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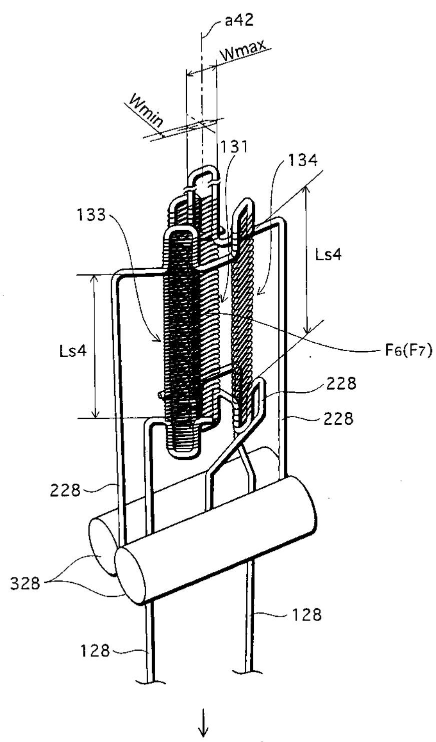
(54) **LAMP BULB, LAMP BULB WITH REFLECTING MIRROR, AND LIGHTING SYSTEM**

(57) To make a filament assembly compact and improve converging efficiency, a lamp to be built into a reflection mirror or a reflection-mirror-equipped lamp of the present invention includes a filament assembly including a plurality of filament elements each formed with a single wound coil. A central filament element is placed such that a coil axis thereof is the same as an optical axis of the reflection mirror, and peripheral filament elements are placed such that winding axes thereof are parallel to the coil axis of the central filament element. An outline of each filament element is substantially noncircular. Also, to improve central luminance and light distribution properties, $0.2 \le L_S/L_C \le 0.9$ is satisfied, where L_C is a length of the central filament element and L_S is a length of the peripheral filament element. Further, to realize a long life, $0.25 \le r/R \le 0.75$ is satisfied, where R is a maximum inner diameter of the bulb and r is a maximum outer diameter of the filament assembly.

FIG.4



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Description

Technical Field

[0001] The present invention relates to a lamp, a reflection-mirror-equipped lamp and a lighting apparatus, and particularly relates to a structure of wiring of a filament.

Background Art

[0002] A reflection-mirror-equipped lamp, such as a reflection-mirror-equipped halide lamp, has a structure in which a halide lamp is built into a concave reflection mirror. Such a lamp is used for studio lighting and a general lighting in a commercial establishment as a spot light, for example.
There is a demand for a higher converging efficiency of the halide lamp. Here, the term "the converging efficiency" means illuminance per power [lx/W].
[0003] The halide lamp includes a bulb and a filament assembly set up within the bulb. It is well known that the filament assembly can be almost a point light source by miniaturizing the filament assembly, and the converging efficiency can be improved by using a reflection mirror with the bulb. However, generally, if the rated voltage [V], the rated power [W] and the rated lifetime (e.g. 3000 hours) are determined, the wire length and the wire diameter of the tungsten wire included in the filament assembly will be determined accordingly. This means that it is impossible to miniaturizing the filament assembly by simply shortening the wire length.
[0004] If the rated voltage and the rated power are determined, the resistance Rof the filament assembly will be determined. For instance, if the wire length is shortened, the wire diameter is required to be smaller to keep the resistance R. However, if the wire diameter is made small, the tungsten wire dwindles and easily burns out during the lighting, due to the evaporation of the tungsten. This shortens the lifetime. Meanwhile, if the wire diameter is made large to keep the lifetime, the wire length is required to be long to keep the resistance R. However, if the wire length is too long, it is necessary to narrow the pitch and make the tension on the filament assembly smaller, because the size of the filament assembly is required to be within a certain range in accordance with the size of the bulb and so on. This might weaken the mechanical strength of the filament assembly, which might cause the burnout of the filament assembly. Therefore, to satisfy the predetermined rated voltage, rated power and rated lifetime, the wire length and the wire diameter will be almost uniquely determined, and it is difficult to miniaturize the filament assembly.
[0005] In the case of a reflection-mirror-equipped halide lamp for general lighting, such as a commercially available spot light whose beam angle is 10° and the mirror diameter φ of the reflection mirror is 50 [mm], the central illuminance reaches 6500 [lx] (equal to 6500 [cd] of central brightness) under a condition that the rated power is 65 [W] (the rated voltage is 110 [V]). However, further improvement of the central illuminance is desired.
[0006] Here, the term "the central illuminance" means the illuminance of an intersection point of the optical axis of the reflection mirror and the irradiated area.
Further, the lifetime of the lamp is demanded to be longer.
To improve the converging efficiency and the central illuminance under the above-described limitation, the following inventions have been made.
[0007] One of the inventions is a reflection-mirror-equipped halide lamp for studio lighting using a filament assembly including a plurality of filament elements each being spirally wound and extending linearly to increase the central illuminance by improving the converging efficiency (e.g. Patent Document 1). These filament elements are positioned to be parallel to the optical axis of the reflection mirror and form a regular triangle or a square so as to be substantially symmetrical about the optical axis.
[0008] Also, another invention is a reflection-mirror-equipped halide lamp wherein an infrared reflecting film is formed on the outer surface of the glass bulb to particularly improve the luminous efficiency (e.g. Patent Document 2) by efficiently returns the infrared rays reflected from the infrared reflecting film back to the filament elements. In this halide lamp, another filament element spirally wound and extending linearly is set up in the above-described optical axis in addition to the filament elements of the above-described conventional reflection-mirror-equippedhalide lamp. In other words, the filament element set up in the above-described optical axis (hereinafter called "the center filament element") and the other at least three filament elements (hereinafter called "the peripheral filament elements") set up to be substantially symmetrical about the center filament element are included in the filament assembly.
[0009] Here, the term "the luminous efficiency" means luminous flux per power [lm/W].
Further, for a halide lamp whose rated voltage is more than or equal to 100 [V], a double-wound coil is often used as the filament assembly to miniaturize the filament assembly so as to be almost a point light source. Another invention suggests a halide lamp in which a triple-wound coil is used as the filament assembly for further miniaturization (e.g. Patent Document 3).
[Patent Document 1] Japanese Laid-open Patent Application Publication No.H06-510881

[Patent Document 2] Japanese Laid-open Patent Application Publication No.2002-63869
[Patent Document 3] Japanese Laid-open Patent Application Publication No.2001-345077

Disclosure of the Invention

Problems to be Solved

[0010] However, it is very difficult to realize a reflection-mirror-equipped halide lamp such as a spot light for general lighting, especially of a narrow beam angle type, by applying the above-described techniques. FIG.34 shows a result of an examination of the light distribution curves of the conventional reflection-mirror-equipped halide lamps for general lighting whose rated power is 65 [W] and beam angle is 10°. One of the lamps uses the filament disclosed by the Patent Document 1, and the other uses the filament disclosed by the Patent Document 2. In FIG.34, the light distribution curve of the lamp using the filament disclosed by the Patent Document 1 is represented by the dotted line (i), and the light distribution curve of the lamp using the filament disclosed by the Patent Document 2 is represented by the solid line (ii). As FIG. 34 shows, in the former case, the illuminance is high in a peripheral region around the optical axis due to the filament elements placed around the optical axis, whereas the central illuminance (angle 0°) is remarkably lower than that of the peripheral region. In the latter case, the illuminance is increased in the peripheral region as well as the region around the optical axis, and the irradiated light covers the whole irradiated area. The beam angle is not less than 13°.

[0011] The main stream of the beam angle of commercially available reflection-mirror-equipped halide lamps of a narrow angle type for general lighting is 10°. According to the IEC 60357 standard, an allowable range of an error of the beam angle (10°) is ±25%. This means that if the beam angle is 10°, the allowable range of the beam angle is from 7.5° to 12.5°. Therefore, in the case of applying the above-described conventional filament assembly to the reflection-mirror-equipped halide lamp for general lighting such as a spot light, the beam angle will be out of the allowable range, and it is impossible to achieve the desired beam angle (e.g. 10°).

[0012] Such a problem does not arise remarkably in the case where the lamp is used for studio lighting. Supposedly, the main reason is the difference of the mirror diameter Φ of the reflection mirror. That is to say, the mirror diameter Φ of the reflection mirror of the halide lamp for general lighting is mainly in the range from 35 [mm] to 100 [mm], whereas the mirror diameter Φ of the reflection mirror of the halide lamp for studio lighting is mainly in the range of 200 [mm] to 400 [mm], which is relatively large. Regarding the reflection mirror, a region contributing to the central illuminance (hereinafter simply called "the central illuminance contributing region") includes the focal point of the reflection mirror and its vicinity. The area of the central illuminance contributing region increases as the mirror diameter Φ increases, and decreases as the mirror diameter Φ decreases. Accordingly, the central illuminance contributing region of the reflection-mirror-equipped halide lamp for studio lighting is large. As a result, the light emitted from the filament elements positioned around the optical axis greatly contributes to the central illuminance.

[0013] If such a reflection-mirror-equipped halide lamp is used for studio lighting, the required rated lifetime is 200 to 500 hours, and it is sometimes 2000 hours. If it is used for general lighting, as a spot light for instance, the required rated lifetime is 2000 to 3000 hours, and it is sometimes more than 3000 hours. The above-described reflection-mirror-equipped halide lamp is marketed as a product for studio lighting which is not required to have a particularly long lifetime, and its lifetime has not been fully considered. Therefore, especially if such a halide lamp is used for general lighting, as spot light for instance, the lamp leaves much to be improved as to the lifetime.

[0014] Furthermore, if a coil used for the filament assembly is a double or triple-wound coil, the resistance to vibration becomes low. Therefore, to improve the resistance to vibration, especially in the case of setting up a triple-wound coil as the filament assembly in the bulb, the triple-wound coil is required to be electrically and physically connected to the internal lead and so on under a condition where the triple-wound coil is pulled in the longitudinal direction thereof, which means that the triple-wound coil is under tension. However, if this is the case, the pitch of the third coil of the triple-wound coil becomes large, and the length of the whole triple-wound coil increases in the longitudinal direction. This is a bottleneck in the miniaturization of the filament assembly and improvement of the converging efficiency. Therefore, another means alternative to the use of the triple-wound coil is demanded.

[0015] The present invention is made in view of the above-described problems. The object of the present invention is to provide a lamp, a reflection-mirror-equipped lamp and a lighting apparatus that can improve the converging efficiency, increase the central illuminance, realize excellent light distribution especially in the case of a narrow beam angle type, and realize a long lifetime.

Means for Solving the Problem

[0016] To improve the converging efficiency, the present invention provides a lamp that is to be built into a reflection mirror of a lighting apparatus, a rated voltage of the lamp being from 100 [V] to 250 [V] inclusive, the lamp comprising: a bulb; and a filament assembly that is set up within the bulb, wherein the filament assembly includes a plurality of filament elements and is placed such that a focal point of the reflection mirror is included within the filament assemblywhen the lamp is built into the reflection mirror, the filament elements are single-wound coils, one of the filament elements being placed in an optical axis of the reflection mirror and one or more of the other filament elements being placed to be parallel to the optical axis, and an outline of each filament element is noncircular as viewed in a coil axis direction of the filament element.

[0017] Also, the present invention provides a reflection-mirror-equipped lamp comprising: a reflection mirror having a concave reflection surface; and a lamp built into the reflection mirror, a rated voltage of the lamp being from 100 [V] to 250 [V] inclusive, wherein the lamp includes a bulb and a filament assembly that is set up within the bulb, the filament assembly includes a plurality of filament elements and is placed such that a focal point of the reflection mirror is included within the filament assembly, the filament elements are single-wound coils, one of the filament elements being placed in an optical axis of the reflection mirror and one or more of the other filament elements being placed to be parallel to the optical axis, and an outline of each filament element is noncircular as viewed in a coil axis direction of the filament element.

[0018] To improve the central illuminance and the light distribution properties, the present invention provides a reflection-mirror-equipped lamp comprising: a reflection mirror having a concave reflection surface; and a lamp built into the reflection mirror, wherein the lamp includes a bulb and a filament assembly that is set up within the bulb, the filament assembly includes a central filament element whose central axis is substantially the same as an optical axis of the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element, the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axis of the central filament element and the plane, and $0.2 \le L_S/L_C \le 0.9$ is satisfied, where L_C is a length of the central filament element and L_S is a length of the peripheral filament element.

[0019] Also, the present invention provides a lamp that is to be built into a reflection mirror of a lighting apparatus, the lamp comprising: a bulb; and a filament assembly that is set up within the bulb, wherein the filament assembly includes a central filament element whose central axis is substantially the same as an optical axis of the reflection mirror when the lamp is built into the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element, the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axes of the central filament element and the plane, and $0.2 \le L_S/L_C \le 0.9$ is satisfied, where L_C is a length of the central filament element and L_S is a length of the peripheral filament element.

[0020] To realize a long life, the present invention provides a lamp comprising: a bulb; and a filament assembly that is set up within the bulb and includes at least three straight filament elements, wherein the filament elements are arranged around a central axis of the bulb such that central axes of the filament elements are parallel to the central axis of the bulb, and intersection points of the central axes of the filament elements and a plane vertical to the central axis of the bulb substantially form a regular polygon whose centroid is an intersection point of the central axis of the bulb and the plane, and $0.25 \le r/R \le 0.75$ is satisfied, where R is a maximum inner diameter of a portion of the bulb corresponding to the filament assembly, and r is a maximum outer diameter of the filament assembly.

[0021] Also, the present invention provides A lamp built into a reflection mirror of a lighting apparatus, the lamp comprising: a bulb; and a filament assembly that is set up within the bulb, wherein the filament assembly includes a central filament element whose central axis is substantially the same as an optical axis of the reflection mirror when the lamp is built into the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element; the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axes of the central filament element and the plane, and $0.25 \le r/R \le 0.75$ is satisfied, where R is a maximum inner diameter of a portion of the bulb corresponding to the filament assembly, and *r* is a maximum outer diameter of the filament assembly.

[0022] Furthermore, the present invention provides a reflection-mirror-equipped lamp comprising: a reflection mirror having a concave surface; and a lamp built into the reflection mirror, wherein the lamp includes a bulb and a filament assembly that is set up within the bulb, the filament assembly includes a central filament element in a straight shape, whose central axis is substantially the same as an optical axis of the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element, the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axis of the central filament element and the plane, and $0.25 \le r/R \le 0.75$ is satisfied, where R is a maximum inner diameter of the bulb and r is a maximum outer diameter of the filament assembly.

Advantageous Effect of the Present Invention

[0023] As described above, the present invention provides a lamp that is to be built into a reflection mirror of a lighting apparatus, a rated voltage of the lamp being from 100 [V] to 250 [V] inclusive, the lamp comprising: a bulb; and a filament assembly that is set up within the bulb, wherein the filament assembly includes a plurality of filament elements and is placed such that a focal point of the reflection mirror is included within the filament assembly when the lamp is built into the reflection mirror, and the filament elements are single-wound coils. Therefore, the resistance to vibration is improved from a multiple-wound coil.

[0024] Also, since the filament elements are single-wound coils, the pitch can be smaller than that of multiple-wound coils. Furthermore, since one of the filament elements is placed in an optical axis of the reflection mirror and one or more of the other filament elements are placed to be parallel to the optical axis, the central illuminance and the converging efficiency are improved compared to a case where a filament element is not positioned in the optical axis of the reflection mirror.

[0025] Furthermore, since an outline of each filament element is noncircular as viewed in a coil axis direction of the filament element, the length of the filament assembly in the optical axis direction is shorter than the case where the outline of the filament element viewed in the coil axis direction is substantially circular, that is a perfect circle or a shape close to a perfect circle, but distorted due to the variation in processing accuracy. Therefore, the space in the central illuminance contributing region within the reflection mirror occupied by the filament assembly is increased compared to the conventional lamp. Accordingly, the central illuminance and the converging efficiency are improved.

[0026] If the outline is in the flattened shape, the filament element can be easily manufactured.
If the outline is in the rectangular shape, the racetrack shape, or the ellipsoidal shape, the filament element can be more easily manufactured. In this case, in particular, the filament can be manufactured using a core conventionally used for manufacturing the filament element. Therefore, it is very easy to manufacture the filament element, and it is preferable that the outline is in the racetrack shape or the ellipsoidal shape.

[0027] If the number of the plurality of filament elements is three, the number of peripheral filament elements is decreased, and this prevents that the light emitted from the central filament element is blocked by the peripheral filament elements. This increases the central illuminance and improves the converging efficiency. Also, since the number of the filament elements is decreased, the distance between each filament element can be lengthened, and this improves the resistance to shock and vibration, and realizes a long life.

[0028] It is preferable that the three filament elements are arranged in the bulb such that their winding axes are in the same plane, because the light distribution on the irradiated region can be consistent.
It is preferable that the reflection surface of the reflection mirror is in the shape of a spheroid or a paraboloid of revolution, and the inner diameter of the opening of the reflection mirror is from 30 [mm] to 100 [mm] inclusive, because it becomes easy to adjust the beam angle in a range from 7.5° to 12.5° inclusive, which is a so-called narrow angle.

[0029] The same effect as described above can be achieved by attaching a reflection mirror having a concave surface to the above-described lamp.
The same effect as described above can be achieved by incorporating the above-described lamp into a lighting fixture having a reflection mirror.
As described above, the present invention provides a reflection-mirror-equipped lamp comprising: a reflection mirror having a concave reflection surface; and a lamp built into the reflection mirror, wherein the lamp includes a bulb and a filament assembly that is set up within the bulb, the filament assembly includes a central filament element whose central axis is substantially the same as an optical axis of the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axis of the central filament element and the plane, and $0.2 \leq L_S/L_C \leq 0.9$ is satisfied, where L_C is a length of the central filament element and L_S is a length of the peripheral filament element.
Therefore, the length L_S of the peripheral filament element can be relatively longer than the length L_C of the central filament element or the length L_C of the central filament element can be relatively shorter than the length L_S of the peripheral filament element. This improves the central illuminance from the conventional reflection-mirror-equipped lamp, and the maximum central illuminance can be achieved, and the beam angle can be narrowed. Therefore, with the reflection-mirror-equipped lamp of the present invention, the central illuminance is improved from that of the conventional reflection-mirror-equipped lamp, and favorable light distribution properties can be achieved with a narrow angle type.

[0030] If the distance D_1 between the central filament element and each peripheral filament element is from 0.1 [mm] to 2. 2 [mm] inclusive, the space in the central illuminance contributing region within the reflection mirror occupied by the filament assembly can be increased. Also, it becomes possible to prevent the arc discharge caused between the central filament element and each peripheral filament element which are included in the above-described filament assembly. Accordingly, the converging efficiency can be improved from the conventional reflection-mirror-equipped lamp, and the burnout of each filament element can be prevented.

[0031] The above-described effect is not limited to the case where the reflection mirror is attached to the lamp, but can be achieved by the case where the reflection mirror is included in the lighting apparatus to which the lamp is to be attached. In this case, however, the central axis of the lamp should be the same as the optical axis of the reflection mirror. Also, the above-described effect is not limited to the case of the reflection-mirror-equipped lamp, but can be achieved if the reflection mirror is removed from the reflection-mirror-equipped lamp, and the lamp without the reflection mirror is incorporated into the lighting apparatus including the reflection mirror. In this case, however, the central axis of the lamp, not equipped with the reflection mirror, should be the same as the optical axis of the reflection mirror.

[0032] The above-described effect can be achieved in the case where the reflection-mirror-equipped lamp is attached to a lighting apparatus.
As described above, the present invention provides a lamp comprising: a bulb; and a filament assembly that is set up within the bulb and includes at least three straight filament elements, wherein the filament elements are arranged around a central axis of the bulb such that central axes of the filament elements are parallel to the central axis of the bulb, and intersection points of the central axes of the filament elements and a plane vertical to the central axis of the bulb substantially form a regular polygon whose centroid is an intersection point of the central axis of the bulb and the plane, and $0.25 \leq r/R \leq 0.75$ is satisfied, where R is a maximum inner diameter of a portion of the bulb corresponding to the filament assembly, and *r* is a maximum outer diameter of the filament assembly. Therefore, the convection zone generated between the bulb and the filament assembly during the lighting is thin, and this suppresses the amount of evaporation of the tungsten included in the filament assembly. Also, this suppresses increase of the temperature of the bulb and the filament assembly, and prevents the burnout of the filament assembly, blackening of the internal surface of the bulb caused by the evaporated material of the filament assembly adhered to the bulb, and damage to the bulb. This means that the lamp of the present invention achieves a longer life than the conventional lamp.

[0033] The above effect can be achieved in the case where the lamp is equipped with the reflection mirror, and the central axis of the bulb in the longitudinal direction is the same as the optical axis of the reflection mirror.
Also, the same effect can be achieved by a lamp built into a reflection mirror of a lighting apparatus, the lamp comprising: a bulb; and a filament assembly that is set up within the bulb, wherein the filament assembly includes a central filament element whose central axis is substantially the same as an optical axis of the reflection mirror when the lamp is built into the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element; the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axes of the central filament element and the plane, and $0.25 \leq r/R \leq 0.75$ is satisfied, where R is a maximum inner diameter of a portion of the bulb corresponding to the filament assembly, and r is a maximum outer diameter of the filament assembly.

[0034] Also the same effect can be achieved by a reflection-mirror-equipped lamp comprising: a reflection mirror having a concave surface; and a lamp built into the reflection mirror, wherein the lamp includes a bulb and a filament assembly that is set up within the bulb, the filament assembly includes a central filament element in a straight shape, whose central axis is substantially the same as an optical axis of the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element, the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axis of the central filament element and the plane, and $0.25 \leq r/R \leq 0.75$ is satisfied, where R is a maximum inner diameter of the bulb and r is a maximum outer diameter of the filament assembly.

[0035] If the $0.2 \leq L_S/L_C \leq 0.9$ is satisfied where L_C is a length of the central filament element and L_S is a length of the peripheral filament element, the length L_S of the peripheral filament element can be relatively shorter than the length L_C of the central filament element or the length L_C of the central filament element can be relatively longer than the length L_S of the peripheral filament element. This improves the central illuminance from the conventional reflection-mirror-equipped lamp, and the central illuminance can become the highest within the irradiated area, and the beam angle can be narrowed. Therefore, with the reflection-mirror-equipped lamp of the present invention, the central illuminance is improved from that of the conventional reflection-mirror-equipped lamp, and favorable light distribution properties can be achieved with a narrow angle type.

[0036] If the distance D_1 between the central filament element and each peripheral filament element is from 0.1 [mm] to 2.2 [mm] inclusive, the space in the central illuminance contributing region within the reflection mirror occupied by the filament assembly can be increased. Also, it becomes possible to prevent the arc discharge caused between the central filament element and each peripheral filament element which are included in the above-described filament assembly. Accordingly, the converging efficiency can be improved from the conventional reflection-mirror-equipped lamp, and the burnout of each filament element can be prevented. This is preferable because this realizes a long life

[0037] The same effect can be achieved by a lighting apparatus that includes the above-described lamp.

The above-described effect can be achieved in the case where the reflection-mirror-equipped lamp is incorporated in a lighting apparatus.

Brief Description of the Drawings

[0038]

[FIG.1] A structure view schematically showing a structure of a lighting apparatus according to the first embodiment, in which a halide lamp is built into a reflection-mirror-equipped lighting fixture.
[FIG.2] A structure view schematically showing a structure of a halide lamp according to the first embodiment, which is to be built into the lighting apparatus.
[FIG.3] A perspective view schematically showing a lead and a support lead which support a filament assembly included in a halide lamp according to the first embodiment.
[FIG.4] A perspective view schematically showing a filament assembly set up within a bulb of a halide lamp according to the first embodiment, and a lead and a support lead which support the filament assembly.
[FIG.5] A cross-sectional view schematically showing a filament assembly included in a halide lamp according to the first embodiment, cut in a direction vertical to a bulb axis.
[FIG.6] A perspective view schematically showing a lead and a support lead which support a filament assembly included in a halide lamp according to the second embodiment.
[FIG.7] A perspective view schematically showing a filament assembly set up within a bulb of a halide lamp according to the second embodiment.
[FIG.8] A cross sectional view schematically showing a filament assembly included in a halide lamp according to the second embodiment, cut in a direction vertical to a bulb axis.
[FIG.9] A graph showing a relation between a central illuminance of a filament assembly and a distance between filament elements (coils) based on a simulation result, in regard to the first embodiment and the second embodiment.
[FIG.10] A graph showing a relation between a central illuminance of a filament assembly including three filament elements and a distance between filament elements (coils) based on a simulation result, in regard to the second embodiment.
[FIG.11] A graph showing a relation between a central illuminance of a filament assembly including three filament elements and a distance between filament elements (coils) based on a actual measurement, in regard to the second embodiment.
[FIG.12] A graph showing a relation between a beam angle and a distance between filament elements based on a actual measurement, in regard to a filament assembly according to the second embodiment, including three filament elements.
[FIG.13] A structure view schematically showing an arrangement of coils in a plane vertical to coil axes in regard to each sample used in examinations of light distribution properties and a central illuminance according to the second embodiment.
[FIG.14] A cross sectional view schematically showing a reflection-mirror-equipped halide lamp according to the third embodiment.
[FIG.15] A cross sectional view schematically showing a reflection-mirror-equipped halide lamp according to the fifth embodiment.
[FIG.16] A cross sectional view schematically showing a filament assembly included in a reflection-mirror-equipped halide lamp according to the fifth embodiment, cut in an optical axis direction.
[FIG.17] A cross sectional view schematically showing a filament assembly included in a reflection-mirror-equipped halide lamp according to the fifth embodiment, cut in a direction vertical to an optical axis direction.
[FIG.18] A graph showing a ratio between a length of a central filament element and a length of each peripheral filament element, and a beam angle, inregardtoareflection-mirror-equippedhalidelampaccording to the fifth embodiment.
[FIG. 19] A graph showing a lighting distribution curve when a ratio of a length of a central filament element to a length of a peripheral filament element is 0.9, in regard to a reflection-mirror-equipped halide lamp according to the firth embodiment.
[FIG.20] A graph showing a lighting distribution curve when a ratio of a length of a central filament element to a length of a peripheral filament element is 0.6, in regard to a reflection-mirror-equipped halide lamp according to the firth embodiment.
[FIG.21] A structure view schematically showing a halide lamp according to the eighth embodiment.
[FIG. 22] A cross sectional view showing a filament assembly included in a halide lamp according to the eighth embodiment, cut in a bulb axis direction.
[FIG.23] A cross sectional view showing a filament assembly included in a halide lamp according to the eighth

embodiment, cut in a direction vertical to a bulb axis direction.

[FIG.24] A cross sectional view showing another variation of filament assembly included in a halide lamp according to the ninth embodiment, cut in a direction vertical to a bulb axis direction.

[FIG.25] A structure view showing a structure of a lighting apparatus according to the ninth embodiment in which a halide lamp is built into a reflection-mirror-equipped lighting fixture.

[FIG.26] A cross sectional view showing a filament element included in a halide lamp according to the ninth embodiment and the twelfth embodiment, cut in an optical axis direction.

[FIG.27] A cross sectional view showing a filament element included in a halide lamp according to the ninth embodiment and the twelfth embodiment, cut in a direction vertical to an optical axis direction.

[FIG. 28] A cross sectional view showing another variation of filament assembly included in a halide lamp according to the ninth embodiment, cut in a direction vertical to a bulb axis direction.

[FIG.29] A structure view showing a structure of a reflecting-mirror-equipped halide lamp according to the tenth embodiment.

[FIG.30] A structure view showing a structure of a reflection-mirror-equipped halide lamp according to the eleventh embodiment.

[FIG. 31] A graph showing a relation between a beam angle and a ratio of a length of a central filament element to a length of a peripheral filament element, in regard to a reflection-mirror-equipped halide lamp according to the eleventh embodiment.

[FIG.32] A graph showing a lighting distribution curve when a ratio of a length of a central filament element to a length of a peripheral filament element is 0.9, in regard to a reflection-mirror-equipped halide lamp according to the eleventh embodiment.

[FIG.33] A graph showing a lighting distribution curve when a ratio of a length of a central filament element to a length of a peripheral filament element is 0.6, in regard to a reflection-mirror-equipped halide lamp according to the eleventh embodiment.

[FIG. 34] A graph showing a light distribution curve of a conventional reflection-mirror-equipped halide lamp.

Explanation of References

[0039]

1, 79, 88	reflection-mirror-equipped halide lamp
2, 80, 89, 112, 138	reflection mirror
3, 31, 53, 90, 114, 139	halide lamp
4, 34, 81, 91, 116, 140	base
4a, 4b, 35a, 35b, 92a, 92b, 117a, 117b, 141a, 141b	terminal
5, 57, 59, 82, 93, 111, 143	opening part
6, 83, 94, 144	neck part
7, 61, 84, 95, 119, 145	reflection surface
8, 60, 85, 96, 118, 146	front glass
9, 33, 87, 97, 121, 147	adhesive
10, 36, 62, 98, 122, 149	chip-off part
11, 37, 63, 99, 123, 150	light emitting part
12, 40, 66, 100, 120, 148	sealing part
13, 32, 56, 101, 115, 142	bulb
14, 42, 52, 68, 78, 102	filament assembly
15, 43, 69, 103	internal lead
16, 44, 104, 129	metal foil
17, 45, 105, 128	internal lead
18	assembly
19, 70, 74, 106	central filament assembly
20, 21, 22, 71, 72, 73, 75, 76, 77, 107, 108, 109	peripheral filament element
38, 64, 124	short-diameter part
39, 65, 125	cylinder part
41, 67, 126	visible light transmitting and infrared reflecting filter
46, 47, 48, 49, 50, 51	filament element
54, 110, 137	lighting apparatus
55	reflection mirror
58, 113	lighting fixture

86	base
127, 135, 136	filament assembly
130	external lead
131, 132, 133, 134	coil (filament element)
228	support lead
328	stem glass

Best Mode for Carrying Out the Invention

<First Embodiment>

[0040] The following describes embodiments of the present invention, with reference to the drawings.
FIG.1 is a structure view schematically showing a part of a lighting apparatus according to the first embodiment, which includes a halide lamp that is built into a lighting fixture having a reflection mirror.
A lighting apparatus 110 as the first embodiment of the present invention, which is shown in FIG.1, is a spot light or the like mainly used for general lighting, for instance. A light is emitted from an opening part 111. The lighting apparatus 110 includes a cylindrical lighting fixture 113 in which a reflection mirror 112 is housed, and a halide lamp 114 whose rated power is 65 [W] (rated voltage is 110 [V]). The halide lamp 114 is built into the reflection mirror 112.
The rated voltage of the halide lamp 114 is not limited to the above-described value, and it may be any value in a range from 100 [V] to 250 [V] inclusive.
A central axis X_6 in the longitudinal direction of a bulb 115 of the halide lamp 114 is substantially the same as an optical axis Y_6 of the reflection mirror 112.
A receiver (not illustrated), to which a base 116 (see FIG.2) is attached, is set up at the bottom of the lighting fixture 113.
[0041] A front glass 118 is attached to the reflection mirror 112, and a reflection surface 119 is formed on the internal surface of the reflection mirror 112. The reflection surface 119 is in the shape of an external surface of a spheroid, a paraboloid, or the like. An interference multilayer film formed of metal films such as aluminum and chrome, and silicon dioxide (SiO_2), titanium dioxide (TiO_2), magnesium fluoride (MgF) and zinc sulfide (ZnS) and so on is formed on the reflection surface 119. If necessary, a facet may be formed on the reflection surface of the reflection mirror.
[0042] According to the lighting apparatus 110, the reflection mirror 112 is detachable from the lighting fixture 113 for replacement of the halide lamp 114. Alternatively, the reflection mirror 112 may be fixed to the lighting fixture 113 and the front glass 118 may be detachable from the reflection mirror 112.
The shape of the lighting fixture 113 is not limited to the cylindrical shape. Other well-known shapes are applicable.
[0043] The lighting fixture 113 , which includes the reflection mirror 112, is well known. Therefore, the details of the lighting fixture 113 are not explained here, and only the details of the halide lamp 114, which possesses the main characteristic portion of the present invention, are explained below. This means that various kinds of well-known lighting fixtures (including that for studio use) may be used instead of the lighting fixture 113 shown in FIG.1.
FIG.2 is a structure view schematically showing a part of a halide lamp according to the first embodiment, which is to be built into the lighting apparatus.
[0044] As FIG. 2 shows, the halide lamp 114 includes a bulb 115 formed of silica glass, hard glass or the like, and a base 116 of an E type for instance, which is fixed to the bulb 115 with an adhesive on the side closer to a sealing part 120. The bulb 115 includes, as integral parts, a chip-off part 122 as a remainder resultant from chipping off of the sealing, a light emitting part 123 substantially in a shape of a spheroid, a short-diameter part 124, a cylinder part 125 substantially in a cylindrical shape, and a sealing part 120 formed by the well-known pinch seal method. An infrared reflecting film 126 that transmits a visible light is formed on the outer surface of each of the chip-off part 122, the light emitting part 123 and the short-diameter part 124.
[0045] Here, the term "substantially in a shape of a spheroid" includes, in addition to a perfect spheroid, a shape transformed from a perfect spheroid due to variation in accuracy of glass processing.
The shape of the bulb 115 is not limited to the above-described shape including, as integral parts, the chip-off part 122, the light emitting part 123 substantially in a shape of a spheroid, the short-diameter part 124, the cylinder part 125 substantially in a cylindrical shape, and the sealing part 120. Alternatively, well-known bulbs in various shapes may be used. For instance, the bulb 115 may include, as integral parts, the chip-off part (sometimes not included), the light emitting part, the short-diameter part and thesealingpart. Alternatively, the bulb 115 may include the chip-off part (sometimes not included), the light emitting part and the sealing part. Alternatively, the bulb 115 may include the chip-off part (sometimes not included), a light emitting part substantially in a cylindrical shape and the sealing part.
As a matter of course, the light emitting part may be substantially in a spherical or substantially in a shape of a combination of a plurality of ellipsoids, instead of the above-described spheroidal shape.
[0046] A filament assembly 127 is set up within the light emitting part 123, and a predetermined amount of a halogen substance and a rare gas, or a halogen substance and a rare gas and a nitrogen gas, are enclosed within the light

emitting part 123.

One end of an internal lead 128 made of tungsten or the like is electrically and physically connected to the filament assembly, and the other end of the internal lead is connected to one end of the external lead 130 via a metal foil 129 made of molybdenum sealed by the sealing part 120. The other end of the external lead 130 is extended outside of the bulb 115, and electrically connected to terminals 117a and 117b of the base 116. In addition, one end of a support lead 228, used for realizing the following structure of the filament elements included in the filament assembly 127, is connected to a stem glass 328.

[0047] FIG. 3 is a perspective view schematically showing a lead and a support lead for supporting and feeding the filament assembly included in the halide lamp according to the first embodiment. FIG. 4 is a perspective view schematically showing the filament assembly set up within the bulb of the halide lamp according to the first embodiment and a lead and a support lead for supporting and feeding the filament assembly. FIG.5 is a cross-sectional view schematically showing the cross section of the filament assembly included in the halide lamp according to the first embodiment which is cut in the direction vertical to the bulb axis X_6.

[0048] As FIG.3 to FIG.5 show, the filament assembly 127 includes a plurality of (e.g. four) filament elements (coils) 131, 132, 133 and 134. These four filament elements (coils) 131, 132, 133 and 134 are electrically connected in series. The filament assembly 127 is positioned to include a focal point F_6 of the reflection mirror 112. In other words, if the four filament elements (coils) are assumed as one column body (represented by dotted lines in FIG.5), the focal point F_6 is positioned within the column or on the surface of the column. This means, in reality, that the focal point F_6 is positioned within or on the surface of any of the filament elements (coils) 131, 132, 133 and 134, or positioned between any two of the coils (131 and 132, 131 and 133, 131 and 134, 132 and 133, 132 and 134, or 133 and 134). In this embodiment, the center point of the filament assembly is substantially the same as the focal point F_6 of the reflection mirror 112. However, a point F_0 on the surface of the filament assembly may be positioned at the focal point F_6 as FIG.5 shows.

[0049] Note that FIG.1 schematically shows the filament elements (coils) 131, 132, 133 and 134 assumed as one column. FIG.5 shows only the outline of the filament elements (coils) 131, 132, 133 and 134 schematically.

Each of the filament elements (coils) 131, 132, 133 and 134 is made of tungsten, and is a single-wound coil substantially extending linearly. The outline of each filament element viewed in the longitudinal direction is not in a substantially circular shape. Preferably, the outline of each filament element is in a flattened shape, such as in a rectangular shape, or substantially in a racetrack (an ellipse) shape, which includes two semicircles facing each other such that the curved lines spread outward and two parallel straight lines connecting the two semicircles.

[0050] If each of the filament elements (coils) 131, 132, 133 and 134 are formed such that the outline of each filament element viewed in the longitudinal direction is substantially in a shape of a racetrack (an ellipse) shape, a length L_{S4} (see FIG.4) of each of the filament elements (coils) 131, 132, 133 and 134 can be shortened compared to the length of the conventional coil.

Here, the above-described term "substantially circular shape" includes, in addition to the perfect circle, a shape close to the perfect circle but transformed from a perfect circle due to variation in accuracy of the manufacturing process or the like. That is to say, "not in a substantially circular shape" means that the shape is different from both the perfect circular shape and the above-described shape that is close to the perfect circular shape. Also, "substantially extending linearly" means that the coil wound around the core is not bent by intention, but may be bent due to the variation in accuracy of the manufacturing process, or the like. Also, the single-wound coil substantially extending linearly may be twisted around the central axis of the single-wound coil.

