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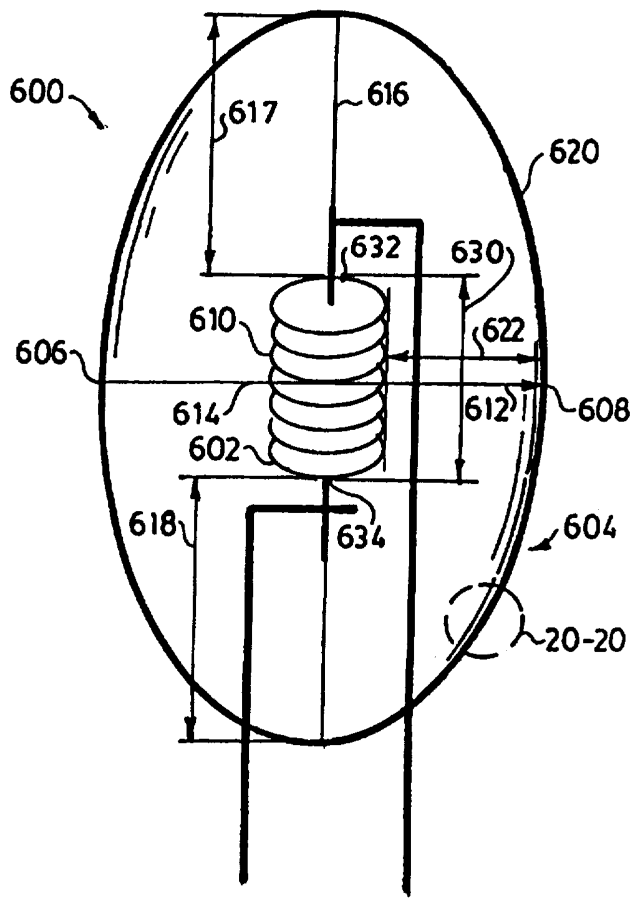
(54) Title: NOVEL DAYLIGHT LAMP

(57) Abstract

A lamp (600) for producing a spectral light distribution which is substantially identical in uniformity to the spectral light distribution of a desired daylight throughout the entire visible light spectrum from about 380 to about 780 nanometers. The lamp (600) contains a lamp envelope (604) comprised of an exterior surface, a light-producing element (602) substantially centrally disposed within said lamp envelope (604), and a coating (620) on said exterior surface of said lamp envelope (604).



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Description

Novel Daylight Lamp

Technical Field

An integral lamp for producing a daylight spectrum.

Background Art

Many attempts have been made to simulate natural daylight by artificial means. Some of the more successful devices for this purpose are described in United States patents 5,079,683; 5,083,252; and 5,282,115.

In United States patent 5,418,419, a lamp assembly adapted to produce daylight is described; the entire disclosure of this United States patent is hereby incorporated by reference into this specification. This lamp contains a lamp disposed within a reflector body whose interior surface is coated so that its reflectance level reflects radiance of every wavelength of the entire visible spectrum.

Most light fixtures are not adapted to receive a reflector assembly. Furthermore, the reflector component of such assembly is expensive to make.

It is an object of this invention to provide a lamp suitable for producing a daylight spectrum which does not require the presence of a reflector.

It is another object of this invention to provide a daylight lamp which is substantially more efficient than the daylight lamp assembly of United States patent 5,418,419.

It is another object of this invention to provide a daylight lamp whose spectral output does not contain substantial amounts of ultraviolet light.

It is another object of this invention to provide a daylight lamp which can be substantially smaller than the daylight lamp assembly of United States patent 5,418,419.

It is another object of this invention to provide a daylight lamp which, when used in conjunction with a standard reflector, provides a directional daylight beam.

It is another object of this invention to provide a lamp whose spectral output and irradiance can be varied.

Summary of the invention

In accordance with this invention, there is provided a lamp for producing a spectral light distribution which is substantially identical in uniformity to the spectral light distribution of a desired daylight throughout the entire visible light spectrum from about 400 to about 700 nanometers. The lamp contains a lamp envelope comprised of an exterior surface, a light-producing element substantially centrally disposed within said lamp envelope, and a coating on said exterior surface of said lamp envelope.

Brief description of the drawings

The present invention will be more fully understood by reference to the following detailed description thereof, when read in conjunction with the attached drawings, wherein like reference numerals refer to like elements, and wherein:

Figure 1 is a sectional view of one preferred embodiment of the lamp of this invention;

Figure 2 is a sectional view of the coating used in the lamp of Figure 1;

Figure 3 is a sectional view of another preferred embodiment of the lamp of this invention;

Figure 4 is graph of the spectral output of the light-emitting element of the lamp of Figure 1;

Figure 5 is a graph of the transmission of the coating of the lamp envelope of the lamp of Figure 1;

Figure 6 is a graph of a typical daylight spectrum produced by the lamp of Figure 1; and

Figure 7 is a sectional view of another preferred lamp assembly of this invention whose spectral output and irradiance can be varied.

Description of the preferred embodiments

Figure 1 is a sectional view of a preferred lamp 600. Lamp 600 is comprised of filament 602 centrally disposed within lamp envelope 604.

