

[DESCRIPTION]

[Title of Invention] ILLUMINATION APPARATUS

[Technical Field]

[0001]

5 The present invention relates to an illumination apparatus, and in particular to an illumination apparatus which improves visibility of text on a display.

[Background Art]

[0002]

10 Various examinations have been made on ambient light emitted while a user is working on a task. For example, an illumination apparatus is used in order to improve the visibility of text on paper during a visual task of viewing text on a document on a desk, for instance.

[0003]

15 In view of this, examinations have been made to achieve an illumination apparatus which further improves the visibility of text on paper, compared to a conventional apparatus. For example, Patent Literature (PTL) 1 discloses an illumination apparatus which emits illumination light that allows text on paper to be readily read, by making the paper appear whiter.

20 [Citation List]

[Patent Literature]

[0004]

[PTL 1] Japanese Unexamined Patent Application Publication No. 2014-075186

25 [PTL 2] Japanese Unexamined Patent Application Publication No. 2006-349835

[Summary of Invention]

[Technical Problem]

[0005]

In recent years, most of the visual tasks in, for instance, an office have been visual display terminal (VDT) operations conducted using a display such as a liquid crystal display monitor. Accordingly, there has been a demand for an environment in which improvement in text readability is achieved by improving text visibility during a VDT operation, and studies have been conducted from various viewpoints, in addition to the viewpoint focusing on ambient light emitted by an illumination apparatus. For example, PTL 2 proposes a method for adjusting the color of a color monitor such that a colorimetric value matches a reference colorimetric value.

[0006]

However, how text on a screen appears which mainly depends on the display function of a display has been merely examined so far, and a relation between a display and ambient light emitted by the illumination apparatus in order to improve visibility of text has not been revealed.

[0007]

In addition, although a display setting considered to be suitable for users can be set for a display, a user does not know which display setting is suitable, and thus often uses the display with the display setting originally set when purchased.

[0008]

Accordingly, it cannot be said that a conventional illumination apparatus emits illumination light optimal for a display. In view of this, an illumination apparatus which can improve visibility of text on a display is examined.

[0009]

However, if an illumination apparatus which can improve visibility of text on a display is used as it is as an environmental lighting fixture (an ambient lighting fixture), a user may be given odd feeling.

[0010]

5 The present invention has been conceived to address such a problem, and an object thereof is to provide an illumination apparatus which can improve visibility of text on a display without giving odd feeling to a user.

[Solution to Problem]

[0011]

10 In order to achieve the above object, an illumination apparatus according to an aspect of the present invention includes: a light emitter, wherein when a direction directly downward from the light emitter has a vertical angle of 0° when the illumination apparatus is installed on a ceiling, first light emitted in the direction having the vertical angle of 0° has a
15 correlated color temperature in a range from 4000 K to 5800 K, and $u'v'$ chromaticity coordinates in an XYZ colorimetric system in a range which satisfies $0.7125u' + 0.3284 < v' < 0.7125u' + 0.3339$, the first light being included in illumination light emitted from the illumination apparatus, and
20 second light emitted in an area defined by an angle greater than or equal to a predetermined vertical angle has a correlated color temperature higher than the correlated color temperature of the first light, the second light being included in the illumination light emitted from the illumination apparatus.

[Advantageous Effects of Invention]

[0012]

25 The visibility of text on a display can be improved without giving a user odd feeling.

[Brief Description of Drawings]

[0013]

FIG. 1 is a perspective view of an illumination apparatus according to an embodiment;

FIG. 2 is an exploded perspective view of the illumination apparatus
5 according to the embodiment;

FIG. 3 is a cross-sectional view of a light source unit in the illumination apparatus according to the embodiment;

FIG. 4 is a perspective view when a light emitter side of the light source unit in the illumination apparatus according to the embodiment is viewed;

10 FIG. 5 is a cross-sectional view of the illumination apparatus according to the embodiment;

FIG. 6 illustrates a spectral distribution of light emitted by the light emitter and light emitting diode (LED) elements in the illumination apparatus according to the embodiment;

15 FIG. 7 illustrates an absorption spectrum of a filter in the illumination apparatus according to the embodiment;

FIG. 8 illustrates transmittance of another filter in the illumination apparatus according to the embodiment;

20 FIG. 9 illustrates a skeletal structure of a tetraaza porphyrin compound contained in the filter in the illumination apparatus according to the embodiment;

FIG. 10 illustrates a distribution curve of luminous intensity of the illumination apparatus according to the embodiment;

25 FIG. 11 illustrates a relation between vertical angle θ and correlated color temperature T_c of illumination light emitted by the illumination apparatus according to the embodiment;

FIG. 12 illustrates evaluation of visibility of text on a display based on

space cutoff frequencies;

FIG. 13 illustrates a correlated color temperature of light which provides good visibility of text on a display;

FIG. 14 illustrates a region which includes a light color which provides
5 high visibility of text on a display;

FIG. 15 illustrates an example of a flat layout in a room in which the illumination apparatuses according to the embodiment are disposed;

FIG. 16 illustrates an example of a cross section of the room at and around the wall, in which the illumination apparatus according to the
10 embodiment is disposed;

FIG. 17 is a cross-sectional view of an illumination apparatus according to Variation 1; and

FIG. 18 is a cross-sectional view of an illumination apparatus according to Variation 2.