[0051] The outline of the filament elements (coils) 131, 132, 133 and 134 viewed in the longitudinal direction, which is not substantially in the circular shape, may be substantially in an ellipsoid shape, an oblate ellipsoid shape, a polygon shape, or the like, and the shape is not limited to the above-described shape (i.e. the shape that is not substantially in the circular shape). These outlines can be realized by appropriately changing, in the manufacturing process, the number of cores around each of which the wire is to be wound, the shape of each core, the arrangement of the cores, and so on.

[0052] In the case of forming the filament elements (coils) 131, 132, 133 and 134 such that the outline of the filament elements is substantially in the racetrack (ellipse) shape, each of the filament elements (coils) 131, 132, 133 and 134 is formed by winding tungsten wires each having the diameter (the wire diameter) of 0.015 [mm] to 0.100 [mm] (0. 040 [mm], for instance) around each of two parallel cores adjacent to each other. Here, the pitch of the tungsten wire is 0.05 [mm] to 0.07 [mm] . Accordingly, the radius of each of the above-described semicircle is 0.24 [mm], and length of the above-described straight lines is 0.4 [mm]. Regarding each of the filament elements (coils) 131, 132, 133 and 134, the length L_{S4} (see FIG. 4) is 4 [mm], the maximum width W_{max} (see FIG.5) is 0.88 [mm], and the minimum width W_{min} (see FIG.5) is 0.48 [mm].

[0053] The filament elements (coils) 131, 132, 133 and 134 may be formed by winding the above-described tungsten wire around each of three parallel cores adjacent to each other with the above-described pitch. If this is the case, it is preferable because the length L_{S4} (see FIG.4) of the each of the filament elements (coils) 131, 132, 133 and 134 becomes further shorter, and the ratio of the space occupied by the filament assembly 127 to the region contributing to the central illuminance (hereinafter called "the central illuminance contributing region") within the reflection mirror 112 increases.

[0054] As described above, as the maximum width W_{max} of each of the filament elements (coils) 131, 132, 133 and 134 viewed in the longitudinal direction increases, the acceptable coil length L_{S4} of each of the filament elements (coils) 131, 132, 133 and 134 decreases. However, the distance between the filament elements (coils) decreases at the same time, and accordingly, the resistance to vibration and shock, and the lifetime decreases. Therefore, it is preferable that the maximum width W_{max} is determined so as not to decrease the resistance to vibration and shock, and the lifetime.

[0055] Here, if the filament elements (coils) 131, 132, 133 and 134 are assumed as one coil (i.e. as the filament assembly (represented by the dotted lines in FIG.3 and FIG.5)), the size and the shape of the filament assembly 127 (the shape (except for the substantially circular shape), the size and the arrangement (including the distance between the coils (filament elements)) of each of the filament elements (coils) 131, 132, 133 and 134) are determined such that the one coil (the filament assembly) combined with the reflection mirror 112 is set up within the region contributing to the central illuminance (hereinafter simply called "the central illuminance contributing region"). Therefore, the size and the shape of the filament assembly 127 (the shape (except for the substantially circular shape), the size and the arrangement of each of the filament elements (coils) 131, 132, 133 and 134) are not limited to those described above as long as the filament assembly is set up within the above-described central illuminance contributing region. As described above, generally, the wire length and the wire diameter of the tungsten wire included in the filament assembly 127 are appropriately determined by the rated voltage, the rated power, and the rated lifetime (e.g. 3000 hours) of the halide lamp 114. Accordingly, the shape (except for the substantially circular shape) and the size of each of the filament elements (coils) 131, 132, 133 and 134 is determined within the range determined by the wire length and the wire diameter. For instance, the wire length of the tungsten wire used in a halide lamp whose rated power is 65 [W] is 420 [mm] to 480 [mm] and the wire diameter is 0.02 [mm] to 0.03 [mm] . Thewire length of the tungsten wire used in a halide lamp whose rated power is 100 [W] is 540 [mm] to 620 [mm] and the wire diameter thereof is 0.07 [mm] to 0.08 [mm].

[0056] Next, the positional relation between each of the filament elements (coils) is shown in FIG.4 and FIG.5.
As FIG.4 and FIG.5 show, one end surface of each of the filament elements (coils) 131, 132, 133 and 134 is substantially in the same plane. Also, since the coil length L_{S4} of each of the filament elements (coils) 131, 132, 133 and 134 is the same, the other end surface of each of the filament elements (coils) 131, 132, 133 and 134 is substantially in the same plane. In particular, among the two end surfaces of each of the filament elements (coils), it is preferable that the one end surface further from the sealing part 120 is substantially in the same plane. This is because the illuminance of each of the filament elements (coils) 131, 132, 133 and 134 can be consistent across the irradiated area, and the light distribution curves can be uniformed.

[0057] As FIG.5 shows, in the case of viewing the filament elements (coils) 131, 132, 133 and 134 in the longitudinal direction, a central axis a_{41} of the filament element (coil) 131 is identical with a central axis X_6 of the bulb 115, and central axes a_{41}, a_{42}, a_{43} and a_{44} of the filament elements (coils) 131, 132, 133 and 134 are parallel to the central axis X_6 of the bulb 115. When viewed in a plane vertical, to the coil axis direction, the filament element (coil) 132 is positioned such that a center line b_{42}, which passes through the center point of the filament element 132 shown in the figure and includes the part having the maximum width, is parallel to a center line b_{41}, which passes through the center point of the filament element 131 shown in the figure and includes the part having the maximum width, and the distance r_4 between the central axis a_{42} of the filament element (coil) 132 and the central axis of the a_{41} of the filament element (coil) 131 is 0.88 [mm].

[0058] When viewed in a plane vertical to the coil axis direction, the filament element (coil) 133 is positioned such that a center line b_{43}, which passes through the center point of the filament element 133 shown in the figure and includes the part having the maximum width, and a center line b_{41}, which passes through the center point of the filament element 131 shown in the figure and includes the part having the maximum width intersect with each other at an angle of 30 [°], and the distance r_4 between the central axis a_{43} of the filament element (coil) 133 and the central axis a_{41} of the filament element (coil) 131 is 0.88 [mm]. The distance r_5 between the central axis a_{43} of the filament element (coil) 133 and the central axis a_{44} of the filament element (coil) 134 is 1.52 [mm].
When viewed in a plane vertical to the coil axis direction, the filament element (coil) 134 is positioned such that a center line b_{44}, which passes through the center point of the filament element 134 shown in the figure and includes the part having the maximum width, and a center line b_{41}, which passes through the center point of the filament element 131 shown in the figure and includes the part having the maximum width intersect with each other at an angle of 30 [°], and the distance r_4 between the central axis a_{44} of the filament element (coil) 134 and the central axis a_{41} of the filament element (coil) 131 is 0.88 [mm]. The distance r_5 between the central axis a_{43} of the filament element (coil) 133 and the central axis a_{44} of the filament element (coil) 134 is 1.52 [mm].

[0059] Here, the filament elements (coils) adjacent to each other, namely (131, 132), (131, 134), (132, 133), (132, 134), (133, 134), are preferably as close as possible to each other to miniaturize the filament assembly 127. However, if the filament elements (coils) (131, 132), (131, 134), (132, 133), (132, 134), (133, 134) are too close to each other, a short circuit might be caused between the filament elements (coils) (131, 132), (131, 134), (132, 133), (132, 134) and (133, 134) if they contact with each other when a halide lamp 114 is vibrated during the lighting. Also, the temperature of the filament elements (coils) 131, 132, 133 and 134 are high in the region where distance between the filament elements (coils) adjacent to each other, namely (131, 132), (131, 134), (132, 133), (132, 134) and (133, 134), is shortest. Accordingly, tungsten of the tungsten wire rapidly evaporates, and this might shorten the lifetime. To avoid the short circuit caused by the contact between the filament elements (coils) (131, 132), (131, 134), (132, 133), (132, 134) and (133, 134) and the short lifetime, the distance r_4 is preferably not less than 0.88 [mm].

<Advantageous Effect of Lighting Apparatus with Halide Lamp according to First Embodiment>

As described above, with the structure of the lighting apparatus 110 according to the first embodiment of the present invention, firstly, due to the single-wound coil, the resistance to vibration is higher than the case where a multiple-winding coil is used, and the pitch of the coil is sufficiently short compared to the case of a multiple-winding coil. Secondly, since the single-wound coil is divided into a plurality of the coils, and furthermore, since each of the coils (filament elements) 131, 132, 133 and 134 viewed in the longitudinal direction is not substantially in a circular shape (preferably in a flattened shape such as a rectangular shape or a racetrack shape (ellipse shape)), the length L_{S4} of the filament elements (coils) 131, 132, 133 and 134 in the axis direction, namely the length of the filament assembly 127 in the longitudinal direction, can be sufficiently shortened. As a result, the space occupied by the filament assembly 127 in the central illuminance contributing region within the reflection mirror 112 can be increased, and accordingly the converging efficiency can be improved.

[0060] Furthermore, in the bulb 115, since the filament element (coil) 131 is positioned such that the central axis a_{41} is the same as the optical axis Y_6 of the reflection mirror 112 (the axis X_6 of the bulb 115), the central illuminance and the converging efficiency can be improved from the case where the filament element (coil) is not positioned in the optical axis Y_6 of the reflection mirror 112 (the axis X_6 of the bulb 115).

[0061] The above-described first embodiment describes the case of using the lighting fixture 113 (including the reflection mirror 112) shown in FIG.1. However, the same advantageous effect can be achieved in the case of using various kinds of well-known lighting fixture (including reflection mirror) instead of the lighting fixture 113. In other words, with the structure of the halide lamp 114 used in the lighting apparatus 110 according to the first embodiment of the present invention, firstly, due to the single-wound coil, the resistance to vibration is higher than the case of a multiple-winding coil is used, and the pitch of the coil is sufficiently short compared to the case of a multiple-winding coil. Secondly, since the single-wound coil is divided into a plurality of the coils, and furthermore, since each of the coils (filament elements) 131, 132, 133 and 134 viewed in the longitudinal direction is not substantially in a circular shape (preferably in a flattened shape such as a rectangular shape or a racetrack shape (ellipse shape)), the length L_{S4} of the filament elements (coils) 131, 132, 133 and 134 in the axis direction, namely the length of the filament assembly 127 in the longitudinal direction can be sufficiently shortened. As a result, in a state where the filament assembly is built into a lighting mirror of a well-known appropriate lighting fixture, the ratio of the filament assembly 127 to the central illuminance contributing region in the reflection mirror can be increased, and accordingly the converging efficiency can be improved.

<Evaluation>

[0062] An evaluation was performed for confirmation of the advantageous effect of the lighting apparatus 110 according to the first embodiment of the present invention. For simplification, the evaluation was performed not using the whole lighting apparatus, but using only the halide lamp 114 (hereinafter called "the present invention A") built into each of the reflection mirror (a narrow angle type) (including the front glass) of a well-known halide lamp (Product Number: JDR110V65WKN/5E11, manufactured by Matsushita Electric Industrial Co., Ltd.), the reflection mirror (a middle angle type) (including the front glass) of a well-known halide lamp (Product Number: JDR110V65WKM/5E11, manufactured by Matsushita Electric Industrial Co., Ltd.) and the reflection mirror (a wide angle type) (including the front glass) of a well-known halide lamp (Product Number: JDR110V65WKW/5E11, manufactured by Matsushita Electric Industrial Co., Ltd.).

[0063] Five reflection-mirror-equipped halide lamps having different mirror angles were manufactured. Each reflection-mirror-equipped halide lamp was lit at the rated power and the rated voltage, and the central illuminance [lx] in an irradiated area that is 1 [m] away from the halide lamp with the reflection mirror was measured. As a matter of course, although the value of the central illuminance measured in this evaluation is not the value of the lighting apparatus, it is substantially equal to the value of the lighting apparatus.

[0064] Also, for comparison, fifteen halide lamps (hereinafter called "the comparative example A") were manufactured. Each of these halide lamp has the rated power of 65 [W] (rated voltage is 110 [V]) and has the same structure as the halide lamp 114 according to the first embodiment of the present invention whose rated power is 65 [W] (rated voltage is 110 [V]), except for that a triple winding coil is used as the filament assembly. Each of each five of the comparative examples A was built into one type of well-known reflection mirrors (including the front glass) that is the same as the present invention *A*, and the central illuminance [lx] was measured.

[0065] Here, regarding the triple-wound coil, the wire length of the tungsten wire is 460 [mm], the wire diameter is 0.052 [mm], the mandrel diameter of the first coil is 0.12 [mm], the pitch of the first coil is 0.14 [mm], the mandrel diameter of the second coil is 0.28 [mm], the pitch of the second coil is 0.55 [mm], the mandrel diameter of the third coil is 1.2

[mm], and the pitch of the third coil is 1.5 [mm].

[0066] The value of the central illuminance [1x] is the average of those of the five samples. Furthermore, since the converging efficiency is defined as the illuminance per power [lx/W] in this description, comparing the central illuminance of the present invention A and the central illuminance of the comparative example A substantially means comparing the converging efficiency of the present invention A and the converging efficiency of the comparative example A.

The result of the evaluation shows that, regarding the case of the present invention *A*, the central illuminance of the narrow angle type is 9390 [lx], the central illuminance of the middle angle type is 5092 [lx], and the central illuminance of the wide angle type is 2072 [lx], whereas, regarding the case of the comparative example *A*, the central illuminance of the narrow angle type is 5587 [lx], the central illuminance of the middle angle type is 3005 [lx], and the central illuminance of the wide angle type is 1421 [lx].

[0067] As described above, according to the present invention *A*, compared to the comparative example *A*, the central illuminance is 1.68 times higher in the case of the narrow angle type, 1.69 times higher in the case of the middle angle type, and 1.45 times higher in the case of the wide angle type.

The beam angle of the present invention A of each beam angle type is almost the same as the beam angle of the comparative examples A.

Here, in the above-described comparison, the present invention A and the comparative example A were lit at the same power (65 [W]). Accordingly, the improvement rate of the illuminance is the same as the improvement rate of the converging efficiency [lx/W]. Therefore, it is confirmed that the converging efficiency of the present invention A is improved from that of the comparative example A.

<Second Embodiment>

A lighting apparatus according to the second embodiment is different from the first embodiment only in the structure of the filament assembly. Therefore, other respects are not described in the following.

[0068] FIG.6 is a perspective view schematically showing a lead and a support lead for supporting and feeding the filament assembly included in the halide lamp according to the second embodiment. FIG.7 is a perspective view schematically showing the filament assembly set up within the bulb of the halide lamp according to the second embodiment and a lead and a support lead for supporting and feeding the filament assembly. FIG. 8 is a cross-sectional view schematically showing the cross section of the filament assembly included in the halide lamp according to the second embodiment which is cut in the direction vertical to the bulb axis X_6.

[0069] In the second embodiment, the filament assembly 136 includes three filament elements (coils) 131, 132 and 133 used in the first embodiment as FIG.7 and FIG. 8 show, and the positions of the filament elements 131, 132 and 133 are different from the positions described in the first embodiment. The following is the positions of the coils. As FIG. 7 shows, the central axes a_{41}, a_{42} and a_{43} of the filament elements (coils) 131, 132 and 133 are parallel to the central axis X_6 of the bulb 115 in the longitudinal direction of the bulb 115. Also, when viewed from the longitudinal direction of the filament elements (coils) 131, 132 and 133, the filament element (coil) 131 is positioned such that the central axis a_{41} is the same as the central axis X_6 of the bulb 115. The filament element (coil) 132 is positioned such that the center line C_{42}, which passes through the center point of the filament element 132 shown in the figure and includes the part having the minimum width of the filament element 132, is the same as the center line C_{41}, which passes through the center point of the filament element 131 shown in the figure and includes the part having the minimum width of the filament element 131, and furthermore, the distance r_6 between the central axis a_{42} of the filament element 132 and the central axis a_{41} of the filament element 131 is 0.88 [mm] . The filament element (coil) 133 is positioned such that the center line C_{43}, which passes through the center point of the filament element 133 shown in the figure and includes the part having the minimum width of the filament element 133, is the same as the center line C_{41}, which passes through the center point of the filament element 131 shown in the figure and includes the part having the minimum width of the filament element 131, and furthermore, the distance r_7 between the central axis a_{43} of the filament element 133 and the central axis a_{41} of the filament element 131 is 0.88 [mm].

[0070] The above-described center lines c_{41}, c_{42} and c_{43} are straight lines that respectively pass through the central axes a_{41}, a_{42} and a_{43} of the filament elements (coils) 131, 132 and 133, and in a plane vertical to the central axes a_{41}, a_{42} and a_{43}, respectively intersect with the center lines b_{41}, b_{42} and b_{43} that respectively pass through the center points of the filament elements (coils) 131, 132 and 133 and respectively include the parts having the maximum width.

[0071] Although not illustrated, the filament element (coil) may be manufactured using a wire whose diameter is increased so as to be within a range from 110 [%] to 200 [%], where the wire diameter 0.4 [mm] is the 100 [%]. This is preferable because the length L_S of each of the filament elements (coils) 131, 132 and 133 becomes further shorter, and the ratio of each of the filament elements (coils) 131, 132 and 133 to the central illuminance contributing region increases. In this case, the distance between the filament elements (coils) 131, 132 and 133 becomes short, and the resistance to shock and vibration and the lifetime might be decreased. Therefore, it is more preferable that the distance between the filament elements (coils) 131, 132 and 133 is appropriately modified.

<Advantageous Effect of Lighting Apparatus to which Halide Lamp according to Second Embodiment is Attached>

Regarding the lighting apparatus according to the second embodiment, since the number of the filament elements (coils) whose axis is parallel to the axis of the filament element (coil) 131 positioned in the optical axis Y_6 of the reflection mirror 112 (the central axis X_6 of the bulb 115) is decreased compared to the first embodiment, the light emitted from the filament element (coil) 131 positioned in the optical axis Y_6 of the reflection mirror 112 (the central axis X_6 of the bulb 115) contributes to improvement of the central illuminance without being interrupted by the filament elements (coils) positioned around the filament element (coil) 131. This improves the converging efficiency.

[0072] Also, in the lighting apparatus according to the second embodiment, since the number of the filament elements (coils) included in the filament assembly is decreased compared to the first embodiment, the distance between the filament elements (coils) can be increased. This improves the resistance to shock and vibration, and the lifetime.
Furthermore, in the lighting apparatus according to the second embodiment, the filament elements 131, 132 and 133 are positioned such that the respective axes of the filament elements 131, 132 and 133 are on the same plane. Accordingly, the light distribution on the reflecting region can be consistent.

<Evaluation>

{Comparison of Central Illuminance (Converging Efficiency)}

[0073] An evaluation was performed to confirm that the central illuminance of the lighting apparatus 110 including the filament assembly 136 according to the second embodiment of the present invention is improved compared to the central illuminance of the lighting apparatus 110 including the filament assembly 126 according to the first embodiment of the present invention.

(Size of Filament Element (Coil))
Coil Wire Diameter: 0.053 [mm]
Coil Wire Length: 463 [mm]
Overall Length of Coil: 5.5 [mm]
Coil Pitch (Distance between Central Axes of Coil Wires) : 0.074 [mm] Cross Section Shape of Coil: Racetrack (Ellipse) Shape
Maximum Coil Width (Wmax): 1.0 [mm]
Minimum Coil Width (Wmin): 0.5 [mm]
(Practical Example 1) The filament assembly of a practical example 1 includes three filament elements (coils) described above, and the filament elements (coils) are arranged as shown in the second embodiment. The length of each filament element (coil) is 5.5 [mm].

[0074] (Comparative Example 1) The filament assembly of a comparative example 1 includes four filament elements (coils) described above, and the filament elements (coils) are arranged as shown in the first embodiment. The length of each filament element (coil) is 4.0 [mm]. (Examination)
In this examination, regarding each of the filament assembly of the practical example 1 and the filament assembly of the comparative example 1, a filament element positioned in the optical axis of the reflection mirror (Hereinafter called "the central filament element") was fixed under the following conditions, and the distance between the central filament element and each of the other filament elements positioned around the central filament element were changed. A simulation was performed to measure the central illuminance changing in accordance with the change of the distance.

(Other Conditions)
Rated Power: 65 [W]
Rated Voltage: 110 [V]
Lamp Luminous Flux: 1100 [1m]
Outer Diameter of Reflection mirror: 50 [mm] (Diameter of Opening of Reflection mirror: 41 [mm])
Type of Reflection mirror: Narrow Angle Type (Beam Angle: 10 [°], Error Tolerance Range: ±2.5 [°])
(Result of Examination)

FIG.9 shows the result of the simulation. As FIG.9 shows, in each of the practical example 1 and the comparative example 1, the central illuminance is higher than that of the halide lamp using the conventional filament assembly when the distance between the filament elements is a certain length. Also, it is confirmed that the central illuminance of the practical example 1 is higher than that of the comparative example 1.

(Consideration)

[0075] From the result above, it is believed that the reason why the central illuminance of the comparative example

1 is lower than that of the practical example 1 is because the luminous flux of the central filament element is shielded by the peripheral filament elements, and the number of the peripheral elements of the comparative example 1 is larger than that of the practical example 1.
Therefore, in the case where the filament assembly has a structure in which the central filament element is positioned in the central axis of the optical axis of the reflection mirror and the peripheral filament elements are positioned around the central filament element, it is believed that the central illuminance decreases as the number of the peripheral filament element increases.

{Optimum Distance Evaluation}

[0076] To find the optimum distance between the central filament element and each of the peripheral filament elements that can heighten the central illuminance the most with the filament assembly 136 of the second embodiment, both a simulation and actual measurement were performed.
The size of the filament elements and other conditions are the same as those of the above-described examination. Therefore, they are omitted here.

(Simulation)

[0077] In the halide lamp including the filament assembly according to the practical example 1 used in the evaluation above, the distance between the central filament element and each of the peripheral filament elements were changed, and a simulation was performed to measure the central illuminance changing in accordance with the change of the distance and find the optimum distance at which the highest central illuminance is achieved.

(Result of Simulation)

[0078] FIG.10 shows the result of the simulation. As FIG.10 shows, when the distance between the filament elements is 0.015 [mm], the central illuminance of the practical example 1 is lower than that of the halide lamp including the conventional filament assembly. However, when the distance is between 0.02 [mm] and 0.1 [mm], the central illuminance of the practical example 1 is higher than that of the conventional lamp and the central illuminance increases as the distance increases. When the distance between the filament elements is from 0.1 [mm] to 0.2 [mm] inclusive, the central illuminance is at the maximum. When the distance between the filament elements is equal to or more than 0.2 [mm], the central illuminance decreases as the distance increases. Therefore, it is confirmed that the central illuminance is higher than that of the halide lamp including the conventional filament assembly when the distance between the filament elements is from 0.02 [mm] to 1.3 [mm] inclusive.

(Consideration of Simulation Result)

[0079] It can be assumed that the light emitted by each coil is shielded by each coil when the distance between the filament elements is very close to 0 [mm], and the central illuminance becomes lower than that of the conventional lamp. The central illuminance is at the maximum when the distance between the filament elements is from 0.1 [mm] to 0.2 [mm] inclusive, because the ratio of the filament assembly to the central illuminance contributing region is at the highest under the condition. When the distance is more than 0.2 [mm], the ratio of the filament assembly to the central illuminance contributing region decreases. As a result, the central illuminance becomes lower than that of the conventional lamp when the distance is more than 1.3 [mm].
[0080] Accordingly, under a constraint of the rated voltage and so on, theoretically, when the distance between the filament elements is from 0.02[mm] and 1.3 [mm] inclusive, the central illuminance and the converging efficiency are higher than that of the conventional lamp.
(Actual Measurement)
With the halide lamp including the filament assembly according to the practical example 1 used in the evaluation above, the distance between the central filament element and each of the peripheral filament elements were changed, and the central illuminance changing in accordance with the change of the distance was measured to find the optimum distance at which the highest central illuminance is achieved. At the same time, the beam angle was actually measured with changing the distance, to find the distance that can realize a desired beam angle.
Note that to simplify this comparative examination, a well-known halide lamp (Product Number: JDR110V65WKN/5E11, manufactured by Matsushita Electric Industrial Co., Ltd, Mirror Outermost diameter: 50 [mm], Diameter of Opening of Mirror: 41 [mm]) in that the filament assembly is replaced with the filament assembly according to the comparative examination was used.
[0081] In the comparative examination, regarding each of the sample filament assemblies, the wire diameter is 0.053

[mm], the wire length is 463 [mm] and the pitch is 0.074 [mm], and a filament element formed by winding tungsten is included. The outline of the filament element is substantially in a racetrack (ellipse) shape in a plane that is vertical to the axis of the filament element, and the above-described maximum width Wmax is 1 [mm] and the minimum width Wmin is 0.5 [mm].

(Result of Actual Measurement)

[0082] FIG.11 is the result of the actual measurement showing the relation between the distance between the filament elements and the central illuminance. FIG.12 is the result of the actual measurement showing the relation between the distance between the filament elements and the beam angle.
As FIG .11 shows, when the distance is less than 0.3 [mm], the arc discharge and short circuit occur, and the central illuminance can not be measured. When the distance is equal to or more than 0.3 [mm] and less than 1.25 [mm], the central illuminance is higher than that of the conventional lamp. When the distance is equal to or more than 1.25 [mm], the central illuminance is lower than that of the conventional lamp.
[0083] Also, as FIG. 12 shows, when the distance is less than 0. 3 [mm], the beam angle can not be measured because of the above-described reason. When the distance is from 0.3 [mm] and 0.75 [mm] inclusive, the beam angle is within the standard beam angle range (from 7.5° to 12.5° inclusive). When the distance is more than 0.75 [mm] and equal to or less than 1.1 [mm], the beam angle is less than the lower limit (15°) of the so-called middle angle type. When the distance is more than 1.1 [mm], the beam angle is within the range of the beam angle of the middle angle type.

(Consideration of Result of Actual Measurement)

[0084] In view of the examination result described above, under the constraint of the rated voltage and so on, it is preferable to set the distance from 0.3 [mm] to 0.75 [mm] inclusive to satisfy the standard of the beam angle (from 7.5° to 12.5° inclusive) and increase the central illuminance and the converging efficiency. Here, if the beam angle that is greater than the standard and not greater than the lower limit of the so-called middle angle type is acceptable, the distance may be set from 0.3 [mm] to 1.1 [mm] inclusive.

[Evaluation of Central Illuminance and Light Distribution]

[0085] Evaluation was performed to confirm that the central illuminance can be increased and the light distribution can be consistent with the structure of the filament assembly 136 according to the second embodiment.
The wire diameter of the coil, the wire length of the coil, and the other conditions are the same as described in the comparative examination of the central illuminance (converging efficiency). Therefore, the explanation is omitted here.
[0086] The following describes samples prepared for the evaluation.
FIG.13 schematically shows arrangement of coils of each sample used in this evaluation in a plan view that is vertical to the coil axis.
(Comparative Example 1) FIG. 13A shows a cross section of the filament assembly of a comparative example 1 cut along a plane that is vertical to the axis of a secondary coil. As FIG.13A shows, the filament assembly of the comparative example 1 is a so-called double-wound coil. More specifically, a primary coil formed by winding a tungsten wire is further wound to form the secondary coil.
[0087] (Comparative Example 2) FIG. 13C shows a cross section of the filament assembly of a comparative example 2 cut along a plane that is vertical to the axis of the filament assembly. As FIG.13C shows, four filament elements (coils) are included in the filament assembly of the comparative example 2. In a plane that is vertical to the winding axes of the coils, the coils (filament elements), each substantially in the racetrack (ellipse) shape, are positioned in four directions. The four filament elements are arranged such that an X axis intersects with the maximum width parts of two filament elements, and a Y axis intersects with the maximum width parts of the other two filament elements (coils), and the intersection point of the X axis and the Y axis that intersect at right angles is in the optical axis of the reflection mirror.
[0088] (Comparative Example 3) FIG. 13B shows a cross section of the filament assembly of a comparative example 3 cut along a plane that is vertical to the axis of the filament assembly. As FIG.13B shows, the filament assembly of the comparative example 3 is arranged such that the filament assembly of the comparative example 2 is rotated 45° around the intersection point of the X axis and the Y axis, and the optical axis of the reflection mirror is positioned in the minimum gap between the adjoining two coils (filament elements) whose respective center lines, which pass through the respective maximum width parts, form an angle of 45°. In other words, the central axis of the filament assembly is not the same as the optical axis.

(Comparative Example 4)

[0089] FIG.13D schematically shows a cross section of the filament assembly of a comparative example 4 cut along a plane vertical to the central axis of the filament assembly. As FIG.13D shows, three filament elements (coils) are included in the filament assembly of the comparative example 4, and the coils substantially in the racetrack (ellipse) shape are arranged such that the central axes of the filament elements form a right-angled isosceles triangle in a plane vertical to the winding axes of the coils, and the intersection point of the two sides having the same length is in the optical axis of the ref lection mirror.

[0090] (Practical Example 1) FIG.13E is a cross section of the filament assembly of a practical example 1 cut along a plane vertical to the central axis of the filament assembly. As FIG.13E shows, the filament assembly of the practical example 1 is the same as the filament assembly described in the first embodiment. The filament assembly is positioned such that the center line that passes through the shortest width parts of two filament elements (coils) 131 and 132 is the same as the Y axis, and the Y axis and the X axis intersect to form a right angle, and this intersection point is in the optical axis of the reflection mirror.

[0091] (Practical Example 2) FIG.13F is a cross section of the filament assembly of a practical example 2 cut along a plane vertical to the central axis of the filament assembly. As FIG.13F shows, the filament assembly of the practical example 2 is the same as the filament assembly described in the second embodiment. The filament assembly is positioned such that the center line that passes through the respective shortest width parts of three filament elements (coils) 131, 132 and 133 is in the X axis, and the Y axis and the X axis intersect to form a right angle, and this intersection point is in the optical axis of the reflection mirror.

[0092] (Practical Example 3) FIG.13G is a cross section of the filament assembly of a practical example 3 cut along a plane vertical to the central axis of the filament assembly. As FIG. 13G shows, the filament assembly of the practical example 3 is different from the filament assembly of the practical example 2 only as to the ratio between the maximum width and the minimum width of each filament element (coil) viewed in a plane vertical to the winding axis of the coil. Therefore, the other explanations are omitted here. In each of the filament elements included in the filament assembly, the ratio of the maximum width and the minimum width in the plane vertical to the winding axis of the coil is 3:1.

(Evaluation)

[0093] The above examples were lit under the above-described conditions. The central illuminance on an irradiated area that is 1 [m] away from the light source was measured. The ratio among the illuminance of each sample was measured using the central illuminance of the comparative example 1 as a standard value. Then, the beam angles of the samples were measured in the X axis direction and the Y axis direction on each irradiated area corresponding to the X axis and the Y axis shown in FIG.13. The consistence of the light distribution was evaluated based on the result of the beam angle measurement. The following is a criterion of evaluation: The consistency of the light distribution on the irradiated area is excellent if the beam angle in the X axis direction and the Y axis direction is from 7.5° to 12.5° inclusive and if the difference between the beam angle measured in one of the X and Y axes as a standard angle and the other beam angle is not greater than 10 % of the narrower beam angle.

[0094] (Result of Evaluation)

[0095]

[Table 1]

	Number of Coils	Number of Winding	Shape of Cross-section of Coil	Distance between Coils [mm]	Coil Length [mm]	Coil Width [mm]	Coil Pitch [mm]	Central Illuminance [Lx]	Illuminance Ratio [%]	Beam Angle	Light Distribution Consistency
Comparative Example 1	1	Double	Circle	0.65 [mm] between Second-coil Axis and First-coil Axis	8	First Winding: ϕ0.35 Second Winding: ϕ1.65	First: 0.09 Second: 0.73	6500	100	X: 10° Y: 10°	Good
Comparative Example 2	4	Single	Racetrack (ellipse)	0.5 [mm] between Filament-assembly Axis and Outermost Coil Surface	4	Maximum Width: 1 Minimum Width: 0.5	0.074	5720	88	X: 17.2° Y: 17.4°	Bad
Comparative Example 3	4	Single	Racetrack (ellipse)	0.5 [mm] between Filament-assembly Axis and Outermost Coil Surface	4	Maximum Width: 1 Minimum Width: 0.5	0.074	7610	117	X: 9.0° Y: 13.6°	Bad
Comparative Example 4	3	Single	Racetrack (ellipse)	1.0 [mm] between Coil Axes	5.5	Maximum Width: 1.0 Minimum Width: 0.5	0.074	9080	140	X: 7.4° Y: 11.2°	Bad
Practical Example 1	4	Single	Racetrack (ellipse)	1.0 [mm] between Coil Axes	4	Maximum Width: 1 Minimum Width: 0.5	0.074	8320	128	X: 10.9° Y: 11.3°	Good
Practical Example 2	3	Single	Racetrack (ellipse)	1.0 [mm] between Coil Axes	5.5	Maximum Width: 1 Minimum Width: 0.5	0.074	9100	140	X: 9.2° Y: 9.5°	Good
Practical Example 3	3	Single	Racetrack (ellipse)	1.0 [mm] between Coil Axes	3.5	Maximum Width: 1.5 Minimum Width: 0.5	0.074	11830	182	X: 8.9° Y: 8.8°	Good

[0096] Table 1 shows the result of the evaluation. As Table 1 shows, when the central illuminance and the beam angle of the comparative example 1 is regarded as a standard for evaluating the other samples, the beam angles of the comparative example 2 measured in the X axis direction and the Y axis direction are not much different, but each beam angle is much greater than the desired beam angle that is between 7.5° and 12.5°. Furthermore, the central illuminance of the comparative example 2 is lower than that of the comparative example 1 (12% lower in the illuminance ratio). The distributed light forms concentric circles, but the center part is dark and the light distribution is not consistent.

[0097] Regarding the comparative example 3, the central illuminance is higher than that of the comparative example 1 (17% higher in the illuminance ratio). However, the beam angle in the Y axis direction is greater than 12.5°, and also greater than the beam angle in the X axis direction. The light distribution on the irradiated area is distorted and far from

concentric circles, which means that the light distribution is not consistent.
Regarding the comparative example 4, the central illuminance is higher than that of the comparative example 1 (40% higher in the illuminance ratio). The beam angle in the X axis direction is smaller than 7.5°, and also smaller than the beam angle in the Y axis direction. The light distribution on the irradiated area is distorted and far from concentric circles, which means that the light distribution is not consistent.

[0098] On the contrary, regarding the practical example 1, the central illuminance is higher than that of the comparative example 1 (28% higher in the illuminance ratio), and the beam angles in the X axis and Y axis directions are not much different. Also, each beam angle is within a range between 7.5° and 12.5° inclusive. This means that the desired beam angle and consistent light distribution are achieved.
Regarding the practical example 2, the beam angles in the X axis direction and Y axis direction are not much different. Also, each beam angle is within a range between 7.5°and 12.5° inclusive. The desired beam angle and a central illuminance higher than the practical example 1 are achieved, and the light distribution is more consistent than the practical example 1.

[0099] Regarding the practical example 3, the beam angles in the X axis direction and Y axis direction are not much different. Also, each beam angle is within a range from 7.5°to 12.5° inclusive. The desired beam angle and a central illuminance higher than the practical example 2 are achieved, and the light distribution is more consistent than the practical example 2.
(Consideration)
From the above-described result and consideration, it is believed that decreasing the number of the peripheral filament elements (coils) prevents the light emitted from the central filament elements from being shielded by the peripheral filament elements, and as a result, the central illuminance is increased.

[0100] Furthermore, from the result and the consideration of the comparative example 4 and the practical example 2, it is believed that the light distribution becomes consistent by placing the filament elements in the bulb such that the winding axes of the filament elements are in the same plane.
Furthermore, as the practical example 3 shows, from the result and the consideration above, the length of each filament element in the coil axis direction can be decreased as the maximum width of the filament element is increased so as to be longer than the minimum width in the plane that is vertical to the coil axis of the filament element whose outline is substantially in the racetrack (ellipse) shape. This further increases the space occupied by the filament assembly in the above-described central illuminance contributing region, and further increases the central illuminance. Here, note that it is believed that the resistance to shock and vibration and the lifetime deteriorate as the maximum width is increased so as to be longer than the minimum width. Therefore, it is preferable that the maximum width is longer than the minimum width as long as the deterioration is not caused.
(Third Embodiment)
FIG.14 schematically shows the cross section of a reflection-mirror-equipped halide lamp according to the third embodiment.

[0101] As FIG.14 shows, a reflection-mirror-equipped halide lamp 137 according to the third embodiment, whose rated power is 65 [W] (rated voltage: 110 [V]), includes a reflection mirror 138 having a concave surface whose mirror diameter φ_5 is 35 [mm] to 100 [mm] (outermost diameter is 50 [mm], for instance), a halide lamp 139 housed in the reflection mirror 138, and a base 140 (of an E type, for instance) attached to the end of the reflection mirror 138.

[0102] A central axis X_8 of the halide lamp 139 in the longitudinal direction of the bulb 142 is substantially the same as the optical axis Y_7 of the reflection mirror 138.
The reflection mirror 138 is made of hard glass, silica glass or the like, and an opening part 143 that emits light is formed on the one side of the reflection mirror 138, and a neck part 144 in a cylindrical shape is formed on the other end. A reflection surface 145 in the shape of a spheroid, a paraboloid or the like is formed on the internal surface of the reflection mirror 138. A front glass 146 is fixed to the opening part 143 by a well-known latch (not illustrated). To fix the front grass 146, a well-known adhesive (not illustrated) may be used instead of the latch, or the latch and the adhesive may be used together. As a matter of course, the front glass 146 is not necessarily required.