The filament 602 is the light-emitting element of lamp 600; and it will be referred to hereafter when discussing lamp 600. However, other light-emitting elements can be used in place of or in addition to filament 602.

Thus, by way of illustration, one may generate light by means of an anode-cathode arrangement such as those, e.g., shown in United States patents 5,394,047 (arc discharge lamp), 5,334,906, 5,270,615, 5,239,232 (light balance compensated mercury vapor and halogen high pressure discharge lamp), and the like.

Lamps utilizing such anode-cathode arrangements are well known to those in the art and are commercially available. Thus, e.g., the Oriel Corporation (of 250 Long Beach Blvd., P.O. Box 872, Stratford, Ct.) sells a comprehensive line of light sources including arc, deuterium, quartz tungsten halogen, special calibration lamps, and infrared elements from 10 to 1,000 watts.

In the embodiment depicted in figure 19, filament 602 is centrally disposed within envelope 604 in both the X, Y, and Z directions. Thus, filament 602 is located substantially in the middle of walls 606 and 608 of lamp envelope 604.

If a point 610 is chosen on filament 602, and lines are drawn from such point perpendicularly to each of walls 606 and 608, the distance 612 between point 610 and wall 608 will be substantially equal to the distance 614 between point 610 and wall 606. In general, distance 612 will be from about 0.95 to about 1.05 times as great as distance 614.

Similarly, if a line 616 is drawn through the center of filament 602, the distance 617 from one end of filament 602 to the point at which line 616 intersects lamp envelope 604 is from about 0.95 to about 1.05 times as great as the distance 618 from the other end of filament 602 to a point at which line 616 intersects the opposite portion of lamp envelope 604.

The substantially centrally disposed position of filament 602 has been illustrated in Figure 1 in the X and Y axis. Such illustration has not been made for the Z axis, for such three-dimensional depiction is not easy to illustrate. However, the distances from the center of the filament to wall of the envelope, as measured in the Z axis, is also substantially equidistant, being from about 0.95 to about 1.05 as great as each other.

Referring again to Figure 1, lamp envelope 604 preferably has a substantially elliptical shape. Lamp envelopes with substantially elliptical shapes are well known. Thus, e.g., reference may be had to United States patent 5,418,420, which discloses a lamp with a concave elliptical shape.

Reference also may be had to page 12-20 of the "Optics Guide 5" (Melles Griot, 1770 Kettering Street, Irvine, California, 1990). This page, which deals with ellipsoidal reflectors, discusses the origin, the primary focal point, the secondary focal point, the vertex, the height, and the width for a multiplicity of elliptical devices.

Referring to Figure 1, filament 602 has a length 630 which is less than or equal to the distance between primary focal point 632 and secondary focal point 634.

In one embodiment, light emitting element 602 provides a substantially point-source of light which preferably is created with an anode-cathode arrangement. When the light-emitting element used provides a substantially point-source of light, it is preferred that lamp envelope 604 have a cross-sectional shape which is substantially circular, and have a three-dimensional shape which is substantially spherical. The geometry of lamp envelope 604 provides the maximum amount of reflectance back to light-emitting element 602 and thus provides more heat to element 602.

In one embodiment, at least about fifty percent of the infrared energy with a wavelength of from about 780 to about 2,000 nanometers which is emitted by light emitting source 602 is reflected back to element 602 by lamp envelope 604.

One means of insuring that a substantial amount of infrared energy is reflected back to light emitter 602 is to coat lamp envelope 604. Referring again to Figure 1, it will be seen that lamp envelope 604 is preferably comprised of a coating 620. The coating 620 preferably extends over at least about 90 percent of the exterior surface of lamp envelope 604; and only one such coating is used. In another embodiment, not shown, lamp envelope 604 may contain two or more coatings.

The coating or coatings used may be disposed on either the inside surface of lamp envelope 604, and/or its outside surface. Thus, one may dispose an infrared reflecting coating on the inside surface of lamp envelope 604, and a ultraviolet reflecting coating on the outside surface of lamp envelope 604; in this embodiment, the outside coating will transmit a selective portion of the visible light spectrum.

Coating 620 may be deposited on lamp envelope 604 by conventional means. Thus, one may use the coating technology disclosed in United States patent 5,422,534 (in which an optical interference filter is produced on a vitreous, light transmissive substrate), or the technology disclosed in United States patent 4,048,347 (which describes a method of coating a lamp envelope with a heat reflecting filter).

In one embodiment, the lamp envelope 604 is constructed of a material which, in and of itself, absorbs ultraviolet light. One material which can be used to make such a lamp is sold by the Corning Glass Works of Corning, New York as "spectramax".

Referring again to Figure 1, the maximum distance 622 between envelope 604 and filament 602 is less than about 8 centimeters and, preferably, is less than about 3 centimeters. In an even more preferred embodiment, the distance 622 is less than about 2.0 centimeters.

In one embodiment, envelope 604 is substantially contiguous with filament 602, and the distance between filament 602 and coating 620 is less than about 0.01 centimeters.

The filament 602, when excited by electrical energy, emits radiant energy at least throughout the entire visible spectrum with wavelengths from about 200 to about 2,000 nanometers at non-uniform levels of radiant energy across the visible spectrum.