15 [Description of Embodiments]

[0014]

The following describes embodiments of the present invention. Note that the embodiments described below each show a preferable specific example of the present invention. Thus, the numerical values, elements, the
20 arrangement and connection of the elements, steps, and the processing order of the steps, for instance, shown in the following embodiments are mere examples, and thus are not intended to limit the present invention. Therefore, among the elements in the embodiments below, elements not recited in the independent claim defining the broadest concept of the present invention are
25 described as arbitrary elements.

[0015]

The drawings are schematic diagrams and do not necessarily provide

strict illustration. Note that in the drawings, the same numeral is given to a substantially same configuration, and a redundant description thereof is omitted or simplified.

[0016]

5 In the specification and the drawings, the X axis, the Y axis, and the Z axis represent three axes of a three-dimensional orthogonal coordinate system. In the embodiments, the Z-axis direction is a vertical direction, and a direction perpendicular to the Z axis (a direction parallel to the X-Y plane) is a horizontal direction. The X axis and the Y axis are orthogonal to each other, and are both
10 orthogonal to the Z axis.

[0017]

[Embodiment]

 First, the entire configuration of illumination apparatus 1 according to an embodiment is described with reference to FIGS. 1 and 2. FIG. 1 is a
15 perspective view of illumination apparatus 1 according to the embodiment. FIG. 2 is an exploded perspective view of illumination apparatus 1.

[0018]

 Illumination apparatus 1 is a luminaire attached to a construction material such as a ceiling or a wall. In the present embodiment, illumination
20 apparatus 1 is an elongated ceiling light, for example, and emits white light as illumination light. Illumination apparatus 1 is disposed on the ceiling of a room of an office or a residence, for instance, as an environmental lighting fixture for a space in which a display that a user uses for a visual task is placed, for example.

25 [0019]

 As illustrated in FIGS. 1 and 2, illumination apparatus 1 includes light source unit 100 and device body 200.

[0020]

Light source unit 100 emits white light using power supplied from a power supply (not illustrated). The power supply may be included in illumination apparatus 1 or may be disposed outside illumination apparatus 1.

5 If the power supply is included in illumination apparatus 1, the power supply is housed inside of device body 200, for example.

[0021]

Device body 200 is a holding member that holds light source unit 100, and is, for example, fixed to a ceiling with a hang bolt, for instance. Device
10 body 200 is made of a metal plate, for example, and is formed into an elongated and flat box shape by, for instance, bending the metal plate. Elongated and quadrilateral opening 210 is provided in the undersurface of device body 200. Light source unit 100 is fixed in opening 210 of device body 200.

[0022]

15 The following describes a detailed configuration of light source unit 100, with reference to FIGS. 3, 4, and 5. FIG. 3 is a cross-sectional view of light source unit 100 in illumination apparatus 1 according to the embodiment, and illustrates a cross section taken along line III-III in FIG. 2. FIG. 4 is a perspective view when the light emitter 110 side of light source unit 100 is
20 viewed. FIG. 5 is a cross-sectional view of illumination apparatus 1.

[0023]

As illustrated in FIGS. 3 and 5, light source unit 100 includes light emitter 110, base 130 which supports light emitter 110, and light-transmitting cover 140 which covers light emitter 110.

25 [0024]

Light emitter 110 is a light source of illumination apparatus 1, and emits illumination light. Light emitter 110 is a light source which includes

one or more solid light emitting elements. Specifically, light emitter 110 is a light emitting diode (LED) module which includes one or more LEDs as the one or more solid light emitting elements, and emits white light as illumination light. Light emitter 110 is attached to base 130.

5 [0025]

As illustrated in FIGS. 3 to 5, light emitter 110 includes substrate 111 and LED elements 112 disposed on substrate 111. Light emitter 110 in the present embodiment is a surface mount device (SMD) light emitting module, and LED elements 112 are mounted on substrate 111.

10 [0026]

Substrate 111 is a mounting substrate for mounting LED elements 112. Substrate 111 is, for example, a resin substrate, a metal base substrate, or a ceramic substrate, for example. Substrate 111 is placed on and fixed to base 130. In the present embodiment, substrate 111 has, for example, an elongated quadrilateral shape, but the shape is not limited to this.

15

[0027]

LED elements 112 are mounted on substrate 111. Specifically, plural LED elements 112 are linearly mounted on substrate 111, at predetermined intervals in the longitudinal direction of substrate 111.

20 [0028]

In the present embodiment, each LED element 112 is an SMD light emitting element, and includes a container (package) made of, for instance, resin, an LED chip (bare chip) disposed in the container, and a sealant which seals the LED chip.

25 [0029]

Each LED element 112 is a white LED light source which emits white light. For example, a blue LED chip which emits blue light is used as the LED

chip and a silicone resin (phosphor containing resin) which includes yellow phosphors is used as the sealant with which the container is filled, whereby a white LED light source which emits white light can be achieved. Note that the sealant may include red phosphors in addition to the yellow phosphors. In the present embodiment, each LED element 112 emits white light having a spectral distribution illustrated in FIG. 6. Accordingly, light emitter 110 emits light having the spectral distribution illustrated in FIG. 6.

[0030]

Note that in order to change brightness, light emitter 110 may be configured so as to be dimmable. In order to change the color of light, light emitter 110 may be configured so as to be color-tuning controllable. In this case, plural types of LED elements which emit light having different correlated color temperatures may be used as LED elements 112. For example, a first LED element which emits light having a correlated color temperature of 6500 K and a second LED element which emits light having a correlated color temperature of 2700 K are used and each dimmed, thus tuning the color of light emitted by light emitter 110 within a range in correlated color temperature from 2700 K to 6500 K.

