted to circuit board 110. Solder may mount light source 10 to circuit board 110. Reflective material 120 may adhere to circuit board 110 around light source 10. Circuit board 110 may be mounted to heat sink 80. Heat sink 80 may be mounted to active thermal management device 90. Active thermal management device 90 may draw heat away from heat sink 80. Reflector 30 may be placed around light source 10. Fixture housing 40 may be disposed around light source 10, circuit board 110, reflector 30, wavelength conversion component 20, and heat sink 80. Fixture housing 40 may also be disposed around active thermal management device 90. Drive electronics 60 may be mounted within fixture housing 40 or may be mounted remotely on the outside of fixture housing 40. Drive electronics 60, circuit board 110, light source 10 and active thermal management device 90 may be interconnected with copper wiring, solder, wire-to-board connectors, splices and/or wire nuts.

[0013] Light source 10 may be temperature sensitive. Heat sink 80 and active thermal management device 90 may transport thermal energy away from light source 10. Active thermal management device 90 may be a fan or a cooler.

[0014] Wavelength conversion component 20 may include a transparent material such as, for example, glass and/or plastic. Wavelength conversion component 20 may include phosphors, quantum dots or other wavelength conversion materials with the ability to Stokes shift higher energy shorter electromagnetic waves into lower energy longer electromagnetic waves or the ability to anti-Stokes shift lower energy longer electromagnetic waves into higher energy shorter electromagnetic waves. Materials with the ability to Stokes or anti-Stokes shift may convert a wavelength of electromagnetic waves directed at the material by absorbing the electromagnetic wave energy and consequently enter into an excited state. Materials with the ability to Stokes or anti-Stokes shift may release the energy from the excited state by emitting electromagnetic wave energy at a different wavelength based on characteristics, such as a bandgap, of the material. Wavelength conversion component 20 may include phosphors, quantum dots, or other wavelength conversion material adhered to one side of the transparent material. Phosphors may be a substance that exhibits the phenomenon of luminescence and may be used in fluorescent, metal halide, neon, and LED lamps. Quantum dots may be nanocrystals made of semiconductor materials and may also exhibit fluorescence. Wavelength conversion component 20 may include phosphors, quantum dots, or other wavelength conversion material mixed within the transparent material. Wavelength conversion component 20 may be configured as fibers, reflective components, and other form factors other than purely transmissive components. Wavelength conversion component 20 may include a phosphor wheel or slide and include multiple wavelength conversion subcomponents 21, 22, 23, 24, 25, and 26. Wavelength conversion subcomponents 21, 22, 23, 24, 25, and 26 may each be different wavelength conversion component materials and may each respectively convert a wavelength of electromagnetic waves directed at each respective subcomponent to a different respective wavelength of electromagnetic wave energy. Wavelength conversion component 20 may be adjacent to reflector 30 and may sit within an opening of fixture housing 40. Retaining component 50 may connect to fixture housing 40 and may secure wavelength conversion component

20, or one or more wavelength conversion subcomponents of a wavelength conversion component, within the opening of fixture housing 40. As shown in more detail below, reflector 30 placed around light source 10 may direct emitted electromagnetic waves from light source 10 towards secured wavelength conversion component 20.

[0015] Fig. 2 is a schematic illustrating an example of wavelength conversion component 20 converting electromagnetic waves from light source 10, arranged in accordance with at least some embodiments presented herein. Those components in Fig. 2 that are labeled identically to components of Fig. 1 will not be described again for the purposes of clarity.

[0016] Light source 10 may generate electromagnetic waves 210. Light source 10 may generate electromagnetic waves 210 with a wavelength in a range of from about 10nm to about 10,000nm. Electromagnetic waves 210 may be directed towards wavelength conversion component 20. Reflector 30 may define a cylindrical or conical optical cavity from light source 10 to wavelength conversion material 20. Reflector 30 may be reflective, and may reflect and direct electromagnetic waves 210 emitted from light source 10 towards wavelength conversion material 20. Reflector 30 may be reflective paper, reflective metal, reflective paint, or any other reflective material. Reflector 30 may reflect greater than 90 percent of light emitted towards reflector 30. Electromagnetic waves 210 incident on the wavelength conversion component 20 may be reflected, transmitted or converted. When electromagnetic waves 210 are reflected or converted and re-emitted in a direction towards light source 10, reflector 30 may reflect the electromagnetic waves towards wavelength conversion component 20. Wavelength conversion component 20 may convert electromagnetic waves 210 into electromagnetic waves 220. Electromagnetic waves 220, converted by wavelength conversion component 20, may have a wavelength in a range of from about 10nm to about 10,000nm. Electromagnetic waves 210 may be higher energy electromagnetic waves or electromagnetic waves with a shorter wavelength than electromagnetic waves 220. Wavelength conversion component 20 may convert higher energy electromagnetic waves 210 into electromagnetic waves 220 at a desired wavelength.

[0017] In an example, electromagnetic waves 210 generated by light source 10 may be blue light and have a wavelength of 450nm. 450nm wavelength electromagnetic waves 210 may be directed towards wavelength conversion component 20. Wavelength conversion component 20 may convert 450nm wavelength electromagnetic waves 210 into electromagnetic waves 220. Electromagnetic waves 220 may be red light and may have a wavelength of 660nm, a longer wavelength than 450nm wavelength electromagnetic waves 210. 660nm wavelength electromagnetic waves 220 may have lower energy than 450nm wavelength electromagnetic waves 210.

[0018] As discussed in more detail below, wavelength conversion material 20 may be located independent from light source 10 and may be configured to be removed and/or replaced with a different wavelength conversion component 230. Replacement of wave conversion component 20 with wave conversion component 230 may be accomplished without changing light source 10.