It is preferred that filament 602 emit radiant energy in such a manner that in excess of thirty percent of said radiant energy is produced at wavelengths in excess of 700 nanometers. The spectral output of a filament may be measured by a spectral radiometer.

It is preferred that filament 602 emit radiant energy in such a manner that it have a color temperature of at least about 2,800 degrees Kelvin.

It is preferred that the characteristics of coating 620 on lamp envelope 604 be such that, on average, from about 80 to about 90 percent of all of the radiant energy with a wavelength between about 380 and 500 nanometers is transmitted, on average, at least from about 50 to about 60 percent of all of the radiant energy with a wavelength between about 500 and 600 nanometers is transmitted, on average at least about 40 to about 50 percent of all of the radiant energy with a wavelength between about 600 and 700 nanometers is transmitted, and on average at least about 10 to about 20 percent of all of the radiant energy with a wavelength between about 700 and 780 nanometers is transmitted.

It is also preferred that the coating 620 on lamp envelope 604 have reflectance properties such that said coating prevents the transmission of at least about 10 percent of the ultraviolet radiation with a wavelength of from about 300 to about 380 nanometers emitted by said filament. In a more preferred embodiment, at least about 90 percent of such ultraviolet radiation is reflected.

It is also preferred that coating 620 prevents the transmission of at least about 20 percent of the ultraviolet radiation with a wavelength of from about 200 to about 300 nanometers emitted by said filament. Preferably, coating 620 will reflect at least about 90 percent of such ultraviolet radiation.

It is also preferred that coating 620 reflects at least about 50 percent of the infrared radiation with a wavelength of from about 780 to about 1,000 nanometers emitted by said filament. In another embodiment, coating 620 reflects at least about 90 percent of such infrared radiation.

It is also preferred that coating 620 reflect at least about 25 percent of the infrared radiation with a wavelength of from about 1,000 to about 2,000 nanometers. In a more preferred embodiment, at least about 90 percent of such radiation is reflected.

In general, it is preferred that coating 620 have a reflectance level in substantial accordance with the formula: $T(l) = [D(l) - [S^{*}(l) \times (1-N)]]/[S(l) \times N]$, wherein: T(l) is the transmission of said envelope coating for said wavelength l (wavelength is from 380 to 780 nanometers), D(l) is the radiance of said wavelength for the desired daylight, S(l) is the radiance of said filament at said wavelength at normal incidence to said lamp envelope, $S^{*}l$ is the radiance of said filament at said wavelength at non-normal incidence to said lamp envelope, and N is the percentage of visible spectrum radiant energy directed normally towards said exterior surface of said lamp envelope. surface.

In general, coating 620 and lamp envelope 604 have optical properties such that they reflect back to said filament 602 at least thirty percent of all of the radiation emitted by said filament.

The transmission and reflectance values of coating 620 on lamp envelope 604 may be measured by means of a spectrophotometer.

Figure 2 is an enlarged view of a portion of the lamp of Figure 1, illustrating coating 620. Coating 620 is comprised of substrate 640, first coated layer 642, second coated layer 644, third coated layer 646, and fourth coated layer 648.

Substrate 640 preferably consists essentially of a transparent material such as, e.g., plastic or glass and has a thickness of from about 0.5 to about 1.0 millimeters. In one preferred embodiment, the substrate material is transparent borosilicate glass. In another embodiment, transparent synthetic fused quartz glass is used as the substrate.

Referring again to Figure 2, each of coatings 642, 644, 646, and 648 consists essentially of a dielectric material (such as magnesium fluoride, silicon oxide, zinc sulfide, and the like) which has an index of refraction which differs from the index of refraction of any other layer adjacent and contiguous to such layer. In general, the indices of refraction of these coatings range from about 1.3 to about 2.6. Each of the layers is deposited sequentially onto the substrate as by vapor deposition or by other well know methods.

Coating 620 intercepts a multiplicity of light rays (not shown) including normal incident light ray 650. A portion 652 of light ray 650 is reflected; another portion 654 of light ray 650 is transmitted.

Non-normal incident light rays, such as light ray 656, also intersect coating 620. A portion 658 of this non-normal incident ray is reflected, and another portion 660 of this non-normal incident ray is transmitted. The non-normal incident rays will have more of its red light component transmitted than do the normally incident rays.

With a conventional spectroradiometer, one may measure the optical output for any given lamp system with a specified coating and filament. By knowing the properties of the filament and the coating, and by measuring the spectral output of the lamp, one may calculate the S^* and/or the N variables in such equation.

Referring again to Figure 2, in some embodiments substrate 640 may be designed to absorb ultraviolet radiation which it is desired neither to transmit nor reflect. Such radiation generally will have wavelength of from about 200 to about 380 nanometers; it is preferred to absorb at least about 90 percent of this radiation.

Referring again to Figure 2, an infrared coating 662 is preferably coated on the inside surface of substrate 640.

Figure 3 is a top view of the lamp 600 of Figure 1. Light rays 664, 666, 668, and 670 are transmitted from filament 602 in a substantially normally incident fashion; portions 672, 674, 676, and 678 of these light rays are transmitted through coating 620; and portions 680, 682, 684, and 686 of these light rays are reflected from coating 620 back towards filament 602. In this embodiment, lamp envelope 604 has a substantially circular cross-sectional shape which, preferably, is used in conjunction with a light-emitting element 602 which produces a substantially point source beam of light. Regardless of whether one uses an elliptical or spherical shaped lamp envelope 604, the cross-section of such envelope will be substantially circular.