[0103] Outside the neck part 144, the base 140 is placed to cover the whole body of the neck part 144, and fixed with an adhesive 147. Inside the neck part 144, a sealing part 148 of the halide lamp 139 is inserted into the neck part 144, and fixed with the adhesive 147 in the same manner.
On the reflection surface 145, a multilayer interference film including silicon dioxide (SiO_2), titanium dioxide (TiO_2), magnesium fluoride (MgF), zinc sulfide (ZnS), and so on is formed in addition to a metal film, such as aluminum and chrome. If necessary, a facet may be formed on the reflection surface 145.

[0104] The halide lamp 139 includes the bulb 142 made of silica glass, hard glass or the like, and a light emitting body 127 used with the halide lamp 114 included in the lighting apparatus 110 according to the first embodiment of the present invention. This means that the halide lamp 139 has the same structure as the halide lamp 114, except for the shape of the bulb 142. Therefore, as to the structure of the halide lamp 139, only the differences from the halide lamp 114 are described next.

[0105] One end of an internal lead 128 made of tungsten are electrically and physically connected to both ends of the light emitting body 127. The other end of the internal lead 128 is extended to the outside the bulb 142, and electrically connected to terminals 141a and 141b of the base 140.

[0106] The bulb 142 includes, as integral parts, a chip-off part 149 as a remainder resultant from chipping off of the sealing, a light emitting part 150 substantially in a cylindrical shape and whose one end is tapered, and a sealing part 148 formed by a well-known pinch seal method. A visible light transmitting and infrared reflecting film is not formed on the outer surface of the bulb 142. However, the visible light transmitting and infrared reflecting film may be formed on the outer surface of the light emitting part 150 and so on, if necessary.

[0107] The structure of the bulb 142 is not limited to the structure including, as integral parts, the chip-off part 149, a light emitting part 150 substantially in a cylindrical shape and whose one end is tapered and a sealing part 148. Instead, various types of well-known bulbs may be used. For example, the bulb may include, as integral parts, a chip-off part (may not be included in some cases), a light emitting part substantially in a cylindrical shape and not having a tapered end and a sealing part. Alternatively, the bulb may include, as integral parts, a chip-off part (may not be included in some cases), a light emitting part substantially in a spheroidal shape, a reduced-diameter part, a sealing part and a cylinder part. Alternatively, the bulb may include, as integral parts, a chip-off part (may not be included in some cases), a light emitting part substantially in a spheroidal shape, a reduced-diameter part and a sealing part. Alternatively, the bulb may include, as integral parts, a chip-off part (may not be included in some cases), a light emitting part substantially in a spheroidal shape and a sealing part. As a shape of the light emitting part, in addition to the substantial spheroid shape, a substantial spherical shape, and a substantial compound spheroid shape are acceptable as well.

[0108] As FIG. 4 and FIG.5 show, the light emitting body 127 includes a plurality of, for instance, four coils 131, 132, 133 and 134. These four coils 131, 132, 133 and 134 are electrically connected serially. The light emitting body 127 is positioned to include a focal point F_7 of the reflection mirror 138. In other words, if the four coils 131, 132, 133 and 134 are assumed as one column (illustrated with dotted lines in FIG. 4 and FIG. 5), the focal point F_7 positions within the column or on the surface of the column. Accordingly, the focal point F_7 positions within or on the surface of any of the coils 131, 132, 133 and 134 in the actual light emitting body 127, or between two of the coils, namely (131 and 132), (131 and 134), (132 and 133), (132 and 134) and (133 and 134). In the example shown in FIG.14, the central point of the light emitting body 127 substantially positions at the focal point F_7 of the reflection mirror 138. However, a point F_0 on the surface of the light emitting body may be positioned at the focal point F_7.

[0109] Regarding FIG.14, note that the coils 131, 132, 133 and 134 are assumed as one body, and schematically illustrated as the light emitting body 127.
The positional relation among the coils 131, 132, 133 and 134 is shown in FIG.4 and FIG.5.
That is to say, one end of each of the coils 131, 132, 133 and 134 is substantially on the same plane. Since the coil length L_{S4} of each of the coils 131, 132, 133 and 134 is the same, the other end of each of the coils is on the same plane as well. It is especially preferable that the end of each coil which is far from the sealing part 120 is substantially on the same plane. This makes the illuminance on the area irradiated by each coil consistent. As a result, the light distribution curve can be uniformed.

[0110] Also, as FIG. 5 shows, when viewed in the longitudinal direction of the coils 131, 132, 133 and 134, the coils 131 and 133 oppose to each other with a gap of 1.2 [mm] so as to sandwich a central axis X_7 of the bulb 142, and the longitudinal axis direction b_{42} (b_{44}) of the coils 132 and 134 are substantially the same and vertical to the central axis X_7. The longitudinal axis direction b_{41} (b_{43}) and the longitudinal direction b_{42} and (b_{44}) are vertical to each other and their intersection point is on the central axis X_7.

[0111] The adjacent two coils (131, 132), (131, 134), (132, 133), (132, 134) and (133, 134) are as close as possible to each other to make a light emitting body 127 compact. However, if the adjacent two coils (131, 132), (131, 134), (132, 133), (132, 134) and (133, 134) are too close to each other, a short circuit might be caused when the halide lamp 114 is vibrated during the lighting and the coils touch each other. Furthermore, the temperature of the part of the coil closest to the adjacent coil is higher than the other parts. Accordingly, tungsten included in the tungsten lead is evaporated rapidly, and the lifetime might be shortened. Therefore, to avoid the short circuit caused when the coils touch each other when the halide lamp 114 is vibrated during the lighting, and that the lifetime becomes short, it is preferable to set the gap to be not less than 0.2 [mm].

[0112] As described above, with the structure of the reflection-mirror-equipped halide lamp 137 according to the third embodiment of the present invention, firstly, since a single-wound coil is used, resistance to vibration is improved compared to the case using a multiple winding coil, and the pitch can be reduced enough compared to the multiple winding coil. Secondly, since the single-wound coil is divided into a plurality of coils, and the shape of each of the coils 131, 132, 133 and 134 (see FIG.4 and FIG.5) viewed in the longitudinal direction is not substantially circular, the length of the light emitting body 127 in the optical axis Y_7 is shortened. As a result, the space occupied by the light emitting body 127 in the region contributing to the central illuminance in the reflection mirror 138 increases, and the converging efficiency can be improved.

[0113] Also, since the central illuminance can be improved in the above manner, it becomes unnecessary to form the visible light transmitting and infrared reflecting film to improve the central illuminance. This means that the prevention can achieve central illuminance as high as that of a conventional reflection-mirror-equipped halide lamp and using a double-wound coil, on the outer surface of the whose bulb a visible light transmitting and infrared reflecting film is formed. Therefore, it is possible to reduce the cost of the visible light transmitting and infrared reflecting film and the cost of the forming process for it. Also, since it is possible to omit the process for forming the film, manufacturing efficiency can be markedly improved.

[0114] Note that the same effect as the effect described above can be realized with the reflection-mirror-equipped halide lamp 137 according to the third embodiment if the filament assembly 136 according to the second embodiment is used instead of the filament assembly 127 shown in FIG.4 and FIG.5.

(Fourth Embodiment)

The lighting apparatus as a fourth embodiment of the present invention has the same structure as the lighting apparatus 110 as the first embodiment of the present invention, except for that in the lighting apparatus as the fourth embodiment, the reflection-mirror-equipped halide lamp 137 according to the third embodiment of the present invention is attached to the lighting fixture 113 (without the reflection mirror 112) of the lighting apparatus 110 according to the first embodiment of the present invention shown in FIG.1.

[0115] As described above, with the structure of the lighting apparatus according to the fourth embodiment, firstly, since a single-wound coil is used, resistance to vibration is improved compared to the case using a multiple winding coil, and the pitch can be reduced enough compared to the multiple winding coil. Secondly, since the single-wound coil is divided into a plurality of coils, and the shape of each of the coils 131, 132, 133 and 134 (see FIG.4 and FIG.5) viewed in the longitudinal direction is not substantially circular, the length of the light emitting body 127 (see FIG.1 and so on) in the optical axis Y_6 is shortened. As a result, the space occupied by the light emitting body 127 in the region contributing to the central illuminance in the reflection mirror 138 (see FIG.14) increases, and the converging efficiency can be improved.

[0116] Note that the same effect as the effect described above can be realized with the lighting apparatus according to the forth embodiment if the filament assembly 136 according to the second embodiment is used instead of the filament assembly 127 shown in FIG.4 and FIG.5.

(Fifth Embodiment)

The following describes the fifth embodiment of the present invention, with reference to drawings.

[0117] As FIG.15 shows, a reflection-mirror-equipped halide lamp 1 according to the fifth embodiment of the present invention, whose rated power is 65 [W] (rated voltage: 110 [V]), includes a reflection mirror 2 having a concave surface, a halide lamp 3 housed in the reflection mirror 2, and a base 4 (of an E type, for instance) attached to the end of the reflection mirror 2.

The mirror diameter φ_1 of the reflection mirror 2 is any value between 35 [mm] to 100 [mm] inclusive, and set to 50 [mm] in this embodiment.

[0118] The central axis X_1 of the halide lamp 3 in the longitudinal direction is substantially the same as the optical axis Y_1. The reflection mirror 2 is made of hard glass, silica glass or the like, and an opening part 5 that emits light is formed on the one s ide of the ref lection mirror 2, and a neck part 6 in a cylindrical shape is formed on the other end. A reflection surface 7 in the shape of a spheroid, a paraboloid or the like is formed on the internal surface of the reflection mirror 2. If necessary, a facet may be formed on the reflection surface 7.

[0119] A front glass 8 is fixed to the opening part 5 by a well-known latch (not illustrated). To fix the front grass 8, a well-known adhesive (not illustrated) may be used instead of the latch, or the latch and the adhesive may be used together. As a matter of course, the front glass 8 is not necessarily required.

Outside the neck part 6, the base 4 is placed to cover approximately a half of the body of the neck part 6, and fixed with an adhesive 9. Inside the neck part 6, a sealing part 12 of the halide lamp 3, which is described later, is inserted into the neck part 6, and fixed with the adhesive 9 in the same manner.

[0120] On the reflection surface 7, a multilayer interference film including silicon dioxide (SiO_2), titanium dioxide (TiO_2), magnesium fluoride (MgF), zinc sulfide (ZnS), and so on is formed in addition to a metal film, such as aluminum and chrome.

The halide lamp 3 includes a bulb 13, which is made of silica glass, hard glass or the like and includes, as integral parts, a chip-off part 10 as a remainder resultant from chipping off of the sealing, a light emitting part 12 substantially in a cylindrical shape, and a sealing part 148 formed by a well-known pinch seal method. The halide lamp 3 also includes an assembly 18 including, as integral parts, a filament assembly 14 as a light emitting body, an internal lead 15, a metal foil 16 and an external lead 17.

[0121] A visible light transmitting and infrared reflecting film may be formed on the outer surface of the bulb 13, if necessary.

Above-described filament assembly 14 is placed within a light emitting part 11, and a predetermined amount of a halogen substance and a rare gas within the light emitting part 11. One end of the internal lead 15 made of tungsten or the like is connected to the both ends of the filament assembly 14, and the other end of the internal lead is connected to one end of the external lead 17 via a metal foil 16 made of molybdenum sealed by the sealing part 12. The other end of the external lead 17 is extended outside of the bulb 3, and electrically connected to terminals 4a and 4b of the base 4.

[0122] As FIG.16 and FIG.17 show, the filament assembly 14 includes a plurality of single-wound coils extending linearly. These coils are constituted by a central filament element 19 and three peripheral filament elements 20, 21 and 22, which are electrically connected in series and each of which is made of tungsten. The wire diameter of the tungsten wire included in each single-wound coil is 0.015 [mm] to 0.100 [mm], and for instance, it is 0.050 [mm].

[0123] In FIG.16 and FIG.17, the central filament element 19 and the peripheral filament elements 20, 21 and 22 are schematically illustrated as a column.

The central axis a1 of the central filament element 19 is substantially the same as the optical axis Y_1 of the reflection mirror 2. The peripheral filament elements 20, 21 and 22 are positioned around the central filament element 19 such that their respective central axes b1, c1 and d1 are substantially parallel to the central axis a1 of the central filament element 19. Also, as FIG.17 shows, the three peripheral filament elements are positioned such that the intersection points of the central axes b1, c1 and d1 with an arbitrary plane P_1 that is vertical to the central axis of the central filament element 19 substantially form an equilateral triangle having a point in the central axis a1 as a center of gravity (center of figure). In other words, a distance D_1 between the central filament element 10 and each of the peripheral filament elements 20, 21 and 22 is the same, and a distance D_2 between the peripheral filament element 20 (or 21 or 22) and each of the adjacent two peripheral filament elements 21 and 22 (20 and 22 or 20 and 21) is the same.

[0124] Here, "substantially the same" means that it is preferable that the central axis a1 is completely the same as the optical axis Y_1 of the ref lection mirror 2 , but the central axis a1 might be misaligned from the optical axis Y_1 due to the variation in the positioning accuracy of the manufacturing process. The expression "substantially the same" includes such a case as well. The expressions "substantially parallel" and "substantially form an equilateral triangle" means that it is difficult to forma perfect parallel and a perfect equilateral triangle due to variation in assembling accuracy during the assembling process of the filament assembly 14 and sometimes the axes might be misaligned. The expressions include such a case. Regarding the distances D_1 and D_2, the expression "substantially the same" is also used in the same manner.

[0125] As FIG.16 shows, the central filament element 19 is positioned such that the central filament element 19 includes a focal point F_1 of a body of revolution forming the reflection surface 7 and a central point A_1 in the central axis a1 of the central filament element 19 is further from the opening part 5 than the focal point F_1. In the same manner, the peripheral filament elements 20, 21 and 22 respectively include points F_{b1}, F_{c1} and F_{d1} (FIG.16 only shows the points F_{b1} and F_{c1}) included in the reflection mirror 2 and described later, and central points B_1, C_1 and D_1 respectively in the central axes b1, c1 and d1 of the peripheral filament elements 20, 21 and 22 (FIG. 16 only shows the points B_1 and C_1) are further from the opening part 5 than the points F_{b1}, F_{c1} and F_{d1}. Here, note that the points F_{b1}, F_{c1} and F_{d1} include the focal point F_1 of the body of revolution forming the reflection surface 7, and represent the intersection points of the central axes b1, c1 and d1 with a plane Q_1 that is vertical to the optical axis Y_1 of the reflection mirror 2. For example, the distance between the focal point F_1 and the central point A_1 is 2.35 [mm], and the distance between the points F_{b1}, F_{c1} and F_{d1} and the central points B_1, C_1 and D_1 is 1.21 [mm].

[0126] Here, it is preferable that the end of each of the filament elements 20, 21 and 22 on the side of the opening part 5 is substantially on the same plane. This makes the illuminance on the area irradiated by the filament elements 20, 21 and 22 consistent, and makes the light distribution curve uniform.

Such a filament assembly 14 can be assumed as one filament including the central filament element 19 and the peripheral filament elements 20, 21 and 22 which virtually form a column.

[0127] The coil lengths of the central filament element 19 and the peripheral filament elements 20, 21 and 22 are set to satisfy $0.2 \leq L_{S1}/L_{C1} \leq 0.9$ for the following reason, where the coil length of the central filament element 19 is L_{C1} [mm] and the coil length of each of the peripheral filament elements 20, 21 and 22 is L_{S1} [mm] . The coil length L_{S1} of each of the filament elements 20, 21 and 22 is substantially the same. This expression "substantially the same" means that the coil length L_{S1} might vary due to variation of accuracy in the manufacturing process of the coil, in the same manner as described above.

[0128] Generally, the length of the tungsten wire included in the coil of the filament assembly 14 is determined by the rated power of the halide lamp 3. For example, the length of the tungsten wire used with the halide lamp 3 whose rated power is 65 [W] is 420 [mm] to 480 [mm] inclusive, the length of the tungsten wire used with the halide lamp 3 whose rated power is 20 [W] is 250 [mm] to 300 [mm] inclusive, and the length of the tungsten wire used with the halide lamp 3 whose rated power is 100 [W] is 540 [mm] to 620 [mm] inclusive. Accordingly, the coil lengths L_{C1} and L_{S1} can be adjusted by appropriately changing the pitch p (distance between the adj acent coils) and the maximum outer diameter R_1 of the coil. For example, the pitch p of the single-wound coil used with the halide lamp whose rated power is 65 [W] is set to be 0.05 [mm] to 0.07 [mm] inclusive regarding any of the central filament element 19 and the peripheral filament elements 20, 21 and 22. The maximum outer diameter of the single-wound coil R_1 is set to be 0.5 [mm] to 1.2 [mm] inclusive regarding any of the central filament element 19 and the peripheral filament elements 20, 21 and 22.

[0129] It is preferable that the distance D_1 between the central filament element 19 and each of the peripheral filament elements 20, 21 and 22 is set to be 0.1 [mm] to 2.2 [mm] . This increases the space occupied by the filament assembly

14 in the above-described central illuminance contributing region, and prevents that an arc discharge is caused during the lighting between the central filament element 19 and each of the peripheral filament elements 20, 21 and 22 and the central filament element 19 and the peripheral filament elements 20, 21 and 22 are burnt out. Meanwhile, if the distance D_1 is shorter than 0.1 [mm], it is possible that an arc discharge is caused during the lighting between the central filament element 19 and each of the peripheral filament elements 20, 21 and 22 and the central filament element 19 and the peripheral filament elements 20, 21 and 22 are burnt out. If the distance D_1 is longer than 2.2 [mm], the space occupied by the filament assembly 14 in the central illuminance contributing region decreases and the central illuminance might not be increased suf ficiently or the illuminance of the periphery of the irradiated area might be increased by the periphery filament elements 20, 21 and 22.

[0130] Instead of a single-wound coil, a double-wound coil or a triple-wound coil may be used as a coil included in the central filament element 19 and the peripheral filament elements 20, 21 and 22. However, from the viewpoint of increasing the central illuminance, the single wining coil is preferable than the double-wound coil and the triple-wound coil. This is because with the single-wound coil, the pitch can be small and the space occupied by the filament assembly 14 in the central illuminance contributing region can be increased.

[0131] Next, the following describes the reason why the coil lengths of the central filament element and the peripheral filament elements 20, 21 and 22 are set to satisfy $0.2 \leq L_{S1}/L_{C1} \leq 0.9$, where the coil length of the central filament element 19 is L_{C1} [mm] and the coil length of each of the peripheral filament elements 20, 21 and 22 is L_{S1} [mm].

Firstly, regarding the reflection-mirror-equipped halide lamp 1, whose rated power is 65 [W], five samples with different coil lengths were manufactured for each of the central filament element 19 and the peripheral filament elements 20, 21 and 22 by changing the coil length L_{C1} of the central filament element 19 and the coil length L_{S1} of each of the peripheral filament elements 20, 21 and 22 as Table 2 shows. Then, the lamp with each coil was lit at the rated power, and the beam angle (degrees) and the central illuminance [lx] were measured. The result (The relation between L_{S1}/L_{C1} and the beam angle) is shown in FIG.18 and Table 2. As representative examples, a light distribution curve in the case where $L_{S1}/L_{C1} = 0.9$ is shown in FIG.19 and a light distribution curve in the case where $L_{S1}/L_{C1} = 0.6$ is shown in FIG.20.

[0132] In the manufactured samples, each of the central filament element 10 and the peripheral filament elements 20, 21 and 22 includes the single-wound coil, the pitch p of each is 0. 05 [mm] to 0.07 [mm], and the maximum outer diameter R_1 is 0.65 [mm]. The distance D_1 is 1.5 [mm].

In Table 2, the "beam angle" represents an average of the beam angles of the five samples. The criterion of the beam angle is 10° (allowable range: 7.5° to 12.5°), which is the main stream of the beam angle of commercially available lamps.

[0133] The "central illuminance" represents an average of the central illuminance of the five examples. The central illuminance of a currently commercially available reflection-mirror-equipped halide lamp (hereinafter called "the conventional example"), whose beam angle is 10° and rated power is 65 [W] (rated voltage: 110 [V]) is, for instance 6500 [cd]. Accordingly, in consideration of the demands of the market, the criterion is approximately 10% greater than the central illuminance (6500 [lx]) (the central luminous intensity: 6500 [cd]), which is 7200 [lx] (the central luminous intensity: 7200 [cd]).

[0134]

[Table 2]

L_{S1}/L_{C1}	L_{S1} [mm]	L_{C1} [mm]	Beam Angle [°]	Central Illuminance [lx]	Evaluation
0	0	16.0	7.5	5500	Bad
0.1	1.20	12.0	7.5	7000	Bad
0.2	2.00	10.0	7.5	8500	Good
0.3	2.46	8.2	8.0	9000	Good
0.4	2.84	7.1	8.7	9300	Good
0.5	3.15	6.3	9.5	9700	Good
0.6	3.42	5.7	10.0	9800	Good
0.7	3.57	5.1	10.8	9500	Good
0.8	3.68	4.6	11.5	9300	Good
0.9	3.87	4.3	12.5	9000	Good
1.0	4.00	4.0	13.0	8500	Bad

[0135] As Table 2 clearly shows, when $0.2 \leq L_{S1}/L_{C1} \leq 0.9$ is satisfied, for instance, when L_{S1}/L_{C1} = (0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9), the central illuminance is more than the central illuminance of the conventional example (6500 [lx]. 6500 [cd] in central luminous intensity), and more than 8500 [lx] (8500 [cd] in central luminous intensity). Also, the beam angle is in the range between 7.5° to 12.5°. This satisfies the above-described criterion. This is also shown by the light distribution curve in FIG.19 and FIG.20. The illuminance of the central part on the irradiated area is high, and the irradiating light is not spread to the peripheral part around the central part. On the other hand, when L_{S1}/L_{C1} > 0.9 is satisfied, for instance, when L_{S1}/L_{C1} = (1.0), although the central illuminance is more than the central illuminance of the conventional example (6500 [lx]. 6500 [cd] in central luminous intensity) and satisfies the criterion, the beam angle is 13.0° which does not satisfy the criterion. When L_{S1}/L_{C1} < 0. 2 is satisfied, for instance, when L_{S1}/L_{C1} = (0, 0.1), although the beam angle is 7.5° and satisfies the criterion, the central illuminance does not satisfy the criterion. The following is the reason for this result: It is possible to appropriately shorten the coil length L_{S1} of the peripheral filament elements 20, 21 and 22 that greatly contribute to increase and decrease of the illuminance on the peripheral part of the central part of the irradiated area by lengthening the coil length L_{C1} of the central filament element 19 that greatly contribute to increase and decrease of the illuminance (the central illuminance) on the central part of the irradiated area in an appropriate range so as to be relatively longer than the coil length L_{S1} of the peripheral filament elements 20, 21 and 22. As a result, firstly, it is possible to decrease the illuminance of the peripheral part of the central part of the irradiated area as much as possible while keeping the contribution of the peripheral filament elements 20, 21 and 22 to the increase of the illuminance on the central part of the irradiated area. Secondly, due to the increase of the coil length L_{C1} of the central filament element 19, the illuminance of the central part of the irradiated area can be further increased. These first and second effects result in the favorable light distribution curves shown in FIG.19 and FIG.20. However, when L_{S1}/L_{C1} < 0.2 is satisfied, although the coil length L_{C1} of the central filament element 19 is relatively long, a large part of the central filament element 19 is out of the central illuminance contributing region within the reflection mirror 2, and the coil length L_{S1} of the peripheral filament elements 20, 21 and 22 is relatively too short compared to the coil length L_{C1} of the central filament element 19. This greatly decreases the effect of disposing the peripheral filament elements 20, 21 and 22. When L_{S1}/L_{C1} > 0.9 is satisfied, since the coil length L_{C1} of the central filament element 19 is not relatively long compared to the coil length L_{S1} of the peripheral filament elements 20, 21 and 22, it is believed that the illuminance of the peripheral area around the central part of the irradiated area is increased by the peripheral filament elements 20, 21 and 22 and accordingly the desired beam angle can not be achieved.

[0136] Therefore, to increase the central illuminance by contribution of the central filament element 19 and the peripheral filament elements 20, 21 and 22, and achieve the desired beam angle (narrow angle) to realize favorable light distribution properties, $0.2 \leq L_{S1}/L_{C1} \leq 0.9$ should be satisfied, where the coil length of the central filament element 19 is L_{S1} [mm] and the coil length of the peripheral filament elements 20, 21 and 22 is L_{C1} [mm]. This means that the value (L_{S1}/L_{C1}) should be between 0.2 and 0.9 inclusive.

[0137] As described above, with the structure of the reflection-mirror-equipped halide lamp according to the fifth embodiment of the present invention, it is possible to increase the central illuminance by contribution of the central filament element 19 and the peripheral filament elements 20, 21 and 22, and prevent the spread of the light irradiated by the peripheral filament elements 20, 21 and 22. This realizes a narrow beam angle and favorable light distribution properties.

(Sixth Embodiment)

A lighting apparatus of the sixth embodiment of the present invention is used as a spot light for general lighting for example, and has a structure in which the reflection-mirror-equipped halide lamp 1 according to the fifth embodiment of the present invention, whose rated power is 65 [W], is attached to a well-known lighting fixture (not illustrated).

[0138] With the stated structure of the lighting apparatus according to the sixth embodiment of the present invention, it is possible to provide a lighting apparatus that realize a high central illuminance, a arrow angle, and favorable light distribution properties.

(Seventh Embodiment)

A lighting apparatus of the seventh embodiment of the present invention is used as a spot light for general lighting for example, and includes the halide lamp 3 used with the reflection-mirror-equipped halide lamp 1 according to the fifth embodiment of the present invention, whose rated power is 65 [W], and a well-known base (not illustrated) of an E type for instance, which is attachable to the end of the halide lamp 3 on the sealing part 12's side. Such a halide lamp is attached to the reflection mirror part included in the lighting apparatus.

[0139] The reflection surface of the reflection mirror part is in the shape of a spheroid, a paraboloid, or the like. The reflection mirror part may be fixed to the lighting fixture and not be detachable, or may be detachable and replaced depending on the purpose.

With the stated structure of the halide lamp according to the seventh embodiment of the present invention, in the same manner as the above-described reflection-mirror-equipped halide lamp 1 according to the fifth embodiment of the present invention, it is possible to increase the central illuminance by contribution of the central filament element 19 and the peripheral filament elements 20, 21 and 22, and prevent the spread of the light irradiated by the peripheral filament elements 20, 21 and 22. This realizes a narrow beam angle and favorable light distribution properties.

[0140] In the same manner as the above-described lighting apparatus according to the third embodiment of the present invention, the sixth embodiment can provide a lighting apparatus that can achieve high central illuminance, a narrow angle, and favorable light distribution properties.
In the above-described embodiment, the case where the three filament elements 20, 21 and 22 are arranged to substantially form an equilateral triangle is described. However, the same effect can be achieved when four filament elements are arranged to substantially form a square, when five filament elements are arranged to substantially form an equilateral pentagon, when sixfilament elements are arranged to substantially form an equilateral hexagon, and so on.
[0141] The above-described embodiment describes the case where the halide lamp 3, whose rated power is 65 [W], is used. However, the same effect can be achieved when a halide lamp whose rated power is 20 [W] to 150 [W].
The above-described embodiment describes the case where the bulb 13 of the halide lamp 3 has a structure including series of the chip-off part 10, the light emitting part 11 substantially in a shape of a spheroid and the sealing part 12 are formed. However, the present invention is not limited to this. Well-known bulbs in various shapes may be used. For instance, the bulb 13 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spherical or spheroidal shape and the sealing part. Alternatively, the bulb 13 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spherical shape or spheroidal shape, the short-diameter part and the sealing part. Alternatively, the bulb 13 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spherical shape or spheroidal shape, the short-diameter part, the cylindrical part and the sealing part.
[0142] The above-described embodiment describes a case where the halide lamp 3 is used. However, the same effect can be achieved if a well-know incandescent lamp is used instead of the halide lamp 3.
The following describes embodiments of the present invention with reference to drawings.
(Eighth Embodiment)
As FIG.21 shows, the halide lamp 31 according to the eighth embodiment of the present invention, whose rated power is 65 [W] (rated voltage: 110 [V]), includes a bulb 32 formed of silica glass, hard glass or the like, and a base 34 of an E type for instance, which is fixed to the side of a sealing part 40 of the bulb 32, which is described later, with an adhesive 33.
[0143] The bulb 32 includes a series of a chip-off part 36, which is a remainder resultant from chipping off of the sealing, a light emitting part 37 substantially in a shape of a spheroid, a short-diameter part 38, a cylinder part 39 substantially in a cylindrical shape, and a sealing part 40 formed by the well-known pinch seal method. A visible light transmitting and infrared reflecting film 41 is formed on the outer surface of each of the chip-off part 36, the light emitting part 37 and the short-diameter part.
[0144] Here, the expression "substantially in a shape of a spheroid" includes, in addition to a perfect spheroid, a shape transformed from a perfect spheroid due to the variation in the processing of glass.
A filament assembly 42 is set up within the light emitting part 37, and a predetermined amount of a halogen substance and a rare gas, or a halogen substance, a rare gas and a nitrogen gas are enclosed within the light emitting part 37.
[0145] One end of an internal lead 43 made of tungsten or the like is connected to the filament assembly 42, and the other end of the internal lead 43 is connected to one end of the external lead 45 via a metal foil 44 made of molybdenum sealed by the sealing part 40. The other end of the external lead 45 is extended outside of the bulb 32, and electrically connected to terminals 35a and 35b of the base 34.
[0146] As FIG. 22 and FIG. 23 shows, the filament assembly 42 includes three filament elements 46, 47 and 48. Each of the filament elements 46, 47 and 48 is made of tungsten, and is a single-wound coil substantially extending linearly. They are electrically connected in series. The wire diameter of the tungsten wire included in each single-wound coil is from 0.015 [mm] to 0.100 [mm]. For instance, it is 0.050 [mm].
[0147] FIG.22 and FIG.23 schematically illustrates each of the filament elements 46, 47 and 48 as a column.
As FIG.23 shows, the respective central axes b2, c2 and d2 of the filament elements 46, 47 and 48in the longitudinal direction, are substantially parallel to the central axis X_2 of the bulb 32in the longitudinal direction. The filament elements 46, 47 and 48 are positioned around the central axis X_2 such that the intersection points of the central axes b2, c2 and d2 with an arbitrary plane P_2 that is vertical to the central axis X_2 of the bulb 32 substantially form an equilateral triangle having a point in the central axis X_2 as a center of gravity (center of figure). In other words, a distance D_3 between one filament element 46 (47 or 48) and each of the adjacent filament elements 47 and 48 (46 and 48 or 46 and 47) is substantially the same, and a distance D_4 between each of the filament elements 46, 47 and 48 and the central axis X_2 of the bulb 32 is substantially the same.
[0148] Here, the expressions "substantially parallel" and "substantially form an equilateral triangle" means that it is difficult to form a perfect parallel and a perfect equilateral triangle due to variation in assembling accuracy during the assembling process of the filament assembly 42 and assembling process of the bulb 32 and the filament assembly 42, and sometimes they might be misaligned. The expressions include such a case. Regarding the Distances D_3 and D_4, the expression "substantially the same" is also used in the same manner.
[0149] Such a filament assembly 42 is included in a column in which each filament element has an outer diameter (maximum outer diameter) r_1 [mm]. This column can be assumed as one filament formed by integrating the filament

elements 46, 47 and 48. Regarding the bulb 32, $0.25 \leq r_1/R_2 \leq 0.75$ is satisfied for the following reason, where R_2 [mm] is the maximum inner diameter of a portion of the bulb 32 corresponding to the filament assembly 42 (see FIG. 21), and r_1 [mm] is the maximum outer diameter of the filament assembly 42 assumed as one filament.

[0150] Preferably, at least one of the maximum outer diameter r_0 and the coil length L_{S2} of the filament elements 46, 47 and 48 is the same, and it is more favorable that both of the them are the same. Note that the maximum outer diameter r_0 and the coil length L_{S2} might vary due to variation in accuracy in the manufacturing process.

[0151] Also, regarding the ends of each of the filament elements 46, 47 and 48, it is preferable that one of the ends that is farther from the sealing part 40 is substantially on the same plane. This makes the illuminance on the area irradiated by each coil consistent. As a result, the light distribution curve can be uniformed.

The maximum outer diameter r_1 can be adjusted by changing the maximum outer diameter r_0 and the distance D_3 between the adjacent two filament elements (or the distance D_4). Generally, the length of the tungsten wire included in the coil of the filament assembly 42 is determined by the rated power of the halide lamp. For example, the length of the tungsten wire used with the halide lamp whose rated power is 65 [W] is 420 [mm] to 480 [mm] inclusive, the length of the tungsten wire used with the halide lamp whose rated power is 20 [W] is 250 [mm] to 300 [mm] inclusive, and the length of the tungsten wire used with the halide lamp whose rated power is 100 [W] is 540 [mm] to 620 [mm] inclusive. Accordingly, the maximum outer diameter r_0 of each of the filament elements 46, 47 and 48 can be adjusted by changing the coil length L_{S2} of the each of the filament elements 46, 47 and 48 and the pitch (between adjacent coils).

For example, if the coils are for use with a halide lamp whose rated power is 65 [W], and if the filament assembly 42 includes three filament elements 46, 47 and 48 each made from a single-wound coil having the same size as FIG.8 and FIG.9 show, the coil length L_{S2} is set to 4.0 [mm] to 6.7 [mm]. The pitch of the coil is set to 0.05 [mm] to 0.07 [mm].

[0152] As a coil constituting each of the filament elements 46, 47 and 48, a double-wound coil or triple-wound coil may be used instead of the single-wound coil.

The following describes the reason why r_1/R_2 is set to satisfy $0.25 \leq r_1/R_2 \leq 0.75$, where R_2 [mm] is the maximum inner diameter of a portion of the bulb 32 corresponding to the filament assembly 42, and r_1 [mm] is the maximum outer diameter of the filament assembly 42.

[0153] Firstly, using the above-described halide lamp 31 whose rated power is 65 [W], ten samples were made for each of the lamps shown in Table 3. Regarding each lamp, the maximum inner diameter R_2 measured at a portion of the bulb 32 corresponding the filament assembly 42 was set to a constant value 12 mm, and the maximum outer diameter r_1 [mm] of the filament assembly 42 was changed by appropriately changing the distance D_3 between adj acent two filament elements. Each sample was lit at the rated power. Regarding each lamp, the number of the samples whose filament assembly 42 had been burnt out when 3500 or 4000 hours passed was counted. Also, among the samples whose filament assembly 42 had not been burnt out when 4000 hours passed, the number of the samples the internal surface of whose bulb 32 had been blackened was counted. Table 3 shows the result.

[0154] In the filed "burnt out" of Table 3, the denominator shows the total number of the samples, and the numerator shows the number of samples whose filament assembly 42 suffered the burnt out. In the field "blackening", the dominator shows the number of samples whose filament assembly did not suffer the burnt out, and the numerator shows, among the samples whose filament assembly did not suffer the burnt out, the number of samples the internal surface of whose bulb 32 was blackened. The blackening was checked with eyes. The blackening is caused by tungsten of filament assembly 42, evaporating and adhering to the internal surface during the lighting.

[0155] The lamp was turned on for 5.5 hours and turned off for 0.5 hours in continuous cycles. The "lighting time" means the total of the period during which the lamp is turned on.

In each sample, each of the filament elements 46, 47 and 48 includes the same single-wound coil having the same size and shape, and the pitch p is 0.05 [mm] to 0.07 [mm], the maximum outer diameter r_0 is 0.65 [mm], and the coil length L_{S2} is 5. 4 [mm].

[0156]

[Table 3]

r/R	Maximum outer diameter r [mm]	Maximum inner diameter R [mm]	After 3500 hour's lighting	After 4000 hour's lighting		Evaluation
			Burnout	Burnout	Blackening	
0.20	2.40	12	2/10	8/10	0/2	Bad
0.25	3.00	12	0/10	2/10	0/8	Good
0.35	4.20	12	0/10	0/10	0/10	Excellent
0.50	6.00	12	0/10	0/10	0/10	Excellent
0.75	9.00	12	0/10	0/10	0/10	Excellent
0.80	9.60	12	0/10	0/10	10/10	Bad

[0157] As Table 3 shows, when $0.25 \leq r_1/R_2 \leq 0.75$ is satisfied, for instance, when r_1/R_2 = (0.25, 0.35, 0.50, 0.75), the filament assembly 42 of any sample had not been burnt out when 3500 hours passed, and the internal surface of the bulb 32 of any sample had been blackened. Especially, when $0.35 \leq r_1/R_2 \leq 0.75$ is satisfied, for instance, when r_1/R_2 = (0.35, 0.50, 0.75), the filament assembly 42 of any sample had not been burnt out when 4000 hours passed.

[0158] When $0.25 > r_1/R_2$ is satisfied, for instance, when r_1/R_2 = (0.20), the filament assembly 42 of eight samples out of ten samples had been burnt out when 4000 hours passed, but the internal surface of the bulb 32 of any of the remaining two samples had not been blackened. When $r_1/R_2 > 0.75$ is satisfied, for instance, when r_1/R_2= (0.80), although the filament assembly 42 of any of the ten samples had not been burnt out when 4000 hours passed, the internal surface of the bulb 32 of all the samples had been blackened.

[0159] Regarding all the samples, the burnout was caused in the vicinity of the center part of each of the filament elements 46, 47 and 48.

The result can be analyzed as follows.