[0031]

In the present embodiment, light emitter 110 can emit illumination light for illuminating a display as illumination light which improves visibility of text on a display. Specifically, the color of illumination light (illumination light for illuminating a display) emitted by light emitter 110 has a correlated color temperature in a range from 4000 K to 5800 K, and $u'v'$ chromaticity coordinates in an XYZ colorimetric system in a range which satisfies $0.7125u' + 0.3284 < v' < 0.7125u' + 0.3339$.

[0032]

Light emitter 110 having such a configuration is attached to base 130. Specifically, substrate 111 of light emitter 110 is fixed to base 130. Base 130 is an elongated metal casing, and can be formed by, for instance, bending a metal plate such as a cold rolled steel plate (steel plate cold commercial (SPCC)), for
5 example.

[0033]

As illustrated in FIGS. 3 and 5, light emitter 110 attached to base 130 is covered by light-transmitting cover 140. Light-transmitting cover 140 is a light-transmitting cover member which transmits light from light emitter 110
10 (LED elements 112). Light-transmitting cover 140 has an elongated, substantially semi-cylindrical shape, for example.

[0034]

Light-transmitting cover 140 is made of a light-transmitting material. For example, light-transmitting cover 140 is made of a light-transmitting resin
15 material such as acrylic or polycarbonate, or is made of a glass material, for example.

[0035]

In the present embodiment, light-transmitting cover 140 further has light diffusibility (light scattering properties). Specifically, light-transmitting
20 cover 140 is a light-diffusing cover which has light transmissibility and light diffusibility, rather than a transparent cover. In this manner, strongly directional light from LED elements 112 can be scattered by giving light diffusibility to light-transmitting cover 140, and thus spotty lighting (poor luminance uniformity) due to a difference in brightness of light emitted by
25 plural LED elements 112 can be inhibited.

[0036]

For example, light-transmitting cover 140 is formed by dispersing, in

the light-transmitting resin material, a light-diffusing material such as light-reflecting particles or is formed by forming an opaque white light-diffusing film which includes, for instance, a light-diffusing material on the surface (the inner or external surface) of light-transmitting cover 140 which is made of a transparent member, whereby light diffusibility can be given to light-transmitting cover 140. Alternatively, rather than using a light-diffusing material, light-transmitting cover 140 may be given light diffusibility by forming fine unevenness in the surface of light-transmitting cover 140 through, for instance, texturing light-transmitting cover 140 made of a transparent member, or by printing a dot pattern on the surface of light-transmitting cover 140 made of a transparent member.

[0037]

Filter 150 is disposed on light-transmitting cover 140. Filter 150 is a wavelength-selective filter which selectively absorbs light having a particular wavelength in a visible light region. Specifically, filter 150 has a function of changing the color of light which passes therethrough by selectively absorbing a portion of the passing light which has a particular wavelength. In the present embodiment, filter 150 increases a correlated color temperature of white light passing therethrough. Thus, the correlated color temperature of white light which has passed through filter 150 is higher than the correlated color temperature of white light before passing through filter 150.

[0038]

In the present embodiment, filter 150 is a pigment added filter to which a tetraaza porphyrin (TAP) wavelength selectively absorbing pigment is added as a wavelength-selective absorber. In this case, for example, filter 150 may be a resin composition in which a wavelength selectively absorbing pigment is dispersed, or may be obtained by applying, onto the surface of a transparent

base material, a material that contains wavelength selectively absorbing pigments and curing the material.

[0039]

As an example, filter 150 has an absorption spectrum as illustrated in FIG. 7. FIG. 7 illustrates an example of an absorption spectrum of filter 150 according to the embodiment. As illustrated in FIG. 7, filter 150 in the present embodiment has the highest absorption wavelength in a range from 500 nm to 650 nm, and mainly absorbs components from yellow to red components.

[0040]

Note that a filter having a transmission property as illustrated in FIG. 8 may be used as filter 150. FIG. 8 illustrates transmission properties of six types of wavelength selectively absorbing pigments, namely "FDG-004", "FDG-005", "FDG-006", "FDG-007", "TAP", and "FDR-001". The six types of wavelength selectively absorbing pigments are all tetraaza porphyrin pigments made of tetraaza porphyrin compounds.

[0041]

Tetraaza porphyrin compounds have a sharp absorption peak, and are highly robust against light emitted by a light source, so that the compounds can be suitably used. Such a tetraaza porphyrin compound is expressed by the chemical formula illustrated in FIG. 9, for example.

[0042]

In FIG. 9, "M" indicates the central metal of a tetraaza porphyrin compound, and is cobalt (Co), lead (Pd), copper (Cu), nickel (Ni), or vanadium(II) oxide (VO), for instance. In FIG. 9, "R" indicates a substituent, and is fluoroethoxy or fluorobenzo, for instance. Such a tetraaza porphyrin compound has a main absorption peak wavelength that varies depending on a

substituent and the central metal of a skeleton. Note that the six types of pigments illustrated in FIG. 8 have main absorption peak wavelengths, central metals, and substituents illustrated in Table 1 below.