Referring again to Figure 3, lamp 600 is disposed within a directional reflector 690 which tends to reflect rays 672, 674, 676, and 678. In one embodiment, these rays are reflected in a direction substantially parallel to the axis of filament 602, which is also substantially perpendicular to the direction of light rays 672, 674, 676, and 678.

Although the coating on reflector 690 may be a conventional one, the light it reflects will have a spectral distribution. substantially identical to daylight.

Figure 4 is a graph of the spectral output of a typical filament, such as filament 602, with color temperature of 2,900 degrees Kelvin.

Figure 5 is a graph of the spectral transmission of the coating 620 of the lamp of Figure 1.

Figure 6 is the spectral output of the rays 672, 674, 676, and 678 et seq. which are produced by combining filament 602, coating 620, and lamp envelope 604 in the precise manner described. The spectral output produced is substantially daylight.

As the desired daylight spectra to be produced changes (from, e.g., a a color temperature of 3,500 to 10,000 degrees Kelvin), the properties of the filament 602 and/or the coating 620 must also be changed.

Referring to Figure 7, as the reflector 702 is moved in the direction of arrow 704 (up), or 706 (down), or 708 (out) or 710 (in), the color temperature of the spectral output of the lamp, and its irradiance, will be varied.

One may use conventional means to movably connect reflector 702 to lamp 700. Thus, e.g., one may use a worm gear, a friction fit, an electrical stepping motor, etc. In the embodiment depicted in Figure 7, a ratchet 711 is connected to a gear 712.

In the embodiment depicted in Figure 7, reflector 702 preferably consists essentially of rigidized aluminum.

As the reflector 702 is moved closer to reflector 12, the rays 714 which normally would escape the system are reflected back towards it (see rays 716) and are incorporated into the spectral output of the system, thereby increasing the foot candles of the output but decreasing its color temperature (because a majority of these rays 714 contain more red light than blue light).

In one embodiment, cover lens 23 is a diffuse material rather than a clear material. In this embodiment, both the foot candles and the color temperature of the spectral output will be decreased.

It is to be understood that the aforementioned description is illustrative only and that changes can be made in the apparatus, in the ingredients and their proportions, and in the sequence of combinations and process steps, as well as in other aspects of the invention discussed herein, without departing from the scope of the invention as defined in the following claims.

I claim:

1. A lamp for producing a spectral light distribution substantially identical in uniformity to the spectral light distribution of a desired daylight with a color temperature of from about 3500 to about 10,000 degrees Kelvin throughout the entire visible light spectrum from about 380 to about 780 nanometers, comprising:

(a) an enclosed lamp envelope having an interior surface and an exterior surface;

(b) a light-producing element substantially centrally disposed within said lamp envelope and which, when excited by electrical energy, emits radiant energy throughout the entire visible spectrum with wavelengths from about 200 to about 2,000 nanometers at non-uniform levels of radiant energy across the visible spectrum; and

(c) at least one coating on at least one of said surfaces and having a transmittance level in substantial accordance with the formula $T(1) = [D(1) - [S^*(1) \times (1-N)]]/[S(1) \times N]$, wherein T(1) is the transmission of said envelope coating for said wavelength 1 from about 380 to about 780 nanometers, D(1) is the radiance of said wavelength for the desired daylight, S(1) is the radiance of said element at said wavelength at normal incidence to said lamp envelope, $S^*(1)$ is the radiance of said element at said wavelength at non-normal incidence to said lamp envelope, and N is the percentage of visible spectrum radiant energy directed normally towards said exterior surface of said lamp envelope.

2. A lamp according to claim 1, wherein the element has a color temperature of at least about 2,800 degrees Kelvin.

3. A lamp according to claim 1, wherein the coating is on the exterior surface of the lamp envelope and prevents both the transmission of at least about 10 percent of the ultraviolet radiation with a wavelength of from about 300 to about 380 nanometers emitted by said element and the transmission of at least about 20 percent of the ultraviolet radiation with a wavelength of from about 200 to about 300 nanometers emitted by said element.

4. A lamp according to claim 1, wherein the coating reflects back towards the element both at least about 50 percent of the infrared radiation with a wavelength of from about 780 to about 1,000 nanometers emitted by said element and at least about 25 percent of the infrared radiation with a wavelength of from about 1,000 to about 2,000 nanometers.

5. A lamp according to claim 1, wherein the envelope is substantially elliptical in cross section with an axis of rotation and having two focal points along the axis, the element being centrally disposed within the envelope in all directions along the axis and each point on the element being from about 0.95 to about 1.05 times the distance of the envelope from the axis and having a length not exceeding the distance between the focal points.

6. A lamp according to claim 1, and further comprising a second coating on said envelope, one of said coatings comprising an infrared-reflecting coating on one of the surfaces of the envelope, and the other coating including an ultraviolet reflecting layer on the other surface of the envelope.