[0019] Fig. 3 is a schematic illustrating an example of removal and replacement of a wavelength conversion component, arranged in accordance with at least some embodiments presented herein. Those components in Fig. 3 that are labeled identically to components of Figs. 1-2 will not be described again for the purposes of clarity.

[0020] Light source 10 may convert electrical energy into electromagnetic waves 210. Circuit board 110 may hold the light source 10 in place and may also connect light source 10 to a power source of electrical energy. Light source 10 may be configured for alternating current operation. Drive electronics 60 may be configured to receive alternating current and provide electrical energy in the form of a current and a voltage to light source 10. Insulated copper wire 310 may carry electrical energy from drive electronics 60 to light source 10.

[0021] Retaining component 50 may be attachable to, and removable from, fixture housing 40 and may secure wavelength conversion component 20 in position in fixture housing 40. Removal of retaining component 50 may allow removal and/or replacement of wavelength conversion component 20 with a different wavelength conversion component 300.

[0022] For example, at a first time, T = 1, retaining component 50 may be removed from fixture housing 40. Removal of retaining component 50 may allow for removal of wavelength conversion component 20 from fixture housing 40. At a second time, T = 2, wavelength conversion component 300 may be positioned into fixture housing 40. Retaining component 50 may be secured onto fixture housing 40 and secure wavelength conversion component 300 into fixture housing 40. Wavelength conversion component 300 may convert electromagnetic waves 210 into electromagnetic waves 320. Electromagnetic waves 320 may have a different wavelength than electromagnetic waves 220. Removal of retaining component 50 and replacement of wavelength conversion component 20 or 320 may allow for different electromagnetic wavelengths to be produced from singular light source 10.

[0023] Fig. 4 is a schematic illustrating an example of multiple removals and replacements of different wavelength conversion components, arranged in accordance with at least some embodiments presented herein. Those components in Fig. 4 that are labeled identically to components of Figs. 1-3 will not be described again for the purposes of clarity.

[0024] In an example, light source 10 may produce 450 nm wavelength electromagnetic waves 210. At a first time T=1, 550nm electromagnetic wavelength waves may be required. Wavelength conversion component 20 may convert 450 nm wavelength electromagnetic waves 210 into 550 nm wavelength electromagnetic waves 220.

[0025] At a second time, T=2, 600nm wavelength electromagnetic waves may be required. Retaining component 50 and wavelength conversion component 20 may be removed from fixture housing 40. Wavelength conversion component 300 may be placed into fixture housing 40 and secured with retaining component 50. Wavelength conversion component 300 may convert 450 nm wavelength electromagnetic waves 210 into 600 nm wavelength electromagnetic waves 320.

[0026] At a third time, T=3, 650nm wavelength electromagnetic waves may be required. Retaining component 50 and wavelength conversion component 300 may be removed from fixture housing 40. Wavelength conversion component 400 may be placed into fixture housing 40 and secured with retaining component 50. Wavelength conversion component 400 may convert 450 nm wavelength electromagnetic waves 210 into 650 nm wavelength electromagnetic waves 410.

[0027] At a fourth time, T=4, 600-700nm wavelength electromagnetic waves may be required. Retaining component 50 and wavelength conversion component 400 may be removed from fixture housing 40. Wavelength conversion component 420 may be placed into fixture housing 40 and secured with retaining component 50. Wavelength conversion component 420 may convert 450 nm wavelength electromagnetic waves 210 into 600-700 nm wavelength electromagnetic waves 430.

[0028] As shown in the example, electromagnetic waves of wavelengths of 550nm, 600nm, 650nm, and 600-700nm may be produced from light source 10 through conversion by wavelength conversion components 20, 300, 400, and 420 respectively.

[0029] Fig. 5 is a schematic illustrating an example of removal of a wavelength conversion component, arranged in accordance with at least some embodiments presented herein. Those components in Fig. 5 that are labeled identically to components of Figs. 1-4 will not be described again for the purposes of clarity.

[0030] In another example, light source 10 may produce 450 nm wavelength electromagnetic waves 210. An output of 450nm wavelength electromagnetic waves may be required. Wavelength conversion component 20 may convert 450 nm wavelength electromagnetic waves 210 into 550 nm wavelength electromagnetic waves 220. Retaining component 50 and wavelength conversion component 20 may be removed from fixture housing 40 so that no conversion is performed on electromagnetic waves 210, resulting in an output of required 450nm wavelength electromagnetic waves.

[0031] Fig. 6 is a schematic illustrating an example of a wavelength conversion component arranged to convert electromagnetic waves from an independent light source, arranged in accordance with at least some embodiments presented herein. Those components in Fig. 6 that are labeled identically to components of Figs. 1-5 will not be described again for the purposes of clarity.

[0032] In an example, a light source 600 may illuminate an area 610. Light source 600 may be sunlight or any other light source illuminating area 610. Light source 600 may produce 450 nm electromagnetic waves 620. An output of 550nm wavelength electromagnetic waves may be required in area 630. Wavelength conversion component 20 may convert 450 nm wavelength electromagnetic waves 620 into 550 nm wavelength electromagnetic waves 640. Wavelength conversion component 20 may be positioned within area 610 such that when 450 nm wavelength electromagnetic waves 620 are incident onto wavelength conversion component 20 they are converted into 550 nm wavelength electromagnetic waves 640 in area 630. Wavelength conversion component 20 may be positioned and secured by any securing device, such as a component housing or a fixture.