When $0.25 > r_1/R_2$ is satisfied, the distance between the bulb 32 and the filament assembly 42 is large, and the convection zone generated between the bulb 32 and the filament assembly 42 during the lighting is thick. Accordingly, the tungsten, included in the filament assembly 42 and evaporated during the lighting, moves rapidly, and this increases the amount of evaporation of the tungsten. The tungsten wire of the coil (hereinafter simply called "the tungsten wire") included in the filament assembly 42 becomes thin due to the evaporation of the tungsten, and this is believed to be the cause of the burnout. When $r_1/R_2 > 0.75$ is satisfied, although the distance between the bulb 32 and the filament assembly 42 is small, the bulb 32 is too close to the filament assembly 42, and the temperature of the bulb becomes fairly high during the lighting. It is believed that the radiant heat from the bulb 32 heightens the temperature of the filament assembly 42 to an abnormal level, and the evaporated tungsten adheres to the internal surface of the bulb. In the later case, although the tungsten wire becomes thin due to the evaporation of the tungsten, the burnout is not caused. This is because, in the latter case, the convection zone is thinner than the former case, and the evaporation speed of the tungsten is slower than the former case. Although the bulb 32 was not damaged in this test, if the internal surface of the bulb 32 is blackened, it easily absorbs heat. This further increases the temperature of the bulb 32, and might damage the bulb 32.

[0160] When $0.25 \leq r_1/R_2 \leq 0.75$ is satisfied, the distance between the bulb 32 and the filament assembly 42 is moderately small, and the convection zone generated between the bulb 32 and the filament assembly 42 is extremely thin. As a result, the moving speed of the tungsten evaporated during the lighting is slow, and accordingly, the evaporation speed of the tungsten is markedly decreased. Moreover, it is believed that since the bulb 32 is not too close to the filament assembly 42, the temperature of the bulb 32 does not become excessively high, and therefore the temperature of the filament assembly 42 does not become abnormally high during the lighting.

[0161] As described above, it has been found that to prevent the blackening of the internal surface of the bulb 32 and the burnout of the filament assembly 42 and to achieve a long life, it is preferable that $0.25 \leq r_1/R_2 \leq 0.75$ is satisfied, where R_2 [mm] is the maximum inner diameter of a portion of the bulb 32 corresponding to the filament assembly 42, and r_1 [mm] is the maximum outer diameter of the filament assembly 42. Especially, to achieve a further longer life, it is preferable that $0.35 \leq r_1/R_2 \leq 0.75$ is satisfied.

[0162] As described above, with the stated structure of the halide lamp 31 according to the eighth embodiment of the present invention, it is possible to make the convection zone generated between the bulb 32 and the filament assembly 42 extremely thin, and decrease the amount of evaporation of the tungsten included in the filament assembly 42. As a result, it becomes possible to prevent the burnout of the coils included in the filament assembly 42 due to the thinned tungsten wire of the coil, and achieve a long life. Moreover, since the distance between the bulb 32 and the filament assembly 42 is kept to be moderate distance, it is possible to prevent that the temperature of the bulb 32 and the filament assembly 42 increases to an abnormal level during the lighting. This prevents the damage to the bulb 32 and the blackening of the internal surface of the bulb 32 due to excessive evaporation of the tungsten included in the filament assembly 42.

[0163] In the eighth embodiment, the case where the three filament elements 46, 47 and 48 are arranged to substantially form an equilateral triangle is described. However the same effect can be achieved when four filament elements are arranged to substantially form a square, when five filament elements are arranged to substantially form an equilateral pentagon, when six filament elements are arranged to substantially form an equilateral hexagon, and so on. As a matter of course, the same effect can be achieved by the case where a filament assembly in which another filament element having the same size and shape as the other filaments or different size and shape may be set up in the space among the filament elements so as to be in the central axis X of the bulb 2 in the longitudinal direction of the bulb 2.

[0164] The above-described embodiment describes the case where the bulb 32 has a structure including, as integral parts, the chip-off part 36, the light emitting part 37 substantially in a shape of a spheroid, the short-diameter part 38, the cylinder part 39 and the sealing part 40. However, the present invention is not limited to this. Well-known bulbs in various shapes may be used. For instance, the bulb 32 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spheroidal shape, the short-diameter part and the sealing part. Alternatively, the bulb 32 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spheroidal shape and the sealing part. Alternatively, the bulb 32 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the cylindrical shape and the sealing part. As a matter of course, the light emitting part may be substantially in the spherical shape or substantially in a shape of a combination of a plurality of ellipsoids, instead of the above-described spheroidal shape.

[0165] In the eighth embodiment, the case of using the filament elements 46, 47 and 48 in each of which the tungsten wire is formed in a cylindrical shape is described. In other words, the outline of the cross section of each tungsten wire cut along a plane vertical to the central axes b2, c2 and d2 is circular shape. However, the present invention is not limited to this. For instance, as FIG. 24 shows, filament elements 49, 50 and 51 in each of which the tungsten wire is formed such that the outline of the cross section of the tungsten wire cut along a plane vertical to the central axes b2, c2 and d2 is in an ellipsoidal shape may be used to achieve the same effect. Regarding the example shown in FIG.24, the filament elements 49, 50 and 51 fall within a column whose center point is in the central axis X_2 of the bulb 32 in the longitudinal direction and whose maximum outer diameter is the diameter of a circle circumscribing the filament elements 49, 50 and 51. The maximum outer diameter r_1 of the filament assembly 52 including the filament elements 49 , 50 and 51, whose outline shapes are shown in FIG.24, can be determined in this manner.

(Ninth Embodiment)

As FIG. 25 shows, a halide lamp 53 of the ninth embodiment of the present invention, whose rated power is 65 [W] (rated voltage: 110 [V]), is to be built into a reflection mirror part 55 of a well-known lighting apparatus 54 mainly used as a spotlight for general lighting for example. The halide lamp 53 includes a bulb 56 formed of silica glass, hard glass or the like, and a base (not illustrated) of an E type for instance, which is fixed to the side of a sealing part 66 of the bulb 56, which is described later, with a well-known adhesive (not illustrated).

[0166] The central axis X_3 of the bulb 56 included in the halide lamp 53, which extends in the longitudinal direction of the bulb 56, and the optical axis Y_3 of the reflection mirror part 55 are substantially the same.

A light is emitted from the opening part 57 of the front side of the lighting apparatus 54, and the lighting apparatus 54 includes a lighting fixture 58 in a cylindrical shape in which the reflection mirror part 55 and a receiver (not illustrated), to which a base of the halide lamp 53 is attached are housed.

[0167] A front glass 60 is attached to the opening part 59 of the reflection mirror part 55, and a reflection surface 61 is formed on the internal surface of the reflection mirror part 55. The reflection surface 61 is in the shape of a body of revolution, such as a spheroid and a paraboloid. If necessary, a facet may be formed on the reflection surface 61.

The bulb 56 includes, as integral parts, a chip-off part 62 as a remainder resultant from chipping off of the sealing, a light emitting part 63 substantially in a shape of spheroid, a short-diameter part 64, a cylinder part 65 and a sealing part 66 formed by a well-known pinch seal method. A visible light transmitting and infrared reflecting film 67 is formed on the outer surface of the light emitting part 63 and the short-diameter part 64.

[0168] Here, the expression "substantially in a shape of a spheroid" includes, in addition to a perfect spheroid, a shape transformed from a perfect spheroid due to the variation in the processing of glass.

A filament assembly 68 is set up within the light emitting part 63, and a predetermined amount of a halogen substance and a rare gas, or a halogen substance, a rare gas and a nitrogen gas are enclosed within the light emitting part 63.

[0169] One end of an internal lead 69 made of tungsten or the like is connected to the both ends of the filament assembly 68, and the other end of the internal lead 69 is connected to one end of the external lead (not illustrated) via a metal foil (not illustrated) made of molybdenum sealed by the sealing part 66. The other end of the external lead is extended outside of the bulb 56, and electrically connected to terminals of the base.

[0170] As FIG.26 and FIG.27 shows, the filament assembly 68 includes one central filament element 70 and three peripheral filament elements 71, 72 and 73. Each of the central filament element 70 and the peripheral filament elements 71, 72 and 73 is made of tungsten, and is a single-wound coil substantially extending linearly. They are electrically connected in series. The wire diameter of the tungsten included in each single-wound coil is from 0.015 [mm] to 0.100 [mm]. For instance, it is 0.050 [mm].

[0171] FIG. 26 and FIG. 27 schematically illustrates each of the central filament element 70 and the peripheral filament elements 71, 72 and 73 as a column.

In a state where the halide lamp 53 is built into the reflection mirror part 55 of the lighting apparatus 54, the central axis a3 of the central filament element 70in the longitudinal direction of the central filament element 70, is substantially same as the optical axis Y_3 of the reflection mirror part 55. More specifically, the central filament element 70 is positioned so that the central axis a3 of the central filament element 70 is substantially the same as the central axis X_3 of the bulb 56in the longitudinal direction of the bulb 56. In a state where the halide lamp 53 is built into the reflection mirror part 55, since the central axis X_3 of the bulb 56 is substantially the same as the optical axis Y_3 of the reflection mirror part 55, the central axis of the filament element 70 is naturally the same as the optical axis Y_3 of the reflection mirror part 55.

[0172] Here, "substantially the same" means that it is preferable that the central axis a3 is completely the same as the central axis X_3 of the bulb 56, but the central axis a3 might be misaligned from the central axis X_3 and also be misaligned from the optical axis Y_3 due to the variation in the position accuracy during the manufacturing process. The expression "substantially the same" includes such a case. Of course, the central axis a3 might be misaligned from the central axis X_3 and also be misaligned from the optical axis Y_3 depending on the type of the lighting apparatus in which the halide lamp 53 is built. The expression "substantially the same" includes such a case as well.

[0173] The respective central axes b3, c3 and d3 of the filament elements 71, 72 and 73in the longitudinal direction are positioned around the central filament element 70 so as to be substantially parallel to the central axis a3 of the central filament element 70in the longitudinal direction. As FIG.27 shows, the peripheral filament elements 71, 72 and 73 are positioned such that the intersection points of the central axes b3, c3 and d3 with an arbitrary plane P_3 that is vertical to the central axis a3 of the central filament element 70 substantially form an equilateral triangle having a point on the central axis a3 as a center of gravity (center of figure). In other words, a distance D_5 between the central filament element 70 and each of the peripheral filament elements 71, 72 and 73 is the same, and one peripheral filament element 71 (72 or 73) and each of the adjacent peripheral filament elements 72 and 73 (71 and 73 or 71 and 72) is substantially the same.

[0174] Here, the expressions "substantially parallel" and "substantially form an equilateral triangle" means that it is difficult to form a perfect parallel and a perfect equilateral triangle due to variation in assembling accuracy during the assembling process of the filament assembly 68 and the built-in process of the bulb 56 and the filament assembly 68, and sometimes they might bemisaligned. The expressions include such a case. Regarding the Distances D_5 and D_6, the expression "substantially the same" is also used in the same manner.

[0175] As FIG. 26 shows, the central filament element 70 is positioned so that the central filament element 70 includes a focal point F_2 of a body of revolution forming the reflection surface 61 and a central point A_3 in the central axis a3 of the central filament element 70 is further from the opening part 59 than the focal point F_2. In the same manner, the peripheral filament elements 71, 72 and 73 respectively include points F_{b3}, F_{c3} and F_{d3} (FIG.26 only shows the points F_{b3} and F_{c4}) included in the reflection mirror part 55 described later, and central points B_3, C_3 and D_3 respectively in the central axes b3, c3 and d3 of the peripheral filament elements 71, 72 and 73 (FIG. 26 only shows the points B_3 and C_3) are further from the opening part 59 than the points F_{b3}, F_{c3} and F_{d3}. Here, note that the points F_{b3}, F_{c3} and F_{d3} represent the intersection points of the central axes b3, c3 and d3 with a plane Q_3 that includes the focal point F_2 of the body of revolution forming the reflection surface 61 and is vertical to the optical axis Y_3 of the reflection mirror part 55. For example, the distance between the focal point F_2 and the central point A_3 is 2.35 [mm], and the distance between the points F_{b3}, F_{c3} and F_{d3} and the central points B_3, C_3 and D_3 is 1.21 [mm]. Inthisway, by positioning the central filament element 70 and the peripheral filament elements 71, 72 and 73 so that the central point A_3 of the central filament element 70 and the central points B_3, C_3 and D_3 of the peripheral filament elements 71, 72 and 73 are further from the opening part 59 than the focal point F_2 of the reflection surface 61 of the reflection mirror part 55, the space occupied by the filament assembly 68 in the region including the focal point F_2 and its vicinity (Hereinafter simply called "the central illuminance contributing region") can be increased and the central illuminance can be heightened.

[0176] Regarding such a filament assembly 68, the central filament element 70 and the peripheral filament elements 71, 72 and 73 are within a column body whose outer diameter (the maximum outer diameter) is r_3 [mm], and this column body can be assumed as one filament including the central filament element 70 and the peripheral filament elements 71, 72 and 73. In this case, to prevent the blackening of the internal surface of the bulb 56 and the burnout of the filament assembly 68, and to achieve a long life, $0.25 \leq r_3/R_3 \leq 0.75$ is satisfied, where R_3 [mm] is the maximum inner diameter of a portion of the bulb 56 corresponding to the filament assembly 68 (see FIG.25), and r_3 [mm] is the maximum outer diameter of the filament assembly 68 assumed as one filament. Especially, to achieve a further longer life, it is preferable that $0.35 \leq r_3/R_3 \leq 0.75$ is satisfied.

[0177] When $0.25 \leq r_3/R_3 \leq 0.75$ is satisfied, the distance between the bulb 56 and the filament assembly 68 is moderately small, and the convection zone generatedbetween the bulb 56 and the filament assembly 68 is extremely thin. As a result, the moving speed of the tungsten evaporated during the lighting is slow, and accordingly, the evaporation speed of the tungsten is markedly decreased. This prevents that the tungsten wire of the coil included in the filament assembly 68 becomes thin due to the evaporation of the tungsten and burnt out, and it becomes possible to achieve a long life. Moreover, it is believed that since the bulb 56 is not too close to the filament assembly 68, the temperature of the bulb 56 does not become excessively high, and therefore the temperature of the filament assembly 68 does not become abnormally high during the lighting. This prevents that the amount of the evaporation of the tungsten increases and the evaporated tungsten adheres to the internal surface of the bulb 56, and blackening the internal surface. When $0.25 > r_1/R_2$ is satisfied, the distance between the bulb 56 and the filament assembly 68 is large, and the convection zone generated between the bulb 56 and the filament assembly 68 during the lighting is thick. Accordingly, the tungsten, included in the filament assembly 68 and evaporated during the lighting, moves rapidly, and this increases the amount of evaporation of the tungsten. The tungsten wire of the coil included in the filament assembly 68 becomes thin due to the evaporation of the tungsten, and this is believed to be the cause of the burnout.

When $r_3/R_3 > 0.75$ is satisfied, although the distance between the bulb 56 and the filament assembly 68 is small, the bulb 56 is too close to the filament assembly 68, and the temperature of the bulb 56 becomes fairly high during the lighting. It is believed that the radiant heat from the bulb 56 heightens the temperature of the filament assembly 68 to an abnormal level, and the evaporated tungsten adheres to the internal surface of the bulb 56. In some cases, the temperature of the bulb 56 further increase due to the blackened surface, and this might damage the bulb 56.

[0178] The maximum outer diameter r_3 can be adjusted by changing the maximum outer diameter r_2 of the central filament element 70 and the peripheral filament elements 71, 72 and 73, and the distance D_6 between the adjacent two filament elements (or the above-described distance D_5). Also, the maximum outer diameter r_2 of each of the central filament element 70 and the peripheral filament elements 71, 72 and 73 can be adjusted by changing the coil length L_{C3} of the central filament element 70 or the coil length L_{S3} of the each of the peripheral filament elements 71, 72 and 73 and the pitch.

[0179] Here, the coil length L_{C3} of the central filament element 70 and the coil length L_{S3} of the each of the peripheral filament elements 71, 72 and 73 may be the same. For instance, in the case of a halide lamp whose rated power is 65 [W], it is preferable that the coil lengths L_{C3} and L_{S3} are set to 3.0 [mm] to 5.0 [mm] . Also, although the coil length L_{S3} of the peripheral filament elements 71, 72 and 73 is the same, the coil lengths L_{C3} and L_{S3} may be different. For instance, in the case of a halide lamp whose rated power is 65 [W], it is preferable that the coil length L_{C3} is set to 3.5 [mm] to 15.0 [mm], and the coil length L_{S3} is set to 1. 5 [mm] to 4.5 [mm]. Further, the coil length L_{C3} may be different from the coil length L_{S3} and the coil length L_{S3} may be different for each of the peripheral filament elements 71, 72 and 73. For instance, in the case of a halide lamp whose rated power is 65 [W], it is preferable that the coil length L_{C3} is set to 3.5 [mm] to 15.0 [mm], and each coil length L_{S3} is set to 1.5 [mm] to 4.5 [mm]. The pitch of the single-wound coils is set to 0.05 [mm] to 0.07 [mm] regarding each of the central filament element 70 and the peripheral filament elements 71, 72 and 73.

[0180] However, in the case where $0.25 \leq r_3/R_3 \leq 0.75$ is satisfied, in the viewpoint of making the illuminance on the area irradiated by the peripheral filament elements 71, 72 and 73 consistent, it is preferable that at least one of the maximum outer diameter r_0 and the coil Length L_{S3} is the same, and it is more favorable that both of them are the same. Note that, the maximum outer diameter r_0 and the coil length L_{S3} might vary for each of the peripheral filament elements 71, 72 and 73 due to variation in accuracy in the manufacturing process of the peripheral filament elements 71, 72 and 73.

[0181] Also, regarding the ends of each of the filament elements 70, 71, 72 and 73 it is preferable that one of the ends that is closer to the opening part 59 is substantially on the same plane. This makes the illuminance on the area irradiated by each of the filament elements 70, 71, 72 and 73 consistent. As a result, the light distribution curve can be uniformed. Further, to increase the central illuminance by the contribution of the central filament element 70 and the peripheral filament elements71, 72 and 73, and obtain a desired beam angle (narrow angle. e. g. 10°, the allowable range is from 7.5° to 12.5°) to realize a favorable light distribution, it is preferable that $0.2 \leq L_{S3}/L_{C3} \leq 0.9$. In this case, the coil length L_{S3} of each of the peripheral element 71, 72 and 73 is substantially the same. The expression "substantially the same" means that the coil length L_{S3} might vary due to variation of accuracy in the manufacturing process of the coil.

[0182] When $L_{S3}/L_{C3} \leq 0.9$ is satisfied, the coil length L_{C3} of the central filament element 70 is appropriately longer than the coil length L_{S3} of the peripheral filament elements 71, 72 and 73. The coil length L_{S3} of the peripheral filament elements 71, 72 and 73 greatly contributing to the illuminance of the peripheral part of the irradiated area is appropriately short, and the coil length L_{C3} of the central filament element 70 greatly contributing to the illuminance (central illuminance) of the center part of irradiated area is as long as possible. As a result, firstly, it is possible to keep the contribution by the peripheral filament elements 71, 72 and 73 to the illuminance on the central part of the irradiated area, and decrease the illuminance on the peripheral part of the irradiated area as much as possible. Secondly, it is possible to increase the central illuminance because of the increase of the coil length L_{C3} of the central filament element 70. This synergistic effect results in a favorable light distribution curve. However, when $L_{S3}/L_{C3} < 0.2$ is satisfied, although the coil length L_{C3} of the central filament element 70 is longer, the part sticking out of the above-described central illuminance contributing region within the reflection mirror part 55 increases, and the coil length L_{S3} of the peripheral filament elements 71, 72 and 73 is too shorter than the coil length L_{C3} of the central filament element 70. Accordingly, the effect of placing the peripheral filament elements 71, 72 and 73 decreases. Also, when $L_{S3}/L_{C3} > 0.9$ is satisfied, since the coil length L_{C3} of the central filament element 70 is not longer enough than the coil length L_{S3} of the peripheral filament element 71, 72 and 73, in other words, since the coil length L_{S3} of the peripheral filament elements 71, 72 and 73 is longer than the case where $L_{S3}/L_{C3} \leq 0.9$ is satisfied, the illuminance of the peripheral region around the central region in the irradiated area is increased by the peripheral filament elements 71, 72 and 73, and a desired beam angle, especially a narrow angle (e.g. 10°, the allowable range is 7.5°-12.5°) can not be obtained.

[0183] In this case, it is preferable that the distance D_5 between the central filament element 70 and each of the peripheral filament elements 71, 72 and 73 is set to be 0 .1 [mm] to 2.2 [mm]. This increases the space occupied by the filament assembly 68 in the above-described central illuminance contributing region, greatly heightens the central illuminance, and prevents that an arc discharge, caused during the lighting between the central filament element 70 and each of the peripheral filament elements 71, 72 and 73 and the central filament element 7 0, burns out the central filament element 7 0 and the peripheral filament elements 71, 72 and 73. Meanwhile, if the distance D_1 is shorter than 0.1 [mm], it is possible that an arc discharge is caused during the lighting between the central filament element 70 and each of the peripheral filament elements 71, 72 and 73 and the central filament element 70 and the peripheral filament elements 71, 72 and 73 are burnt out. If the distance D_1 is longer than 2.2 [mm], the space occupied by the filament assembly 68 in the central illuminance contributing region decreases and the central illuminance might not be increased sufficiently or the illuminance of the peripheral region around the central region in the irradiated area might be increased by the periphery filament elements 71, 72 and 73.

[0184] Instead of a single-wound coil, a double-wound coil or a triple-wound coil may be used as a coil included in the filament elements 70, 71, 72 and 73. However, from the viewpoint of increasing the central illuminance of the halide lamp 53 built within the reflection mirror part 55 of the lighting apparatus 54, the single wining coil is preferable than the double-wound coil and the triple-wound coil. This is because with the single-wound coil, the pitch can be small and the space occupied by the filament assembly 68 in the above-described central illuminance contributing region (region within the reflection mirror, contributing to the central illuminance. That is, the region including the focal point of the reflection mirror part 55 and its vicinity) can be increased.

[0185] As described above, with the stated structure of the halide lamp 53 according to the ninth embodiment of the present invention, in the same manner as the halide lamp according to the eighth embodiment, it is possible to make the convection zone generated between the bulb 56 and the filament assembly 68 extremely thin, and decrease the amount of evaporation of the tungsten included in the filament assembly 68. As a result, it becomes possible to prevent the burnout of the coils included in the filament assembly 68 due to the thinned tungsten wire of the coil, and achieve a long life. Moreover, since the distance between the bulb 56 and the filament assembly 68 is kept to be moderate distance, it is possible to prevent that the temperature of the bulb 56 and the filament assembly 68 increases to an abnormal level during the lighting. This prevents the damage to the bulb 56 and the blackening of the internal surface of the bulb 56 due to excessive evaporation of the tungsten included in the filament assembly 68.

[0186] Especially, since $0.2 \leq L_{S3}/L_{C3} \leq 0.9$ is satisfied, where L_{C3} [mm] is the coil length of the central filament element 70 and L_{S3} [mm] is the coil length of the peripheral filament elements 71, 72 and 73, in a state where the halide lamp 53 is built into the reflection mirror part 55 of the lighting apparatus 54, it is possible to increase the central illuminance by contribution of the central filament element 70 and the peripheral filament elements 71, 72 and 73, and prevent the spreading of the light irradiated by the peripheral filament elements 71, 72 and 73. This realizes a narrow angle and a favorable light distribution.

[0187] Also, especially since the D_5 between the central filament element 70 and each of the peripheral filament elements 71, 72 and 73 is set to be 0.1 [mm] to 2.2 [mm], the space occupied by the filament assembly 68 in the above-described central illuminance contributing region is increased, and an arc discharge, caused during the lighting between the central filament element 70 and each of the peripheral filament elements 71, 72 and 73, can be prevented so as not to burn out the central filament element 70 and the peripheral filament elements 71, 72 and 73.

[0188] In the ninth embodiment, the case where the three filament elements 71, 72 and 73 are arranged to substantially form an equilateral triangle is described. However, the same effect can be achieved when four filament elements are arranged to substantially form a square, when five filament elements are arranged to substantially form an equilateral pentagon, when six filament elements are arranged to substantially form an equilateral hexagon, and so on.

[0189] The above-described ninth embodiment describes the case where the bulb has a structure including, as integral parts, the chip-off part 62, the light emitting part 63 substantially in a shape of a spheroid, the short-diameter part 64, the cylinder part 65 and the sealing part 66. However, the present invention is not limited to this. Well-known bulbs in various shapes may be used. For instance, the bulb may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spheroidal shape, the short-diameter part and the sealing part. Alternatively, the bulb may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spheroidal shape and the sealing part. Alternatively,the bulbmay includeseries of the chip-off part (sometimes not included), the light emitting part substantially in the cylindrical shape and the sealing part. As a matter of course, the light emitting part may be substantially in the spherical shape or substantially in a shape of a combination of a plurality of ellipsoids, instead of the above-described spheroidal shape.

[0190] In the ninth embodiment, the case of using the filament elements 70, 71, 72 and 73 in each of which the tungsten wire is formed in a cylindrical shape is described. In other words, the outline of the cross section of each tungsten wire cut along a plane vertical to the central axes a3, b3, c3 and d3 is in a circular shape. However, the present invention is not limited to this. For instance, as FIG. 28 shows, filament elements 74, 75 and 76 and 77 in each of which the tungsten wire is formed such that the outline of the cross section of the tungsten wire cut along a plane vertical to the central axes a3, b3, c3 and d3 is in an ellipsoidal shape may be used to achieve the same effect. Regarding the example shown in FIG. 28, the filament elements 74, 75, 76 and 77 fall within a column whose center point is in the central axis X_3 of the bulb 56 in the longitudinal direction and whose maximum outer diameter is the diameter of a circle circumscribing the filament elements 74, 75, 76 and 77. The maximum outer diameter r_3 of the filament assembly 78 including the filament elements 74, 75, 76 and 77, whose outline shapes are shown in FIG. 28, can be obtained in this manner.

(Tenth Embodiment)

As FIG. 29 shows, a reflection-mirror-equipped halide lamp 79 according to the tenth embodiment, whose rated power is 65 [W] (rated voltage: 110 [V]), includes a reflection mirror 80 having a concave surface whose mirror diameter φ_2 is 35 [mm] to 100 [mm] (outermost diameter is 50 [mm], for instance), a halide lamp 31 (except for the base 34) according to the fifth embodiment housed in the reflection mirror 80, and a base of an E type attached to the end of the reflection mirror 80

[0191] The central axis X_4 of the bulb 32 of the halide lamp 31 in the longitudinal direction is substantially the same as the optical axis Y_4 of the reflection mirror 49.

The reflection mirror 80 is made of hard glass, silica glass or the like, and an opening part 82 that emits light is formed on the one side of the reflection mirror 80, and a neck part 83 in a cylindrical shape is formed on the other end. A reflection surface 84 in the shape of a spheroid, a paraboloid or the like is formed on the internal surface of the reflection mirror 80. If necessary, a facet may be formed on the reflection surface 84.

[0192] A front glass 85 is fixed to the opening part 82 by a well-known latch 86. To fix the front grass 85, a well-known adhesive (not illustrated) may be used instead of the latch 86, or the latch 86 and the adhesive may be used together. As a matter of course, the front glass 85 is not necessarily required.

Outside the neck part 83, the base 81 is set up to cover almost the whole body of the neck part 83, and fixed with an adhesive 87. Inside the neck part 83, a sealing part 40 of the halide lamp 31, which is described later, is inserted into the neck part 83, and fixed with the adhesive 87 in the same manner.

[0193] On the reflection surface 84, a multilayer interference film including silicon dioxide (SiO_2), titanium dioxide (TiO_2), magnesium fluoride (MgF), zinc sulfide (ZnS), and so on is formed in addition to a metal film, such as aluminum and chrome.

As described above, with the stated structure of the halide lamp 79 according to the tenth embodiment of the present invention, in the same manner as the halide lamp according to the eighth embodiment of the present invention, it is possible to make the convection zone generated between the bulb 32 and the filament assembly 42 extremely thin, and decrease the amount of evaporation of the tungsten included in the filament assembly 42. As a result, it becomes possible to prevent the burnout of the coils included in the filament assembly 42 due to the thinned tungsten wire of the coil, and achieve a long life. Moreover, since the distance between the bulb 32 and the filament assembly 42 is kept to be moderate distance, it is possible to prevent that the temperature of the bulb 32 and the filament assembly 42 increases to an abnormal level during the lighting. This prevents the damage to the bulb 32 and the blackening of the internal surface of the bulb 32 due to excessive evaporation of the tungsten included in the filament assembly 42.

[0194] In the tenth embodiment, the case where the three filament elements 46, 47 and 48 are arranged to substantially form an equilateral triangle is described. However the same effect can be achieved when four filament elements are arranged to substantially form a square, when five filament elements are arranged to substantially form an equilateral pentagon, when six filament elements are arranged to substantially form an equilateral hexagon, and so on. As a matter of course, the same effect can be achieved by the case where a filament assembly in which another filament element having the same size and shape as the other filaments or different size and shape may be positioned in the space among the filament elements so as to be in the central axis X_4 of the bulb 2 in the longitudinal direction of the bulb 2.

[0195] The above-described embodiment describes the case where the bulb 32 has a structure including, as integral parts, the chip-off part 36, the light emitting part 37 substantially in a shape of a spheroid, the short-diameter part 38, the cylinder part 39 and the sealing part 40. However, the present invention is not limited to this. Well-known bulbs in various shapes may be used. For instance, the bulb 32 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spheroidal shape, the short-diameter part and the sealing part. Alternatively, the bulb 32 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spheroidal shape and the sealing part. Alternatively, the bulb 32 may include series of the chip-off part (sometimes not included), the light emitting part substantially in the cylindrical shape and the sealing part. As a matter of course, the light emitting part may be substantially in the spherical shape or substantially in a shape of a combination of a plurality of ellipsoids, instead of the above-described spheroidal shape.

[0196] In the tenth embodiment, the case of using the filament elements 46, 47 and 4 8 in each of which the tungsten wire is formed in a cylindrical shape is described. In other words, the outline of the cross section of each tungsten wire cut along a plane vertical to the central axes b3, c3 and d3 is circular shape. However, the present invention is not limited to this. For instance, as FIG. 24 shows, filament elements 49, 50 and 51 in each of which the tungsten wire is formed such that the outline of the cross section of the tungsten wire cut along a plane vertical to the central axes b3, c3 and d3 is in a racetrack shape may be used to achieve the same effect. Regarding the example shown in FIG.24, the filament elements 49, 50 and 51 fall within a column whose center point is in the central axis X_2 of the bulb 32 in the longitudinal direction and whose maximum outer diameter is the diameter of a circle circumscribing the filament elements 49, 50 and 51. The maximum outer diameter r_1 of the filament assembly 52 including the filament elements 49, 50 and 51, whose outline shapes are shown in FIG.24, can be obtained in this manner.

(Eleventh Embodiment)

As FIG. 30 shows, a halide lamp 88 of the eleventh embodiment according to the present invention, whose rated power is 65 [W] (rated voltage: 110 [V]), includes a reflection mirror 89 having a concave surface whose mirror diameter φ_2 is 35 [mm] to 100 [mm] (50 [mm], for instance), a halide lamp 90 housed in the reflection mirror 89, and a base 91 of an E type attached to the end of the reflection mirror 89.

[0197] The central axis X_5 of the bulb 101, which is described later, of the halide lamp 90in the longitudinal direction is substantially the same as the optical axis Y_5 of the reflection mirror 89.

The reflection mirror 89 is made of hard glass, silica glass or the like, and an opening part 93 that emits light is formed on the one side of the reflection mirror 89, and a neck part 94 in a cylindrical shape is formed on the other end. A reflection surface 95 in the shape of a spheroid, a paraboloid or the like is formed on the internal surface of the reflection mirror 89. If necessary, a facet may be formed on the reflection surface 95.

[0198] A front glass 96 is fixed to the opening part 93 by a well-known latch (not illustrated), a well-known adhesive (not illustrated) may be used instead of the latch, or both of them. As a matter of course, the front glass 96 is not necessarily required.

Outside the neck part 94, the base 91 is placed to cover approximately a half of the body of the neck part 94, and fixed with an adhesive 97. Inside the neck part 94, a sealing part 100 of the halide lamp 90, which is described later, is inserted into the neck part 94, and fixed with the adhesive 97 in the same manner.

[0199] On the reflection surface 95, a multilayer interference film including silicon dioxide (SiO_2), titanium dioxide (TiO_2), magnesium fluoride (MgF), zinc sulfide (ZnS), and so on is formed in addition to a metal film, such as aluminum and chrome.

The halide lamp 90 includes a bulb 101 which includes a series of a chip-off part 98, which is a remainder resultant from chipping off of the sealing, a light emitting part 99 substantially in a shape of a spheroid and a sealing part 100 formed by a well-known pinch seal method. A visible light transmitting and infrared reflecting film may be formed on the outer surface of the bulb 101.

[0200] Here, the expression "substantially in a shape of a spheroid" includes, in addition to a perfect spheroid, a shape transformed from a perfect spheroid due to the variation in the processing of glass.

A filament assembly 102 is placed within the light emitting part 99, and a predetermined amount of a halogen substance and a rare gas, or a halogen substance, a rare gas and a nitrogen gas are enclosed within the light emitting part 99.

[0201] One end of an internal lead 103 made of tungsten or the like is connected to the both ends of the filament assembly 102, and the other end of the internal lead 103 is connected to one end of the external lead 105 via a metal foil 104 made of molybdenum sealed by the sealing part 100. The other end of the external lead is extended outside of the bulb 101, and electrically connected to terminals 92a and 92b of the base.

[0202] In this embodiment, the structure of the filament assembly 102 is the same as the structure of the filament assembly 68 of the sixth embodiment. Therefore, the filament assembly 102 is described next with reference to FIG.26 and FIG.27.

As FIG. 26 and FIG. 27 shows, the filament assembly 102 includes one central filament element 106 and three peripheral filament elements 107, 108 and 109. Each of the central filament element 106 and three peripheral filament elements 107, 108 and 109 is made of tungsten, and it’s a single-wound coil substantially extending linearly. They are electrically connected in series. The wire diameter of the tungsten wire included in each single-wound coil is from 0.015 [mm] to 0.100 [mm]. For instance, it is 0.050 [mm].

[0203] The central axis a3 of the central filament element 106 is substantially the same as the optical axis Y_5 of the reflection mirror 89. Here, "substantially the same" means that it is preferable that the central axis a3 is completely the same as the optical axis Y_5 of the reflection mirror 89, but the central axis a3 might be misaligned from the optical axis Y_5 of the reflection mirror 89 due to the variation in the positioning accuracy of the manufacturing process.

[0204] The peripheral filament elements 107, 108 and 109 are positioned around the central filament element 106 such that their respective central axes b3, c3 and d3 are substantially parallel to the central axis a3 of the central filament element 106. Also, as FIG.27 shows, the three peripheral filament elements 107, 108 and 109 are positioned such that the intersection points of the central axes b3, c3 and d3 with an arbitrary plane P_3 that is vertical to the central axis a3 of the central filament element 106 substantially form an equilateral triangle having a point in the central axis a3 as a center of gravity (center of figure). In other words, a distance D_5 between the central filament element 106 and each of the peripheral filament elements 107, 108 and 109 is the same, and a distance D_6 between the peripheral filament element 107 (or 108 or 109) and each of the adj acent two peripheral filament elements 108 and 109 (107 and 109 or 107 and 108) is the same.

[0205] The expressions "substantially parallel" and "substantially form an equilateral triangle" means that it is difficult to form a perfect parallel and a perfect equilateral triangle due to variation in assembling accuracy of the assembling process of the filament assembly 102 and sometimes the axes might be misaligned. The expressions include such a case. Regarding the distances D_5 and D_6, the expression "substantially the same" is also used in the same manner.

[0206] As FIG. 30 shows, the central filament element 106 is positioned such that the central filament element 106 includes a focal point F_2 of a body of revolution forming the reflection surface 95 and a central point A_3 in the central axis a3 of the central filament element 106 is further from the opening part 93 than the focal point F_2. In the same manner, the peripheral filament elements 107, 108 and 109 respectively include points F_{b3}, F_{c3} and F_{d3} described later (FIG.26 only shows the points F_{b3} and F_{c3}) which are included in the reflection mirror 89, and central points B_3, C_3 and D_3 respectively in the central axes b3, c3 and d3 of the peripheral filament elements 107, 108 and 109 (FIG.26 only shows the points B_3 and C_3) are further from the opening part 93 than the points F_{b3}, F_{c3} and F_{d3}. Here, note that the points

F_{b3}, F_{c3} and F_{d3} include the focal point F_2 of the body of revolution forming the reflection surface 95, and represent the intersection points of the central axes b3, c3 and d3 with a plane Q_3 that is vertical to the optical axis Y_5 of the reflection mirror 89. For example, the distance between the focal point F_2 and the central point A_3 is 2.35 [mm], and the distance between the points F_{b3}, F_{c3} and F_{d3} and the central points B_3, C_3 and D_3 is 1. 20 [mm]. In this way, by positioning the central filament element 106 and the peripheral filament elements 107, 108 and 109 so that the central point A_3 of the central filament element 106 and the central points B_3, C_3 and D_3 of the peripheral filament elements are further from the opening part 93 than the focal point F_2 of the reflection surface 95 of the reflection mirror 89, the space occupied by the filament assembly 102 in the region including the focal point F_2 and its vicinity (Hereinafter simply called "the central illuminance contributing region") can be increased and the central illuminance can be heightened.

