SPECIFICATION

TITLE OF THE INVENTION

LIGHT RADIATION DEVICE, LIGHT RADIATION SYSTEM, AND METHOD FOR OPERATING LIGHT RADIATION DEVICE

FIELD OF THE INVENTION

[0001] The present invention relates to a light radiation device, a light radiation system, and a method for operating a light radiation device. More specifically, the present invention relates to a light radiation device, a light radiation system, and a method for operating a light radiation device that can effectively express the OPN5 gene or activate OPN5 by radiating light to an eye.

BACKGROUND ART

[0002] In recent years, the effects of light on a human body have been examined from various perspectives, and reports based on new findings have been made. For example, it has been reported that circadian rhythm is improved by exposure to sunlight (Non-Patent Document 1), light emitted from light-emitting diode (LED) lighting, a liquid crystal display that uses an LED as a backlight, or the like has a significant effect on the body and mind (Non-Patent Document 2), violet light prevents myopia and suppresses an onset of myopia (Patent Document 1), and the like. In particular, the present inventors have recently reported on the effects of violet light on myopia. For example, in Patent Document 1 and Non-Patent Document 3, it is proposed that light having a specific wavelength is effective in preventing and suppressing the progression of myopia, and there are great expectations in recent years with the number of persons with myopia still increasing worldwide.

[0003] Opsin 5 (OPN5) is known as a photoreceptor protein, and research on visual functions and non-visual functions in humans and animals is underway (Non-Patent Document 4).

PRIOR ART DOCUMENTS

Non-Patent Documents

[0004] Non-Patent Document 1: Megumi Hatori, Kazuo Tsubota, Anti-Aging Medicine - Journal of Japanese Society of Anti-aging Medicine, Vol. 11, No. 3, 065 (385) to 072 (392) (2015)
Non-Patent Document 2: Kazuo Tsubota, "Blue Light - Threat to Internal Clock," Shueisha

(November 20, 2013)

Non-Patent Document 3: Hidemasa Torii et al., EBioMedicine, "DOI: http://dx.doi.org/10.1016/j.ebiom.2016.12.007"

Non-Patent Document 4: Takahiro Yamashita, "Novel UV Light-sensitive Photoreceptive Protein in Vertebrates," Seibutsu Butsuri 51 (4), 186 to 187 (2011)

Patent Documents

[0005] Patent Document 1: WO2015/186723A1

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0006] As shown in Fig. 1, OPN5 exhibits an absorption spectrum having a peak at 380 nm. If such OPN5 can be activated, it can be expected that the relationship with visual functions and non-visual functions, as well as with myopia progression suppression, which the present inventors are researching, will be clearly defined.

[0007] The present invention has been made to solve the above-described problems. An object of the present invention is to provide a light radiation device, a light radiation system, and a method for operating a light radiation device that can effectively express the OPN5 gene or activate OPN5 by radiating light to an eye.

Means for Solving the Problems

[0008] (1) A light radiation device according to the present invention is a light radiation device configured to radiate light to an eye to express the OPN5 gene or activate OPN5. The light radiation device includes a light source that radiates light having a wavelength in a wavelength region overlapping an OPN5 absorption spectrum, and a radiation condition of the light radiated from the light source is set to express the OPN5 gene or activate OPN5.

[0009] According to this invention, the light emitted from the light source is radiated toward the eye, and the light has a wavelength in a wavelength region overlapping the OPN5 absorption spectrum (peak wavelength: approximately 380 nm). Therefore, the OPN5 gene present in the retina can be expressed or OPN5 can be activated. Because OPN5 is present in the retina, the light is radiated toward the eye, and direct radiation to the eye is more preferable because it can more effectively express the OPN5 gene or activate OPN5. A larger wavelength overlap between

the spectral data of the light and the OPN5 absorption spectral data means that more of the light is absorbed by OPN5.

[0010] In the light radiation device according to the present invention, the setting may be performed by comparing, in advance or in situ, spectral data of the light obtained by receiving the light radiated from the light source with OPN5 absorption spectral data, and on the basis of the comparison results.

[0011] According to this invention, the actual spectral data of the light obtained by receiving the light radiated from the light source is compared, in advance or in situ, with the OPN5 absorption spectral data, and the radiation condition of the light is set on the basis of the comparison results. Therefore, the OPN5 gene can be more effectively expressed or OPN5 can be more effectively activated.

[0012] In the light radiation device according to the present invention, the spectrum of the light obtained by receiving the light radiated from the light source is set so that a maximum value of a received effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of a spectral irradiance ($W/m^2/nm$) of the light in a wavelength region of 280 to 500 nm and a relative absorbance of the OPN5 absorption spectral data, is 0.2% or more of a maximum value of a reference effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of a spectral irradiance ($W/m^2/nm$) of a sunlight spectrum defined by AM1.5G and the relative absorbance of the OPN5 absorption spectral data.

[0013] According to this invention, the spectrum of the light received by the irradiated subject is set so that the received effective spectral irradiance is 0.2% or more of the maximum value of the reference effective spectral irradiance. In this light radiation device, the light source that radiates light having a wavelength in a wavelength region overlapping the peak wavelength of the OPN5 absorption spectrum may be appropriately selected on the basis of common technical knowledge in the art, and one or two or more conditions selected from the radiation direction of the light, the wavelength range of the light, the irradiance of the light, the radiation time frame of the light, and the radiation duration of the light may be regulated so that the received effective spectral irradiance of the spectrum received by the irradiated subject is 0.2% or more of the reference effective spectral irradiance. As a result, the OPN5 gene can be more effectively expressed or OPN5 can be more effectively activated. Light having a percentage within the above-described

range is calculated on the basis of a light spectrum measured at the irradiated subject or at a position around the irradiated subject.

[0014] As one modification of the light radiation device, the light radiation device may include one or two or more light sources that radiate light having a wavelength in a wavelength region overlapping the peak wavelength of the OPN5 absorption spectrum, and may be configured so that a received effective irradiance (W/m^2), obtained by integrating, over the wavelength region, a received effective spectral irradiance ($W/m^2/nm$) calculated as a product, on a per-wavelength basis, of the spectral irradiance ($W/m^2/nm$) of each wavelength in the wavelength region of 280 to 500 nm of the spectrum of the light received by the irradiated subject and the relative absorbance of the OPN5 absorption spectral data, is set to 0.2% or more of a reference effective irradiance (W/m^2), obtained by integrating, over the wavelength region, a reference effective spectral irradiance ($W/m^2/nm$) calculated as a product, on a per-wavelength basis, of the spectral irradiance ($W/m^2/nm$) of an AM1.5G sunlight spectrum and the relative absorbance of the OPN5 absorption spectrum.

[0015] As another modification of the light radiation device, the light radiation device may include one or two or more light sources that radiate light having a wavelength in a wavelength region overlapping the peak wavelength of the OPN5 absorption spectrum, and may be configured so that a received effective dose (J/m^2), obtained by multiplying a received effective irradiance (W/m^2), obtained by integrating over the wavelength region a received effective spectral irradiance ($W/m^2/nm$) calculated as a product, on a per-wavelength basis, of the spectral irradiance ($W/m^2/nm$) of each wavelength in the wavelength region of 280 to 500 nm of the spectrum of the light received by the irradiated subject and the relative absorbance of the OPN5 absorption spectral data, by a radiation duration (seconds), is set to 0.2% or more of a received reference effective dose (J/m^2), obtained by multiplying a reference effective irradiance (W/m^2), obtained by integrating over the wavelength region a reference effective spectral irradiance ($W/m^2/nm$) calculated as a product, on a per-wavelength basis, of the spectral irradiance ($W/m^2/nm$) of an AM1.5G sunlight spectrum and the relative absorbance of the OPN5 absorption spectrum, by the radiation duration (seconds).