[0033] A system in accordance with the present disclosure may enable a user to generate specific electromagnetic wavelengths from a singular light source. A user may be able to easily change an output wavelength of electromagnetic waves from a light source without having to change or replace the light source.

[0034] A system in accordance with the present disclosure may enable a user to save energy when emitting certain electromagnetic wavelengths for a light source. For example, 450nm wavelength blue light LEDs may have typical conversion efficiencies of up to 60% at 85°C junction temperature. In contrast, 660nm wavelength deep red LEDs may have typical conversion efficiencies of up to 35% at 85°C junction temperature. A wavelength conversion process of converting light generated at 450nm wavelength electromagnetic waves to 660nm wavelength electromagnetic waves may provide energy saving when the conversion from 450nm wavelength electromagnetic waves to 660nm wavelength electromagnetic waves is greater than 58% efficient.

[0035] While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

What is claimed is:

1. A device to convert electromagnetic waves of a first wavelength to electromagnetic waves of a second wavelength, the device comprising:

a light source configured to produce first electromagnetic waves, wherein the first electromagnetic waves have the first wavelength;

a reflector, wherein the reflector defines an optical cavity around the light source, the reflector includes a first end and a second end, the first end is disposed around the light source, and the reflector is configured to reflect and direct the first electromagnetic waves towards the second end;

a wavelength conversion component disposed at the second end of the reflector, the wavelength conversion component configured to absorb the first electromagnetic waves and emit second electromagnetic waves upon the first electromagnetic waves being incident upon the wavelength conversion component, wherein the second electromagnetic waves have the second wavelength, different from the first wavelength;

a fixture housing disposed around the light source and the reflector; and

a retaining component, wherein the retaining component is attachable to, and removable from, the fixture housing and is effective to secure the wavelength conversion component to the fixture housing at the second end of the reflector.

2. The device of claim 1, wherein the first wavelength is from about 10nm to about 10,000nm.

3. The device of claim 1, wherein the second wavelength is from about 10nm to about 10,000nm.

4. The device of claim 1, wherein the second wavelength is from about 495nm to about 570nm.

5. The device of claim 1, wherein the second wavelength is from about 570nm to about 590nm.

6. The device of claim 1, wherein the second wavelength is from about 590nm to about 620nm.

7. The device of claim 1, wherein the second wavelength is from about 620nm to about 750nm.

8. The device of claim 1, wherein the wavelength conversion component includes a material with the ability to Stokes shift higher energy, shorter electromagnetic waves into lower energy, longer electromagnetic waves.

9. The device of claim 1, wherein the wavelength conversion component includes phosphors and/or quantum dots.

10. The device of claim 1, wherein the wavelength conversion component includes a transparent material with phosphors and /or quantum dots adhered to one side of the transparent material.

11. The device of claim 1, wherein the wavelength conversion component includes a transparent material with phosphors and /or quantum dots mixed within the transparent material.

12. The device of claim 1, wherein the reflector includes reflective paper, reflective metal, and/or reflective paint.

13 The device of claim 1, the device further comprising:

a circuit board, wherein the light source is mounted on a first side of the circuit board;

a heat sink, wherein a first side of the heat sink is mounted on a second side of the circuit board, the second side of the circuit board being opposite the first side of the circuit board;

an active thermal management device, wherein the active thermal management device is mounted to a second side of the heat sink, the second side of the heat sink being opposite the first side of the heat sink; and

the fixture housing is further disposed around the circuit board, the heat sink, and the active thermal management device.

14. The device of claim 13, wherein the active thermal management device is a fan or a cooler.

15. A method for converting wavelengths of electromagnetic waves, the method comprising:

securing a first wavelength conversion component to a fixture with a retaining component;

directing first electromagnetic waves from a light source towards the first wavelength conversion component, wherein the first electromagnetic waves have a first wavelength;

causing second electromagnetic waves to be emitted from the first wavelength conversion component, wherein the first wavelength conversion component is effective to absorb the first electromagnetic waves and emit the second electromagnetic waves upon the first electromagnetic waves being incident upon the first wavelength conversion component, the second electromagnetic waves having a second wavelength, different from the first wavelength;

removing the retaining component from the fixture;

removing the first wavelength conversion component from the fixture;

securing a second wavelength conversion component to the fixture with the retaining component;

directing third electromagnetic waves from the light source towards the second wavelength conversion component;

causing fourth electromagnetic waves to be emitted from the second wavelength conversion component, wherein the second wavelength conversion component is effective to absorb the third electromagnetic waves and emit the fourth electromagnetic waves upon the third electromagnetic waves being incident upon the second wavelength conversion component, the fourth electromagnetic waves have a third wavelength, different from the first wavelength and the second wavelength.

16. The method of claim 15, wherein the light source is sunlight.

17. A lighting fixture comprising:

a light source configured to produce first electromagnetic waves, wherein the first electromagnetic waves have a first wavelength;

a circuit board, wherein the light source is mounted on a first side of the circuit board;

a heat sink, wherein a first side of the heat sink is mounted on a second side of the circuit board, the second side of the circuit board being opposite the first side of the circuit board;

an active thermal management device, wherein the active thermal management device is mounted to a second side of the heat sink, the second side of the heat sink being opposite the first side of the heat sink;

a reflector, wherein the reflector defines an optical cavity around the light source, the reflector includes a first end and a second end, the first end is disposed around the light source, and the reflector is configured to reflect and direct the first electromagnetic waves towards the second end;

a fixture housing around the light source, the reflector, the circuit board, the heat sink, and the active thermal management device, wherein an opening in the fixture housing is at the second end of the reflector; and

a retaining component, wherein the retaining component is attachable to, and removable from, the fixture housing and is effective to secure a wavelength conversion component to the opening of the fixture housing at the second side of the reflector, the wavelength conversion component configured to absorb the first electromagnetic waves and emit second electromagnetic waves upon the first electromagnetic waves being incident upon the wavelength conversion component, wherein the second electromagnetic waves have the second wavelength, different from the first wavelength.