[0207] Regarding such a filament assembly 102, the central filament element 106 and the peripheral filament elements 107, 108 and 109 are within a column body whose outer diameter (the maximum outer diameter) is r_3 [mm], and this column body can be assumed as one filament including the central filament element 106 and the peripheral filament elements 107, 108 and 109. In this case, $0.25 \leq r_3/R_3 \leq 0.75$ is satisfied in the following reason, where R_4 [mm] is the maximum inner diameter of a portion of the bulb 101 corresponding to the filament assembly 102, and r_3 [mm] is the maximum outer diameter of the filament assembly 102 assumed as one filament.

[0208] The maximum outer diameter r_3 can be adjusted by changing the maximum outer diameter r_2 of the central filament element 106 and the peripheral filament elements 107, 108 and 109, and the distance D_6 between the adjacent two filament elements (or the distance D_5). Also, the maximum outer diameter r_2 of each of the central filament element 106 and the peripheral filament elements 107, 108 and 109 can be adjusted by changing the coil length L_{C3} of the central filament element 106 or the coil length L_{S3} of the each of the peripheral filament elements 107, 108 and 109 and the pitch.

[0209] Here, the coil length L_{C3} of the central filament element 106 and the coil length L_{S3} of the each of the peripheral filament elements 107, 108 and 109 may be the same. For instance, in the case of a halide lamp whose rated power is 65 [W], it is preferable that the coil lengths L_{C3} and L_{S3} are set to 3. 0 [mm] to 5.0 [mm]. Also, although the coil length L_{S3} of the peripheral filament elements 107, 108 and 109 is the same, the coil lengths L_{C3} and L_{S3} may be different. For instance, in the case of a halide lamp whose rated power is 65 [W], it is preferable that the coil length L_{C3} is set to 3. 5 [mm] to 15. 0 [mm], and the coil length L_{S3} is set to 1. 5 [mm] to 4.5 [mm] . Further, the coil length L_{C3} may be different from the coil length L_{S3} and the coil length L_{S3} may be different for each of the peripheral filament elements 71, 72 and 73. For instance, in the case of a halide lamp whose rated power is 65 [W], it is preferable that the coil length L_{C3} is set to 3. 5 [mm] to 15. 0 [mm], and each coil length L_{S3} is set to 1.5 [mm] to 4.5 [mm] . The pitch of the single-wound coils is set to 0.05 [mm] to 0.07 [mm] regarding each of the central filament element 106 and the peripheral filament elements 107, 108 and 109.

[0210] However, in the viewpoint of making the illuminance on the area irradiated by the peripheral filament elements 107, 108 and 109 consistent, it is preferable that at least one of the maximum outer diameter r_2 and the coil Length L_{S3} is the same, and it is more favorable that both of them are the same. Note that, the maximum outer diameter r_2 and the coil length L_{S3} might vary for each of the peripheral filament elements 107, 108 and 109 due to variation in accuracy in the manufacturing process of the peripheral filament elements 107, 108 and 109.

[0211] Also, regarding the ends of each of the filament elements 106, 107, 108 and 109, it is preferable that one of the ends that is closer to the opening part 93 is substantially on the same plane. This makes the illuminance on the area irradiated by each of the filament elements 106, 107, 108 and 109 consistent. As a result, the light distribution curve can be uniformed.

Further, it is preferable that $0.2 \leq L_{S3}/L_{C3} \leq 0.9$ is satisfied in the reason described later. Note that the coil length L_{S3} of each of the peripheral element 107, 108 and 109 is substantially the same. The expression "substantially the same" means that the coil length L_{S3} might vary due to variation of accuracy in the manufacturing process of the coil.

[0212] In this case, it is preferable that the distance D_5 between the central filament element 106 and each of the peripheral filament elements 107, 108 and 109 is set to be 0.1 [mm] to 2.2 [mm]. This increases the space occupied by the filament assembly 102 in the above-described central illuminance contributing region, and prevents that an arc discharge, caused during the lighting between the central filament element 106 and each of the peripheral filament elements 107, 108 and 109 and the central filament element 106, burns out the central filament element 106 and the peripheral filament elements 107, 108 and 109. Meanwhile, if the distance D_5 is shorter than 0.1 [mm], it is possible that an arc discharge is caused during the lighting between the central filament element 106 and each of the peripheral filament elements 107, 108 and 109 and the central filament element 106 and the peripheral filament elements 107, 108 and 109 are burnt out. If the distance D_5 is longer than 2.2 [mm], the space occupied by the filament assembly 102 in the central illuminance contributing region decreases and the central illuminance might not be increased sufficiently or the illuminance of the peripheral region around the central region in the irradiated area might be increased by the periphery filament elements 107, 108 and 109, and a desired beam angle, especially a narrow angle (e.g. 10°, the allowable range is 7.5°-12.5°) can not be obtained.

[0213] Instead of a single-wound coil, a double-wound coil or a triple-wound coil may be used as a coil included in the central filament element 106 and the peripheral filament elements 107, 108 and 109. However, from the viewpoint of increasing the central illuminance, the single wining coil is preferable than the double-wound coil and the triple-wound coil. This is because with the single-wound coil, the pitch can be small and the space occupied by the filament assembly 102 in the central illuminance contributing region with in the reflection mirror 89 can be increased.

[0214] The following describes the reason why r_3/R_4 are set to satisfy $0.25 \leq r_3/R_4 \leq 0.75$ is satisfied, where R_4 [mm] is the maximum inner diameter of a portion of the bulb 101 corresponding to the filament assembly 102, and r_3 [mm] is the maximum outer diameter of the filament assembly 102.

Firstly, using the above-described halide lamp 88 whose rated power is 65 [W], ten samples were made for each of the lamps shown in Table 4. Regarding each lamp, the maximum inner diameter R_4 measured at a portion of the bulb 101 corresponding to the filament assembly 102 was set to a constant value 9 mm, and the maximum outer diameter r_3 [mm] of the filament assembly 102 was changed by appropriately changing the distance D_6 between adj acent two filament elements. Each sample was lit at the rated power. Regarding each lamp, the number of the samples whose filament assembly 102 had been burnt out when 3500 or 4000 hours passed was counted. Also, among the samples whose filament assembly 102 had not been burnt out when 4000 hours passed, the number of the samples the internal surface of whose bulb 101 had been blackened was counted. Table 4 shows the result.

[0215] In the filed "burnt out" of Table 4, the denominator shows the total number of the samples, and the numerator shows the number of samples whose filament assembly 102 suffered the burnt out. In the field "blackening", the dominator shows the number of samples whose filament assembly did not suffer the burnt out, and the numerator shows, among the samples whose filament assembly did not suffer the burnt out, the number of samples the internal surface of whose bulb 101 was blackened. The blackening was checked with eyes.

[0216] The lamp was turned on for 5.5 hours and turned off for 0.5 hours in continuous cycles. The "lighting time" means the total of the period during which the lamp is turned on.

In each sample, each of the central filament element 106 and the filament elements 107, 108 and 109 includes the same single-wound coil having the same size and shape, and the pitch is 0.05 [mm] to 0.07 [mm], the maximum outer diameter r_2 is 0.65 [mm]. The coil length L_{C3} of the central filament element is 5.7 [mm], and the coil length L_{S3} of the peripheral filament element is 3.4 [mm].

[0217]

[Table 4]

r/R	Maximum outer diameter r [mm]	Maximum inner diameter R [mm]	After 3500 hour' s lighting	After 4000 hour' s lighting		Evaluation
			Burnout	Burnout	Blackening	
0.20	1.80	9	1/10	6/10	0/4	Bad
0.25	2.25	9	0/10	1/10	0/9	Good
0.35	3.15	9	0/10	0/10	0/10	Excellent
0.50	4.50	9	0/10	0/10	0/10	Excellent
0.75	6.75	9	0/10	0/10	0/10	Excellent
0.80	7.20	9	0/10	0/10	10/10	Bad

[0218] As Table 4 shows, when $0.25 \leq r_3/R_4 \leq 0.75$ is satisfied, for instance when r_3/R_4 = (0.25, 0.35, 0.50, 0.75), the filament assembly 102 of any sample had not been burnt out when 3500 hours passed, and the internal surface of the bulb 101 of any sample had been blackened. Especially, when $0.35 \leq r_3/R_4 \leq 0.75$ is satisfied, for instance when r_3/R_4 = (0.35, 0.50, 0.75), the filament assembly 102 of any sample had not been burnt out when 4000 hours passed.

[0219] When $0.25 > r_3/R_4$ is satisfied, for instance when r_3/R_4 = (0.20), the filament assembly 102 of six samples out of ten samples had been burnt out when 4000 hours passed, but the internal surface of the bulb 101 of any of the remaining four samples had not been blackened. When $r_3/R_4 > 0.75$ is satisfied, for instance when r_3/R_4 = (0. 80), although the filament assembly 102 of any of the ten samples had not been burnt out when 4000 hours passed, the internal surface of the bulb 101 of all the samples had been blackened.

[0220] The reason why such a result is obtained is described above.

As described above, it has been found that to prevent the blackening of the internal surface of the bulb 101 and the burnout of the filament assembly 102 and to achieve a long life, it is preferable that $0.25 \leq r_3/R_4 \leq 0.75$ is satisfied, where R_4 [mm] is the maximum inner diameter of a portion of the bulb 101 corresponding to the filament assembly 102 is, and r_3 [mm] is the maximum outer diameter of the filament assembly 102. Especially, to achieve a further longer life, it is preferable that $0.35 \leq r_3/R_4 \leq 0.75$ is satisfied.

[0221] Next, the following describes the reason why the coil length L_{C3} of the central filament element 106 and the coil length L_{S3} of the peripheral filament elements 107, 108 and 109 are set to satisfy $0.2 \leq L_{S3}/L_{C3} \leq 0.9$, where the coil length of the central filament element 106 is L_{C3} [mm] and the coil length of each of the peripheral filament elements 106, 107 and 108 is L_{S3} [mm].

Firstly, regarding the reflection-mirror-equipped halide lamp 88 whose rated power is 65 [W], five samples with different coil lengths were manufactured for each of the central filament element 106 and the peripheral filament elements 107, 108 and 109 by changing the coil length L_{C3} of the central filament element 106 and the coil length L_{S3} of each of the peripheral filament elements 107, 108 and 109 as Table 5 shows. Then, the lamp with each coil was lit at the rated power, and the beam angle (degrees) and the central illuminance [lx] were measured. The result (The relation between L_{S3}/L_{C3} and the beam angle) is shown in Table 5 and FIG. 31. As representative examples, a light distribution curve in the case where L_{S3}/L_{C3} = 0.9 is shown in FIG. 32 and a light distribution curve in the case where L_{S3}/L_{C3} = 0.6 is shown in FIG.33.

[0222] In the manufactured samples, the maximum inner diameter R_4 [mm] of a portion of the bulb 101 corresponding to the filament assembly 102 is 9.0 [mm]. Each of the central filament element 106 and the peripheral filament elements 107, 108 and 109 includes the single-wound coil, the pitch of each is 0.05 [mm] to 0.07 [mm], and the maximum outer diameter r_2 is 0.65 [mm]. The maximum outer diameter r_3 of the filament assembly 102 is 4.50 [mm]. The distance D_5 is 1. 275 [mm].

[0223] In Table 5, the "beam angle" represents an average of the beam angles of the five samples. The criterion of the beam angle is 10° (allowable range: 7.5° to 12.5°), which is the main stream of the beam angle of commercially available lamps.

The "central illuminance" represents an average of the central illuminance of the five examples. The central illuminance of a currently commercially available reflection-mirror-equipped halide lamp (herein after called "the conventional example"), whosebeamangle is 10° and rated power is 65 [W] (rated voltage: 110 [V]) is, for instance 6500 [cd]. Accordingly, in consideration of the demands of the market, the criterion is approximately 10% greater than the central illuminance (6500 [lx]) (the central luminous intensity: 6500 [cd]), which is 7200 [lx] (the central luminous intensity: 7200 [cd]).

[0224]

[Table 5]

L_{S3}/L_{C3}	L_{S3} [mm]	L_{C3} [mm]	Beam Angle [°]	Central Illuminance [lx]	Evaluation
0	0	16.0	7.5	5500	Bad
0.1	1.20	12.0	7.5	7000	Bad
0.2	2.00	10.0	7.5	8500	Good
0.3	2.46	8.2	8.0	9000	Good
0.4	2.84	7.1	8.7	9300	Good
0.5	3.15	6.3	9.5	9700	Good
0.6	3.42	5.7	10.0	9800	Good
0.7	3.57	5.1	10.8	9500	Good
0.8	3.68	4.6	11.5	9300	Good

(continued)

L_{S3}/L_{C3}	L_{S3} [mm]	L_{C3} [mm]	Beam Angle [°]	Central Illuminance [lx]	Evaluation
0.9	3.87	4.3	12.5	9000	Good
1.0	4.00	4.0	13.0	8500	Bad

[0225] As Table 5 clearly shows, when $0.2 \leq L_{S3}/L_{C3} \leq 0.9$ is satisfied, for instance when L_{S3}/L_{C3} = (0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9), the central illuminance is more than the central illuminance of the conventional example (6500 [lx]), and more than 8500 [lx] (8500 [cd] in central luminous intensity). Also, the beam angle is in the range between 7.5° to 12.5°. This satisfies the above-described criterion. This is also shown by the light distribution curve in FIG.32 and FIG. 33. The illuminance of the central part on the irradiated area is high, and the irradiating light is not spread to the peripheral part around the central part.

[0226] On the other hand, when $L_{S3}/L_{C3} > 0.9$ is satisfied, for instance when L_{S3}/L_{C3} = (1.0), although the central illuminance is more than the central illuminance of the conventional example (6500 [lx]) and satisfies the criterion, the beam angle is 13.0° which does not satisfy the criterion. When $L_{S1}/L_{C1} < 0.2$ is satisfied, for instance when L_{S3}/L_{C3} = (0, 0.1), although the beam angle is 7.5° and satisfies the criterion, the central illuminance does not satisfy the criterion.

[0227] The following is the reason for this result:

It is possible to appropriately shorten the coil length L_{S3} of the peripheral filament elements 107, 108 and 109 that greatly contribute to increase and decrease of the illuminance on the peripheral part of the central part of the irradiated area by lengthening the coil length L_{C3} of the central filament element 106 that greatly contribute to increase and decrease of the illuminance (the central illuminance) on the central part of the irradiated area in an appropriate range so as to be relatively longer than the coil length L_{S3} of the peripheral filament elements 107, 108 and 109. As a result, firstly, it is possible to decrease the illuminance of the peripheral part of the central part of the irradiated area as much as possible while keeping the contribution of the peripheral filament elements 107, 108 and 109 to the increase of the illuminance on the central part of the irradiated area. Secondly, due to the increase of the coil length L_{C3} of the central filament element 106, the illuminance of the central part of the irradiated area can be further increased. These first and second effects result in the favorable light distribution curves shown in FIG.32 and FIG. 33. However, when $L_{S3}/L_{C3} < 0.2$ is satisfied, although the coil length L_{C3} of the central filament element 106 is relatively long, a large part of the central filament element 106 is out of the central illuminance contributing region within the reflection mirror 89, and the coil length L_{S3} of the peripheral filament elements 107, 108 and 109 is relatively too short compared to the coil length L_{C3} of the central filament element 106. This greatly decreases the effect of disposing the peripheral filament elements 107, 108 and 109. When $L_{S3}/L_{C3} > 0.9$ is satisfied, since the coil length L_{C3} of the central filament element 108 is not relatively long compared to the coil length L_{S3} of the peripheral filament elements 107, 108 and 109, it is believed that the illuminance of the peripheral area around the central part of the irradiated area is increased by the peripheral filament elements 107, 108 and 109 and accordingly the desired beam angle can not be achieved.

[0228] Therefore, to increase the central illuminance by contribution of the central filament element 106 and the peripheral filament elements 107, 108 and 109, and achieve the desired beam angle (narrow angle) to realize favorable light distribution properties, $0.2 \leq L_{S3}/L_{C3} \leq 0.9$ should be satisfied, where the coil length of the central filament element 106 is L_{S3} [mm] and the coil length of the peripheral filament elements 107, 108 and 109 is L_{C3} [mm].

[0229] As described above, with the stated structure of the halide lamp 88 according to the eleventh embodiment of the present invention, in the same manner as the halide lamp 31 of the above-described eighth embodiment, it is possible to make the convection zone generated between the bulb 101 and the filament assembly 102 extremely thin, and decrease the amount of evaporation of the tungsten included in the filament assembly 102. As a result, it becomes possible to prevent the burnout of the coils included in the filament assembly 102 due to the thinned tungsten wire of the coil, and achieve a long life. Moreover, since the distance between the bulb 101 and the filament assembly 102 is kept to be moderate distance, it is possible to prevent that the temperature of the bulb 101 and the filament assembly 102 increases to an abnormal level during the lighting. This prevents the damage to the bulb 101 and the blackening of the internal surface of the bulb 101 due to excessive evaporation of the tungsten included in the filament assembly 102.

[0230] Especially, since $0.2 \leq L_{S3}/L_{C3} \leq 0.9$ is satisfied, where L_{C3} [mm] is the coil length of the central filament element 106 and L_{S3} [mm] is the coil length of the peripheral filament elements 107, 108 and 109, it is possible to increase the central luminance by contribution of the central filament element 106 and the peripheral filament elements 107, 108 and 109, and prevent the spreading of the light irradiated by the peripheral filament elements 107, 108 and 109. This realizes a narrow angle and a favorable light distribution.

[0231] Also, especially since the D_5 between the central filament element 106 and each of the peripheral filament elements 107, 108 and 109 is set to be 0.1 [mm] to 2.2 [mm], the space occupied by the filament assembly 102 in the above-described central illuminance contributing region is increased, and an arc discharge, caused during the lighting between the central filament element 106 and each of the peripheral filament elements 107, 108 and 109, can be prevented so as not to burn out the central filament element 106 and the peripheral filament elements 107, 108 and 109.

[0232] In the eleventh embodiment, the case where the three filament elements 107, 108 and 109 are arranged to substantially form an equilateral triangle is described. However, the same effect can be achieved when four filament elements are arranged to substantially form a square, when five filament elements are arranged to substantially form an equilateral pentagon, when sixfilament elements are arranged to substantially form an equilateral hexagon, and so on.

[0233] The above-described eleventh embodiment describes the case where the bulb 101 has a structure including, as integral parts, the chip-off part 98, the light emitting part 99 substantially in a shape of a spheroid and the sealing part 100. However, the present invention is not limited to this. Well-known bulbs in various shapes may be used. For instance, the bulb may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spheroidal shape and the sealing part. Alternatively, the bulb may include series of the chip-off part (sometimes not included), the light emitting part substantially in the spheroidal shape, the short-diameter part and the sealing part. Alternatively, the bulb may include series of the chip-off part (sometimes not included), the light emitting part substantially in the cylindrical shape, the short-diameter part, the cylinder part and the sealing part. As a matter of course, the light emitting part may be substantially in the spherical shape or substantially in a shape of a combination of a plurality of ellipsoids, instead of the above-described spheroidal shape.

[0234] In the eleventh embodiment, the case of using the filament elements 106, 107, 108 and 109 in each of which the tungsten wire is formed in a cylindrical shape is described. In other words, the outline of the cross section of each tungsten wire cut along a plane vertical to the central axes a3, b3, c3 and d3 is circular shape. However, the present invention is not limited to this. For instance, as FIG.28 shows, filament elements 74, 75 and 76 and 77 in each of which the tungsten wire is formed such that the outline of the cross section of the tungsten wire cut along a plane vertical to the central axes a3, b3, c3 and d3 is in an ellipsoidal shape may be used to achieve the same effect.

(Twelfth Embodiment)

A lighting apparatus of the twelfth embodiment of the present invention is used as a spot light for general lighting for example, and has a structure in which the reflection-mirror-equipped halide lamp 31 according to the tenth embodiment of the present invention, whose rated power is 65 [W], is attached to a well-known lighting fixture (not illustrated).

[0235] The lighting fixture usually includes a reflecting plate having a flat surface or a curved surface, or a reflection mirror having a concave surface. The light from the halide lamp 31 is reflected by the reflection mirror, and emitted through an opening part of the lighting fixture.

With such a lighting apparatus according to the twelfth embodiment, it is possible to realize a lighting apparatus having a long life.

(Thirteenth Embodiment)

A lighting apparatus of the thirteenth embodiment of the present invention is used as a spot light for general lighting for example, and has a structure in which the reflection-mirror-equipped halide lamp 53 according to the ninth embodiment of the present invention, whose rated power is 65 [W], is attached to a well-known lighting fixture (not illustrated).

[0236] The lighting fixture includes a concave reflection mirror whose reflection surface is in a spheroidal shape or a paraboloidal shape. The reflection mirror may be fixed to the lighting fixture and not be detachable, or may be detachable and replaced depending on the purpose. The light from the halide lamp 53 is reflected by the reflection mirror, and emitted through an opening part of the lighting fixture.

[0237] With such a lighting apparatus according to the thirteenth embodiment, it is possible to realize a lighting apparatus having a long life.

(Fourteenth Embodiment)

A lighting apparatus of the fourteenth embodiment of the present invention is used as a spot light for general lighting for example, and has a structure in which the reflection-mirror-equipped halide lamp 79 according to the tenth embodiment of the present invention, whose rated power is 65 [W], is attached to a well-known lighting fixture (not illustrated).

[0238] With such a lighting apparatus according to the fourteenth embodiment, it is possible to realize a lighting apparatus having a long life.

(Fifteenth Embodiment)

A lighting apparatus of the fifteenth embodiment of the present invention is used as a spot light for general lighting for example, and has a structure in which the reflection-mirror-equipped halide lamp 88 according to the eleventh embodiment of the present invention, whose rated power is 65 [W], is attached to a well-known lighting fixture (not illustrated).

[0239] With such a lighting apparatus according to the fifteenth embodiment, it is possible to realize a lighting apparatus having a long lifetime.

Although the embodiment above describes the case where the halide lamp whose rated power is 65 [W] is used, the present invention is not limited to this. For instance, in the case where a halide lamp whose rated power is 20 [W] to 150 [W] is used, the same effect can be achieved.

[0240] Also, although the embodiment above describes the case where a halide lamp is used, the same effect can be achieved if a well-known incandescent lamp is used instead of the halide lamp.

Industrial Applicability

[0241] The present invention does not use a multiple winding coil, and this makes the light emitting body compact, and accordingly the light converging efficiency is improved. Also, the present invention can be mass-produced.
The present invention increases the central illuminance, and realizes favorable light distribution properties especially in the case of the narrow angle type. Therefore, the present invention meets demands for miniaturization of a bulb and for highlighting a display, which are on a light for general use, especially on a lamp for use in a store.
Furthermore, a long life can be realized by the present invention. This extends the life cycle of the lamp, and avoids the trouble of having to change the lamp. This means the industrial applicability of the present invention is wide.

Claims

1. A lamp that is to be built into a reflection mirror of a lighting apparatus, a rated voltage of the lamp being from 100 [V] to 250 [V] inclusive, the lamp comprising:

    a bulb; and
    a filament assembly that is set up within the bulb, wherein
    the filament assembly includes a plurality of filament elements and is placed such that a focal point of the reflection mirror is included within the filament assembly when the lamp is built into the reflection mirror,
    the filament elements are single-wound coils, one of the filament elements being placed in an optical axis of the reflection mirror and one or more of the other filament elements being placed to be parallel to the optical axis, and
    an outline of each filament element is noncircular as viewed in a coil axis direction of the filament element.

2. A reflection-mirror-equipped lamp comprising:

    a reflection mirror having a concave reflection surface; and
    a lamp built into the reflection mirror, a rated voltage of the lamp being from 100 [V] to 250 [V] inclusive, wherein the lamp includes a bulb and a filament assembly that is set up within the bulb,
    the filament assembly includes a plurality of filament elements and is placed such that a focal point of the reflection mirror is included within the filament assembly,
    the filament elements are single-wound coils, one of the filament elements being placed in an optical axis of the reflection mirror and one or more of the other filament elements being placed to be parallel to the optical axis, and
    an outline of each filament element is noncircular as viewed in a coil axis direction of the filament element.

3. The lamp of Claim 1, wherein
the outline of each filament element is in a flattened shape.

4. The reflection-mirror-equipped lamp of Claim 2, wherein
the outline of each filament element is in a flattened shape.

5. The lamp of Claim 1, wherein
the outline of each filament element is in a rectangular shape, a racetrack shape, or an ellipsoidal shape.

6. The reflection-mirror-equipped lamp of Claim 2, wherein
the outline of each filament element is in a rectangular shape, a racetrack shape, or an ellipsoidal shape.

7. The lamp of Claim 1, wherein
the filament assembly includes three filament elements.

8. The reflection-mirror-equipped lamp of Claim 2, wherein
the filament assembly includes three filament elements.

9. The lamp of Claim 7, wherein
the three filament elements are arranged in the bulb such that central axes of the three filament elements are in the same plane.

10. The reflection-mirror-equipped lamp of Claim 8, wherein
the three filament elements are arranged in the bulb such that central axes of the three filament elements are in the same plane.

11. The lamp of Claim 1, wherein
a reflection surface of the reflection mirror is in a shape of a spheroid or a paraboloid of revolution, and an inner diameter of an opening of the reflection mirror is from 30 [mm] to 100 [mm] inclusive.

12. The reflection-mirror-equipped lamp of Claim 2, wherein
the reflection surface of the reflection mirror is in a shape of a spheroid or a paraboloid of revolution, and an inner diameter of an opening of the reflection mirror is from 30 [mm] to 100 [mm] inclusive.

13. A lighting apparatus comprising:

a lighting fixture including a reflection mirror; and
the lamp of Claim 1 that is built into the reflection mirror.

14. A lighting apparatus comprising:

a lighting fixture; and
the reflection-mirror-equipped lamp of Claim 2, which is attached to the lighting fixture.

15. A reflection-mirror-equipped lamp comprising:

a reflection mirror having a concave reflection surface; and
a lamp built into the reflection mirror, wherein
the lamp includes a bulb and a filament assembly that is set up within the bulb,
the filament assembly includes a central filament element whose central axis is substantially the same as an optical axis of the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element,
the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axis of the central filament element and the plane, and
$0.2 \leq L_S/L_C \leq 0.9$ is satisfied, where L_C is a length of the central filament element and L_S is a length of the peripheral filament element.

16. The reflection-mirror-equipped lamp of Claim 15, wherein
a distance D_1 between the central filament element and each peripheral filament element is from 0.1 [mm] to 2.2 [mm] inclusive.

17. A lamp that is to be built into a reflection mirror of a lighting apparatus, the lamp comprising:

a bulb; and
a filament assembly that is set up within the bulb, wherein
the filament assembly includes a central filament element whose central axis is substantially the same as an optical axis of the reflection mirror when the lamp is built into the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element,
the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axes of the central filament element and the plane, and
$0.2 \leq L_S/L_C \leq 0.9$ is satisfied, where L_C is a length of the central filament element and L_S is a length of the peripheral filament element.

18. The lamp of Claim 17, wherein
a distance D_1 between the central filament element and each peripheral filament element is from 0.1 [mm] to 2.2 [mm] inclusive.

19. A lighting apparatus comprising:

a lighting fixture; and
the reflection-mirror-equipped lamp of Claim 15 or Claim 16, which is attached to the lighting fixture.

20. A lighting apparatus comprising:

a lighting fixture including a reflection mirror; and
the lamp of Claim 17 or Claim 18, which is built into the reflection mirror.

21. A lamp comprising:

a bulb; and
a filament assembly that is set up within the bulb and includes at least three straight filament elements, wherein the filament elements are arranged around a central axis of the bulb such that central axes of the filament elements are parallel to the central axis of the bulb, and intersection points of the central axes of the filament elements and a plane vertical to the central axis of the bulb substantially form a regular polygon whose centroid is an intersection point of the central axis of the bulb and the plane, and
$0.25 \leq r/R \leq 0.75$ is satisfied, where R is a maximum inner diameter of a portion of the bulb corresponding to the filament assembly, and r is a maximum outer diameter of the filament assembly.

22. A lamp built into a reflection mirror of a lighting apparatus, the lamp comprising:

a bulb; and
a filament assembly that is set up within the bulb, wherein
the filament assembly includes a central filament element whose central axis is substantially the same as an optical axis of the reflection mirror when the lamp is built into the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element;
the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axes of the central filament element and the plane, and
$0.25 \leq r/R \leq 0.75$ is satisfied, where R is a maximum inner diameter of a portion of the bulb corresponding to the filament assembly, and r is a maximum outer diameter of the filament assembly.

23. The lamp of Claim 22, wherein
$0.2 \leq L_S/L_C \leq 0.9$ is satisfied, where L_C is a length of the central filament element and L_S is a length of the peripheral filament element.

24. The lamp of Claim 23, wherein
a distance D_1 between the central filament element and each peripheral filament element is from 0.1 [mm] to 2.2 [mm] inclusive.

25. A reflection-mirror-equipped lamp comprising:

a reflection mirror having a concave reflection surface; and
the lamp of Claim 21 built into the reflection mirror, wherein
the central axis of the bulb of the lamp is substantially the same as an optical axis of the reflection mirror.

26. A reflection-mirror-equipped lamp comprising:

a reflection mirror having a concave surface; and
a lamp built into the reflection mirror, wherein
the lamp includes a bulb and a filament assembly that is set up within the bulb,

the filament assembly includes a central filament element in a straight shape, whose central axis is substantially the same as an optical axis of the reflection mirror, and at least three peripheral filament elements whose central axes are substantially parallel to the central axis of the central filament element,
the peripheral filament elements are arranged such that intersection points of the central axes of the peripheral filament elements and a plane vertical to the central axis of the central filament element substantially form a regular polygon whose centroid is an intersection point of the central axis of the central filament element and the plane, and
$0.25 \leq r/R \leq 0.75$ is satisfied, where R is a maximum inner diameter of the bulb and r is a maximum outer diameter of the filament assembly.

27. The reflection-mirror-equipped lamp of Claim 26, wherein
$0.2 \leq L_S/L_C \leq 0.9$ is satisfied, where L_c is a length of the central filament element and L_s is a length of the peripheral filament element.

28. The reflection-mirror-equipped lamp of Claim 27, wherein
a distance D_1 between the central filament element and each peripheral filament element is from 0.1 [mm] to 2.2 [mm] inclusive.

29. A lighting apparatus comprising:

a lighting fixture; and
the lamp of Claim 21 which is attached to the lighting fixture.

30. A lighting apparatus comprising:

a lighting fixture including a reflection mirror; and
the lamp of any of Claims 22 to 24, which is built into the reflection mirror.

31. A lighting apparatus comprising:

a lighting fixture; and
any of the reflection-mirror-equipped lamp of Claims 25 to 28, which is attached to the lighting fixture.

FIG. 1

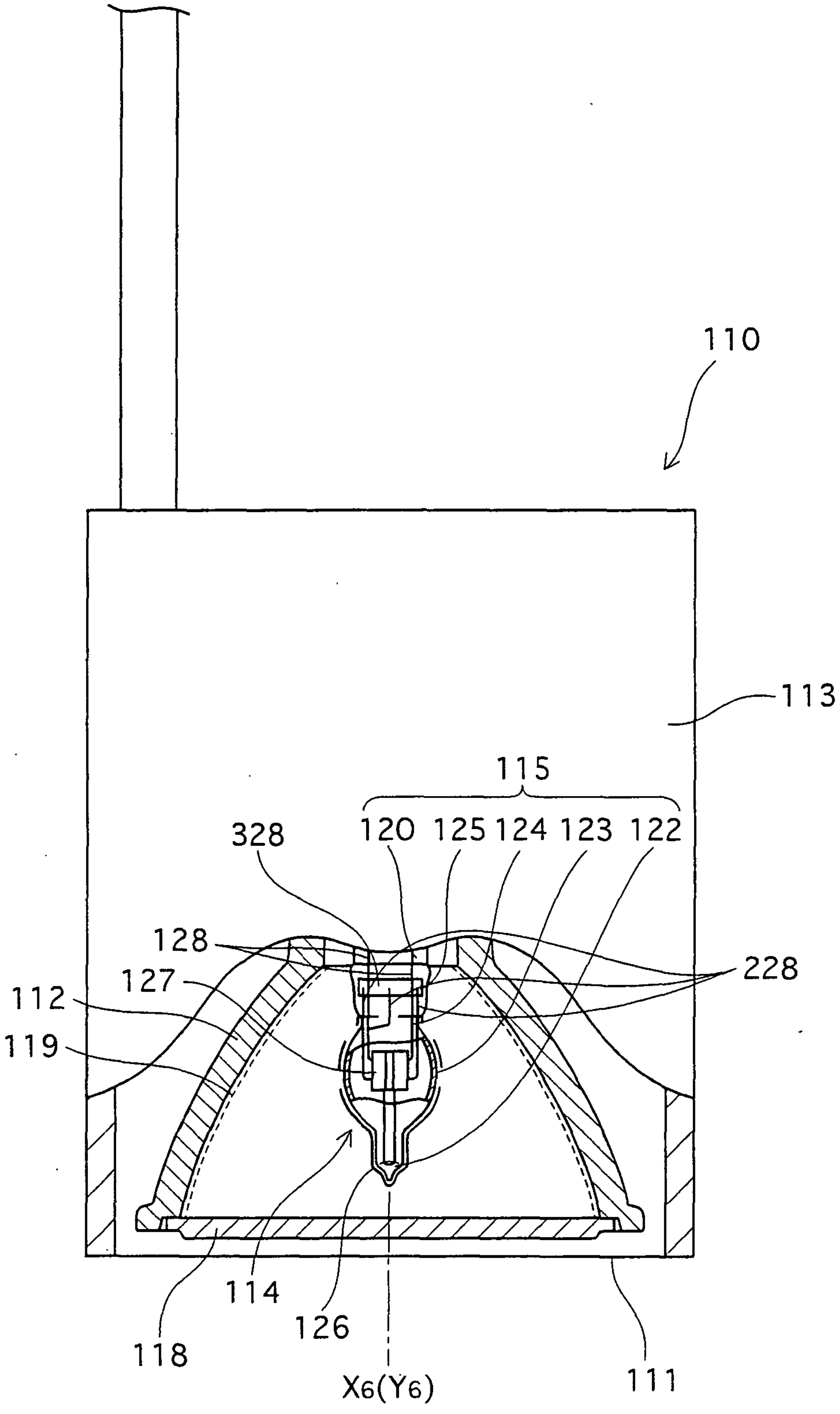

110
113
115
328
120
125
124
123
122
128
228
127
112
119
114
126
118
X6(Y6)
111

FIG.2

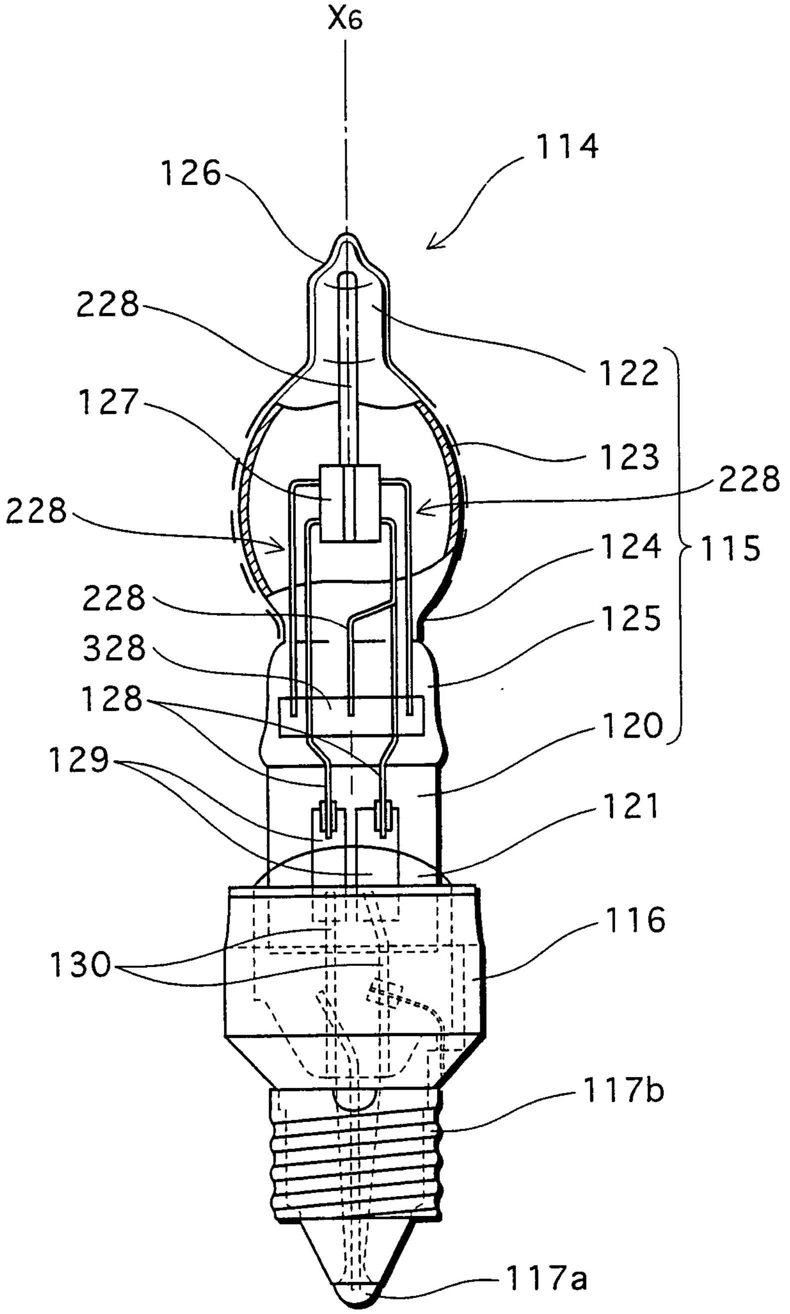

X6
114
126
228
122
127
123
228
228
124
115
228
125
328
128
120
129
121
116
130
117b
117a