[0043]

5 [Table 1]

Pigment	Main Peak Wavelength	Central Metal	Substituent
FDG-004	578 nm	Co	Fluoroethoxy
FDG-005	583 nm	Pd	Fluorobenzo
FDG-006	585 nm	Pd	Fluoroethoxy
FDG-007	594 nm	Cu	Fluorobenzo
TAP	590 nm	Ni	Fluorobenzo
FDR-001	609 nm	VO	Fluorobenzo

[0044]

Note that in the present embodiment, a tetraaza porphyrin pigment is used as a wavelength selectively absorbing pigment of filter 150, yet the present invention is not limited to this. A phthalocyanine pigment may be
 10 used as a wavelength selectively absorbing pigment of filter 150.

[0045]

Filter 150 having such a configuration is disposed at a position where a portion of light emitted by light emitter 110 passes. In the present embodiment, filters 150 are disposed on light-transmitting cover 140, as
 15 illustrated in FIG. 5.

[0046]

Specifically, in a cross section of illumination apparatus 1 normal to the longitudinal direction of illumination apparatus 1, when the direction directly downward from light emitter 110 has a vertical angle of 0° and an arbitrary
 20 vertical angle relative to the vertical angle of 0° is θ when illumination

apparatus 1 is installed on ceiling 2, filters 150 are each disposed on a portion defined by an angle greater than or equal to a predetermined vertical angle, over the inner circumferential surface of light-transmitting cover 140.

[0047]

5 In the present embodiment, each filter 150 is disposed on a portion defined by vertical angle θ that is greater than or equal to 75° . Specifically, a pair of filters 150 are disposed on right and left in circumferential portions of light-transmitting cover 140 that satisfy $75^\circ \leq \theta \leq 90^\circ$. The pair of filters 150 further extend in the longitudinal direction of light-transmitting cover 140.

10 [0048]

 Since filters 150 are disposed on light-transmitting cover 140 which covers light emitter 110 in this manner, a portion of illumination light emitted by light emitter 110 passes through filter 150 and then through light-transmitting cover 140. On the other hand, another portion of illumination light emitted by light emitter 110 passes through light-transmitting cover 140 without passing through filter 150.

[0049]

 Accordingly, first light which is included in illumination light emitted by light emitter 110 and has passed through light-transmitting cover 140 without passing through filter 150 has the color identical to the color of the illumination light immediately after being emitted by light emitter 110 (that is, illumination light before entering filter 150).

[0050]

 On the other hand, second light which is included in illumination light emitted by light emitter 110 and has passed through light-transmitting cover 140 after passing through filter 150 has a color different from the color of the illumination light immediately after being emitted by light emitter 110, since a

portion of the second light having a particular wavelength is absorbed when the second light passes through filter 150. Specifically, filter 150 has an absorption spectrum as illustrated in FIG. 7, and thus absorbs yellow to red components of illumination light emitted by light emitter 110 when the illumination light passes therethrough. As a result, the correlated color temperature of the second light becomes higher than the correlated color temperature of the first light.

[0051]

With regard to illumination apparatus 1 having such a configuration, FIGS. 10 and 11 illustrate light distribution characteristics and correlated color temperature T_c for vertical angle θ of illumination light emitted by illumination apparatus 1 (that is, illumination light emitted through light-transmitting cover 140). FIG. 10 illustrates a distribution curve of luminous intensity of illumination apparatus 1 according to the embodiment. FIG. 11 illustrates a relation between vertical angle θ and correlated color temperature T_c of illumination light emitted by illumination apparatus 1 according to the embodiment. Note that FIG. 11 illustrates correlated color temperature T_c for vertical angle θ in the cross section illustrated in FIG. 5.

[0052]

As illustrated in FIG. 10, illumination light emitted by illumination apparatus 1 has a Lambertian light distribution in which light intensity in the direction directly downward from light emitter 110 (the direction of a vertical angle of 0°) is the highest. Specifically, a half light-distribution angle of the illumination light emitted by illumination apparatus 1 is approximately 120° .

[0053]

As illustrated in FIG. 11, out of illumination light emitted by illumination apparatus 1, the correlated color temperature of illumination light

emitted in the direction directly downward from light emitter 110 (the direction of a vertical angle of 0°) is 4600 K. Furthermore, the correlated color temperature of illumination light emitted by illumination apparatus 1 increases with an increase in vertical angle θ .

5 [0054]

In the present embodiment, filters 150 are disposed on the portions defined by vertical angle θ which satisfies $75^\circ \leq \theta \leq 90^\circ$. Accordingly, a rate of increase in correlated color temperature of illumination light emitted by illumination apparatus 1 (that is, illumination light emitted through
10 light-transmitting cover 140) increases around when vertical angle θ exceeds 60° . Illumination light emitted by illumination apparatus 1 at a vertical angle of 60° has a correlated color temperature that is higher by 250 K than that of illumination light emitted by illumination apparatus 1 at a vertical angle of 0° . Illumination light emitted by illumination apparatus 1 at a vertical angle of 90°
15 has a correlated color temperature that is higher by 600 K than that of illumination light emitted by illumination apparatus 1 at a vertical angle of 0° .

[0055]

Note that although filters 150 are disposed on the portions defined by $\theta \geq 75^\circ$, illumination light emitted by illumination apparatus 1 has a high
20 correlated color temperature at around $\theta = 60^\circ$, which is considered to be influenced by scattering of light.

[0056]

Here, the following describes in detail optical characteristics of illumination light emitted by illumination apparatus 1, also mentioning the
25 circumstances which led to the present invention.

[0057]

Examinations on ambient light that allows text on paper to be readily

read by making the paper appear whiter have been made so far, yet no optimal ambient light for text on a display has been recommended, and thus it is difficult to obtain ambient light that allows text on a display to be readily read, with a conventional illumination apparatus.