[0016] In the light radiation device according to the present invention, the radiation condition is one or two or more selected from the radiation direction of the light, the wavelength range of the

light, the wavelength profile of the light, the irradiance of the light, the radiation time frame of the light, and the radiation duration of the light.

[0017] According to this invention, the radiation condition is one or two or more selected from the radiation direction, wavelength range, wavelength profile, irradiance, radiation time frame, and radiation duration of the light. Therefore, one or two or more conditions capable of effectively expressing the OPN5 gene or activating OPN5 can be set in accordance with the manner in which the light is emitted from the light source toward the eye. In a preferred mode of the setting, one or two or more selected from the radiation direction, wavelength range, wavelength profile, irradiance, radiation time frame, and radiation duration of the light are regulated.

[0018] In the light radiation device according to the present invention, the radiation condition of the light radiated from the light source is set by a light setting unit provided together with the light source or provided separately from the light source.

[0019] According to this invention, the radiation condition of the light radiated from the light source is set by the light setting unit provided together with the light source or separately from the light source. Therefore, the light setting unit can perform the setting on the basis of the comparison results. As a result, a setting appropriate for a radiation purpose or the like can be performed by the light radiation device or by a separately provided device. When the light radiation device does not include the light setting unit, a control device connected separately by wireless or wired communication, such as a mobile communication terminal including a control computer (for example, a smartphone) or a centralized control device, may perform the setting appropriate for the radiation purpose or the like. The setting also includes, for example, setting firmware at the manufacturing stage so that the radiation condition of the light is satisfied when use for a specific radiation purpose is known in advance.

[0020] In the light radiation device according to the present invention, the radiation condition of the light is set, on the basis of the comparison results, in accordance with a predetermined degree of expression of the OPN5 gene or a predetermined degree of activation of OPN5.

[0021] According to this invention, the radiation condition of the light is set in accordance with the predetermined degree of expression of the OPN5 gene or the predetermined degree of activation of OPN5 on the basis of the comparison results. Therefore, the radiation condition is set in accordance with the degree of expression of the OPN5 gene or the degree of activation of

OPN5 predetermined for the environment in which the light radiation device is installed. As a result, effective radiation appropriate for a radiation purpose or the like can be performed in the environment in which the light radiation device is installed. Although the comparison results described above may be results obtained by comparison in advance or results obtained by comparison in situ, the term "comparison results" as used here refers to results obtained by comparison in advance because results obtained in situ may be difficult to predetermine.

[0022] In the light radiation device according to the present invention, the light is preferably light having a wavelength of 360 to 400 nm overlapping the OPN5 absorption spectrum.

[0023] According to this invention, light having a wavelength of 360 to 400 nm mainly overlaps the OPN5 absorption spectrum (peak wavelength: approximately 380 nm), and is not dazzling. Therefore, the light can be radiated directly toward the eye. As a result, the OPN5 gene can be effectively expressed or OPN5 can be effectively activated.

[0024] In the light radiation device according to the present invention, the light source is disposed at a position selected from a position where the light is radiated directly toward the eye, a position in a field of view, a position in a visual line direction, a position where the light is radiated to the eye as diffused light diffused by a diffusing material, and a position where the light is radiated to the eye as reflected light reflected by a reflecting material.

[0025] According to this invention, for example, light having a wavelength of 360 to 400 nm is not dazzling, and therefore the light source is desirably disposed at a position where the light is radiated directly toward the eye. On the other hand, even when the light is not radiated directly toward the eye, the light source may be disposed at a position in the field of view or in the visual line direction, at a position where the light is radiated to the eye as diffused light diffused by a diffusing material, or at a position where the light is radiated to the eye as reflected light reflected by a special reflecting material appropriately provided to reflect light of, for example, 360 to 400 nm. For deskwork, the light source is desirably installed at a position directly in front of the eye, a position in the field of view, or a position in the visual line direction. Even when installation at these positions is impossible or difficult, a diffusing material or a reflecting material is preferably provided so that the light is diffused or reflected by the material and radiated to the eye as diffused light or reflected light. The diffusing material may be selected from various diffusing materials on the basis of diffusion-angle properties and transmittance properties. The reflecting material may be a special reflecting material that reflects the above-

described light that is otherwise difficult to reflect, and use of such a material as a fixed, movable, or portable member increases the degree of freedom in selecting the installation location of the light source.

[0026] In the light radiation device according to the present invention, (i) when the light source is provided at a position where the light is radiated directly toward the eye, the irradiance of the light is set in accordance with a distance and/or an angle from the light source to the person; (ii) when the light source is provided at a position in the field of view or in the visual line direction, the irradiance of the light is set in accordance with a distance and/or an angle from the light source to the person; (iii) when the light source is provided at a position where the light is radiated to the eye as diffused light diffused by a diffusing material, the irradiance of the light is set in accordance with a distance and/or an angle from the light source and the diffusing material to the person, and/or a diffusion angle and a transmittance of the diffusing material; and (iv) when the light source is provided at a position where the light is radiated to the eye as reflected light reflected by a reflecting material, the irradiance of the light is set in accordance with a distance and/or an angle from the light source and the reflecting material to the person, and/or a reflectance of the reflecting material.

[0027] According to this invention, the irradiance of the light is set in accordance with each of (i) to (iv), and therefore light having an irradiance necessary to express the OPN5 gene in the retina or activate OPN5 can be delivered to the person.

[0028] In the light radiation device according to the present invention, non-limiting examples of the light source include a structure-attached light source attached to a floor (including underfoot), a wall, a ceiling (including by suspension therefrom), or another structure; an installation-attached light source attached to a desk, a table, a partition (divider or screen), a shelf, a desktop member, a personal computer, a display, a PC keyboard, a television, an audio device, or another device or installation; a built-in or attached light source of a portable personal computer, a tablet, a smartphone, or another mobile terminal; a body-accessory-attached light source attached to, or detachably mounted by an attachment on, a vision correcting aid, eye protective equipment, face protective equipment, a neck-hanging accessory, an ear-hooking accessory, head-mounted equipment, or another body accessory; and a functional-device-attached light source attached to a functional device for augmented reality (AR), virtual reality (VR), or mixed reality (MR), including goggles, a headset, or another functional device.

[0029] According to this invention, the light source is preferably attached to a structure, device, installation, mobile terminal, body accessory, functional device, or the like, and light emitted from such a light source can be effectively radiated to the person. As described above, the light source is desirably installed at a position where light emitted from the light source is radiated directly to the eye. In other cases, a reflecting material is preferably utilized to radiate the light toward the eye.

[0030] In the light radiation device according to the present invention, the orientation or position of the light source is set manually or automatically.

[0031] According to this invention, the orientation or position of the light source can be set manually or automatically, and therefore the mode in which light is efficiently radiated directly toward the person or by reflection can be changed as desired. As a result, the OPN5 gene in the retina can be expressed or OPN5 can be activated. "Setting the orientation" means setting by rotating the light source as desired in each of the three-dimensional X, Y, and Z directions, and "setting the position" means setting by moving the light source as desired in each of the three-dimensional X, Y, and Z directions.

[0032] In one mode of the light radiation device according to the present invention, a received effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of the spectral irradiance ($W/m^2/nm$) of each wavelength in the wavelength region of 280 to 500 nm of the spectrum of the received light and the relative absorbance of the OPN5 absorption spectral data, is compared with a reference effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of the spectral irradiance ($W/m^2/nm$) of an absorption spectrum of sunlight defined by AM1.5G and the relative absorbance of the OPN5 absorption spectrum.