7. A lamp according to claim 1, wherein the lamp envelope is constructed of a material that absorbs ultraviolet light.

8. A lamp according to claim 1, wherein the envelope consists essentially of a light transmitting material having a thickness from about 0.5 to about 1.0 millimeters and the coating

comprises at least four layers each consisting essentially of a dielectric material having an index of refraction within a range of from about 1.3 to 2.6 and which differs from the index of refraction of any other layer which is adjacent and contiguous.

9. A lamp according to claim 1, further comprising a reflector.

10. A reflector lamp combination for producing a spectral composition comprising:

(a) a bulb including a filament which, when excited by electrical energy, emits radiant energy at least within and throughout the visible spectrum with wavelengths (l) from about 380 to about 780 nanometers, but with the levels of radiant energy at each wavelength across the spectrum not being uniform in intensity;

(b) a light transmitting reflector body with a surface to intercept such visible spectrum radiant energy, wherein said filament is positioned within said reflector so that at least about 60 percent of said visible spectrum radiant energy is directed towards said reflector surface;

(c) filter coating means on the surface of said reflector body, for reflecting in a desired direction radiance from among the entire said visible spectrum radiant energy directed towards said reflector surface, which when combined with the radiance of the visible spectrum radiant energy emitted by the filament and not directed towards said reflector surface produces a total usable visible light or relatively uniform radiance throughout the visible spectrum which is substantially identical to daylight color temperature and contains relatively uniform levels of radiant energy throughout the visible light spectrum from about 380 to about 780 nanometers, the balance of the radiant energy directed towards said reflector surface not reflected by the coating means being transmitted by said reflector body in directions other than the desired direction;

(d) second reflector means positioned adjacent to said reflector body for reflecting the light transmitted by the reflector body toward the desired direction;

(e) means for moving the second reflector means parallel to the desired direction for varying the color temperature of the visible light as viewed from the desired direction; and

(f) a diffuser.

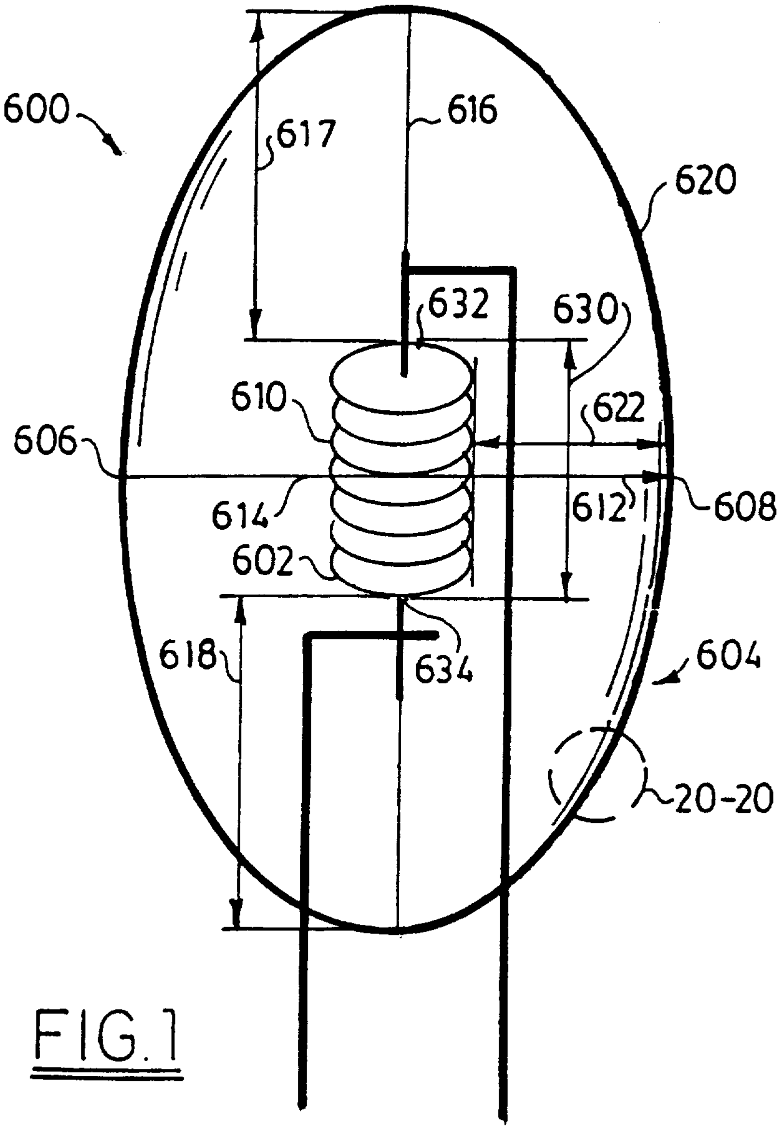
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FIG.1

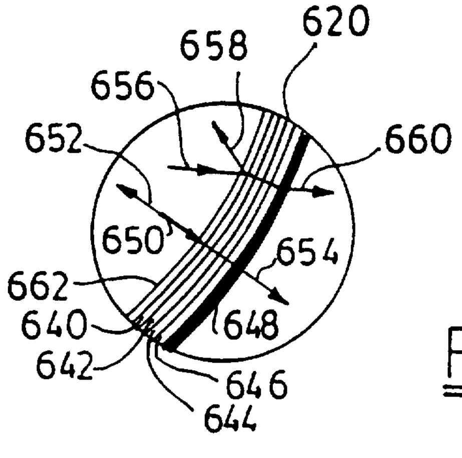
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FIG.2