18. The fixture of claim 17, wherein the reflector includes reflective paper, reflective metal, and/or reflective paint.

19. The fixture of claim 17, wherein the active thermal management device is a fan or a cooler.

20. The fixture of claim 17, further comprising a wavelength conversion component disposed at the second end of the reflector and secured by the retaining component.

Fig. 1

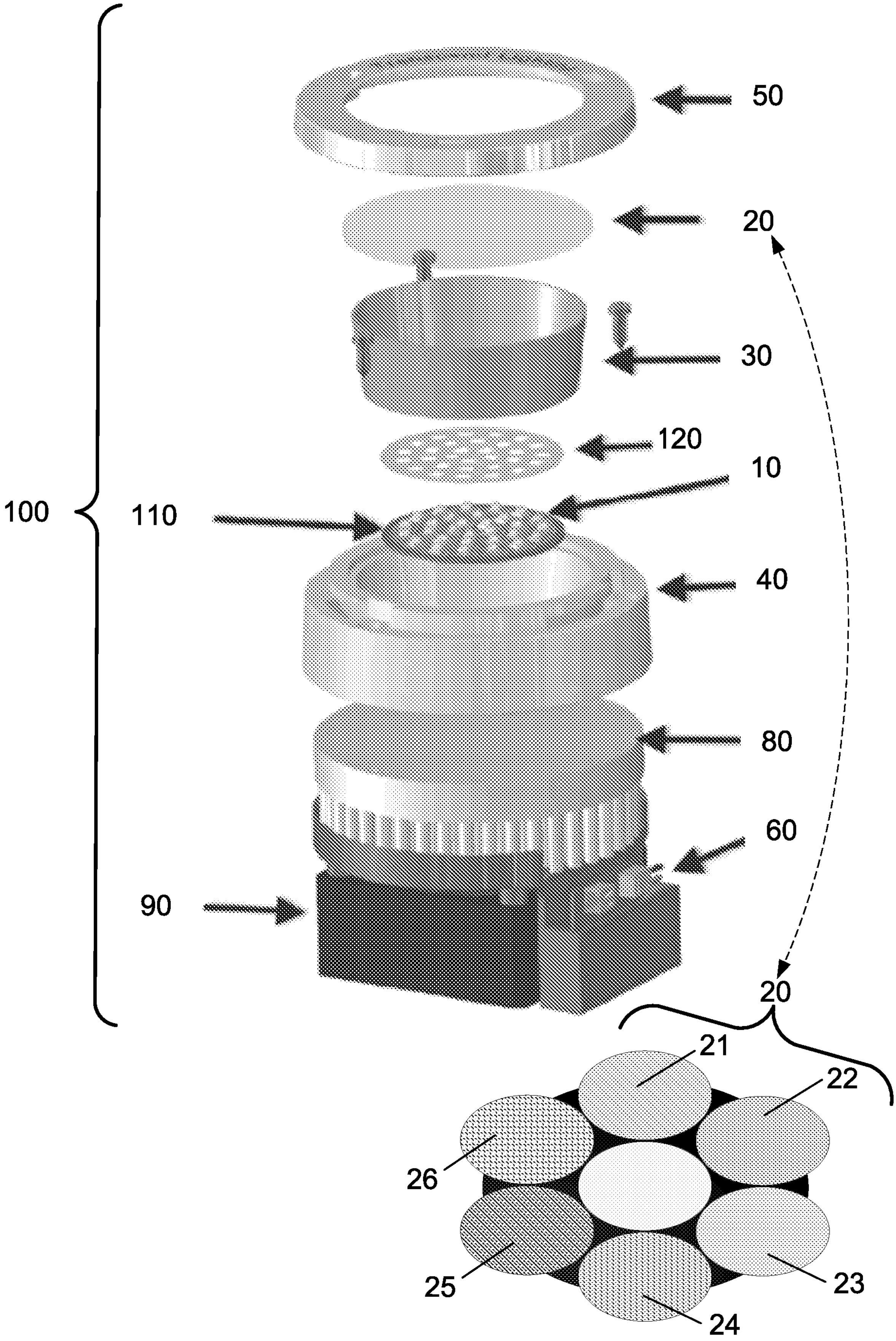

Fig. 2

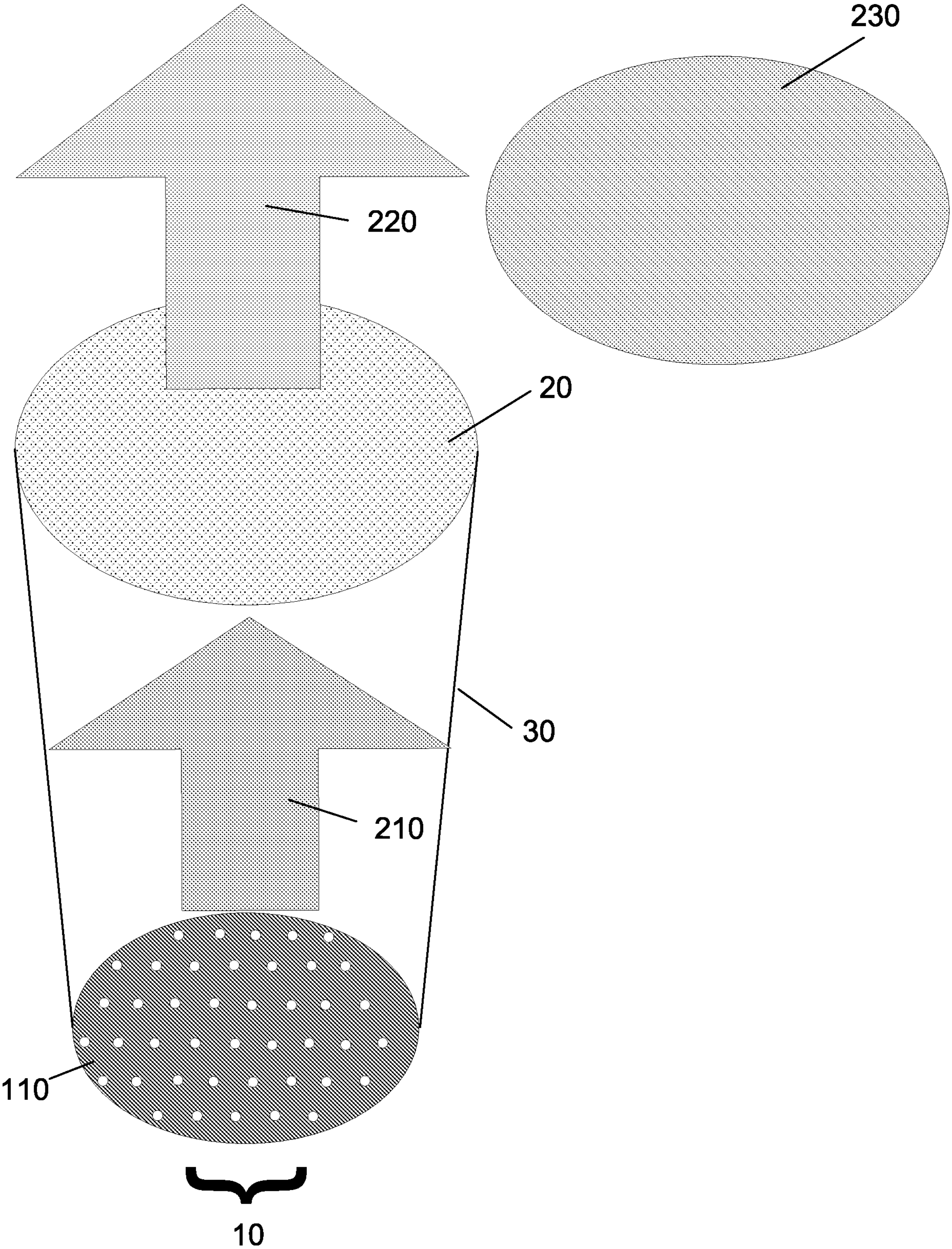

Fig. 3

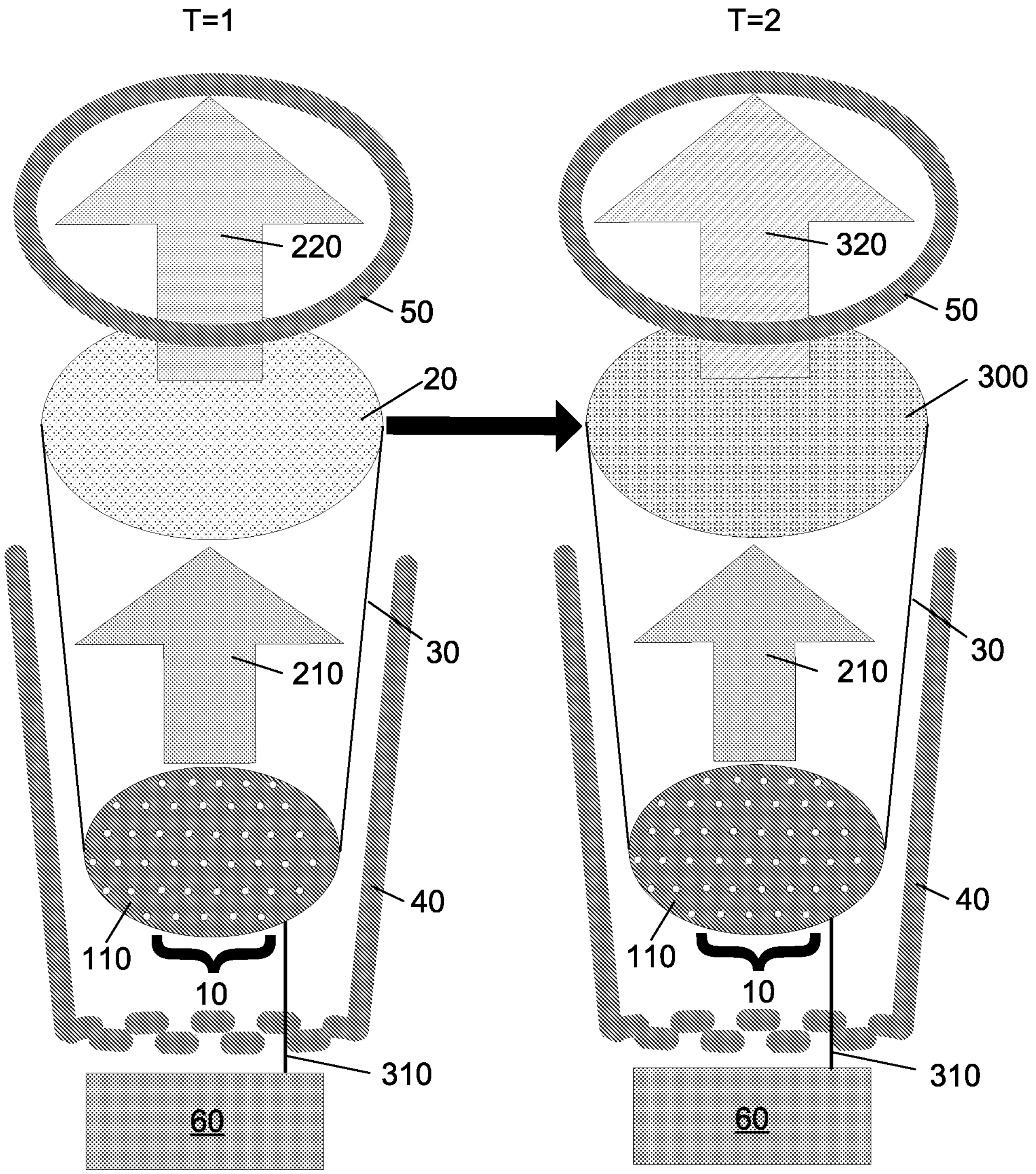
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Fig. 4