[0033] According to this invention, the received effective spectral irradiance ($W/m^2/nm$), which is the product of the two values at each wavelength, is compared with and evaluated against the reference effective spectral irradiance ($W/m^2/nm$), which is the product, on a per-wavelength basis, of the spectral irradiance of the absorption spectrum of sunlight defined by AM1.5G and the OPN5 absorption spectrum. Therefore, the degree (for example, percentage) of the actual received effective spectral irradiance relative to the common reference effective spectral irradiance can be evaluated in a generalized manner regardless of the measurement region or measurement time. As a result, an objective relationship with the effect of expressing the OPN5

gene in the retina or activating OPN5 can be clarified, and the device can be utilized to clarify such a relationship.

[0034] In the above-described mode, the received effective spectral irradiance is preferably set to 0.2% or more of the reference effective spectral irradiance.

[0035] In one mode of the light radiation device, the spectral data of the light and the OPN5 absorption spectral data may each be normalized, and the overlapping portions of the normalized spectral data may be compared. In this case, a larger overlapping portion is preferable.

[0036] In the light radiation device according to the present invention, as one mode of the comparison, the received effective spectral irradiance ($W/m^2/nm$) is integrated over a wavelength region to be compared to obtain a received effective irradiance (W/m^2), the reference effective spectral irradiance ($W/m^2/nm$) is similarly integrated over the same wavelength region to obtain a reference effective irradiance (W/m^2), and the received effective irradiance and the reference effective irradiance thus obtained are compared.

[0037] In the above-described mode, the received effective irradiance is preferably set to 0.2% or more of the reference effective irradiance.

[0038] In one mode of the light radiation device described above, a received effective dose (J/m^2), obtained by multiplying the received effective irradiance (W/m^2) by a radiation duration (seconds), may be compared with a received reference effective dose (J/m^2), obtained by multiplying the reference effective irradiance (W/m^2) by the radiation duration (seconds).

[0039] According to this invention, the received effective irradiance and the reference effective irradiance are compared, and the received effective dose (J/m^2) and the received reference effective dose (J/m^2) are further compared. The comparison results (for example, a percentage) make it possible to evaluate the radiation-duration dependency of light with respect to the effect of expressing the OPN5 gene in the retina or activating OPN5.

[0040] In the above-described mode, the received effective dose is preferably set to 0.2% or more of the received reference effective dose.

[0041] In the light radiation device according to the present invention, measurement for the comparison is performed by a measurement unit. The mode of the measurement unit is not particularly limited as long as the measurement can be performed. Non-limiting examples include a mode in which, on the basis of the form of the light source that radiates the light, the measurement unit is provided on eyeglasses, an earphone, a wristwatch, a chest badge, or another

article worn on the body; is worn on the body itself; or is attached to an installation near or around the body.

[0042] According to this invention, the mode of attachment described above is selected as desired on the basis of the installation form of the light source that radiates the light, including the form and installation position of the light source. Therefore, the measurement unit is unlikely to interfere with the person and facilitates measurement of spectral data of the light received by the eye and body.

[0043] In the light radiation device according to the present invention, the light is flickering light and/or constant light. Respective radiation conditions for the flickering light and/or the constant light are set on the basis of results obtained by comparing, in advance or in situ, spectral data of the radiated light with OPN5 absorption spectral data.

[0044] According to this invention, respective radiation conditions for the flickering light and/or constant light are set on the basis of results obtained by comparing, in advance or in situ, the spectral data of the radiated light with the OPN5 absorption spectral data. Therefore, effective radiation with light (flickering light and/or constant light) appropriate for a radiation purpose or the like can be performed in the environment in which the light radiation device is installed. As a result, the OPN5 gene in the retina can be expressed or OPN5 can be activated.

[0045] (2) A light radiation system according to the present invention is characterized in that two or more light radiation devices according to the present invention described above are combined, or the system includes two or more light sources constituting the light radiation device according to the present invention described above.

[0046] According to this invention, the light radiation system is a system in which two or more light radiation devices are combined or two or more light sources included in a light radiation device are combined. In a light radiation system in which two or more light radiation devices having respective radiation conditions are combined, each light radiation device can be assigned a role (radiation purpose). As a result, light radiation devices assigned respective roles can be disposed at positions corresponding to behavior or behavioral patterns in a room. In a light radiation system including two or more light sources constituting a light radiation device, radiation conditions corresponding to the role of each light source can be set so that each light source performs a role (radiation purpose) for achieving a specific purpose, thereby configuring

an integrated system. As a result, light set to achieve a specific purpose can be disposed at positions corresponding to behavior or behavioral patterns in a room.

[0047] (3) A method for operating a light radiation device according to the present invention is a method for operating a light radiation device configured to radiate light to an eye to express the OPN5 gene or activate OPN5. The method includes: a light-source placement step of placing a light source that radiates light having a wavelength in a wavelength region overlapping the OPN5 absorption spectrum; a light-data comparison step of comparing, in advance or in situ, spectral data of the light obtained by receiving the light radiated from the light source placed in the light-source placement step with OPN5 absorption spectral data; and a light setting step of setting a radiation condition of the light on the basis of results obtained in the light-data comparison step to express the OPN5 gene or activate OPN5.

[0048] According to this invention, particularly in the light setting step, the radiation condition of the light radiated from the light source is set on the basis of the results obtained in the light-data comparison step to express the OPN5 gene or activate OPN5. Therefore, a setting appropriate for a radiation purpose or the like can be performed. The light setting step may be performed by the light radiation device or by a separate device. When the step is performed by a separate device, a control device connected separately by wireless or wired communication, such as a mobile communication terminal including a control computer (for example, a smartphone) or a centralized control device, may perform the light setting step and the setting appropriate for the radiation purpose or the like. The setting in the light setting step also includes, for example, setting firmware at the manufacturing stage so that the radiation condition of the light is satisfied when use for a specific radiation purpose is known in advance.

[0049] In the method for operating a light radiation device according to the present invention, the radiation condition of the light set in the light setting step is one or two or more conditions selected from an installation position of the light source, a radiation direction of the light, a wavelength range of the light, a wavelength profile of the light, an irradiance of the light, a radiation time frame of the light, and a radiation duration of the light.

[0050] In the method for operating a light radiation device according to the present invention, the light is light having a wavelength of 360 to 400 nm overlapping the OPN5 absorption spectrum.

Effects of the Invention

[0051] According to the present invention, it is possible to provide a light radiation device, a light radiation system, and a method for operating a light radiation device that can effectively activate OPN5 in the retina of an eye by light.

[0052] In particular, according to the light radiation device and the method for operating the light radiation device of the present invention, the light emitted from the light source is radiated toward the eye, and the light has a wavelength in a wavelength region overlapping the peak wavelength (approximately 380 nm) of the OPN5 absorption spectrum. Therefore, the OPN5 gene present in the retina can be expressed or OPN5 can be activated. Furthermore, the actual spectral data of the light obtained by receiving the light radiated from the light source is compared, in advance or in situ, with the OPN5 absorption spectral data, and the radiation condition of the light is set on the basis of the comparison results. Therefore, the OPN5 gene can be more effectively expressed or OPN5 can be more effectively activated.

[0053] According to the light radiation system of the present invention, in a system in which two or more light radiation devices having respective radiation conditions are combined, each light radiation device can be assigned a role (radiation purpose). As a result, light radiation devices assigned respective roles can be disposed at positions corresponding to behavior or behavioral patterns in a room. In a light radiation system including two or more light sources constituting a light radiation device, radiation conditions corresponding to the role of each light source can be set so that each light source performs a role (radiation purpose) for achieving a specific purpose, thereby configuring an integrated system. As a result, light set to achieve a specific purpose can be disposed at positions corresponding to behavior or behavioral patterns in a room.

BRIEF DESCRIPTION OF THE DRAWINGS

[0054] Fig. 1 shows an absorbance (dimensionless) of an OPN5 absorption spectrum.