5 [0058]

In addition, a display has a function for a user to manually adjust the brightness and contrast of a screen, yet the user does not know what conditions are suitable for ambient light. Thus, the display setting (screen setting) of the display is often maintained in the initial state.

10 [0059]

In view of this, the inventors of the present application examined an illumination apparatus which emits illumination light which can improve readability of text displayed on a screen of a display by improving visibility of the text.

15 [0060]

Specifically, the inventors of the present application conducted an experiment to evaluate the visibility of text displayed on a display under different-color illumination obtained by changing the color of illumination light emitted from the illumination apparatus and serving as ambient light for the display. FIG. 12 illustrates results of the experiment.

[0061]

In the experiment, visibility of text displayed on the display was evaluated using space cutoff frequencies. In FIG. 12, evaluation of visibility of text under different-color illumination according to 25 conditions is illustrated in a contour map having contours through average cutoff frequencies (cdp) in a u'v' chromaticity diagram.

[0062]

Specifically, evaluations were made for light colors according to a total of 25 conditions, that is, correlated color temperatures at five levels (4200 K, 4600 K, 5000 K, 5500 K, and 6200 K) and color deviations (Duv) at five levels (2, 0, -2, -4, and -6).

5 [0063]

In the experiment, under different-color illumination light according to 25 conditions, a cutoff frequency is changed by performing low-pass-filter processing on text displayed on the display, and resolution of the text displayed on the display was changed. At this time, the inventors had 15 subjects (aged 10 25 to 54) to answer up to which cutoff frequency the text appeared clearly.

[0064]

For the light colors according to the 25 conditions, FIG. 12 was obtained by plotting the averages of cutoff frequencies for the 15 subjects when the text on the display appeared clearly, on the u'v' chromaticity diagram in the XYZ 15 color system.

[0065]

Note that the display used in this experiment is a 23-inch liquid crystal display having a screen aspect ratio of 16:9 and a screen intensity of 180 cd/m². Furthermore, illuminance on the surface of a desk (illuminance on a horizontal 20 surface of a desk on which a display is disposed) of illumination light is 750 lx under light color conditions in this experiment.

[0066]

Here, a relation between a cutoff frequency and visibility of text shows that even text having low resolution appears more clearly with a light color 25 obtained when a cutoff frequency is lower. In other words, a lower cutoff frequency achieves a light color which provides higher visibility of text.

[0067]

Thus, the experiment showed that visibility of text on a display is the highest when illumination light has a correlated color temperature of 4600 K and Duv at or near a chromaticity point of -4 , as illustrated in FIG. 12.

[0068]

5 As can be seen from FIG. 12, not only a correlated color temperature, but also Duv influences the visibility of text on a display. Specifically, it can be seen that optimal Duv for visibility of text changes for each correlated color temperature.

[0069]

10 Regarding this point, the experiment shows that light colors for optimal Duv for text visibility are achieved in the cases where Duv is -6 when a correlated color temperature is 4200 K, Duv is -4 when a correlated color temperature is 4600 K, Duv is -2 when a correlated color temperature is 5000 K, and Duv is 0 when a correlated color temperature is 5500 K, except the case
15 where a correlated color temperature is 6200 K. Thus, the experiment shows that optimal Duv for text visibility increases with an increase in a correlated color temperature.

[0070]

 In view of this, assuming that difference values from the average cutoff
20 frequencies under all the light color conditions of the subjects at optimal Duvs for correlated color temperatures are evaluation levels, FIG. 13 illustrates this relation. Stated differently, FIG. 13 illustrates, as evaluation levels, averages of values for all the subjects which are obtained by subtracting average cutoff frequencies under all the light color conditions from cutoff frequencies at
25 optimal Duvs for correlated color temperatures at four levels (4200 K, 4600 K, 5000 K, and 5500 K), excluding 6200 K.

[0071]

In this case, a correlated color temperature for which an evaluation level is less than zero in FIG. 13 provides higher visibility of text on a display than other light color conditions. Note that in FIG. 13, the unit of correlated color temperature is shown as "micro reciprocal degree (mired)", rather than "kelvin (K)".

[0072]

In FIG. 13, curve approximation is performed based on the evaluation levels for the four levels of the correlated color temperatures, and the intersections between the curve and the evaluation level 0 are calculated to be 172 mireds and 250 mireds. Accordingly, the result illustrated in FIG. 13 shows that visibility of text on a display increases in a range in correlated color temperature from 172 mireds to 250 mireds (that is, a range from 4000 K to 5800 K).

[0073]

A summary of the above analysis shows that a light color which provides high visibility of text on a display is included in a region surrounded by straight lines X2, X3, Y1, and Y2 (a displayed text highly visible area) in FIG. 14. FIG. 14 illustrates a region which includes a light color which provides high visibility of text on a display in FIG. 12.

[0074]

Here, in FIG. 14, straight line X1 indicates an approximate line which connects points of optimal Duv for text visibility of correlated color temperatures at u'v' chromaticity coordinates in the XYZ colorimetric system, and can be indicated by (Expression 1) below.

[0075]

Straight line X1: $v' = 0.7125u' + 0.3305 \dots$ (Expression 1)

[0076]

Straight lines X2 and X3 are parallel lines obtained by translating straight line X1 in parallel, and are two straight lines in contact with a range in which cutoff frequency f_c which is an average for all the light color conditions is lower than 13.50 ($f_c < 13.50$). Specifically, straight lines X2 and X3 are boundary lines which indicate the mean value (average) of cutoff frequencies evaluated in the experiment. In this case, straight line X2 can be expressed by (Expression 2) below, and straight line X3 can be expressed by (Expression 3) below.