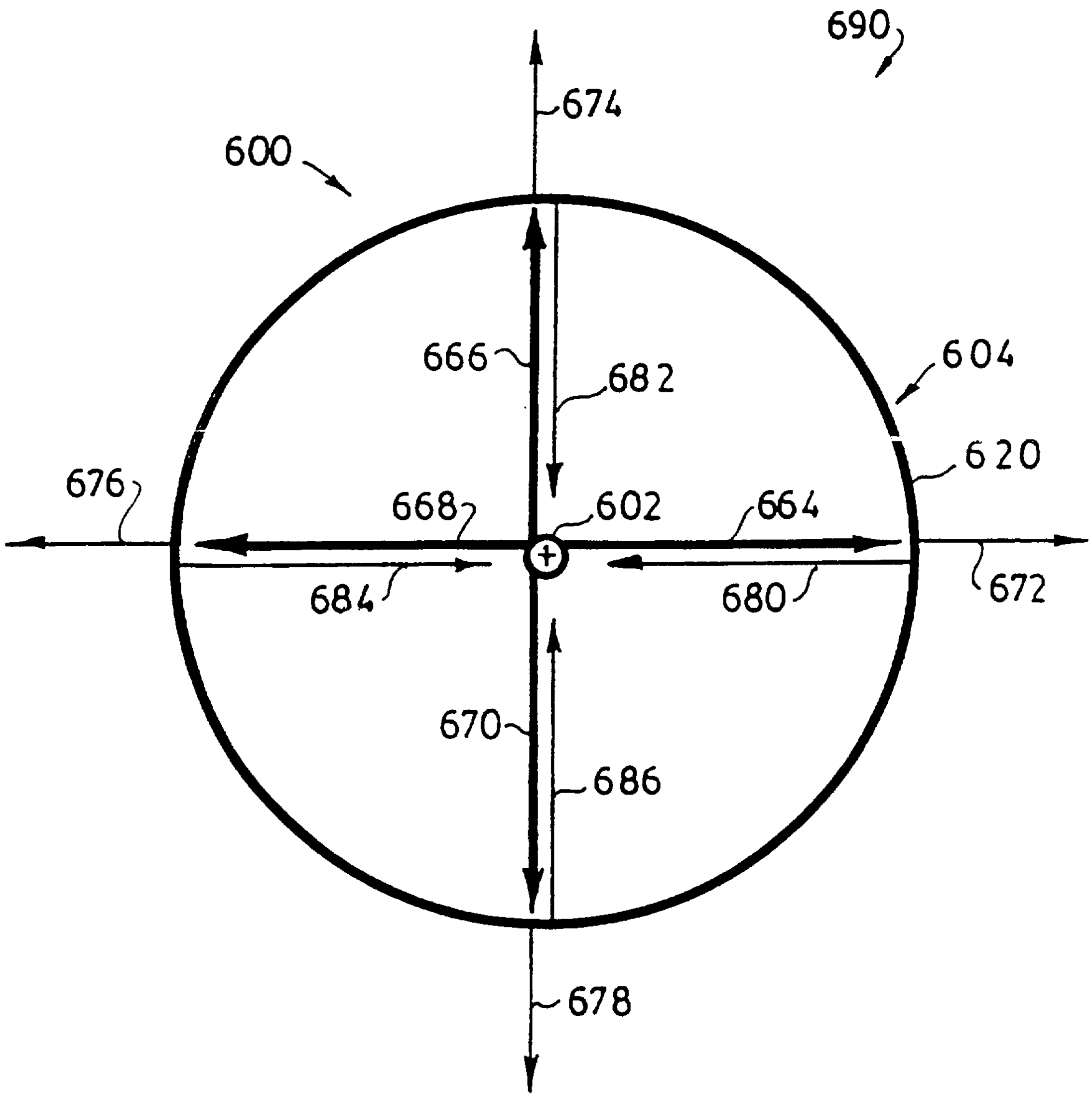
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FIG.3