Fig. 2 shows absorption spectra of OPN5, OPN4, rhodopsin (Rh), and three photopsins (S, M, L).

Fig. 3 shows a standard photopic relative luminous efficiency (upper graph) and a color of light (lower chart) at each wavelength.

Fig. 4 shows an example of a violet light LED having a radiation wavelength range of 360 to 400 nm.

Fig. 5 (A) shows an example of a light source that radiates light having a wavelength within a

wide wavelength range exceeding 400 nm, Fig. 5 (B) shows an example of a light source in which a wavelength range of the radiated light is restricted to 360 to 400 nm by a shielding filter, and Fig. 5 (C) is an explanatory view showing overlap between the restricted radiated light in the above-described Fig. 5 (B) and the OPN5 absorption spectrum.

Fig. 6 illustrates an installation example of the light sources in a large office space.

Fig. 7 illustrates an installation example of the light sources in a home or an office.

Fig. 8 illustrates installation examples of a desktop light source on a desk and a personal-computer-installed light source.

Fig. 9 (A) shows the absorbance (dimensionless) of the OPN5 absorption spectrum, Fig. 9 (B) shows a spectral irradiance of a violet light LED having a peak at 375 nm, and Fig. 9 (C) shows a received effective spectral irradiance found from a product of the two at each wavelength.

Fig. 10 (A) shows the absorbance (dimensionless) of the OPN5 absorption spectrum, Fig. 10 (B) shows a spectral irradiance of a wide-area light source emitting light at 300 nm or greater, and Fig. 10 (C) shows a received effective spectral irradiance found from a product of the two at each wavelength.

Fig. 11 (A) shows the absorbance (dimensionless) of the OPN5 absorption spectrum, Fig. 11 (B) shows a spectral irradiance of an absorption spectrum of sunlight defined by AM1.5G, and Fig. 11 (C) shows a reference effective spectral irradiance found from a product of the two at each wavelength.

Fig. 12 is a graph contrasting the reference effective spectral irradiance (reference sign b) shown in Fig. 11 (C) and the received effective spectral irradiance (reference sign a) shown in Fig. 9 (C).

Fig. 13 is a schematic diagram illustrating an example of a light radiation device.

Fig. 14 is an explanatory diagram of an OPN5 activation mechanism.

DETAILED DESCRIPTION OF THE INVENTION

[0055] Hereinafter, a light radiation device, a light radiation system, and a method for operating a light radiation device according to the present invention will be described with reference to the drawings. The present invention is not limited to the embodiments described below and can be modified into various modes as long as the gist of the present application is included. In this specification, "setting" includes "regulating" or "adjusting" as one mode thereof. The expression "is set" includes both the meaning that a setting can be made and the meaning that a setting has

already been made, although separate expressions representing those respective meanings may also be used.

[0056] [Light Radiation Device]

A light radiation device according to the present invention is a light radiation device configured to radiate light to an eye to express the OPN5 gene or activate OPN5. The light radiation device includes a light source that radiates light having a wavelength in a wavelength region overlapping the OPN5 absorption spectrum, and a radiation condition of the light radiated from the light source is set to express the OPN5 gene or activate OPN5.

[0057] In this light radiation device, the light emitted from the light source is radiated toward the eye and has a wavelength in a wavelength region overlapping the OPN5 absorption spectrum (peak wavelength: approximately 380 nm). Therefore, the OPN5 gene present in the retina can be expressed or OPN5 can be activated. Because OPN5 is present in the retina, the light is radiated toward the eye, and direct radiation to the eye is more preferable because it can more effectively express the OPN5 gene or activate OPN5.

[0058] In this light radiation device, the setting may be performed by comparing, in advance or in situ, spectral data of the light obtained by receiving the light radiated from the light source with OPN5 absorption spectral data, and on the basis of the comparison results. In this way, the OPN5 gene can be more effectively expressed or OPN5 can be more effectively activated.

[0059] In this light radiation device, the spectrum of the light obtained by receiving the light radiated from the light source is set so that a maximum value of a received effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of a spectral irradiance ($W/m^2/nm$) of the light in a wavelength region of 280 to 500 nm and a relative absorbance of the OPN5 absorption spectral data, is 0.2% or more of a maximum value of a reference effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of a spectral irradiance ($W/m^2/nm$) of a sunlight spectrum defined by AM1.5G and the relative absorbance of the OPN5 absorption spectral data. In this way, the OPN5 gene can be more effectively expressed or OPN5 can be more effectively activated. Light having a percentage within the above-described range is calculated on the basis of a light spectrum measured at the irradiated subject or at a position around the irradiated subject.

[0060] Each component will now be described in detail.

[0061] <OPN5 and OPN5 Absorption Spectrum>

Opsin 5 (OPN5) is a photoreceptor protein and is present in the human retina. As shown in Fig. 1, OPN5 exhibits an absorption spectrum having a peak at 380 nm. In the present invention, the "OPN5 absorption spectrum" is defined as the OPN5 absorption spectrum shown in Fig. 1. Fig. 1 is reproduced from Fig. 5A in Kojima D, Mori S, Torii M, Wada A, Morishita R, et al. (2011), "UV-Sensitive Photoreceptor Protein OPN5 in Humans and Mice," PLoS ONE 6(10): e26388, doi:10.1371/journal.pone.0026388, and was understood as standard by those skilled in the art at the time of filing of the present application. The cited document also expressly states that the OPN5 absorption spectrum has an absorption peak at 380 nm, which is understood by those skilled in the art. Radiation of light according to the present invention is expected to express or activate the OPN5 gene present in the retina of the irradiated person, and is expected to contribute to treatment of various diseases or improvement of symptoms, improvement of visual and non-visual functions, suppression of myopia progression, and exploration and development of related research. Fig. 2 shows absorption spectra of OPN5, OPN4, rhodopsin (Rh), and three photopsins (S, M, L), which are also shown in Fig. 5A of the cited document by Kojima et al. OPN5 is located in the lowest wavelength region among these proteins.

[0062] Given 1 as the absorbance at the peak of 380 nm, the OPN5 absorption spectrum has, as shown in Fig. 1, a wavelength range of approximately 300 to approximately 440 nm at an absorbance of 0.1 or higher, a wavelength range of approximately 340 to approximately 420 nm at an absorbance of 0.5 or higher, a wavelength range of approximately 350 to approximately 410 nm at an absorbance of 0.7 or higher, and a wavelength range of approximately 360 to approximately 400 nm at an absorbance of 0.8 or higher. For OPN5 having such absorbance characteristics, radiation with light having a light spectrum in a wavelength range exhibiting high absorbance is preferable for effectively expressing the OPN5 gene or activating OPN5.

[0063] <Light>

The light is radiated from a light source and has a wavelength region overlapping at least part of the OPN5 absorption spectrum. Here, "at least part of the wavelength region of the OPN5 absorption spectrum" means that the wavelength region may overlap the entire wavelength region of the OPN5 absorption spectrum shown in Fig. 1 or may overlap only part thereof. The "entire wavelength region of the OPN5 absorption spectrum" is approximately 270 to 500 nm, as shown in Fig. 1. Examples of "part of the wavelength region of the OPN5 absorption spectrum"

include, as described above, a wavelength range at an absorbance of 0.1 or higher (approximately 300 to approximately 440 nm), a wavelength range at an absorbance of 0.5 or higher (approximately 340 to approximately 420 nm), a wavelength range at an absorbance of 0.7 or higher (approximately 350 to approximately 410 nm), and a wavelength range at an absorbance of 0.8 or higher (approximately 360 to approximately 400 nm). As effective light for solving the problems of the present invention, violet light having a wavelength of 360 to 400 nm overlapping the wavelength range in which the absorbance of the OPN5 absorption spectrum is 0.8 or higher (approximately 360 to approximately 400 nm) is desirable.