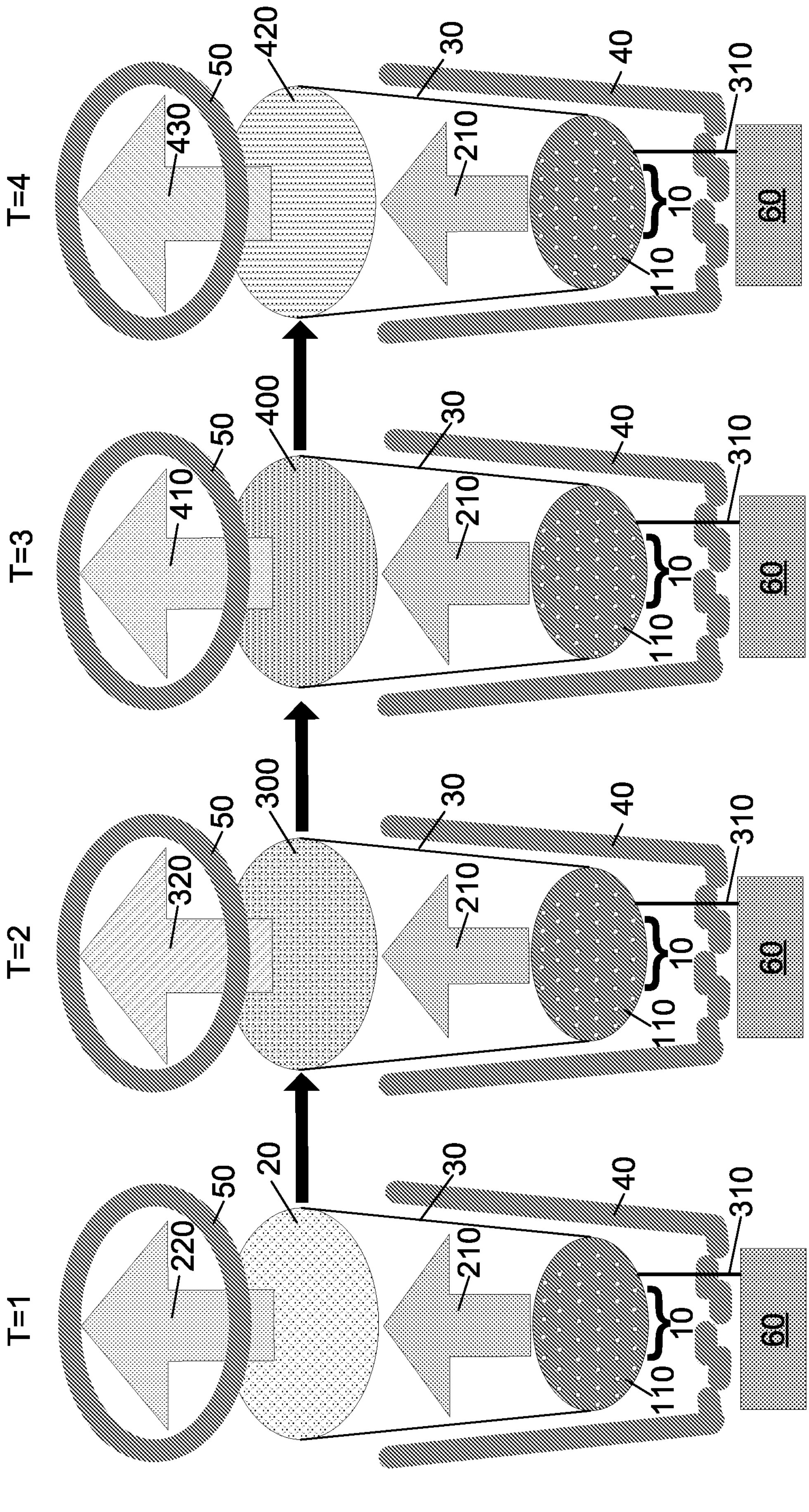
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Fig. 5