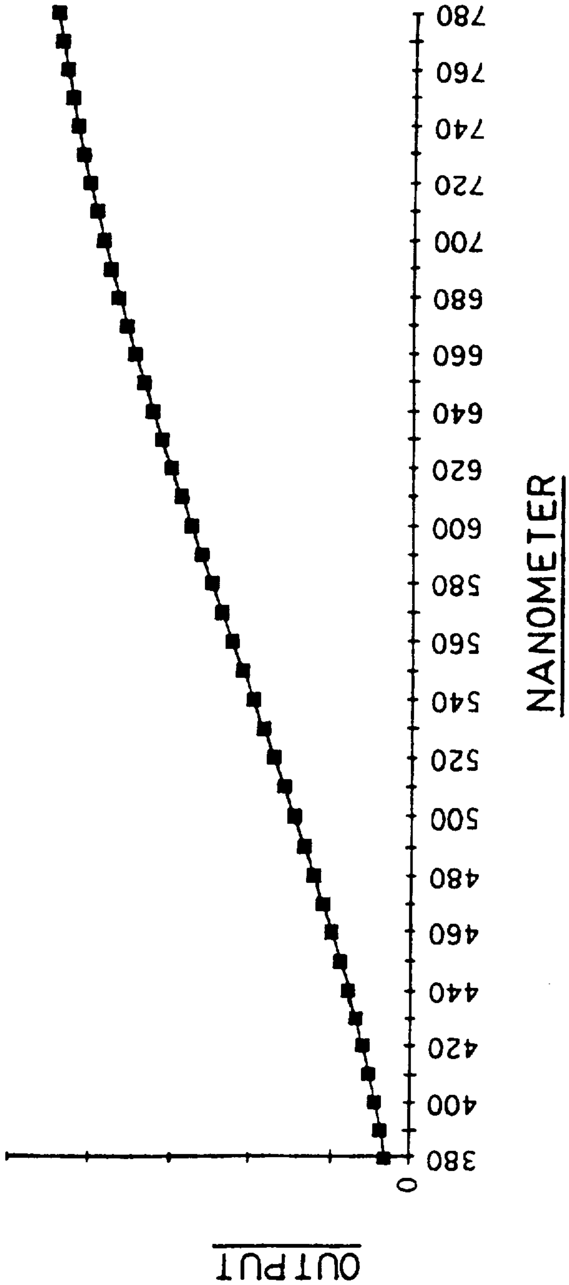
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FIG.4

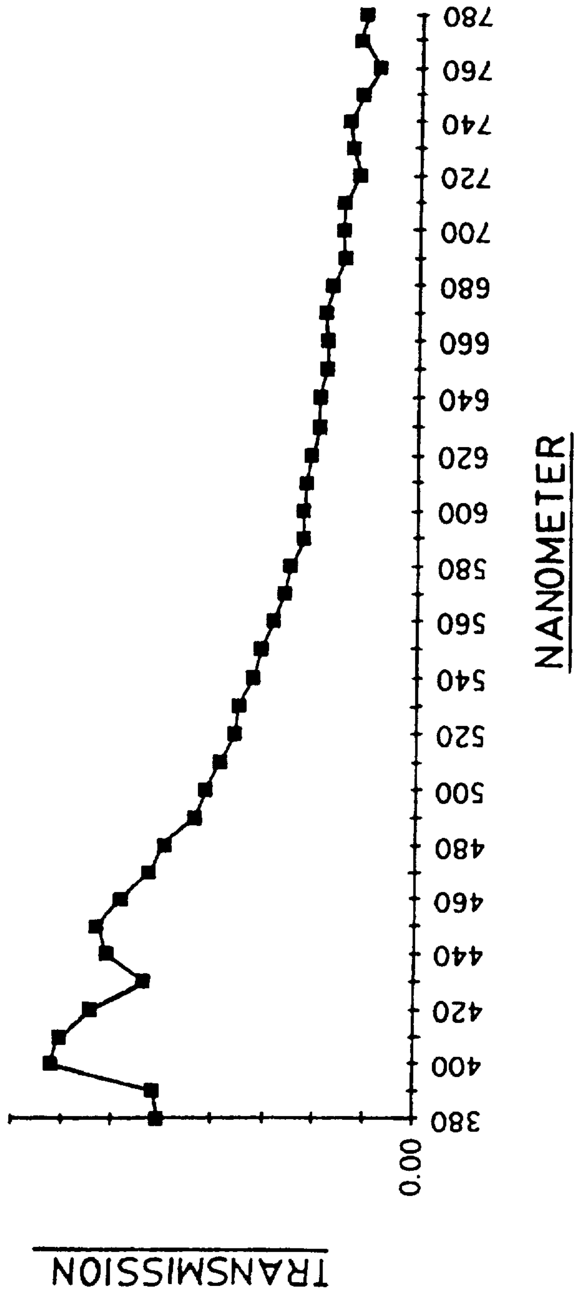
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FIG.5

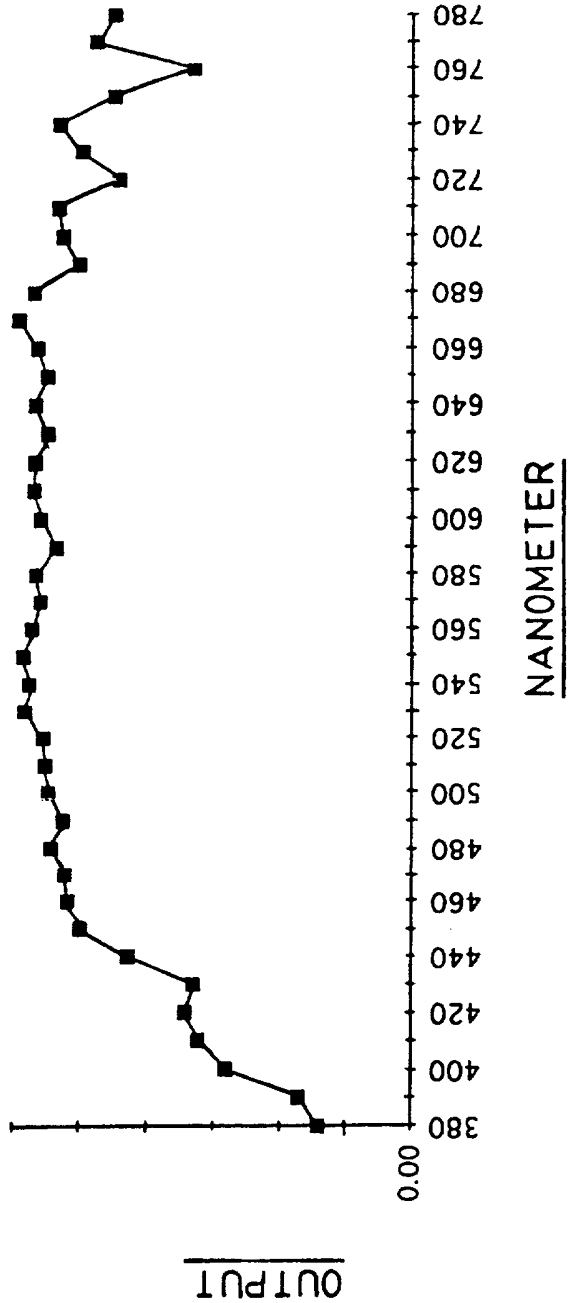
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FIG. 6