FIG.3

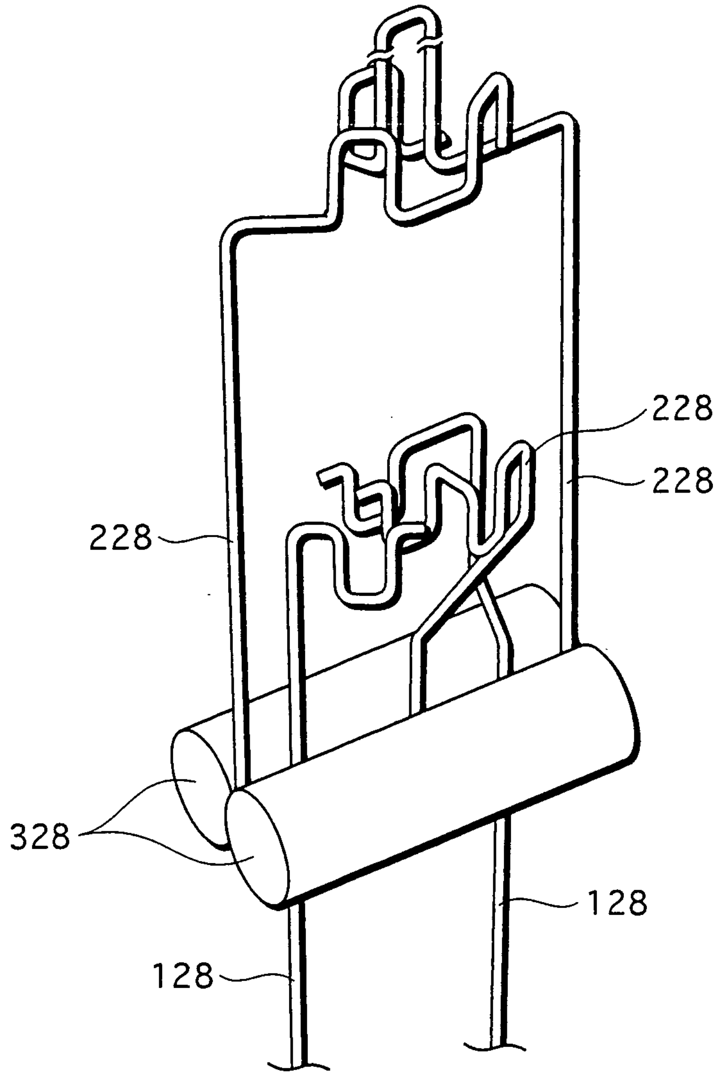
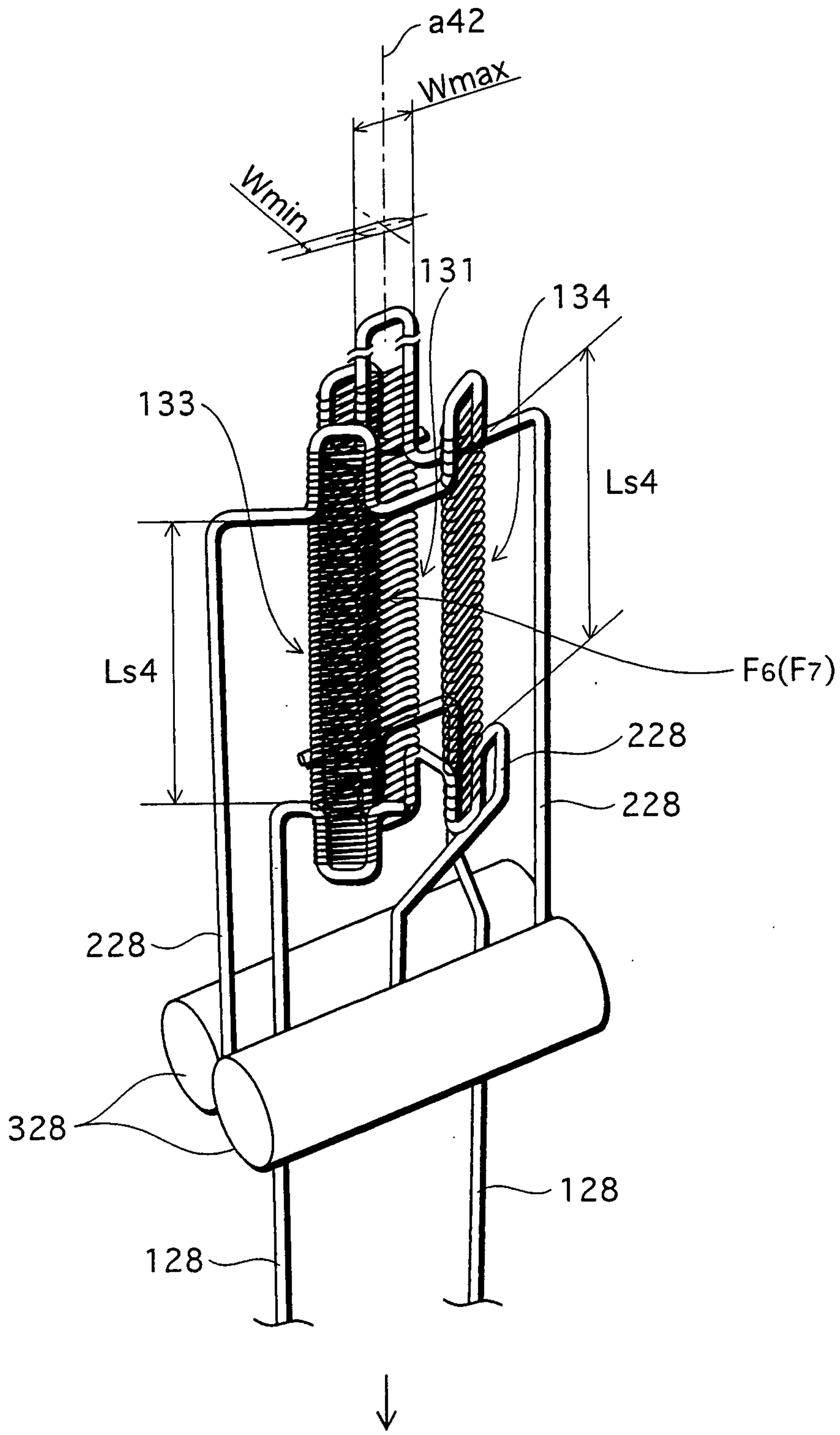


FIG.4



SEALING PART 120

FIG.5

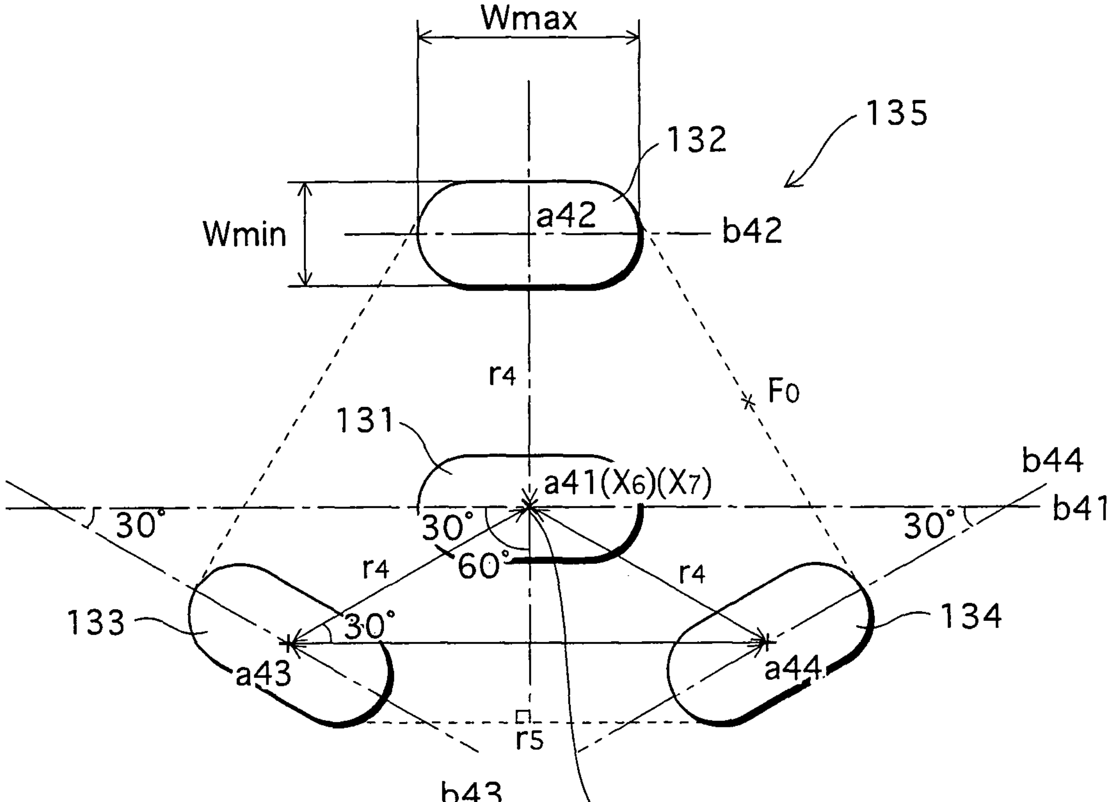

Wmax
135
132
Wmin
a42
b42
r4
F0
131
b44
a41(X6)(X7)
b41
30°
30°
30°
60°
r4
r4
133
30°
134
a43
a44
r5
b43
F6(F7)

FIG. 6

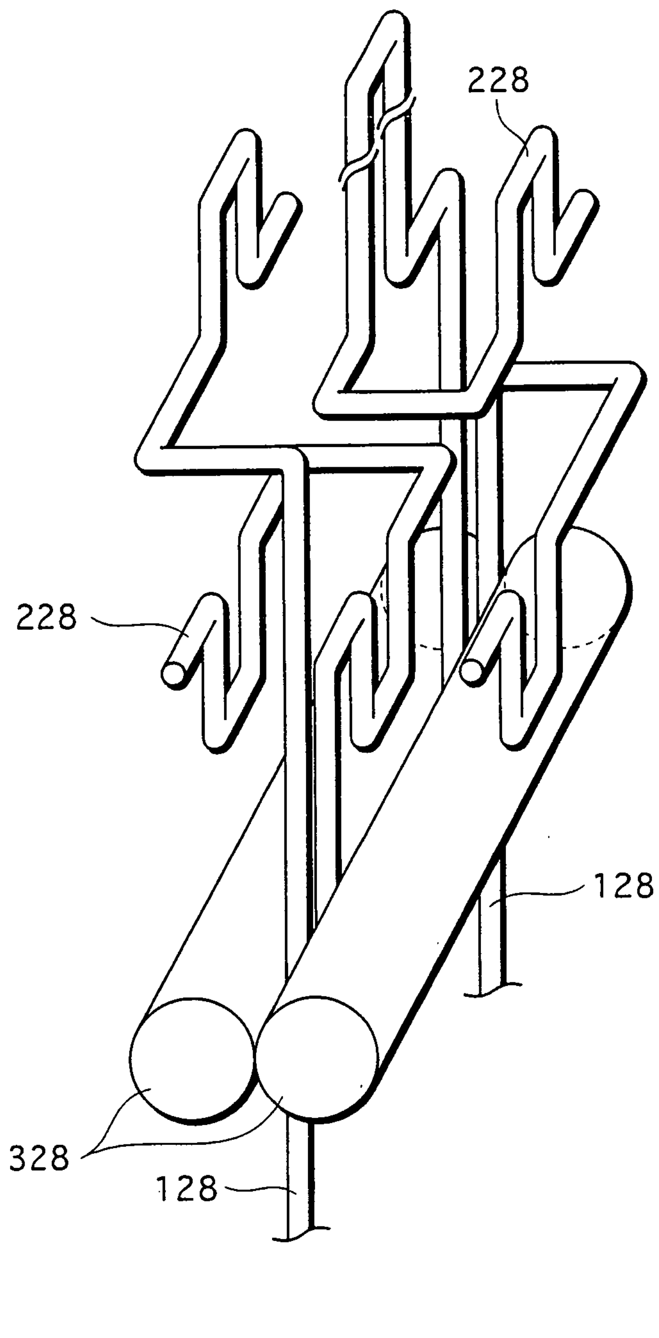


FIG.7

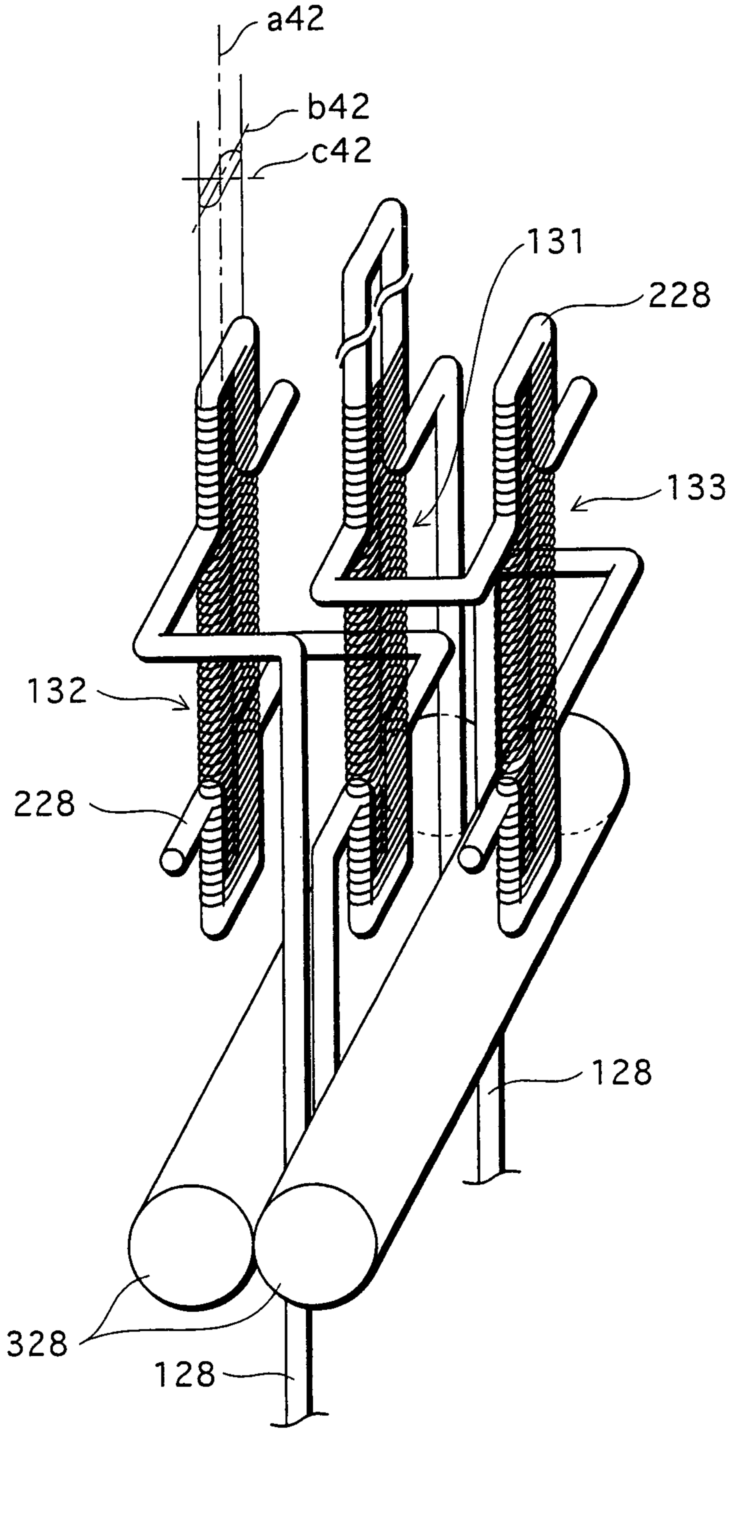


FIG.8

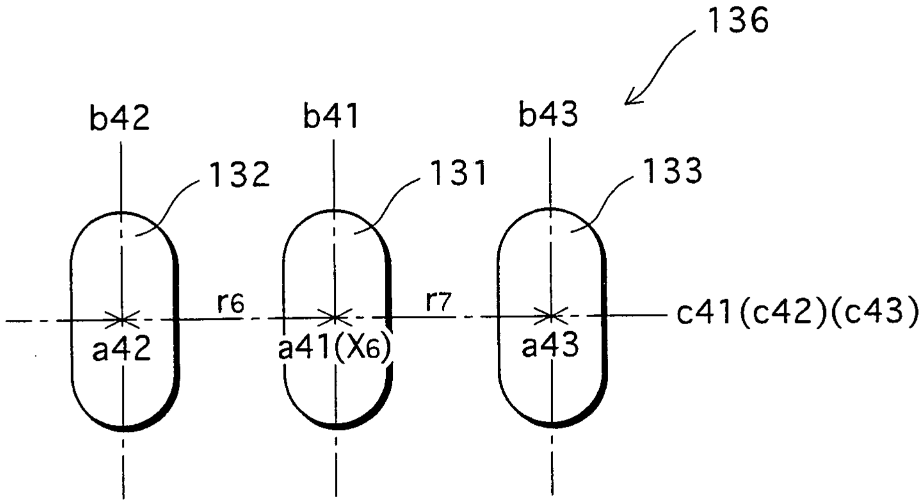


FIG.9

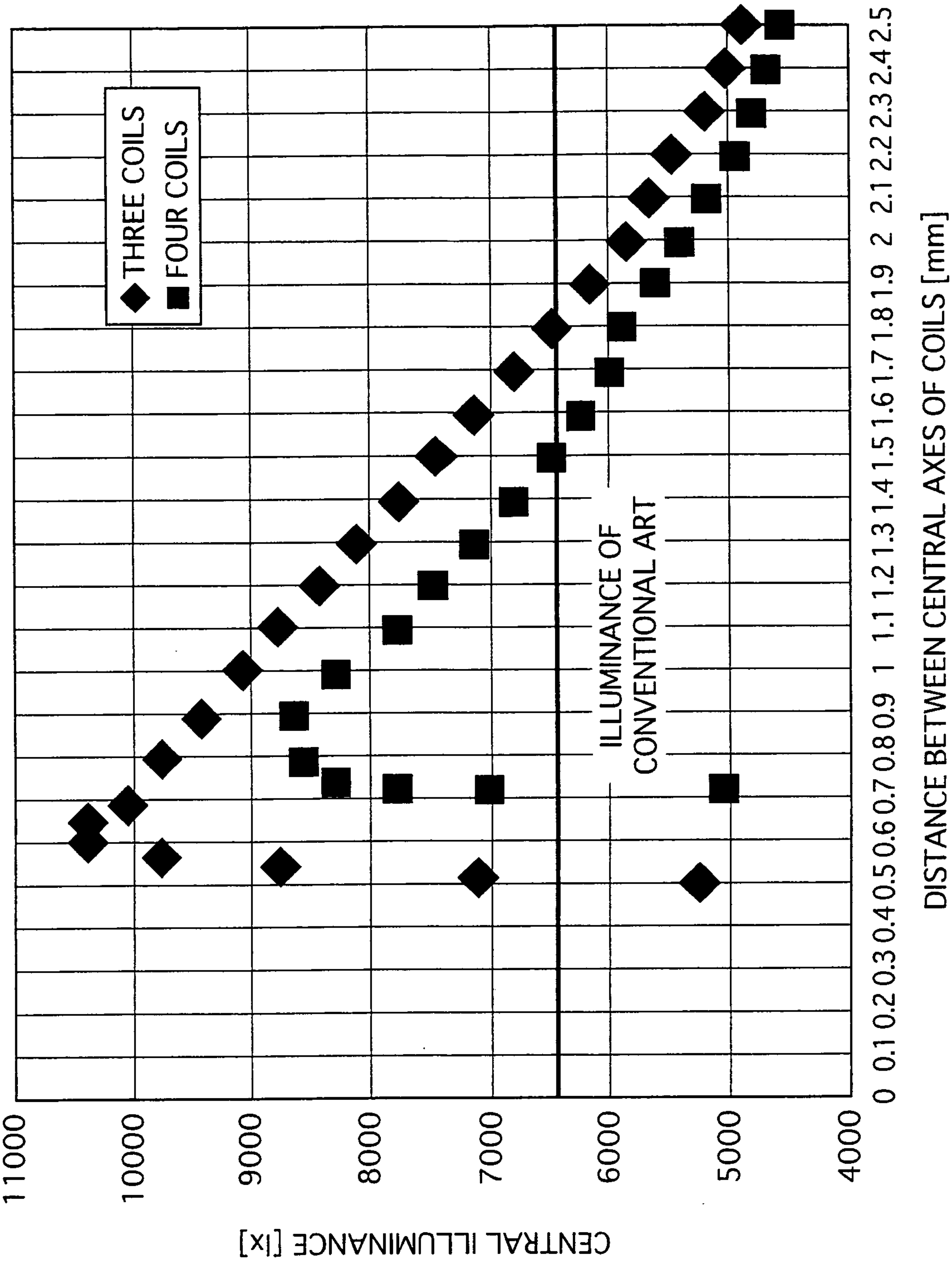

THREE COILS
FOUR COILS
ILLUMINANCE OF CONVENTIONAL ART
CENTRAL ILLUMINANCE [lx]
11000
10000
9000
8000
7000
6000
5000
4000
DISTANCE BETWEEN CENTRAL AXES OF COILS [mm]
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2 2.1 2.2 2.3 2.4 2.5

FIG.10

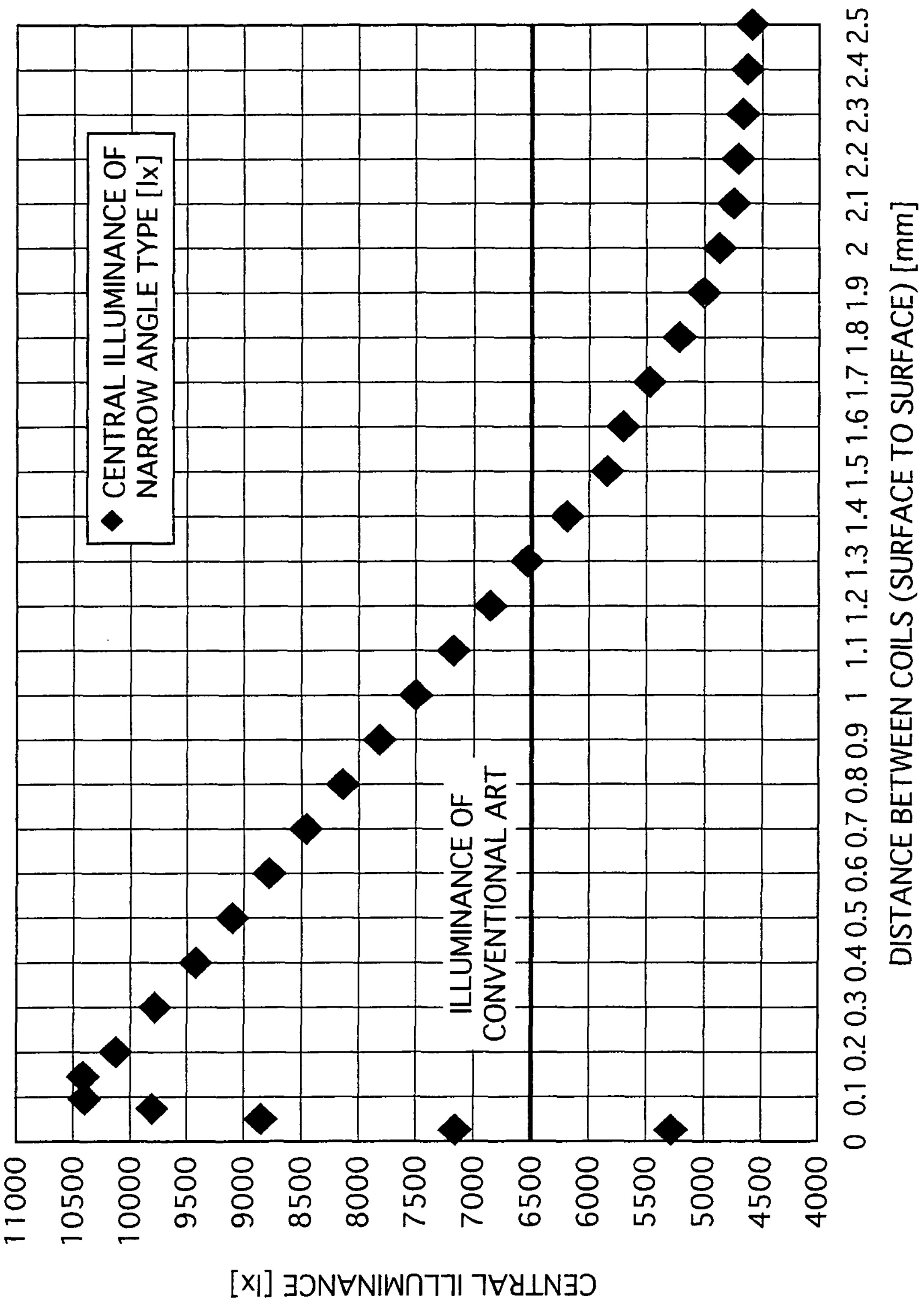

◆ CENTRAL ILLUMINANCE OF NARROW ANGLE TYPE [lx]
ILLUMINANCE OF CONVENTIONAL ART
CENTRAL ILLUMINANCE [lx]
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2 2.1 2.2 2.3 2.4 2.5
DISTANCE BETWEEN COILS (SURFACE TO SURFACE) [mm]

FIG.11

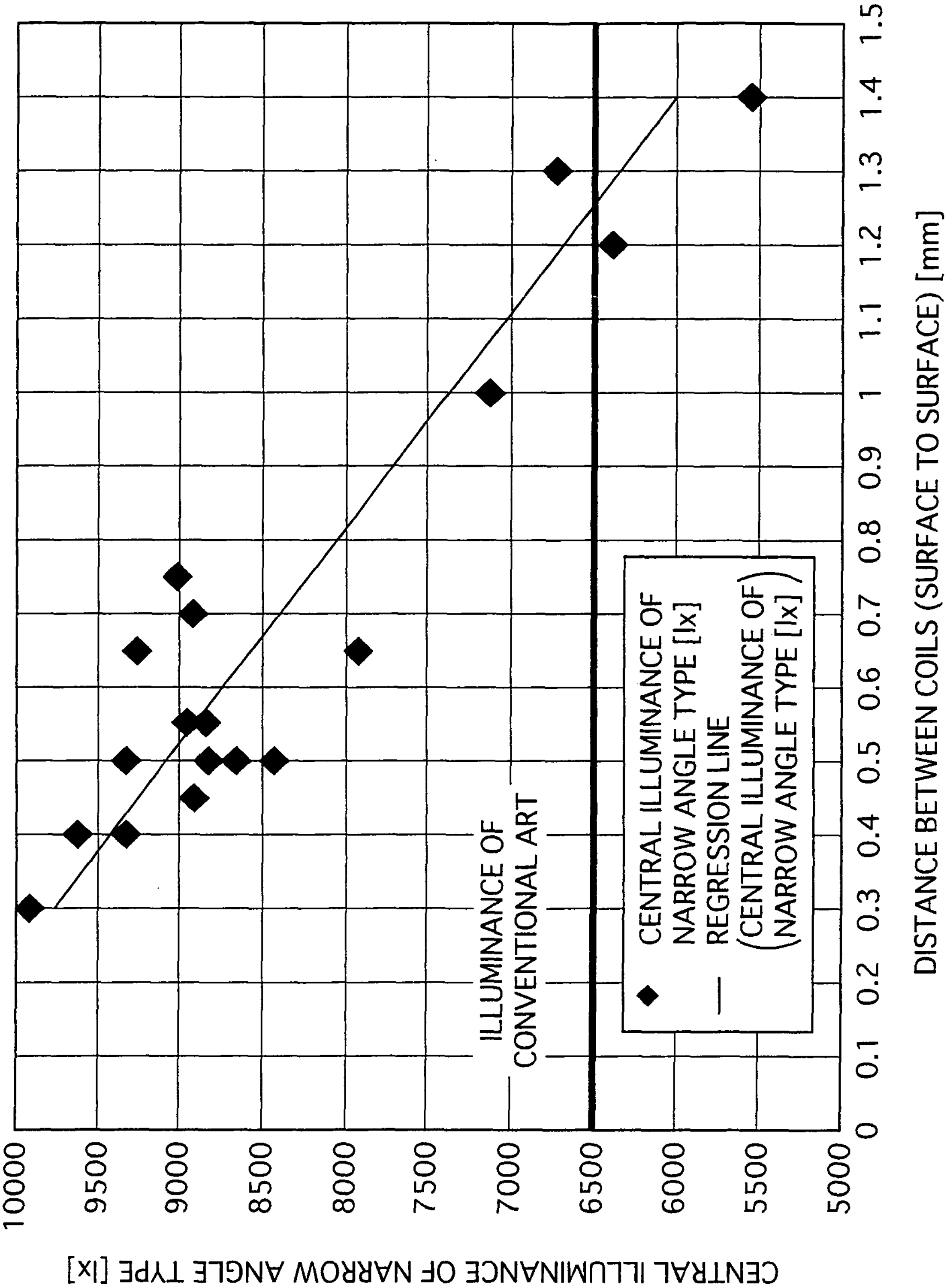

CENTRAL ILLUMINANCE OF NARROW ANGLE TYPE [lx]
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
DISTANCE BETWEEN COILS (SURFACE TO SURFACE) [mm]
ILLUMINANCE OF CONVENTIONAL ART
CENTRAL ILLUMINANCE OF NARROW ANGLE TYPE [lx]
REGRESSION LINE (CENTRAL ILLUMINANCE OF NARROW ANGLE TYPE [lx])

FIG.12

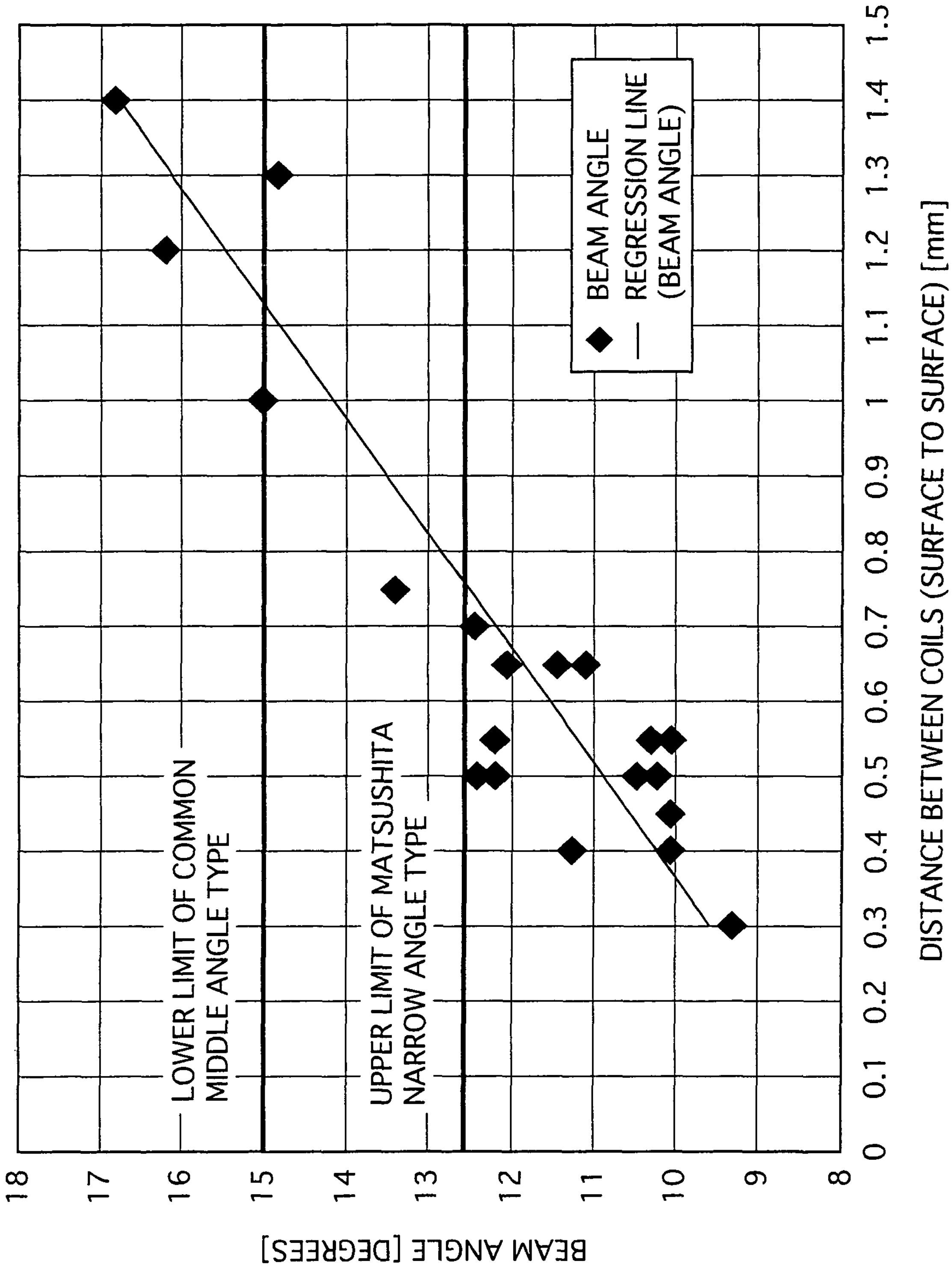

BEAM ANGLE [DEGREES]
DISTANCE BETWEEN COILS (SURFACE TO SURFACE) [mm]
LOWER LIMIT OF COMMON MIDDLE ANGLE TYPE
UPPER LIMIT OF MATSUSHITA NARROW ANGLE TYPE
BEAM ANGLE
REGRESSION LINE (BEAM ANGLE)
18
17
16
15
14
13
12
11
10
9
8
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5