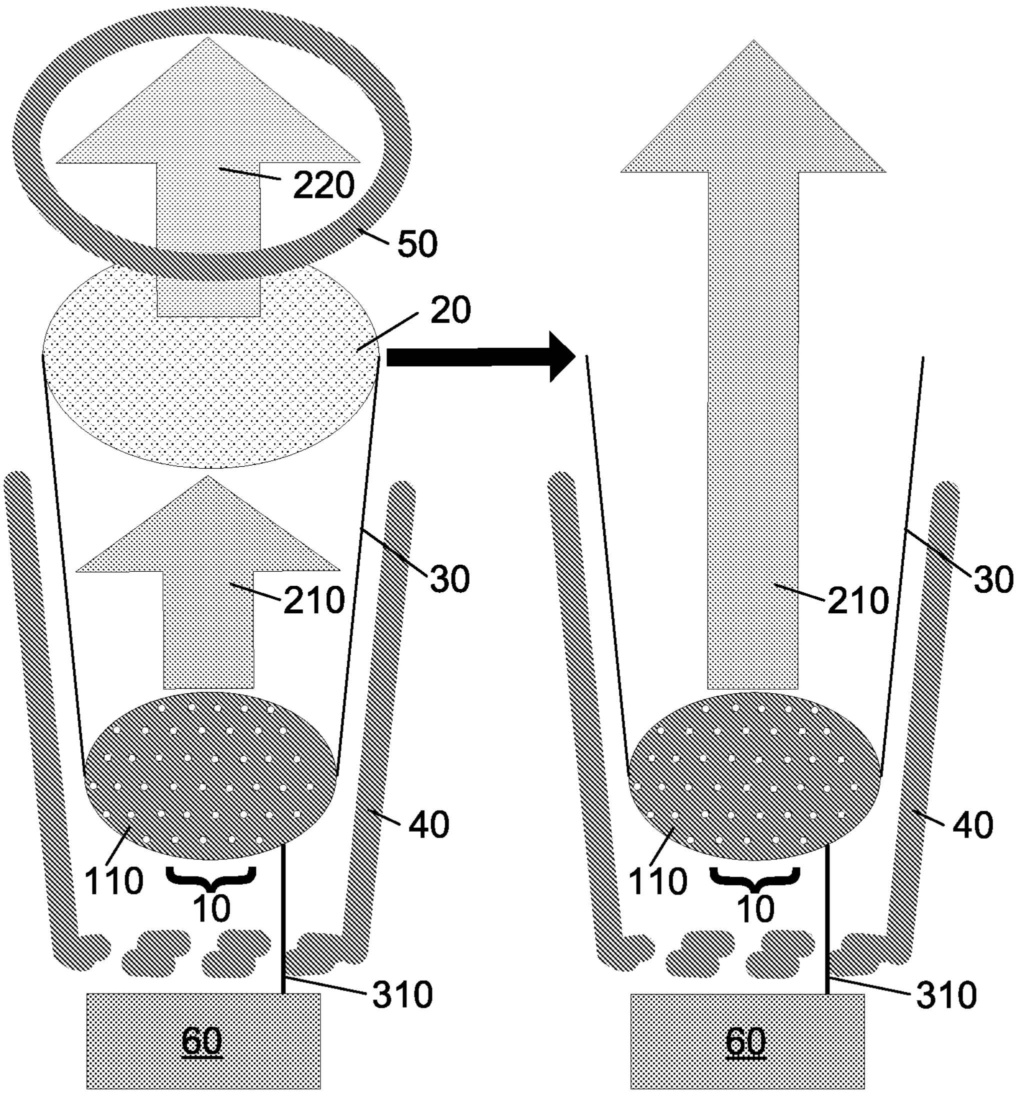
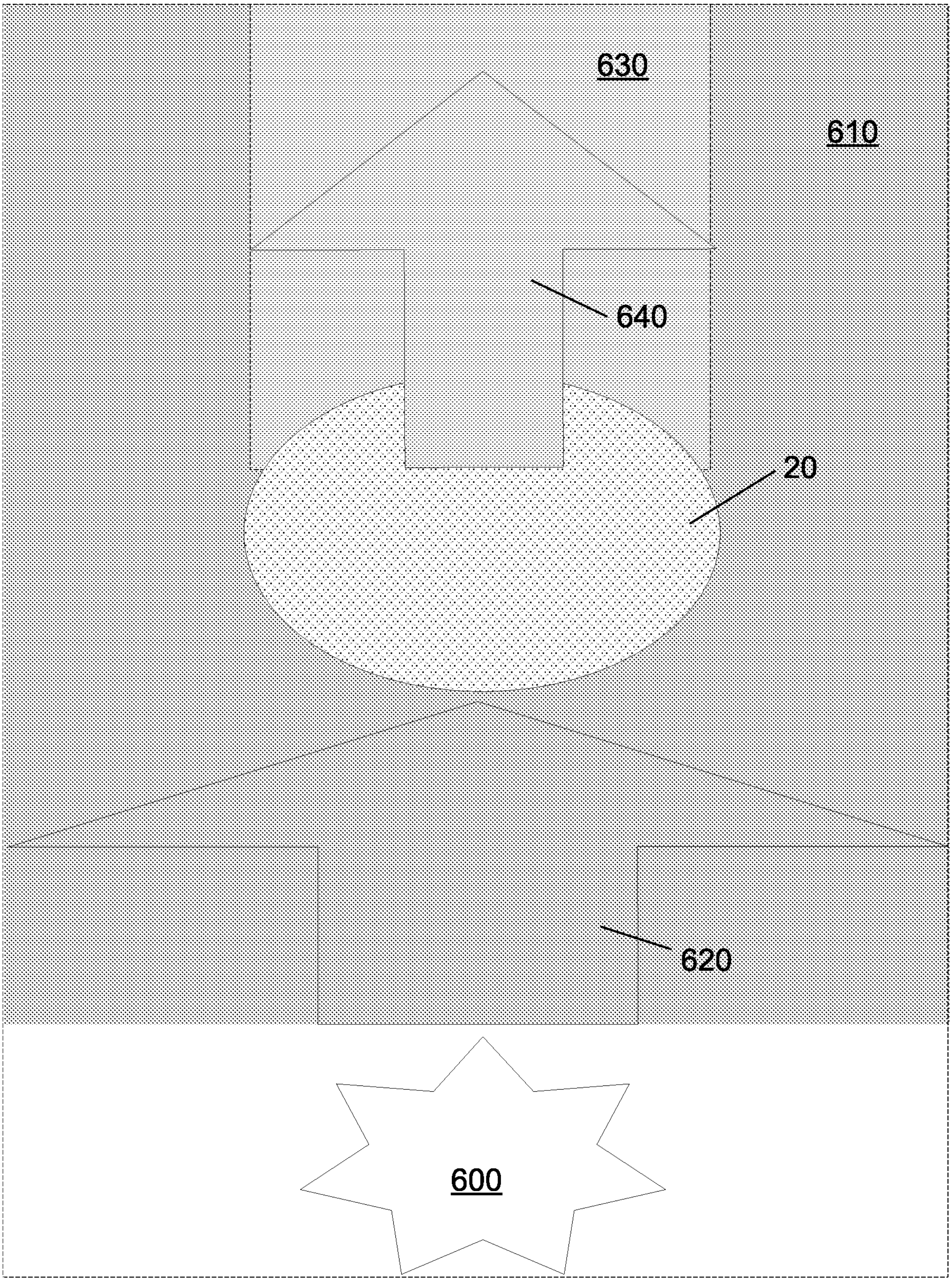