[0077]

10 Straight line X2: $v' = 0.7125u' + 0.3284 \dots$ (Expression 2)

 Straight line X3: $v' = 0.7125u' + 0.3339 \dots$ (Expression 3)

[0078]

 In FIG. 14, straight lines Y1 and Y2 indicate the lower limit (4000 K) and the upper limit (5800 K) of a correlated color temperature which provides high text visibility in FIG. 12.

[0079]

 As can be seen from the above examinations, illumination light having a correlated color temperature in a range from 4000 K to 5800 K and $u'v'$ chromaticity coordinates in the XYZ colorimetric system in a range which satisfies $0.7125u' + 0.3284 < v' < 0.7125u' + 0.3339$ has high visibility of text on a display.

[0080]

 In view of this, illumination apparatus 1 according to the embodiment causes light emitter 110 to emit, as illumination light for illuminating a display, illumination light having a correlated color temperature in a range from 4000 K to 5800 K and $u'v'$ chromaticity coordinates in the XYZ colorimetric system in a range which satisfies $0.7125u' + 0.3284 < v' < 0.7125u' + 0.3339$. This achieves

an improvement in visibility of text on the display. As a result, readability of text on the display improves.

[0081]

However, it has been found that odd feeling is given to a user if such an illumination apparatus that improves visibility of text on a display is used as it is as an environmental lighting fixture (ambient lighting fixture).

[0082]

For example, if an illumination apparatus which improves visibility of text on a display is disposed on the ceiling of an indoor room such as an office, a user may be given odd feeling or although it depends on a person, the user may even feel unpleasant.

[0083]

In particular, the impression of lighting in a room mainly and greatly relates to how the wall appears in the room. Specifically, out of illumination light emitted by an illumination apparatus disposed on the ceiling, illumination light emitted on the wall greatly influences the atmosphere of lighting in the entire room.

[0084]

In view of this, according to illumination apparatus 1 according to the present embodiment, at least first light emitted in the direction of a vertical angle of 0° out of the illumination light emitted by illumination apparatus 1 is caused to have a color which improves visibility of text on a display, and second light emitted in an area defined by an angle greater than or equal to predetermined vertical angle α out of the illumination light emitted by illumination apparatus 1 is caused to have a color which does not give a user odd feeling.

[0085]

Specifically, out of the illumination light emitted by illumination apparatus 1, first light emitted in an area having vertical angle θ in a range from 0° to α ($0^\circ \leq \theta \leq \alpha$) has a correlated color temperature in a range from 4000 K to 5800 K and $u'v'$ chromaticity coordinates in the XYZ colorimetric system in a range which satisfies $0.7125u' + 0.3284 < v' < 0.7125u' + 0.3339$, as mentioned above. On the other hand, out of the illumination light emitted by illumination apparatus 1, the correlated color temperature of second light emitted in an area defined by vertical angle θ that is greater than predetermined vertical angle α ($\theta \geq \alpha$) is caused to be higher than the correlated color temperature of the first light emitted in an area defined by vertical angle θ in a range from 0° to less than α .

[0086]

Accordingly, the visibility of text on a display can be improved by increasing the contrast of the display in black and white, without giving a user odd feeling. Thus, readability of the text on the display can be improved. Hence, this achieves a comfortable illumination space that gives a user no odd feeling when the user works on a visual task.

[0087]

With illumination apparatus 1 according to the present embodiment, predetermined vertical angle α is set to 60° . Specifically, the second light having a correlated color temperature higher than that of the first light is emitted in an area defined by vertical angle θ that is greater than 60° .

[0088]

Accordingly, giving odd feeling to a user is further inhibited while improving the visibility of text on a display.

[0089]

Here, the reason for setting predetermined vertical angle α to 60° , or in

other words, the reason for emitting the second light having a correlated color temperature higher than that of the first light in an area defined by vertical angle θ that is greater than or equal to 60° is to be described below with reference to FIGS. 15 and 16. FIG. 15 illustrates an example of a flat layout in a room in which illumination apparatuses 1 according to the embodiment are disposed. FIG. 16 illustrates an example of a cross section of a room at and around the wall, in which the illumination apparatus according to the embodiment is disposed.

[0090]

As illustrated in FIG. 15, illumination apparatuses 1 are disposed at intervals of 2 meters in both the lengthwise and widthwise directions, for example. Illumination apparatuses 1 near the wall are generally disposed at least 1 meter away from the wall. For example, if illumination apparatuses 1 are disposed at intervals of 2 meters in a room having a length of 10 meters and a width of 14 meters, 35 illumination apparatuses 1 are installed.

[0091]

In this case, as illustrated in FIG. 16, the eye line of a person when he/she sits at a desk on which a display is placed is at a height of approximately 1.2 meters from the floor. Accordingly, visibility of text on the display is greatly influenced by illumination light emitted in an area up to a height of approximately 1.2 meters from the floor. On the other hand, illumination light emitted in an area at a height above 1.2 meters from the floor does not give much influence on the visibility of text on the display.