FIG.13A

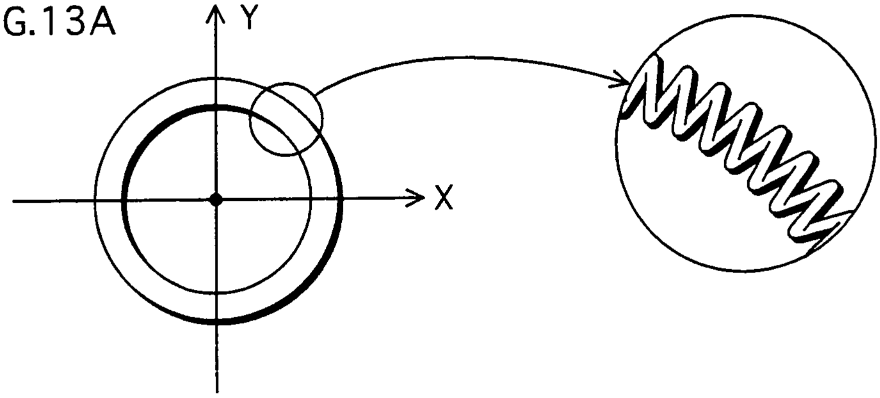


FIG.13B

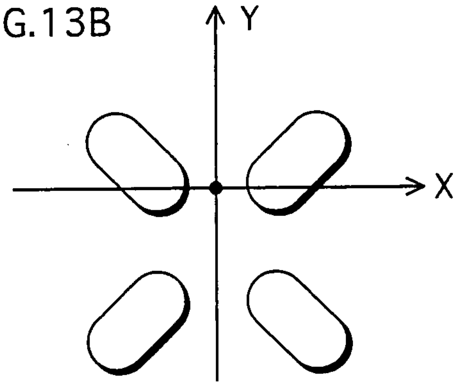


FIG.13E

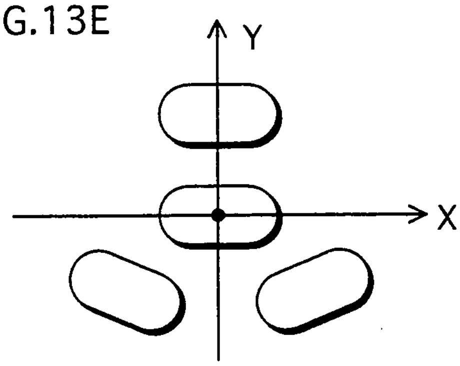


FIG.13C

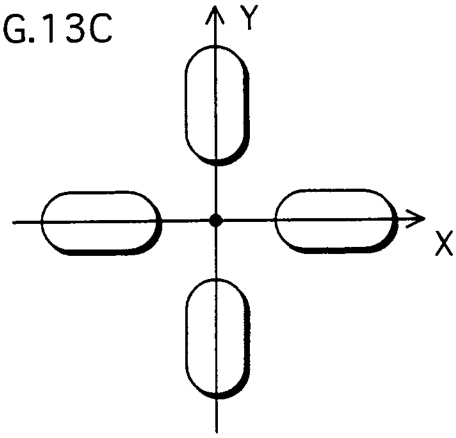


FIG.13F

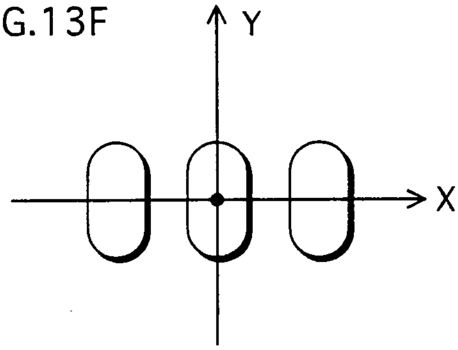


FIG.13D

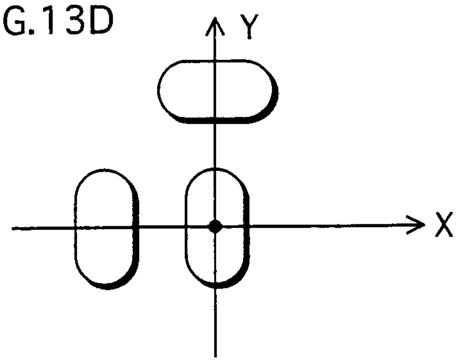


FIG.13G

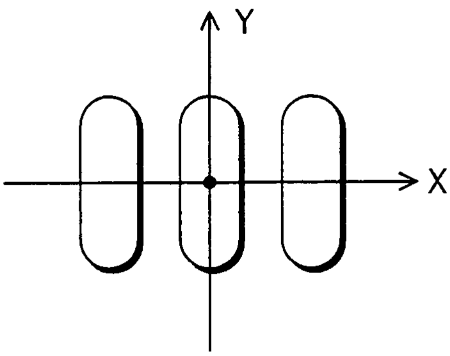


FIG.14

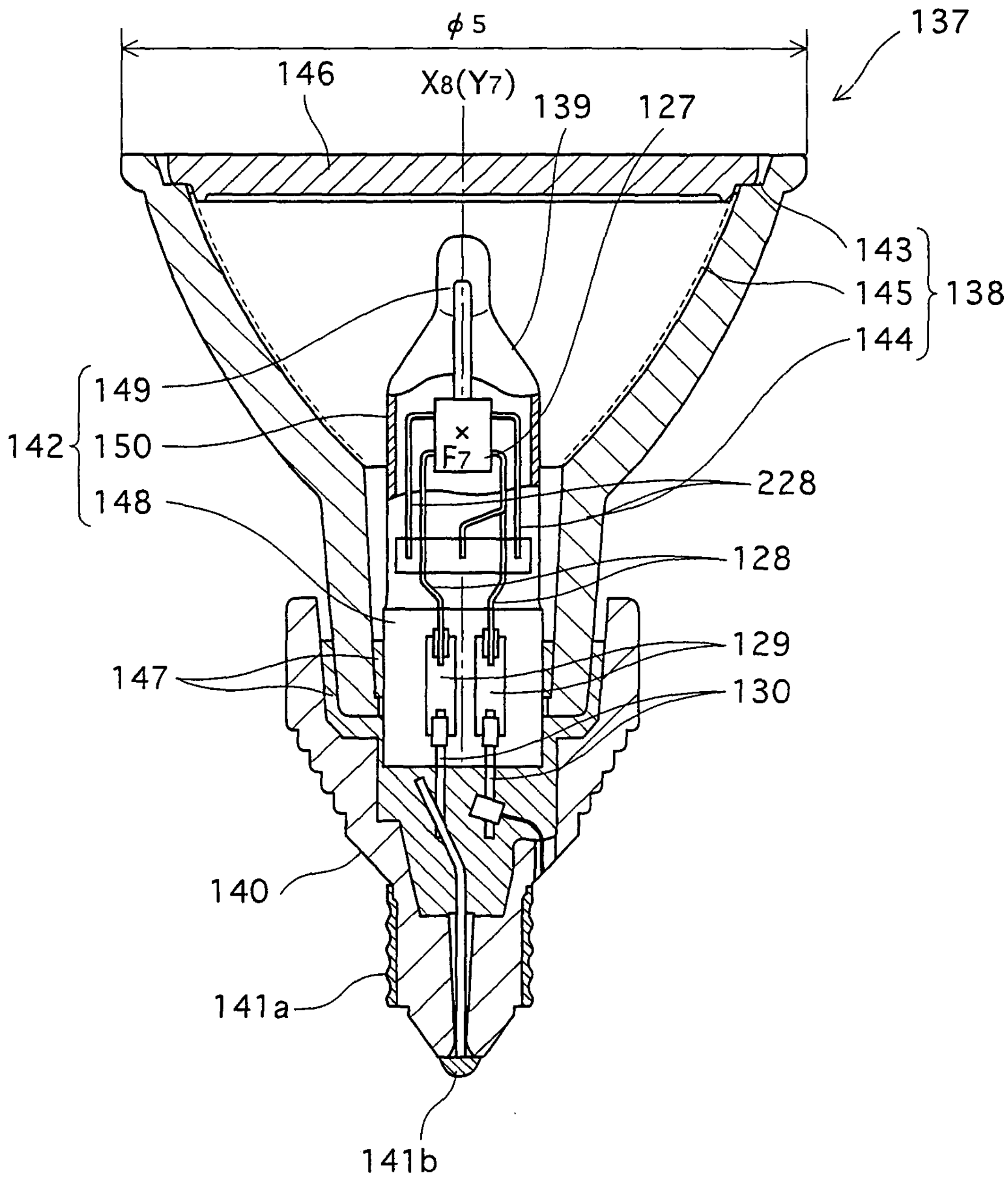

φ5
137
146
X8(Y7)
139
127
143
145
138
144
149
142
150
148
F7
228
128
129
147
130
140
141a
141b

FIG.15

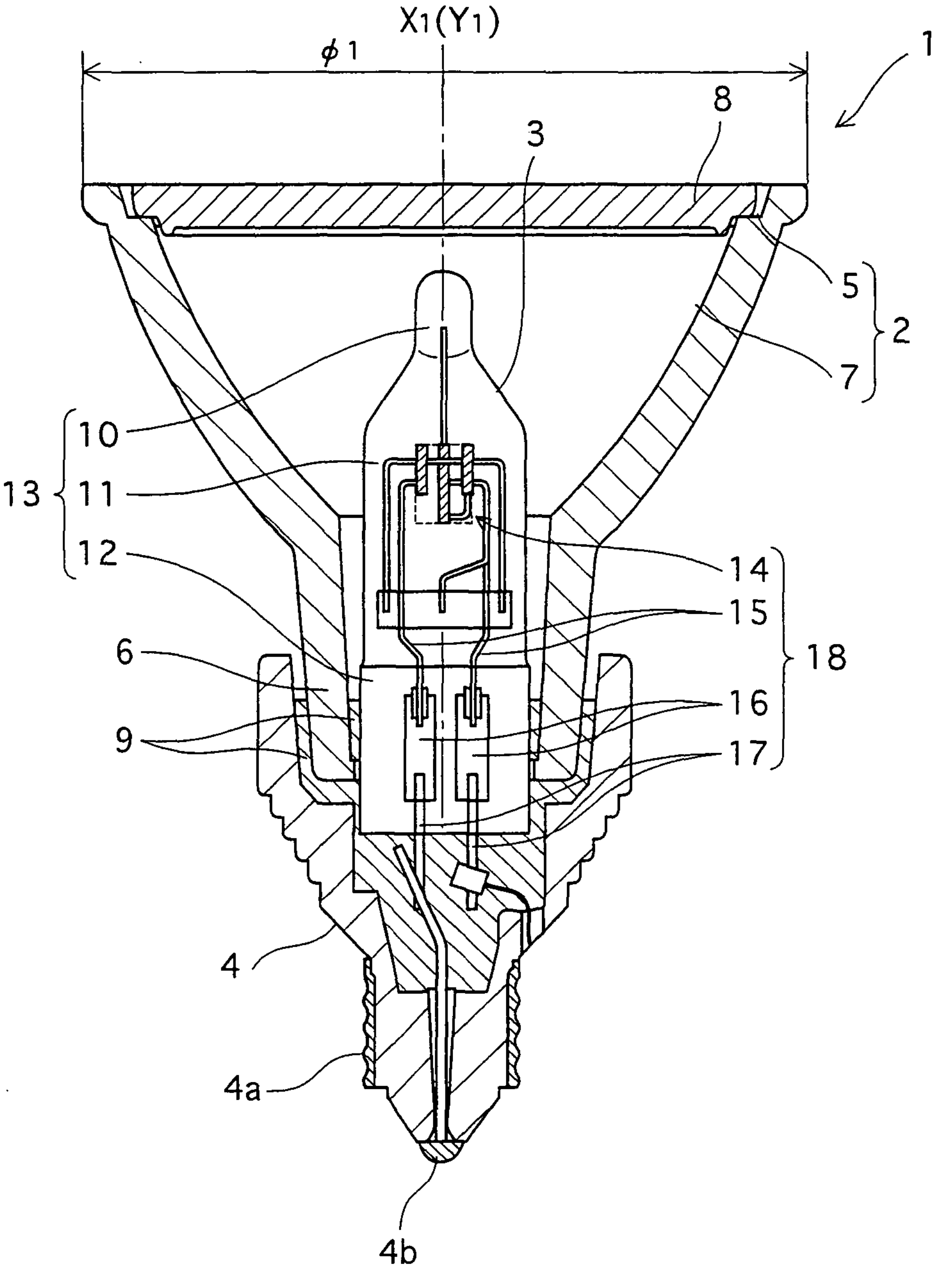


FIG.16

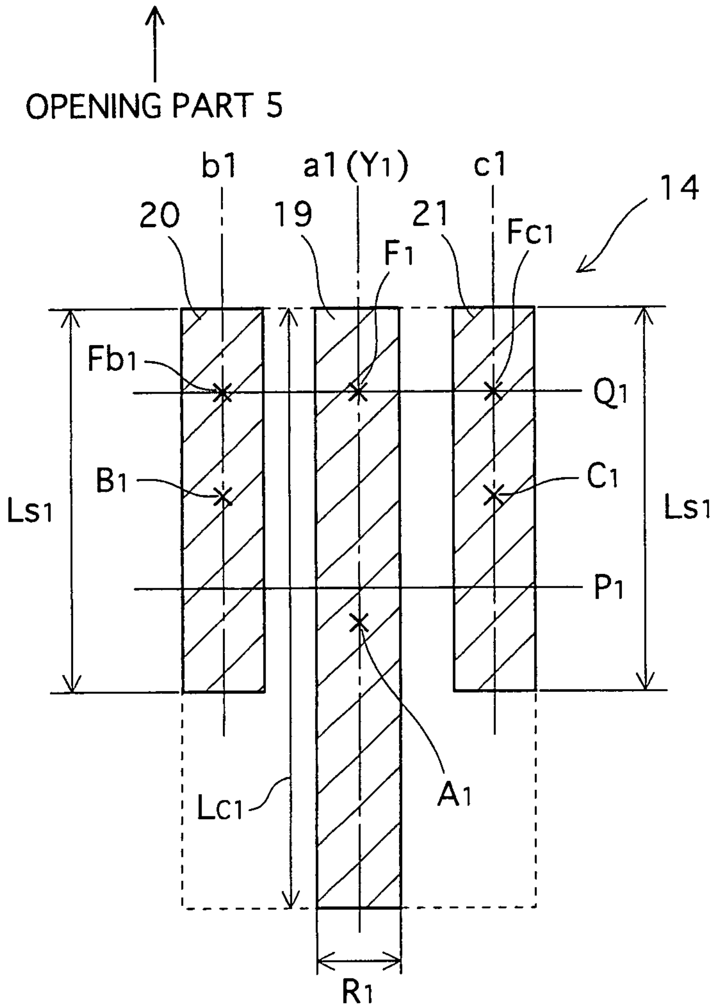

OPENING PART 5
b1
a1 (Y1)
c1
14
20
19
21
Fc1
F1
Fb1
Q1
B1
C1
Ls1
Ls1
P1
A1
Lc1
R1

FIG.17

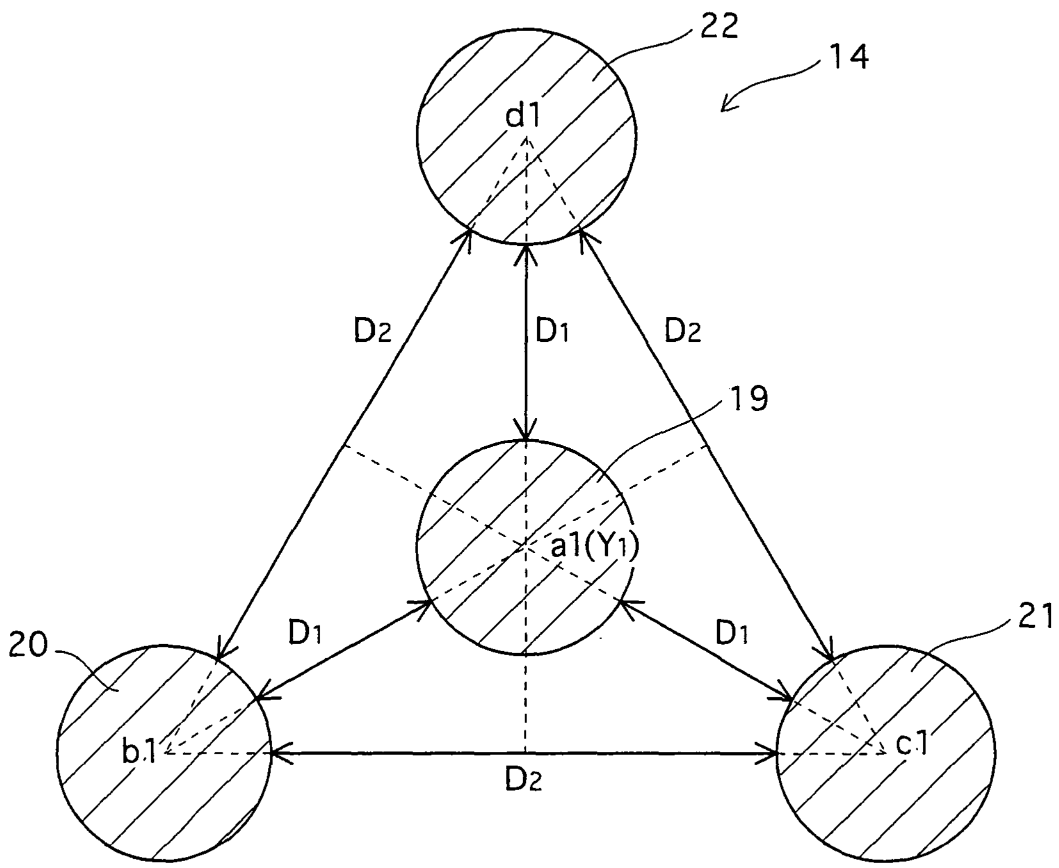


FIG.18

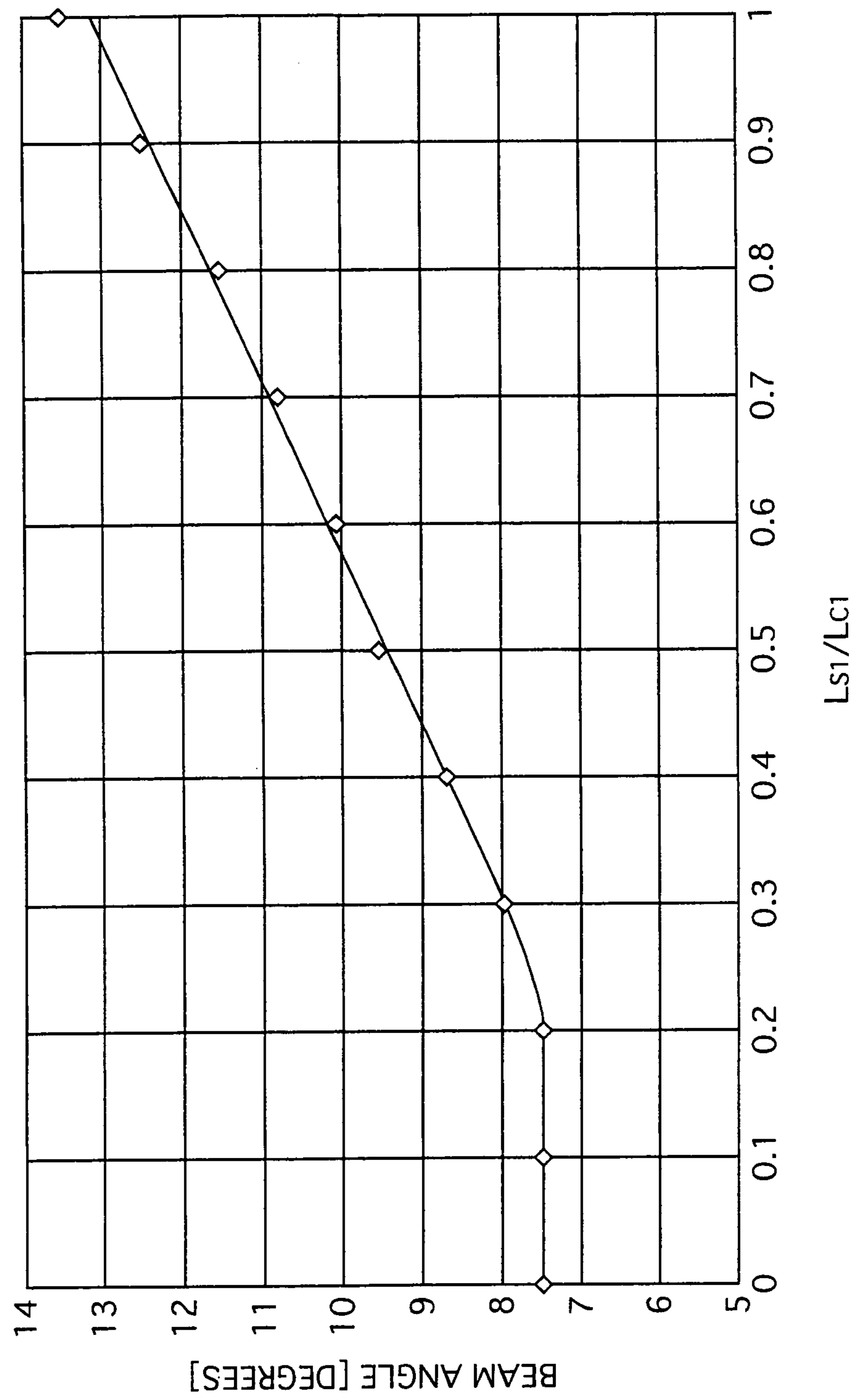
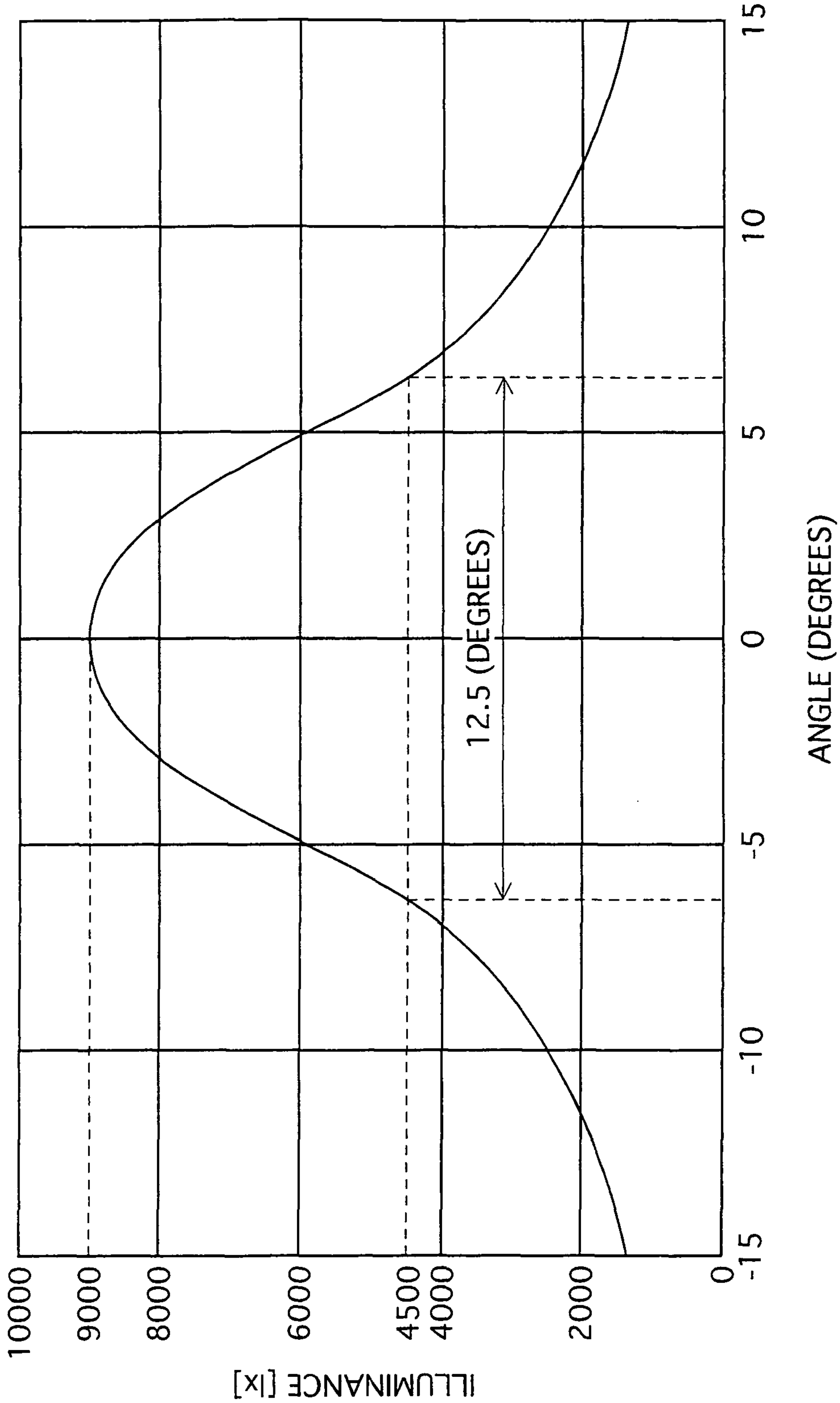

BEAM ANGLE [DEGREES]
14
13
12
11
10
9
8
7
6
5
L_{S1}/L_{C1}
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

FIG.19



ILLUMINANCE [lx]
10000
9000
8000
6000
4500
4000
2000
0
ANGLE (DEGREES)
-15
-10
-5
0
5
10
15
12.5 (DEGREES)

FIG.20

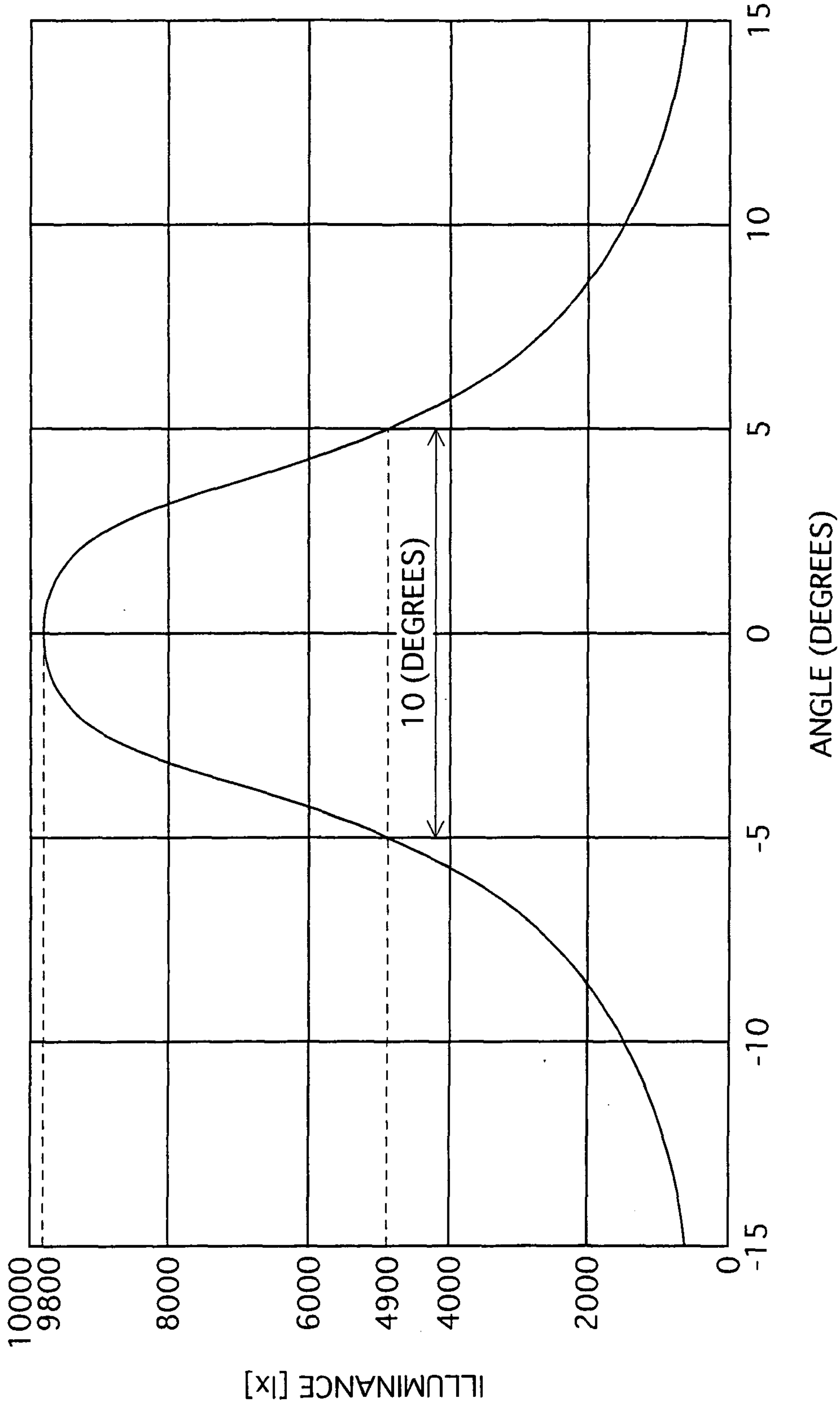

10 (DEGREES)
ANGLE (DEGREES)
ILLUMINANCE [lx]
-15
-10
-5
0
5
10
15
10000
9800
8000
6000
4900
4000
2000
0

FIG.21

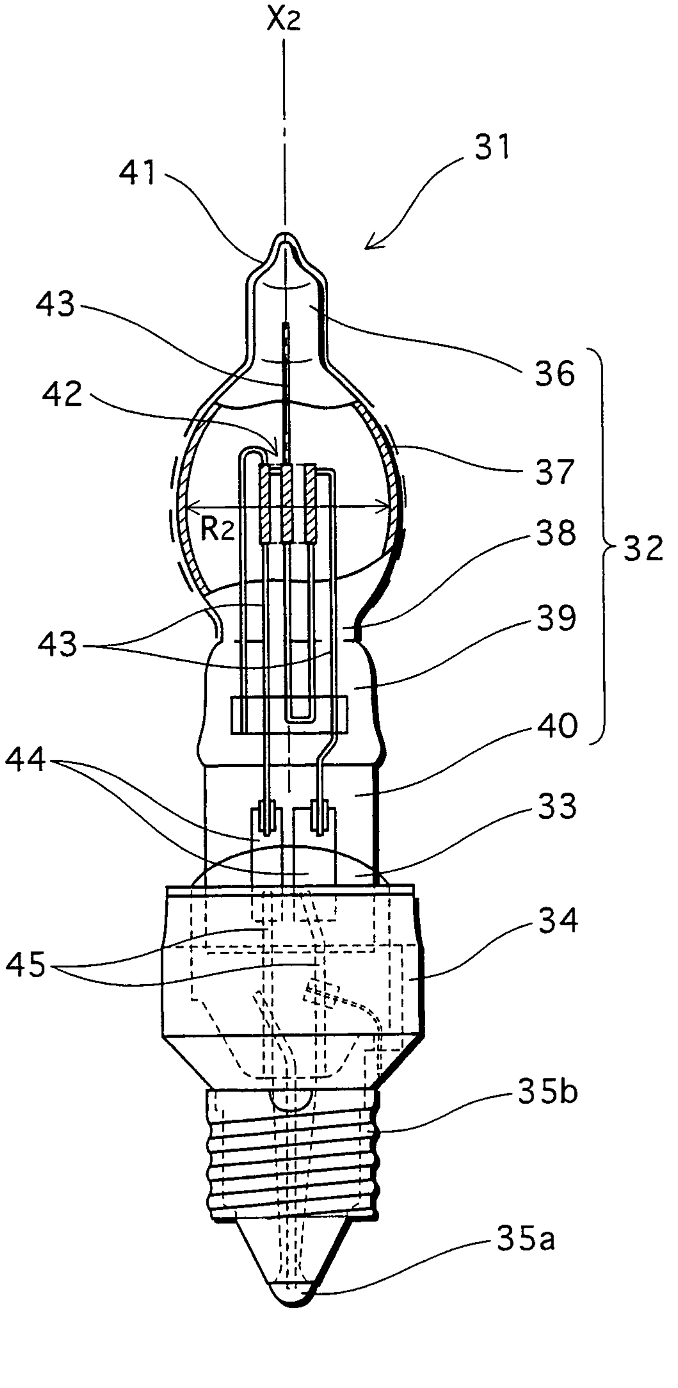
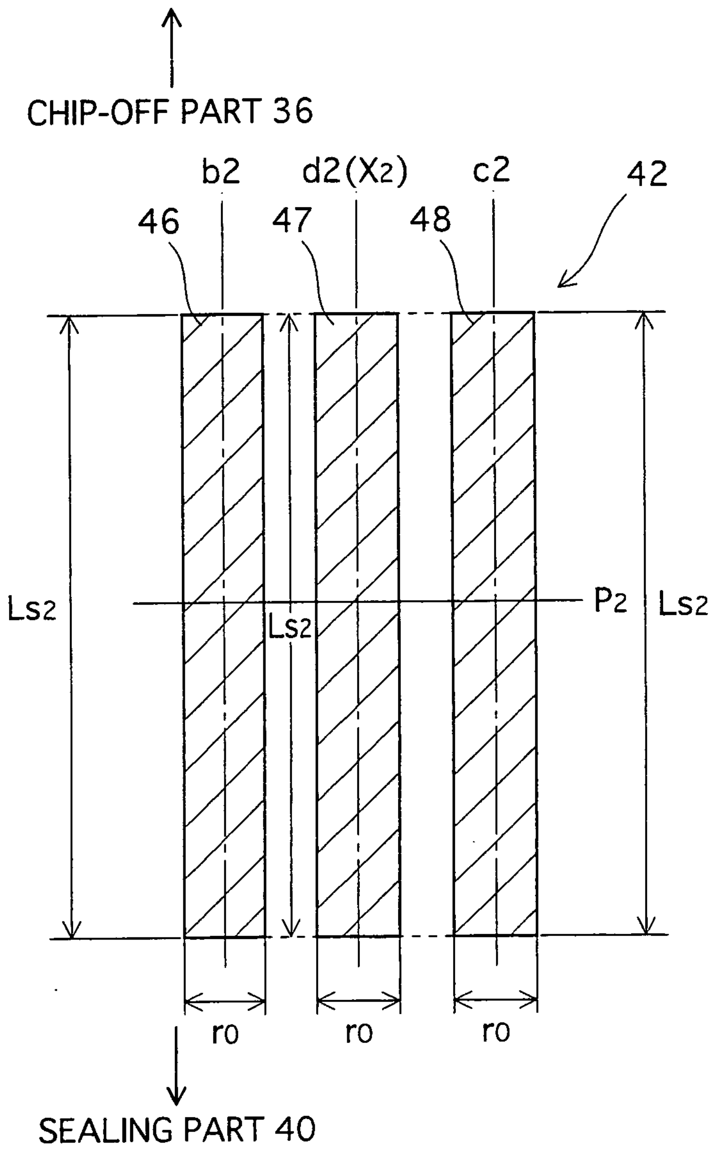


FIG.22



CHIP-OFF PART 36
b2
d2(X2)
c2
42
46
47
48
Ls2
Ls2
P2
Ls2
r0
r0
r0
SEALING PART 40

FIG.23

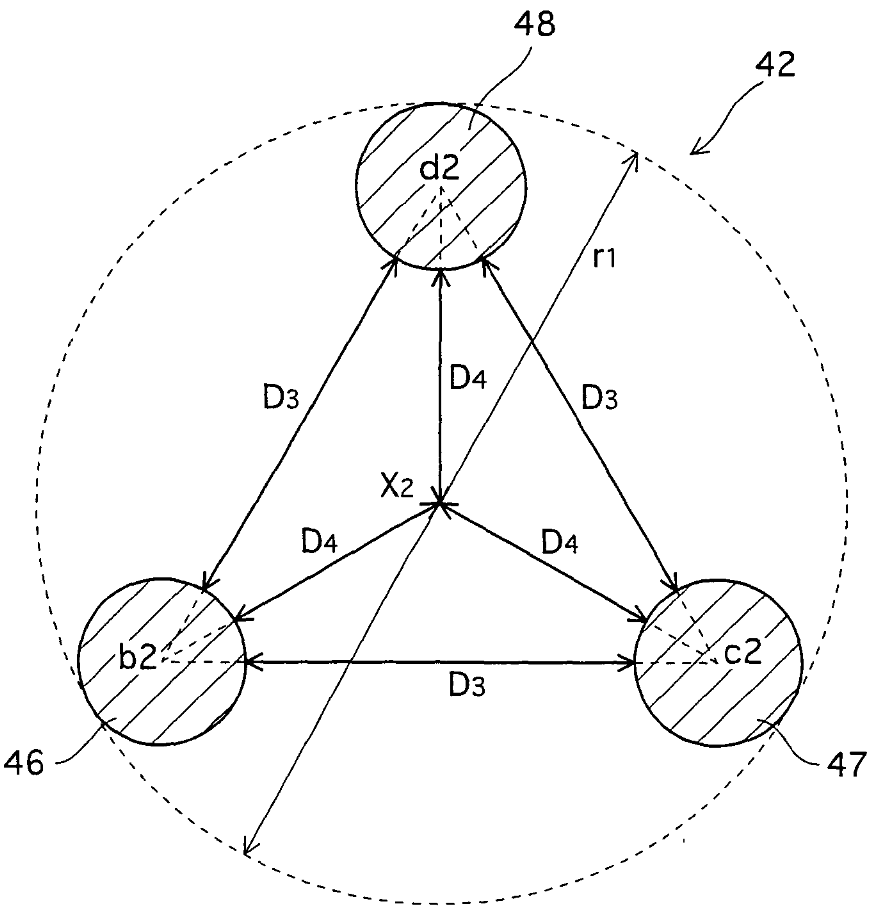


FIG.24

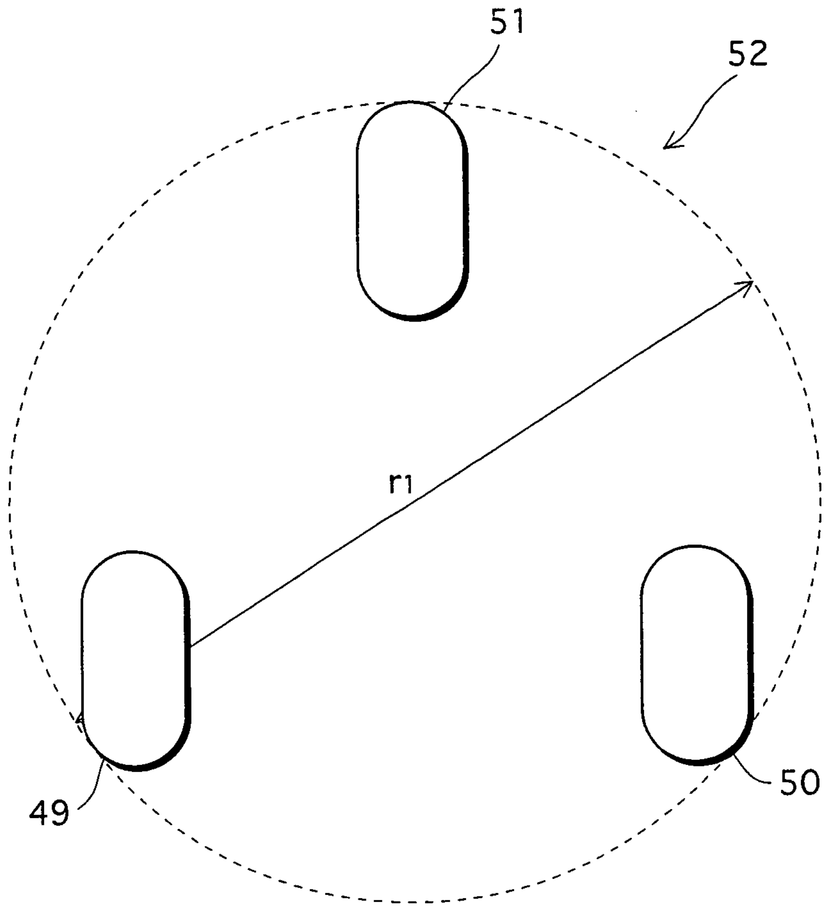


FIG.25

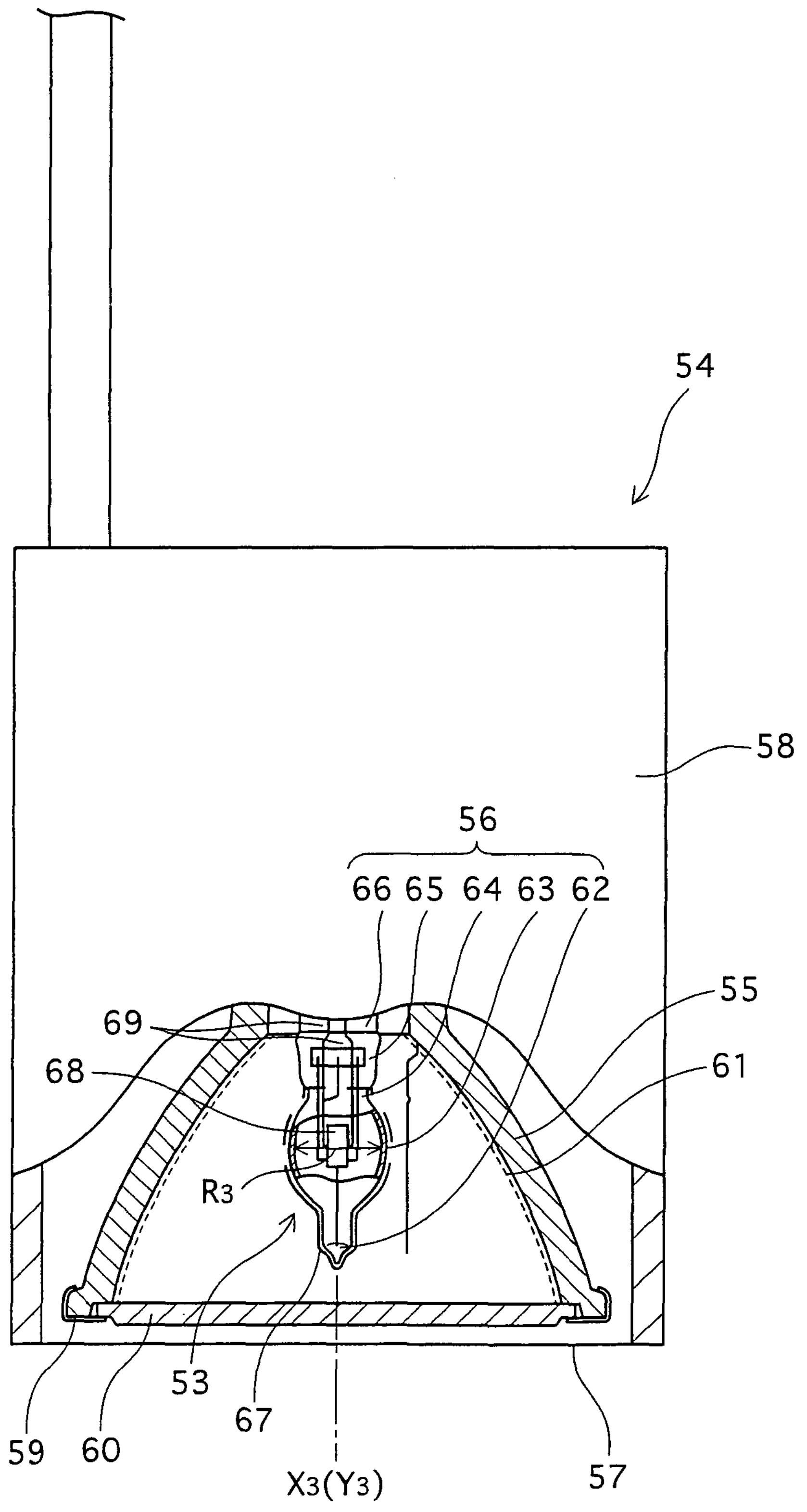
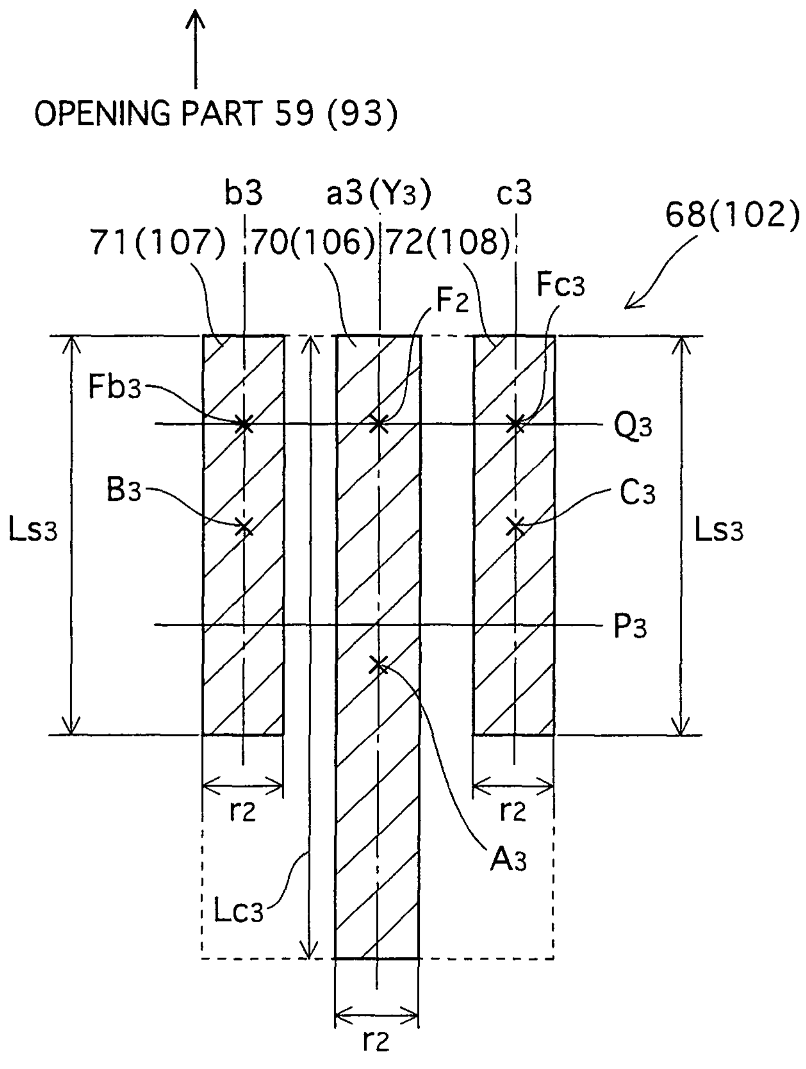