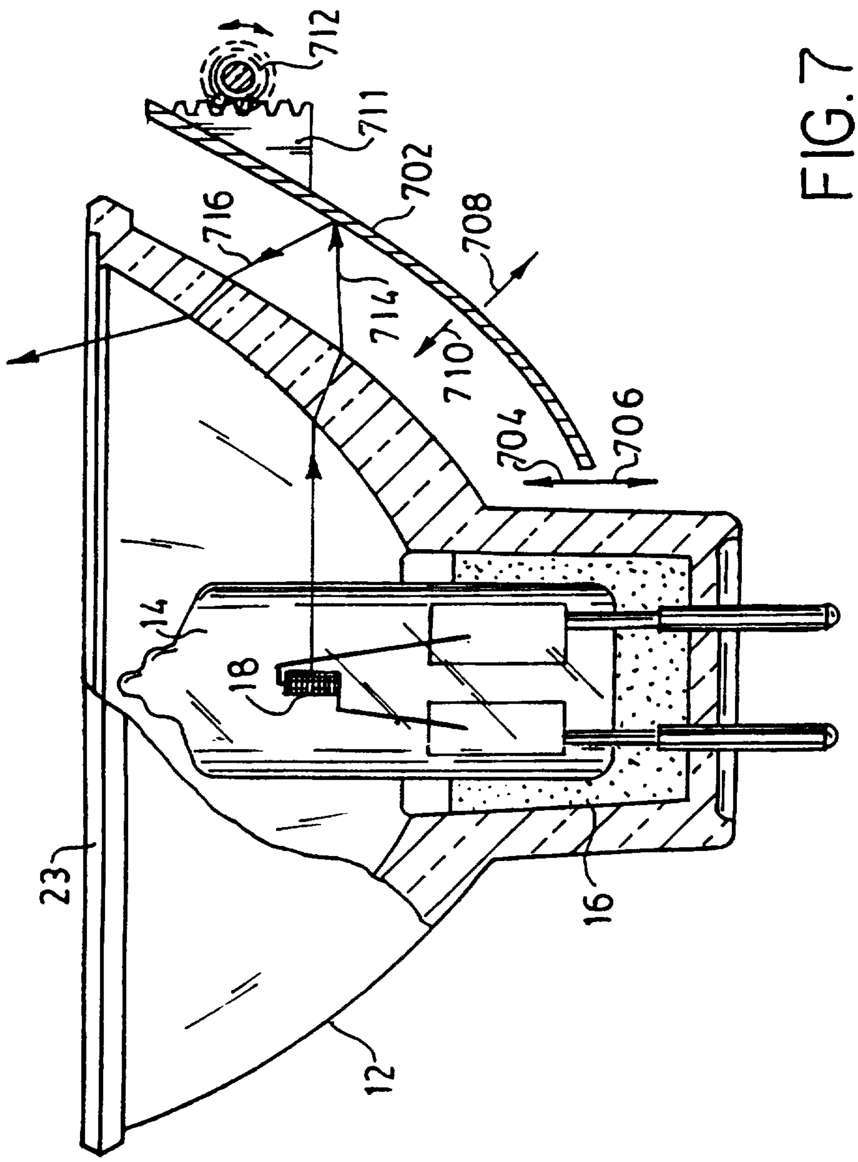

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/02753

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H01J 5/16
US CL :313/110, 113, 112, 116; 315/297
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)

U.S. : 313/110, 113, 112, 116, 114; 315/297, 307, 112; 362/1, 2, 327, 341

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,870,318 A (CSANYI et al.) 26 September 1989, Figures 1 and 2.	1-10
A	US 4,608,512 A (RAKITSCH) 26 August 1986, Figure 1.	1-10
A	US 5,177,396 A (GIELEN et al.) 05 January 1993, Figure 2.	1-10
A	US 4,346,324 A (YOLDAS) 24 August 1982, Figures 1 and 2.	1-10
A	US 5,272,409 A (VAN DULMEN et al.) 21 December 1993, Figure 1.	1-10

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

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