[0064] (Wavelength Range of Light)

For humans, light having a wavelength of less than 315 nm is said to have an adverse effect on the eye. Therefore, the lower-limit wavelength of the light is preferably 340 nm, 350 nm, or 360 nm. Which of these wavelengths is used as the lower limit depends on the irradiance of light in the lower-limit region. If the irradiance near the lower limit is small, the lower limit may be 340 nm, but preferably is 350 nm and more preferably is 360 nm. In the OPN5 absorption spectrum shown in Fig. 1, the absorbance is 0.7 or higher in a wavelength range of approximately 350 to approximately 410 nm and is 0.8 or higher in a wavelength range of approximately 360 to approximately 400 nm. Therefore, a light source that mainly radiates light in a wavelength range of approximately 350 to approximately 410 nm or approximately 360 to 400 nm can contribute to expression of the OPN5 gene or activation of OPN5.

[0065] The light preferably has an upper-limit wavelength of 400 nm or less or 410 nm or less. Light having such a wavelength has a low relative luminous efficiency. Light having a low relative luminous efficiency is non-dazzling light and/or light that is not bright. "Non-dazzling light" means light that is not dazzling to the irradiated person. Even when such light is radiated, the person does not perceive, or has difficulty perceiving, glare, and therefore the light is advantageous in enabling long-duration radiation toward the person. "Light that is not bright" means light having low illuminance. "Radiation of light having a wavelength of 400 nm or less or 410 nm or less and having a low relative luminous efficiency" includes radiation from a light source that does not emit or substantially does not emit light having a wavelength exceeding 400 nm or 410 nm. Particularly preferred examples of such a light source include a source of violet light having a wavelength of 360 to 400 nm or light of 350 to 410 nm. Light having a wavelength of 400 nm or less or 410 nm or less can also be radiated from a light source including a filter that

blocks light having a wavelength exceeding 400 nm or 410 nm, or even from a light source that also emits light having a wavelength exceeding 400 nm or 410 nm.

[0066] Relative luminous efficiency can be measured, for example, by a direct comparison method, a flicker photometry method, an iteration method, a minimally distinct border (MDB) method, or an absolute threshold method, as described in Masanori Takase, Katsunori Okajima, Keiji Uchikawa, and Mitsuo Ikeda, "Change of Brightness of Colored Lights Measuring by the Direct Comparison Method," Japanese Journal of Optics, Vol. 19, No. 3 (1990). The CIE standard relative luminous efficiency function is described as being determined mainly by the flicker photometry method, and in general relative luminous efficiency is evaluated by the direct comparison method and the flicker photometry method. Data for relative luminous efficiency (spectral luminous efficiency) is listed in Appendix Table 8 at https://elaws.e-gov.go.jp/download?law_unique_id=404M50000400080_20161001_000000000000000&file_type=PDF_H1. Relative luminous efficiency in photopic vision is normalized to light having a wavelength of 555 nm (green light). According to the table, a relative luminous efficiency of 0.01 or less corresponds, on the short-wavelength side, to a wavelength region of less than 430 nm. Thus, humans perceive green light as brightest, and the sensation of brightness decreases as the wavelength increases or decreases from 555 nm. Relative luminous efficiency is expressed as a comparison value for the brightness of another wavelength having the same energy, with the brightness at 555 nm set to 1. Fig. 3 shows the standard photopic relative luminous efficiency. There are individual differences in the degree to which light is perceived as non-dazzling, and it is therefore difficult to define a specific relative value on the vertical axis of Fig. 3. However, light having a wavelength of 400 nm or less or 410 nm or less is at a shorter wavelength than the wavelength region below 430 nm having a relative luminous efficiency of 0.01 or less, and therefore has an even lower relative luminous efficiency, at least less than 0.01. Regardless of individual differences, light having a wavelength of 400 nm or less or 410 nm or less with such an extremely low relative luminous efficiency can be regarded as less dazzling than light in another wavelength region having a relative luminous efficiency exceeding 0.01. Consequently, such light is advantageous for radiation toward a person and for long-duration radiation without causing the person to perceive glare. In this application, the irradiated subject, the person, and the person's eye have the same meaning and may be used interchangeably. Such light has a large overlap with the OPN5 absorption spectrum and is non-dazzling, and therefore is unobtrusive

even when entering the eye and can, for example, express the OPN5 gene present in the retina or activate OPN5.

[0067] As described above, in the OPN5 absorption spectrum shown in Fig. 1, the absorbance is 0.7 or higher in a wavelength range of approximately 350 to 410 nm and is 0.8 or higher in a wavelength range of approximately 360 to 400 nm. Therefore, use of a light source that mainly radiates light in a wavelength range of 350 to 410 nm or 360 to 400 nm can contribute to activation of OPN5. The present inventors refer to light in the wavelength range of 360 to 400 nm as violet light, and therefore light in this wavelength range may be referred to below as "violet light."

[0068] <Expression of OPN5 Gene or Activation of OPN5>

With respect to expression of the OPN5 gene, prior-art literature including the present inventor, WO2020/027305A1, describes that OPN5 gene expression can be quantified and that the degree of gene expression can be evaluated using such quantification. For example, a value obtained without exposure to light having a wavelength of 360 to 400 nm, at which the absorbance of the OPN5 absorption spectrum is 0.8 or higher, may be used as a comparison reference value; the extent to which the gene is expressed relative to the comparison reference value may be evaluated as the degree of OPM5 gene expression; and the radiation conditions and effects on a disease may be comprehensively evaluated to determine desirable radiation conditions and a desirable installation position of the light source. When determining radiation conditions and an installation position of the light source for radiating light to the retina, the light radiation device according to the present invention can be implemented from the perspective of expressing the OPN5 gene, and effects on various diseases can therefore be expected.

[0069] Activation of OPN5 can be evaluated in the same manner as expression of the OPN5 gene. In evaluation of OPN5 activation, brain waves produced in response to light radiation may be measured to evaluate the degree of activation. The same prior-art literature described above, WO2020/027305A1 and https://www.mdpi.com/2075-4426/11/6/557, reports specific brain activity (brain waves) when exposed to light having a wavelength of 360 to 400 nm, and OPN5 activation can therefore be evaluated by the occurrence of brain waves. Because OPN5 is a Gi-type G-protein-coupled receptor (GPCR), when activity is measured at the cellular level, cells are cultured and exposed to light, and an increase in the intracellular level of K+ ions and an increase in cAMP are measured. A paper at https://www.pnas.org/doi/10.1073/pnas.1012498107

also describes that OPN5 is activated by light at 380 nm, K+ flows into the cell, intracellular cAMP increases, and signaling is increased. When determining radiation conditions and an installation position of the light source for radiating light to the retina, the light radiation device according to the present invention can be implemented from the perspective of activating OPN5, and effects on various diseases can therefore be expected.

[0070] As illustrated in Fig. 14, activation of OPN5 by exposure to light having a wavelength of 360 to 400 nm occurs through a mechanism in which OPN5 protein in retinal ganglion cells of the retina is activated, stimulation is transmitted to the central region of the brain, myelin increases, and neural transmission efficiency thereby increases. This mechanism is also introduced in the present inventors' paper, "Violet light modulates the central nervous system to regulate memory and mood" (https://www.biorxiv.org/content/10.1101/2021.11.02.466604v1). Myelin is important for proper transmission of neural signals in the brain and is known to be related to various brain functions and brain disorders, including dementia, depression, sleep, and Parkinson's disease. Accordingly, radiation of light in the wavelength range of 360 to 400 nm according to the present invention can increase myelin and neural transmission efficiency. When determining radiation conditions and an installation position of the light source for radiating light to the retina, the invention can be implemented from the perspective of activating OPN5, and effects on various diseases can therefore be expected.