[0092]

In view of this, as described above, what influences the impression of a room is mainly how the wall, for instance, appears, and thus out of illumination light emitted onto wall 3 by illumination apparatus 1 disposed near the wall,

illumination light emitted in an area at a height above 1.2 meters from the floor is caused to have a color which gives little odd feeling to a user, and illumination light which improves visibility of text on a display is maintained for illumination light emitted in an area at a height up to about 1.2 meters from the floor, out of the illumination light emitted onto wall 3 by illumination apparatus 1 disposed near the wall.

[0093]

At this time, if the height from the floor to ceiling 2 is 2.8 meters, vertical angle θ of illumination light emitted on the surface of wall 3 at a position approximately 1.2 meters from the floor is about 60° when illumination apparatus 1 is near the wall. In view of this, illumination apparatus 1 according to the present embodiment emits illumination light for illuminating a display (first light) in an area having vertical angle θ smaller than 60° , and in an area defined by vertical angle θ greater than or equal to 60° , illumination light (second light) having a correlated color temperature higher than that in the area where vertical angle θ is smaller than 60° .

[0094]

Specifically, as illustrated in FIG. 16, illumination light emitted in an area at a height of 1.2 meters on the surface of wall 3 from the floor has a lower color temperature. On the other hand, illumination light emitted in an area between ceiling 2 and the position on the surface of wall 3 at a height of 1.2 meters from the floor has a higher color temperature.

[0095]

In illumination apparatus 1 according to the present embodiment, light emitter 110 emits illumination light (illumination light for illuminating a display) which improves visibility of text on a display, and filter 150 transmits a portion of the illumination light for illuminating the display emitted by light

emitter 110, so as to convert the illumination light into illumination light having a color which gives a user little odd feeling.

[0096]

Specifically, filters 150 are disposed on portions between vertical angles
5 θ of 75° and 90° , both inclusive. Accordingly, out of illumination light emitted outward through light-transmitting cover 140, illumination light which travels in an area defined by a predetermined vertical angle that is smaller than 60° (for example, illumination light which travels in the direction having a vertical angle of 0° which is the direction directly downward from light emitter 110) is
10 first light that does not pass through filter 150 out of the illumination light for illuminating the display emitted by light emitter 110.

[0097]

On the other hand, out of the illumination light outwardly emitted through light-transmitting cover 140, illumination light which travels in an
15 area defined by the predetermined vertical angle that is greater than or equal to 60° is second light resulting from light emitted by light emitter 110 passing through filter 150, and has a correlated color temperature higher than that of the illumination light for illuminating the display which is the first light. Note that the second light may be emitted in an area at least between vertical
20 angles of 60° and 75° , both inclusive.

[0098]

Accordingly, use of filters 150 readily achieves illumination apparatus 1 which improves visibility of text on a display, without giving a user odd feeling. Specifically, LED elements which emit illumination light (illumination light for
25 illuminating a display) having a color which improves visibility of text on the display, and LED elements which emit illumination light having a color which gives a user little odd feeling may be separately prepared, yet use of filters 150

achieves illumination apparatus 1 which improves visibility of text on a display without giving the user odd feeling by using one type of LED elements.

[0099]

Note that in the present embodiment, LED elements 112 which emit illumination light having a color which improves visibility of text on a display are used, and a portion of the illumination light is caused to pass through filter 150 so as to convert the color of the illumination light into a color which gives a user little odd feeling, yet the present invention is not limited thereto. For example, LED elements which emit illumination light having a color which gives a user little odd feeling may be used, and a portion of the illumination light may be caused to pass through the filter so as to convert the portion of the illumination light into illumination light having a color which improves visibility of text on a display.

[0100]

In illumination apparatus 1 according to the present embodiment, a difference between a correlated color temperature of the second light that has passed through filter 150 and a correlated color temperature of the first light that does not pass through filter 150 may be in a range from 250 K to 1700 K.

[0101]

Accordingly, with regard to the MacAdam ellipse illustrated in FIG. 14, a difference between a correlated color temperature of the second light that has passed through filter 150 and a correlated color temperature of the first light that does not pass through filter 150 can be caused to fall within a range from 5-step to 18-step MacAdam ellipses.

[0102]

Here, a range of colors which a person can perceive as the same color is smaller than a 5-step MacAdam ellipse. The 5-step MacAdam ellipse that is

approximately 5 times the standard deviation is just a noticeable difference for color differentiation. Note that a preferable permissible level of color unevenness for a red hue is a 5-step MacAdam ellipse (the variable range is 1/2 the range for blue), a preferable permissible level of color unevenness for a green hue is a 6-step MacAdam ellipse or less (the variable range is 3/5 the range for blue), and a preferable permissible level of color unevenness for a blue hue is a 10-step MacAdam ellipse or less.

[0103]

Thus, a difference between the correlated color temperature of the second light which has passed through filter 150 and the correlated color temperature of the first light which does not pass through filter 150 is set to at least a 5-step MacAdam ellipse, so that a user can recognize the difference in color between the second light which has passed through filter 150 and the first light which does not pass through filter 150.

[0104]

A difference between the correlated color temperature of the second light which has passed through filter 150 and the correlated color temperature of the first light which does not pass through filter 150 is set to at most a 18-step MacAdam ellipse, so that concentration of a user on a visual task can be increased when the second light that is ambient illumination light and the first light that is illumination light for illuminating a display are used together.

[0105]

Accordingly, a difference between the correlated color temperature of the second light which has passed through filter 150 and the correlated color temperature of the first light which does not pass through filter 150 is caused to fall within a range from 250 K to 1700 K, so that visibility of text on a display is improved without giving a user odd feeling and furthermore, concentration of

the user on a visual task can be increased.