Fig. 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/44289

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F21V7/10, F21V7/22, F21V14/04 (2015.01)
CPC - F21V7/10, F21V7/22, F21K9/54
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)
IPC(8) Classification(s): F21V7/10, F21V7/22, F21V14/04, F21V29/505, F21V29/70 (2015.01)
CPC Classification(s): F21V7/10, F21V7/22, F21K9/54, F21K9/56, F21V29/70, F21V29/505, F21V29/67

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)
PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data), Ebscohost, Google Scholar, IEEE, Search Terms: LED, removabl*, lens, wavelength conversion, reflector, stokes, sun, sunlight, solar)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2009/0103296 (A1), (HARBERS, G ET AL), 23 April 2009, paragraphs [0031], [0037], [0041], [0042], [0048], [0057], [0058], [0061], [0073] and [0075]	1-7, 9-15, 17-20 --- 8 and 16
Y	WO 2011/141779 (A1), (OREE, ADVANCED ILLUMINATION SOLUTIONS INC), 17 November 2011, paragraphs [0089] and [0100]	8
Y	US 2012/0087103 (A1), (BING, D ET AL), 12 April 2012, paragraph [0062]	16

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
01 December 2015 (01.12.2015)	30 DEC 2015

Name and mailing address of the ISA/	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/44289

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

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

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

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

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

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

This International Searching Authority found multiple inventions in this international application, as follows:

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

Group I: Claims 1-14 and 17-20 are directed toward a device and lighting fixture for converting electromagnetic waves ahving a reflector.

Group II: Claims 15 and 16 are directed toward a method for converting electromagnetic waves involving changing conversion components.

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

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

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

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

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

Remark on Protest

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

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

☐ No protest accompanied the payment of additional search fees.

-***-Continued from Box III: Lack of Unity of Invention-***-
The special technical features of Group I include a reflector, wherein the reflector defines an optical cavity around the light source, the reflector includes a first end and a second end, the first end is disposed around the light source, and the reflector is configured to reflect and direct the first electromagnetic waves towards the second end, which are not present in Group II.

The special technical features of Group II include removing the first wavelength conversion component from the fixture; securing a second wavelength conversion component to the fixture with the retaining component; directing third electromagnetic waves from the light source towards the second wavelength conversion component; causing fourth electromagnetic waves to be emitted from the second wavelength conversion component, wherein the second wavelength conversion component is effective to absorb the third electromagnetic waves and emit the fourth electromagnetic waves upon the third electromagnetic waves being incident upon the second wavelength conversion component, the fourth electromagnetic waves have a third wavelength, different from the first wavelength and the second wavelength, which are not present in Group I.

The common technical features shared by Groups I and II are securing a first wavelength conversion component to a fixture with a retaining component; directing first electromagnetic waves from a light source towards the first wavelength conversion component, wherein the first electromagnetic waves have a first wavelength; causing second electromagnetic waves to be emitted from the first wavelength conversion component, wherein the first wavelength conversion component is effective to absorb the first electromagnetic waves and emit the second electromagnetic waves upon the first electromagnetic waves being incident upon the first wavelength conversion component, the second electromagnetic waves having a second wavelength, different from the first wavelength; removing the retaining component from the fixture.

However, these common features are previously disclosed by US 2012/0327663 A1 to Doan, T (hereinafter 'Doan'). Doan discloses securing a first wavelength conversion component to a fixture with a retaining component (wavelength conversion lens is retained with an attachment mechanism, paragraph [0018]); directing first electromagnetic waves from a light source towards the first wavelength conversion component, wherein the first electromagnetic waves have a first wavelength; causing second electromagnetic waves to be emitted from the first wavelength conversion component, wherein the first wavelength conversion component is effective to absorb the first electromagnetic waves and emit the second electromagnetic waves upon the first electromagnetic waves being incident upon the first wavelength conversion component, the second electromagnetic waves having a second wavelength, different from the first wavelength wavelength conversion lenses receive electromagnetic emissions from an LED module and convert them to a different wavelength, paragraphs [0017] and [0022]); removing the retaining component from the fixture (attachment mechanism may be removed, paragraph [0018]).

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