[0071] <Light Source>

The light source is not particularly limited as long as it radiates light in the wavelength range described above. "Radiates light in the wavelength range" means that the emission spectrum of the light source itself may have the above-described wavelength range (for example, light having a wavelength of 360 to 400 nm or 350 to 410 nm), or that, even when the emission spectrum of the light source itself exceeds the upper limit of the wavelength range, the light may be radiated within the wavelength range through a shielding filter. When mainly radiating non-dazzling light within the wavelength range, a light source that does not emit or substantially does not emit light having a wavelength exceeding 400 nm, such as a violet-light LED light source having a peak wavelength at 375 nm, may be used as shown in Fig. 4. Alternatively, for a light source that radiates light over a wide wavelength range including wavelengths exceeding 400 nm as shown in Fig. 5(A), a light source including the shielding filter shown in Fig. 5(B) may be used. Fig. 5(B) shows an example in which the wavelength range of radiated light is restricted to 360 to

400 nm by a shielding filter, and Fig. 5(C) is an explanatory view showing overlap between the light radiated from the light source and the OPN5 absorption spectrum.

[0072] For example, light having a wavelength of 360 to 400 nm or 350 to 410 nm has a large overlap with the OPN5 absorption spectrum having a peak at 380 nm and has a low relative luminous efficiency, and is therefore non-dazzling. Accordingly, even when such light is radiated to the eye as direct light, diffused light, or reflected light, the light is relatively unobtrusive and can, for example, express the OPN5 gene present in the retina or activate OPN5.

[0073] The light source is more preferably a light source that emits light mainly overlapping a range of ±20 nm around 380 nm, which is the peak wavelength of the OPN5 absorption spectrum. Such a light source can express the OPN5 gene or activate OPN5 by radiation of light having a wavelength of 360 to 400 nm, which mainly overlaps the range of ±20 nm around 380 nm. "Light mainly overlapping" may be light having an emission spectrum with a peak within the range of ±20 nm around 380 nm, as illustrated in Fig. 4, or may be light having an emission spectrum that does not have a peak within that range but exhibits a high spectral irradiance within the range, as illustrated in Fig. 5(A). Such a light source produces a principal overlap between the light radiated from the light source and the OPN5 absorption spectrum, as illustrated in Fig. 5(C).

[0074] <Installation Form of Light Source>

One or two or more light sources are provided. The light source is preferably an indoor-installed light source, such as a light source directly attached inside a house or room of a private home, a school building or classroom, a government building, a company building, office or workplace, a gymnasium or indoor athletic facility, or another building, including a building covered by a roof but having no walls, or a light source attached to furniture or another installation. The light source may also be a portable light source that can be carried by a person or a light source that can be worn by a person.

[0075] Examples of a portable light source that can be carried by a person include a light source attachable to a mobile terminal such as a portable personal computer, a tablet, or a smartphone. Examples of a light source that can be worn by a person include a light source attached to a vision correcting aid, eye protective equipment, face protective equipment, a neck-hanging accessory, an ear-hooking accessory, or head-mounted equipment. A light source that can be worn by a person may be an eyeglasses-mounted light source attached to eyeglasses that can be

worn regardless of whether the eyeglasses have a vision-correction function, an attachment light source attachable to and detachable from such eyeglasses, or a light source attached to a goggle-type device for functional use, AR use, VR use, or MR use.

[0076] The light source may be selected from a structure-attached light source attached to a floor (including underfoot), a wall, a ceiling (including by suspension therefrom), or another structure; an installation-attached light source attached to a desk, a table, a partition (divider or screen), a shelf, a desktop member, a personal computer, a display, a PC keyboard, a television, an audio device, or another device or installation; a built-in or attached light source of a portable personal computer, a tablet, a smartphone, or another mobile terminal; a body-accessory-attached light source attached to, or detachably mounted by an attachment on, a vision correcting aid, eye protective equipment, face protective equipment, a neck-hanging accessory, an ear-hooking accessory, head-mounted equipment, or another body accessory; and a functional-device-attached light source attached to a functional device for AR, VR, or MR, including goggles, a headset, or another functional device. In accordance with its installation form, the light source is preferably an installed light source installed on a structure, installation, device, mobile terminal, or the like, a body-accessory-type light source, or a functional-device-installed light source, and light emitted from the light source can be radiated to a person as direct light, diffused light, or reflected light. Figs. 6 to 8 illustrate installation examples of the light sources. Fig. 6 illustrates light sources in a large office space, Fig. 7 illustrates light sources in a home or office, and Fig. 8 illustrates a desktop light source on a desk and a personal-computer-installed light source. Thus, the light source can be installed in various modes.

[0077] The expression "one or two or more light sources" means one or two or more light sources selected from the various light sources described above, including an installed light source, a body-accessory-type light source, and a functional-device-installed light source. When one light source is used, the light source is desirably arranged so that light emitted from the light source is directed toward the eye.

[0078] As a specific installation form of an installed light source, when the direction of the visual line does not change much, such as during deskwork in an office or study work at a school, study room, or home as illustrated in Figs. 6 and 7, an installed light source 10 is desirably disposed ahead in the visual line, and the orientation of the installed light source 10 is set so that light is emitted in an eye direction D. In Figs. 6 and 7, light sources 10 are disposed at positions in the

field of view or in the visual line direction, and may be disposed at such positions. Even when a light source 10 is not directed toward the person, the light source 10 may be disposed at a position where light can be radiated to the eye, such as a position outside the field of view or outside the visual line direction, by using a diffusing material or a reflecting material 11. Thus, one or two or more light sources 10 can be provided at various positions. Figs. 6 and 7 illustrate examples of installed light sources mainly provided on walls, suspended from ceilings, or provided on desks, tables, floors (including underfoot), and the like, but the light sources may be provided on other structures or on partitions (dividers or screens), shelves, desktop members, or other installations. As illustrated in Fig. 8, an installed light source 10 is desirably provided, with its orientation set, at a position in the field of view or in the visual line direction, such as a position on a frame portion of a display or an extension thereof, or a position beside a keyboard of a personal computer.

[0079] As illustrated in Fig. 7, when the direction of the visual line may change at work, at home, or the like, two or more installed light sources 10 are desirably disposed, and the positions and orientations of the light sources 10 are set so that light is emitted toward the eye to the extent possible. For example, when the person often sits on a chair or sofa, the installed light sources 10 are desirably disposed at eye height to the extent possible and installed so as to face toward the eye at that height to the extent possible. Similarly, when the person often stands, the installed light sources 10 are desirably disposed at eye height to the extent possible and installed so as to face toward the eye at that height to the extent possible. When the person both sits and stands, installed light sources 10 are desirably installed to satisfy both conditions and to face toward the eye at the respective heights to the extent possible.

[0080] The above-described light, such as light having a wavelength of approximately 400 nm or less, is ordinarily difficult to reflect. Therefore, the light source is desirably disposed at a position where the light is radiated directly toward the eye. On the other hand, even when the light is not radiated directly toward the eye, (a) the light source may be disposed at a position in the field of view or in the visual line direction, (b) the light source may be disposed at a position where the light is radiated to the eye as diffused light diffused by a diffusing material, or (c) a special reflecting material that reflects light having a wavelength of 400 nm or less may be appropriately provided and the light source may be disposed at a position where the light is radiated to the eye as reflected light reflected by the reflecting material. For deskwork, the light source is desirably

installed at a position directly in front of the eye, a position in the field of view, or a position in the visual line direction. However, when installation at these positions is impossible or difficult, or even when sunlight is used as the light source but wall and floor materials of the room do not readily reflect or diffuse the light and prevent it from entering the room, a suitable diffusing material or reflecting material is preferably used so that light is diffused or reflected by the material and radiated to the eye as diffused light or reflected light. One or two or more of these means are preferably used in combination to radiate light to the eye. The diffusing material can be selected from various diffusing materials on the basis of diffusion-angle and transmittance characteristics. The reflecting material may be a special reflecting material that reflects the above-described light that is difficult to reflect, and use of such a material as a fixed, movable, or portable member increases the degree of freedom in selecting the installation location of the light source.