[0106]

In this case, a difference between the correlated color temperature of the second light which has passed through filter 150 and the correlated color temperature of the first light which does not pass through filter 150 may be
5 caused to fall within a range from 250 K to 600 K.

[0107]

Accordingly, visibility of text on a display is improved without giving a user odd feeling and furthermore, concentration of the user on a visual task can
10 be further increased.

[0108]

Note that in the present embodiment, illuminance on the surface of a desk (horizontal illuminance) of illumination light emitted by illumination apparatus 100 may be at most 1000 lx. That is because if the illuminance on
15 the surface of a desk exceeds 1000 lx, the brightness is too high so that text on a display may be invisible due to blown-out highlights.

[0109]

[Variations]

The above has described the illumination apparatuses according to the present invention based on the embodiments, yet the present invention is not
20 limited to the above embodiments.

[0110]

For example, filters 150 are disposed on light-transmitting cover 140 in the above embodiments, yet the present invention is not limited thereto. For
25 example, as shown by illumination apparatus 1A as illustrated in FIG. 17, filters 150A may be disposed on substrate 111 of light emitter 110. Furthermore, as shown by illumination apparatus 1B as illustrated in FIG. 18,

filters 150B may be each formed on the inner surface of side wall 131B of base 130B. Side wall 131B is a sidewall plate which protrudes from a portion of base 130B on which substrate 111 is placed toward the floor, and has an inner surface which is a reflective surface.

5 [0111]

Further, in the embodiments described above, light emitter 110 is an SMD LED module, yet the present invention is not limited thereto. For example, light emitter 110 may be a chip on board (COB) LED module. In this case, light emitter 110 includes substrate 111, one or more LED chips (bare
10 chips) directly mounted on substrate 111 as LED elements 112, and a sealant such as a phosphor containing resin which seals the one or more LED chips.

[0112]

The above embodiment and the variations thereof have shown examples in which light source unit 100 (light emitter 110) in illumination
15 apparatus 1 emits only illumination light for illuminating a display, yet the present invention is not limited thereto. For example, illumination apparatus 1 may have a display illuminating mode (first mode) in which light source unit 100 (light emitter 110) emits illumination light for illuminating a display and a paper illuminating mode (second mode) in which light source unit 100 (light
20 emitter 110) emits illumination light for illuminating paper which makes text on paper readily readable, and may be configured so as to switch between the modes.

[0113]

The present invention may also include embodiments obtained as a
25 result of adding, to the embodiment and the variations thereof described above, various modifications that may be conceived by those skilled in the art, and embodiments obtained by combining elements and functions in the

embodiment and the variations thereof described above in any manner without departing from the spirit of the present invention.

[Reference Signs List]

[0114]

5	1, 1A, 1B	illumination apparatus
	2	ceiling
	110	light emitter
	111	substrate
	112	LED element (light source)
10	140	light-transmitting cover
	150, 150A, 150B	filter

[CLAIMS]

[Claim 1]

An illumination apparatus, comprising:

a light emitter, wherein

5 when a direction directly downward from the light emitter has a vertical angle of 0° when the illumination apparatus is installed on a ceiling,

 first light emitted in the direction having the vertical angle of 0° has a correlated color temperature in a range from 4000 K to 5800 K, and $u'v'$ chromaticity coordinates in an XYZ colorimetric system in a range which
10 satisfies $0.7125u' + 0.3284 < v' < 0.7125u' + 0.3339$, the first light being included in illumination light emitted from the illumination apparatus, and

 second light emitted in an area defined by an angle greater than or equal to a predetermined vertical angle has a correlated color temperature higher than the correlated color temperature of the first light, the second light
15 being included in the illumination light emitted from the illumination apparatus.

[Claim 2]

The illumination apparatus according to claim 1, wherein

20 the predetermined vertical angle is 60° .

[Claim 3]

The illumination apparatus according to claim 2, wherein

 the area in which the second light is emitted is at least between vertical
25 angles of 60° and 75° , both inclusive.

[Claim 4]

The illumination apparatus according to any one of claims 1 to 3,
wherein

a difference between the correlated color temperature of the second
light and the correlated color temperature of the first light is in a range from
5 250 K to 1700 K.

[Claim 5]

The illumination apparatus according to any one of claims 1 to 3,
wherein

10 a difference between the correlated color temperature of the second
light and the correlated color temperature of the first light is in a range from
250 K to 600 K.

[Claim 6]

15 The illumination apparatus according to any one of claims 1 to 5,
further comprising:

a filter which absorbs light having a particular wavelength, wherein
the light emitter emits illumination light for illuminating a display,
the illumination light for illuminating the display has a correlated color
20 temperature in a range from 4000 K to 5800 K, and u'v' chromaticity
coordinates in the XYZ colorimetric system in a range which satisfies $0.7125u' + 0.3284 < v' < 0.7125u' + 0.3339$,

the first light is identical to the illumination light for illuminating the
display, and

25 the second light is light resulting from the illumination light for
illuminating the display passing through the filter.

[Claim 7]

The illumination apparatus according to claim 6, further comprising:
a light-transmitting cover which covers the light emitter, wherein
the filter is disposed on the light-transmitting cover.

5

[Claim 8]

The illumination apparatus according to claim 7, wherein
the light-transmitting cover is a light-diffusing cover.

10 [Claim 9]

The illumination apparatus according to claim 6, wherein
the light emitter includes a substrate and a light source disposed on the
substrate, and
the filter is disposed on the substrate.

15