FIG.26



OPENING PART 59 (93)
b3
a3(Y3)
c3
68(102)
71(107)
70(106)
72(108)
Fc3
F2
Fb3
Q3
B3
C3
Ls3
Ls3
P3
A3
r2
r2
Lc3
r2

FIG.27

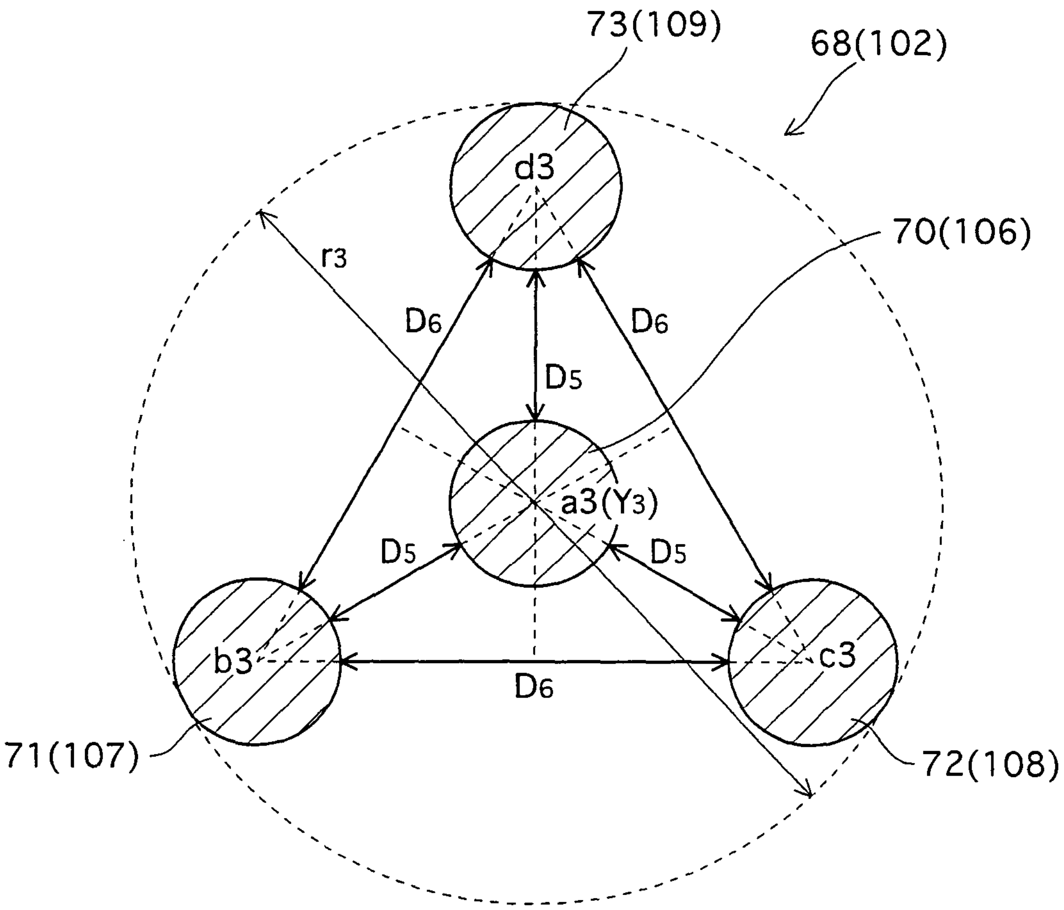


FIG.28

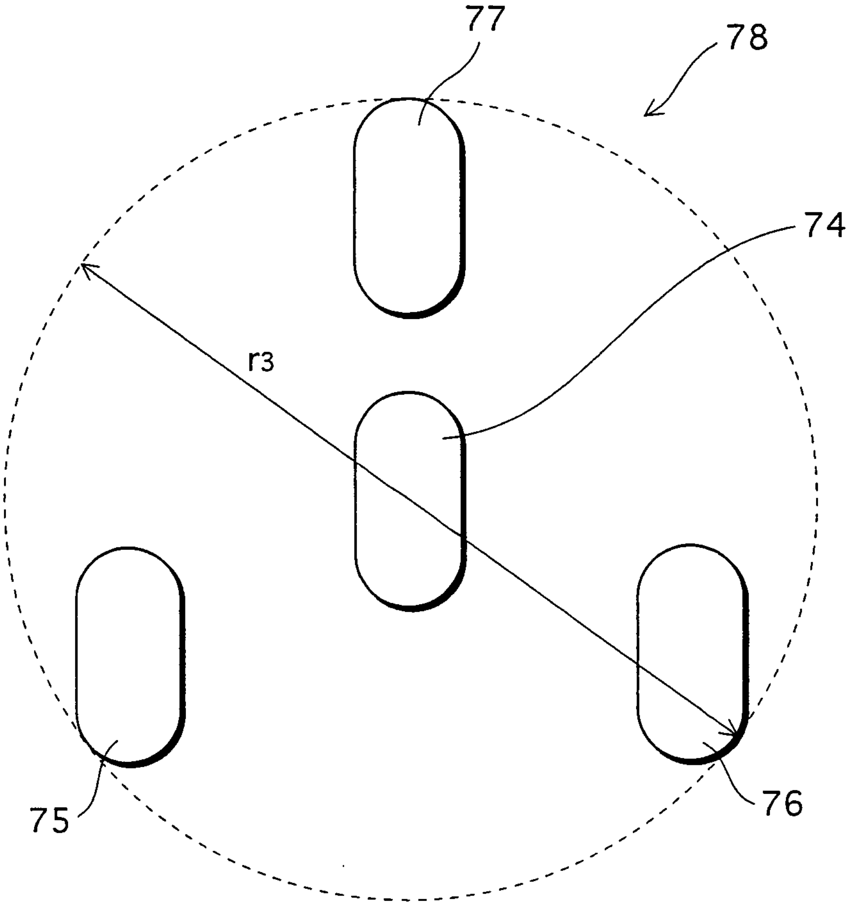


FIG.29

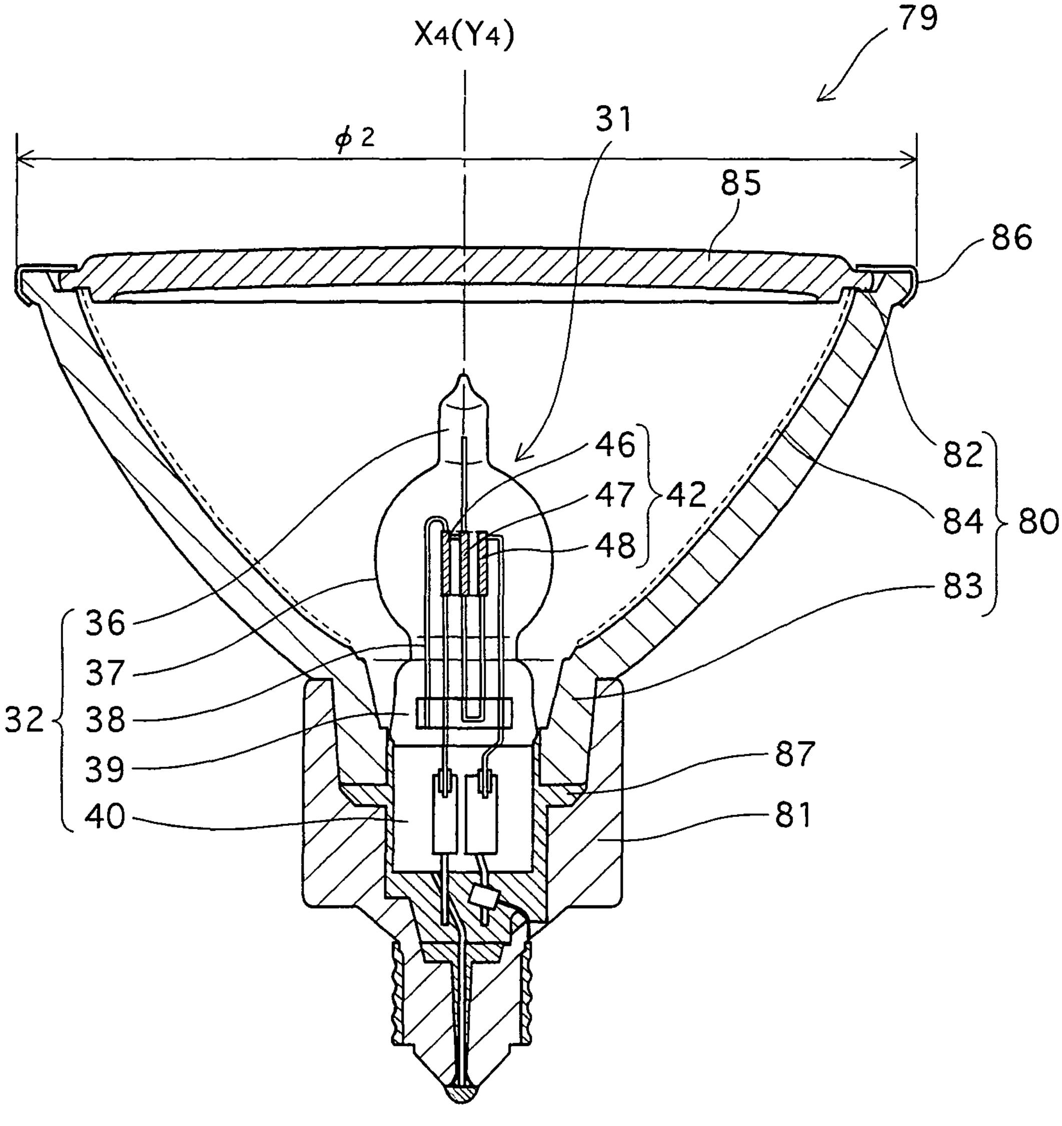


FIG.30

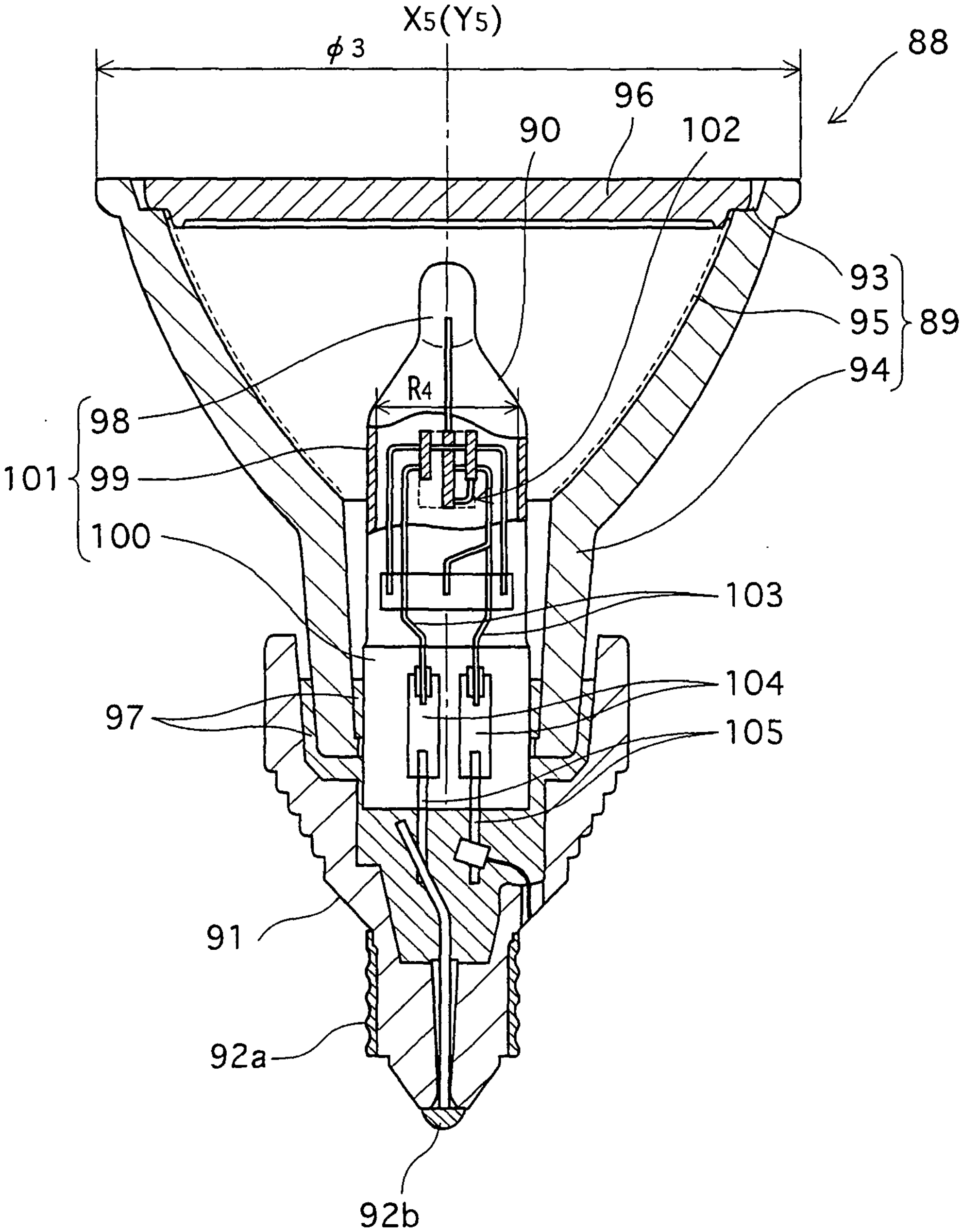

X5(Y5)
φ3
88
96
90
102
93
95
89
94
R4
98
101
99
100
103
104
97
105
91
92a
92b

FIG.31

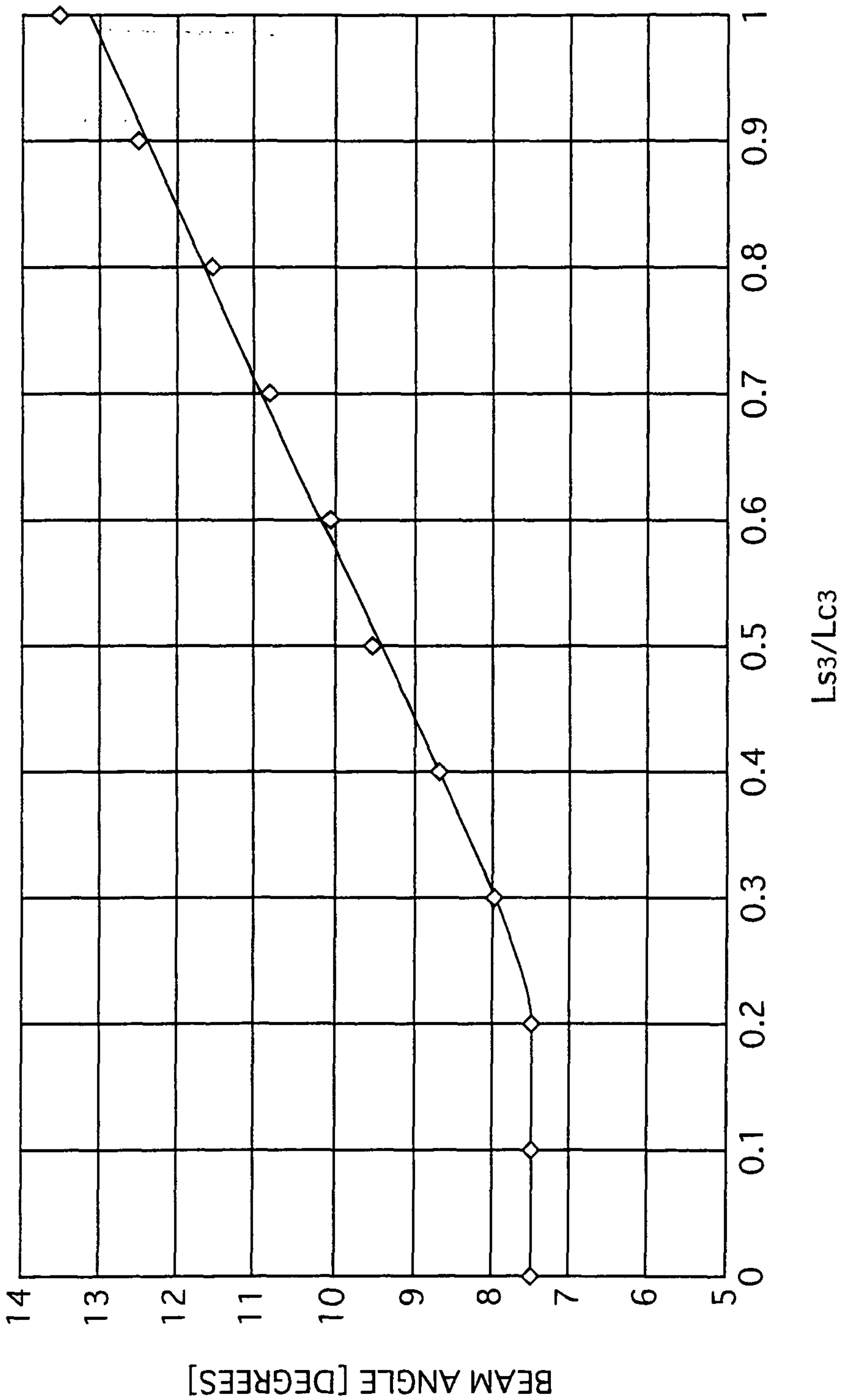

BEAM ANGLE [DEGREES]
14
13
12
11
10
9
8
7
6
5
Ls3/Lc3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

FIG.32

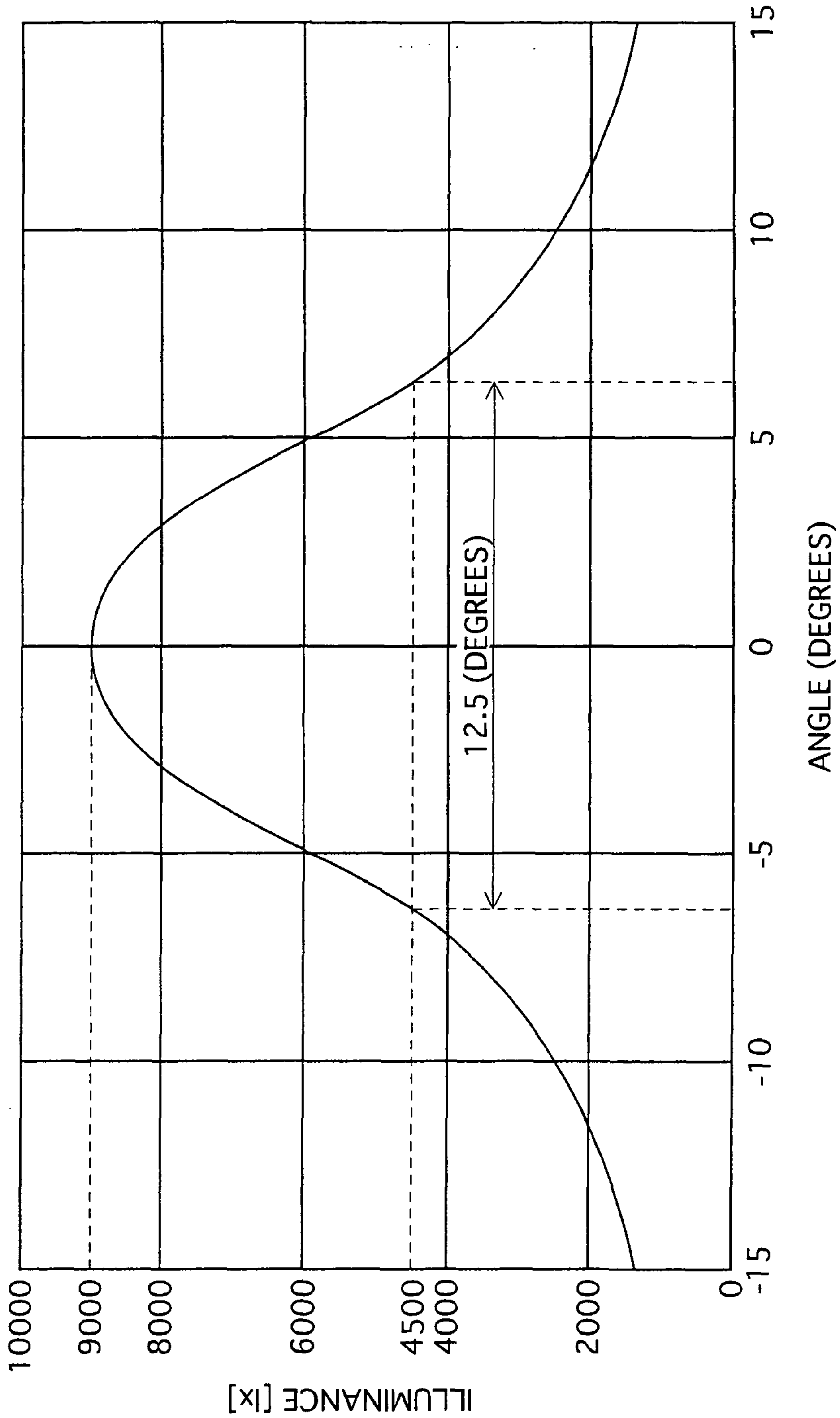

ILLUMINANCE [lx]
10000
9000
8000
6000
4500
4000
2000
0
-15
-10
-5
0
5
10
15
ANGLE (DEGREES)
12.5 (DEGREES)

FIG.33

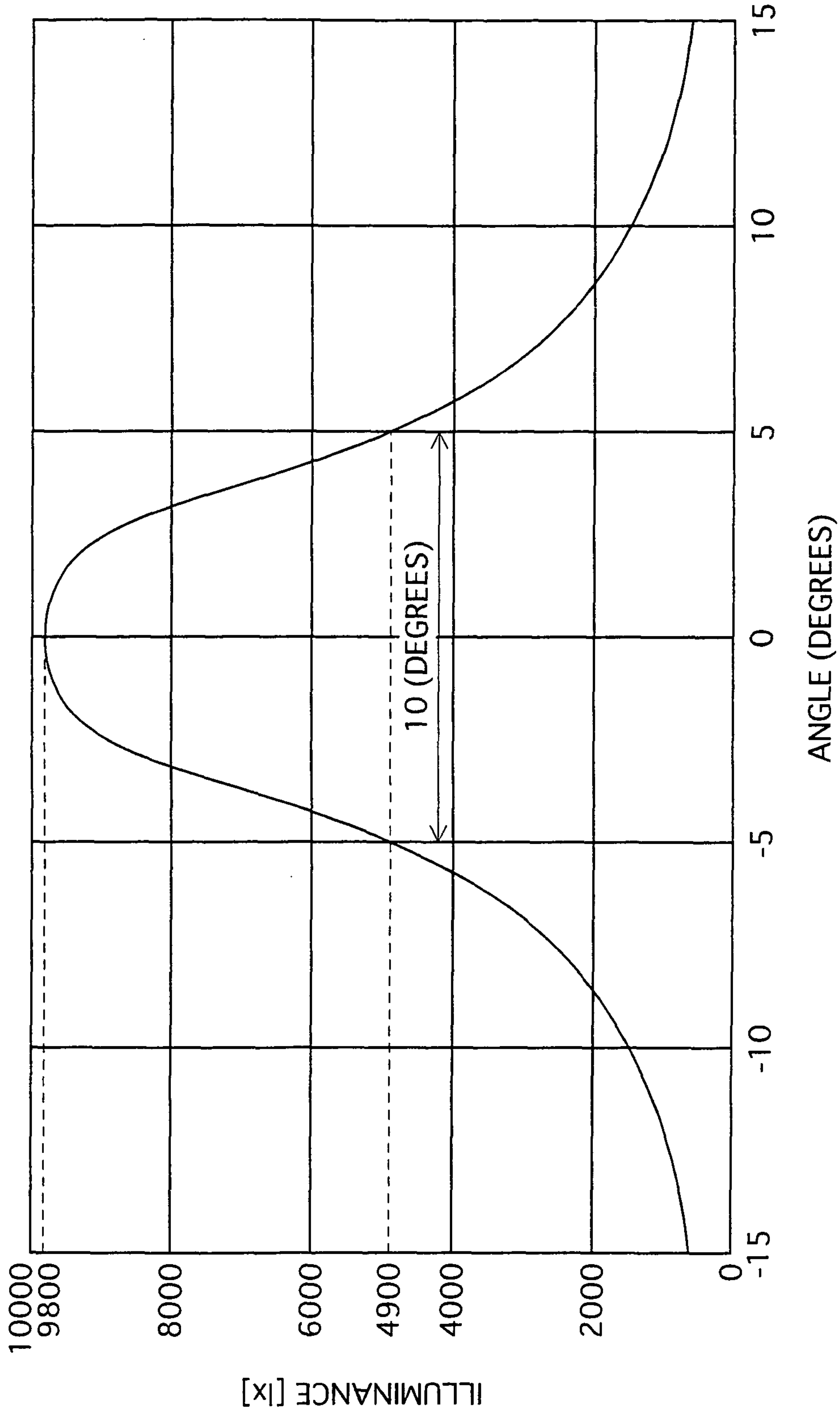
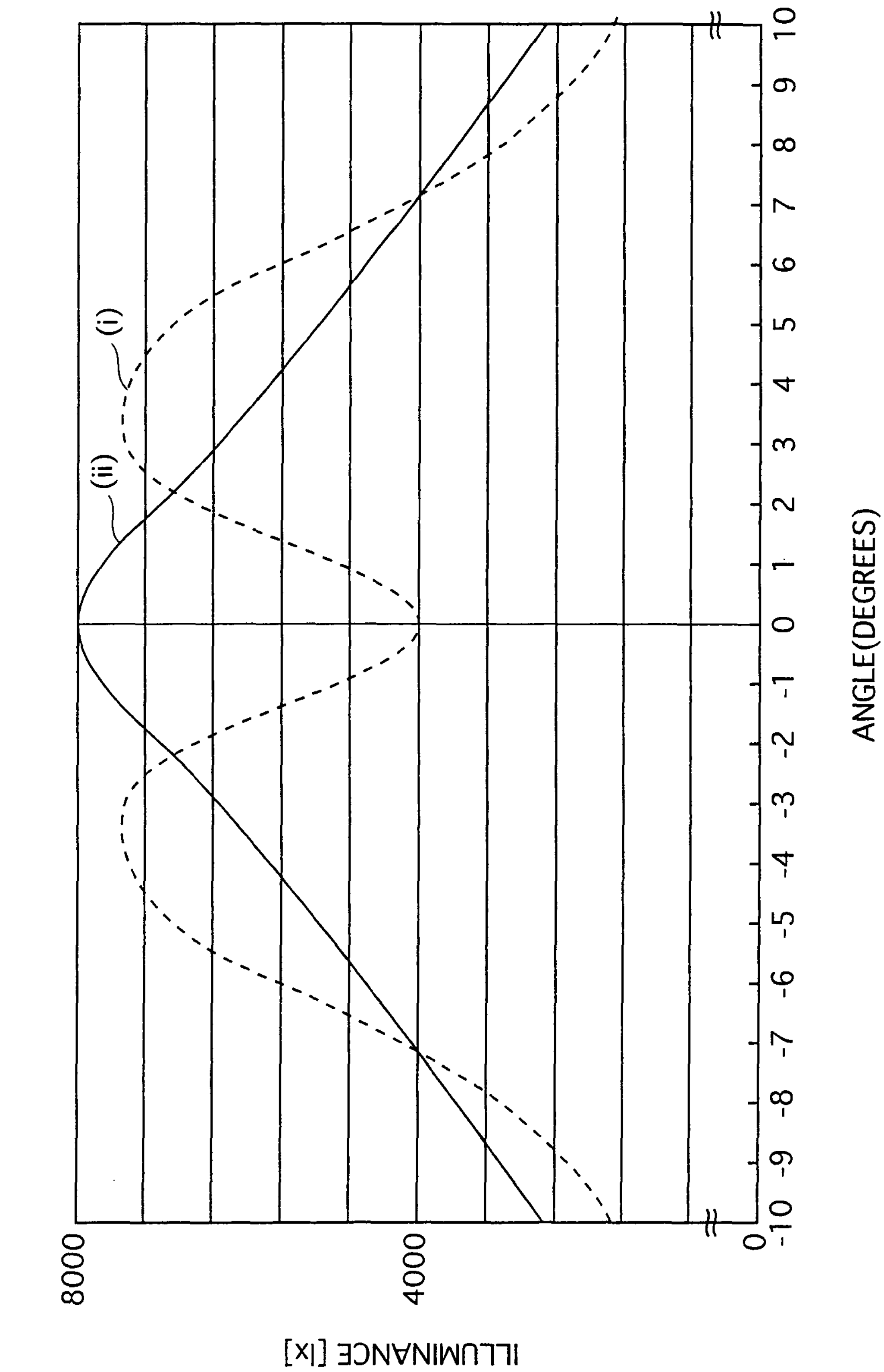

10000
9800
8000
6000
4900
4000
2000
0
ILLUMINANCE [lx]
-15
-10
-5
0
5
10
15
ANGLE (DEGREES)
10 (DEGREES)

FIG.34


ILLUMINANCE [lx]
8000
4000
0
ANGLE(DEGREES)
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
(i)
(ii)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/020976

A. CLASSIFICATION OF SUBJECT MATTER
H01K1/18(2006.01), ***F21S2/00***(2006.01), ***F21V13/00***(2006.01), *F21Y101/00*(2006.01)

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)
H01K1/00-1/70, F21S2/00, F21V13/00-13/14, F21Y101/00-101/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

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.
Y A	JP 2002-63869 A (General Electric Co.), 28 February, 2002 (28.02.02), Claims 1, 14; detailed explanation of the invention; Par. Nos. [0014] to [0020]; Figs. 1, 4 to 6 & SU 2003/0209962 A1 & EP 1154464 A1	1-8,11-14 9,10,15-31
Y A	WO 2003/075317 A1 (Mineta Co., Ltd.), 12 September, 2003 (12.09.03), Description, page 1 & US 2005/0001531 A1 & EP 1482536 A1	1-8,11-14 9,10,15-31
Y A	JP 2000-82444 A (Mineta Co., Ltd.), 21 March, 2000 (21.03.00), Claim 1; detailed explanation of the invention; Par. Nos. [0003], [0005] (Family: none)	1-8,11-14 9,10,15-31

☒ 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
30 January, 2006 (30.01.06)

Date of mailing of the international search report
07 February, 2006 (07.02.06)

Name and mailing address of the ISA/
Japanese Patent Office

Facsimile No.

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/020976

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 6-510881 A (David W. Cunaingham), 01 December, 1994 (01.12.94), Claims 1, 2 & US 5268613 A & EP 0969496 A2 & WO 1993/001613 A1	1-31

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/020976

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:

A common technical feature pertaining to all the inventions in dependent claims 1, 2, 15, 17, 21, 22, and 26 is the lamp bulb which comprises the bulb and the filament body installed in the bulb and having the plurality of filament elements, and in which the longitudinal center axes of the plurality of filament elements are parallel with the optical axis of the reflecting mirror.

However, the result of search reveals that the lamp bulb is not novel since it is described in Documents 1 and 2.

(continued to extra sheet)

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 an additional fee, this Authority did not invite payment of any additional fee.

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

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

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/020976

Continuation of Box No.III of continuation of first sheet(2)

Document 1: JP 6-510881 A (Cunaingham, David W.), 01 Dec., 1994 (01.12.94), Claims 1 and 2.

Document 2: JP 2002-63869 A (General Electric Co.), 28 Feb., 2002 (28.02.02), Claim 1

Since the lamp tube makes no contribution over the prior art, it is not a special technical feature defined in the second sentence of PCT Rule 13.2. Accordingly, there is no special technical feature commonly pertaining to all the inventions in dependent claims 1, 2, 15, 17, 21, 22, and 26.

The number of the inventions in Claims 1-31 involving the dependent claims is three as shown below.

Invention 1: Claims 1-14
Invention 2: Claims 15-20
Invention 3: Claims 21-31

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP H06510881 A **[0009]**
- JP 2002063869 A **[0009]**
- JP 2001345077 A **[0009]**