[0081] Installed light sources are preferably installed in advance with the orientation of light toward the eye or installed at positions in the field of view or in the visual line direction. The installation position of a light source may be changed manually or automatically, and the angle of light emitted from the light source may be changed manually or automatically. It is also effective to provide the light source with a tracking system that detects the eye or movement of a person and radiates light accordingly. It is further effective to swing the light source in various directions or use a light source having a wide directional angle of emission. When a diffusing material or reflecting material is used, the light-source position may be changed or otherwise set, or the type of diffusing material or installation angle of the reflecting material may be changed or otherwise set.

[0082] Examples of a mobile-terminal-installed light source include a light source attachable to a mobile terminal such as a portable personal computer, a tablet, or a smartphone, although a light source attachable to another mobile terminal may also be used. Like an installed light source, the mobile-terminal-installed light source is preferably installed in advance or otherwise set so that the orientation of light is toward the eye. The installation position of the light source may be changed manually or automatically, and the angle of light emitted from the light source may be changed manually or automatically. As described above, it is also effective to provide the light source with a tracking system, to swing the light source in various directions, or to use a light source having a wide directional angle of emission.

[0083] Examples of a body-accessory-type light source include an attachment light source attachable to or detachable from a vision correcting aid, eye protective equipment, face protective equipment, a neck-hanging accessory, an ear-hooking accessory, head-mounted equipment, or the like, although another light source may be used as long as it can be worn on the body. Like the light sources described above, the body-accessory-type light source is preferably installed in advance or otherwise set so that the orientation of light is toward the eye. Because the body-accessory-type light source is at a short distance from the eye, changing its installation position is less necessary than for the light sources described above. However, the position may be changed manually or automatically as necessary, and the angle of light emitted from the light source may be changed manually or automatically.

[0084] A functional-device-installed light source is a light source attached to a functional device for AR, VR, MR, or the like, such as goggles or a headset, although a light source attachable to another device may also be used. Like the body-accessory-type light source described above, the functional-device-installed light source is at a short distance from the eye, and changing its installation position is therefore less necessary than for the light sources described above. However, the position may be changed manually or automatically as necessary, and the angle of light emitted from the light source may be changed manually or automatically.

[0085] <Radiation Form>

Light emitted from the light source is radiated toward a person, particularly preferably toward an eye. "Radiated" means that light emitted from the light source is radiated to the person. The light source may be directed toward the person so that light emitted from the light source is radiated directly to the person; light emitted from a light source at a position in the field of view or in the visual line direction may be radiated; or, without directing the light source toward the person, light emitted from the light source may be radiated as diffused light or reflected light. "Directly or by reflection" means that light may be radiated directly from the light source toward the person, preferably the eye, or may be radiated after reflection by a reflecting material. "Direct radiation" also includes radiation to the eye of diffused light obtained by diffusing light with a diffusing material. The orientation or position of the light source may be set manually or automatically. This makes it possible to change as desired a mode in which light is efficiently radiated directly toward the person or by reflection. As a result, the OPN5 gene can be expressed or OPN5 can be activated. "Setting the orientation" means setting by rotation as desired in each

of the three-dimensional X, Y, and Z directions, and "setting the position" means setting by movement as desired in each of the three-dimensional X, Y, and Z directions.

[0086] In such a light radiation device, preferably (i) when the light source is provided at a position where light is radiated directly toward the eye, the irradiance of the light is set in accordance with a distance and/or an angle from the light source to the person; (ii) when the light source is provided at a position in the field of view or in the visual line direction, the irradiance of the light is set in accordance with a distance and/or an angle from the light source to the person; (iii) when the light source is provided at a position where light is radiated to the eye as diffused light diffused by a diffusing material, the irradiance of the light is set in accordance with a distance and/or an angle from the light source and the diffusing material to the person, and/or a diffusion angle and transmittance of the diffusing material; and (iv) when the light source is provided at a position where light is radiated to the eye as reflected light reflected by a reflecting material, the irradiance of the light is set in accordance with a distance and/or an angle from the light source and the reflecting material to the person, and/or a reflectance of the reflecting material. Because the irradiance of the light is set in accordance with each of (i) to (iv), light having the irradiance necessary to express the OPN5 gene or activate OPN5 can be delivered to the person.

[0087] (Reflecting Material)

The reflecting material is a member that reflects violet light in a specific direction. Violet light is not reflected by a reflecting material that reflects ordinary white light. Therefore, by providing a special reflecting material that reflects violet light, the violet light can be reflected by the reflecting material and radiated toward a person even when the violet light is not radiated directly toward the person, cannot be directly radiated because of installation constraints, or the person is located away from a light source, such as sunlight, for example at a position farther inside a room from a window.

[0088] When a light source cannot be disposed at a position allowing light to be radiated directly toward the eye because of installation circumstances, the special reflecting material described above may be installed at an appropriate position so that reflected light can be radiated toward the eye. For deskwork as illustrated in Fig. 6, for example, the light source 10 is desirably installed in front of the eye. When a light source cannot be installed in front of the eye, the reflecting material 11 is preferably provided in front of the eye so that the reflecting material 11

reflects the light toward the eye. The reflecting material denoted by reference sign 11 in Fig. 6 is an example of a reflecting material that reflects light from a light source scattered downward from a ceiling toward the eye. Use of a fixed, movable, or portable reflecting material increases the degree of freedom in selecting the installation location of the light source. Thus, the light source is desirably installed at a position where light emitted from the light source is radiated directly to the eye, but in other cases a reflecting material is preferably used to radiate the light toward the eye.

[0089] The reflecting material may be installed by applying a resist ink to a plate material or wall. A specific example is an ultraviolet highly reflective white resist ink manufactured by Okamoto Glass Co., Ltd. In an experiment in which a reflecting material formed by applying the white resist ink to a glass substrate at a thickness of 20 μm was irradiated with an NSPU510CS lamp-type LED having a peak wavelength of 375 nm, manufactured by Nichia Corporation, at a distance of 10 cm from the reflecting material and an irradiance of 69 μW/cm², the reflectance was increased by approximately 2.9 times.

[0090] When sunlight is used as the light source, violet light may enter a room through a glass window that transmits violet light or through an open window. However, in measurements performed by the present inventor with the window open and the visual line directed outside through the open window, the intensity of violet light decreased sharply from 326 μW/cm² at the window to 67 μW/cm² at a point one meter inside the room. To deliver violet light farther into the room, a wall material or floor material having a high reflectance may be used or the diffusivity of the window glass may be increased. For this purpose, the window glass itself may be compositionally or structurally configured to diffuse violet light, or a sheet having such a function may be applied to the window glass. Violet light can thereby diffuse farther into the room and reach the eyes of a person whose desk is not located near the window.

[0091] Diffusing materials having distinctive diffusion-angle and transmittance characteristics are commercially available, and an appropriate material may be selected from various diffusing materials on the basis of these characteristics.

[0092] (Directionality)

With respect to the directionality of light, the light source, diffusing material, or reflecting material is desirably installed so that light reaches the orientation of the face, particularly the line of sight. The height of the light source is also an important factor, and the light source is

preferably installed at a position based on a behavioral pattern in an office or home, with the height and direction set accordingly. To increase directionality, the light source is preferably installed so that light emitted from the light source is directed directly toward the eye, or is installed at a position in the field of view or in the visual line direction so that the light can readily reach the eye. When variation of the visual-line axis is relatively small, for example during deskwork as illustrated in Figs. 6 and 8, the light source is preferably installed at a position from which light is radiated at an angle of 30 degrees or less relative to the virtual visual-line axis of the person. This makes it possible to radiate light to the eye and thereby express the OPN5 gene or activate OPN5.

[0093] <Spectral Data>

Important data considered in determining the radiation condition of light and the installation position of a light source in the light radiation device according to the present invention, including light spectral data and OPN5 absorption spectral data, will now be described. Because the light radiation device according to the present invention is capable of radiating light to a person's eye to express the OPN5 gene in the retina or activate OPN5, the device compares data necessary for determining the radiation condition and the installation position of the light source and sets the radiation condition and installation position accordingly.

[0094] A measurement device for acquiring such data may be included in the light radiation device according to the present invention or may be a separate measurement device, as illustrated by way of example in Fig. 13. A measurement device 21 includes a measurement unit 22 that measures received light spectral data and a calculation unit 23 that calculates using the light spectral data and OPN5 absorption spectral data. The calculation unit 23 may be built into the device, or may be external to the device and receive data through communication means. A memory 24 stores OPN5 absorption spectral data and the like. A display unit 25 displays calculation results.

[0095] In this example of the measurement device 21, received light spectral data is measured by the measurement unit 22, and the measured light spectral data and the OPN5 absorption spectral data are calculated by the internal or external calculation unit 23. Data for evaluating whether the OPN5 gene can be expressed or OPN5 can be activated by the light can therefore be obtained. This evaluation data can be used as basic data for evaluating the relationship between the received light and expression of the OPN5 gene or activation of OPN5. In particular, a degree of

overlap between the measured light spectral data and the OPN5 absorption spectral data may be calculated and quantified for objective evaluation of physical effects through OPN5. Such use enables evaluation of, for example, what wavelength range, irradiance, radiation time frame, and radiation duration are effective in relation to physical effects of OPN5. The light in the expression "received light spectral data" is not limited to light from the light source of the light radiation device, but means spectral data including all light being measured. The measurement device 21 is preferably capable of accurately measuring light entering a person's eye and, in particular, preferably is worn on the person or attached to a member worn by the person.

[0096] As illustrated in Figs. 9 and 10, the calculation unit of the measurement device 21 calculates a product, on a per-wavelength basis, of the light spectral data at each wavelength and the OPN5 absorption spectral data as a received effective spectral irradiance ($W/m^2/nm$). The received effective spectral irradiance ($W/m^2/nm$), which is the product of the two at each wavelength, can thereby be used as evaluation data, and the obtained evaluation data can be utilized in a radiation device for clarifying an objective relationship between the evaluation data and physical effects through OPN5.

[0097] Further, in the calculation unit, as illustrated in Fig. 11, a reference effective spectral irradiance ($W/m^2/nm$), consisting of a product, on a per-wavelength basis, of the spectral irradiance ($W/m^2/nm$) of an absorption spectrum of sunlight defined by AM1.5G and the OPN5 absorption spectrum, may be calculated by the calculation unit with the received effective spectral irradiance ($W/m^2/nm$). In this manner, because the reference effective spectral irradiance ($W/m^2/nm$), consisting of a product, on a per-wavelength basis, of the spectral irradiance of the absorption spectrum of sunlight defined by AM1.5G and the OPN5 absorption spectrum, is calculated by the calculation unit with the received effective spectral irradiance ($W/m^2/nm$), the degree (for example, percentage) of the actual received effective spectral irradiance relative to the common reference effective spectral irradiance can be evaluated in a generalized manner. On the basis of the calculation results, an objective relationship with physical effects through OPN5 can be clarified.

[0098] Fig. 12 is a graph contrasting the reference effective spectral irradiance (reference sign b) shown in Fig. 11 (C) and the received effective spectral irradiance (reference sign a) shown in Fig. 9 (C). Thus, for example, the received effective spectral irradiance obtained in Fig. 9 can be evaluated by comparison with the reference effective spectral irradiance ($W/m^2/nm$) found from

the product of the spectral irradiance of the sunlight spectrum defined by AM1.5G at each wavelength and the OPN5 absorption spectrum, on a per-wavelength basis. This allows for a generalized evaluation of the degree (percentage: %) of the actual received effective spectral irradiance relative to the common reference effective spectral irradiance. The results shown in Fig. 12 indicate that, for example, the effective irradiance integrated within the wavelength range of 280 to 500 nm is 57 W/m² for sunlight (reference sign b) and 3.3 W/m² for violet light (reference sign a) and, when the effective irradiance of sunlight is normalized to 100%, the effective irradiance of violet light can be evaluated as 6%. Thus, by comparison with the value normalized to 100% for sunlight, an objective relationship between the comparison results and the physical effects through OPN5 can be clarified. Further, the received effective irradiance obtained can be compared not only with the reference effective irradiance of sunlight but also with the received effective irradiance obtained from another light-source system, thereby allowing comparison among light sources.

[0099] It should be noted that "AM1.5G" is sunlight data that has been adopted at the standard level in solar cell development and the like, and "AM" means air mass. This AM1.5G has been standardized by the American Society for Testing and Materials (ASTM) as indicated at the URL "https://unit.aist.go.jp/rp-envene2022/PV/ja/about_pv/output/measure.html," and the data is published at "https://tinystones.net/pv/pv04.html" (the National Renewable Energy Laboratory (NREL) of the United States Department of Energy; "https://www.nrel.gov/grid/solar-resource/spectra.html").

[0100] From Fig. 11 (C), it can be seen that a maximum value of the effective spectral irradiance is 0.93 W/m²/nm (value at 402 nm). The effective irradiance, as mentioned above, has an integrated value of 57 W/m² in the wavelength region of 280 to 500 nm. An effective dose when exposed to AM1.5G sunlight for three hours per day is a value obtained by multiplying the 57 W/m² described above by 10,800 seconds, which is understood to be 615,600 J/m² (= 615.6 kJ/m²). It should be noted that, given approximately 1 W/m²/nm as the maximum value of the effective spectral irradiance, 10 W/m²/nm, which is 10 times thereof, can be set as the maximum value. The effective irradiance, assuming that the effective spectral irradiance has a square-type spectrum, can be calculated as 10 W/m²/nm × 220 nm = 2,200 W/m², and the effective dose, assuming irradiation for three hours per day at this effective irradiance, can be set as 21,600,000 J/m² (= 21.6 MJ/m²).

[0101] As described above, an effective irradiance integrated within the wavelength range of 280 to 500 nm was 57 W/m² for sunlight and 3.3 W/m² for violet light. For such values, examples of minimum values include 0.01 W/m²/nm for the effective spectral irradiance, 0.1 W/m² for the effective irradiance, and 1,000 J/m² for the effective dose. Further, examples of maximum values include 10 W/m²/nm for the effective spectral irradiance, 2,200 W/m² for the effective irradiance, and 21.6 MJ/m² (M stands for million) for the effective dose. It should be noted that the effective irradiance is a value assuming irradiation for three hours.

[0102] The light spectral data may be compared and calculated over all or part of the wavelength region of the OPN5 absorption spectrum. Thus, even when the received light includes various light spectral data, calculation can be performed by comparison with all or part of the wavelength region of the OPN5 absorption spectrum, so that the method can be applied to any evaluation in which the wavelength region of the light is specified using a filter or the like. As a result, the method can be utilized in a radiation device for clarifying whether physical effects through OPN5 are related to the received effective spectral irradiance over the entire wavelength region of the OPN5 absorption spectrum, to the received effective spectral irradiance in a specific wavelength region of the OPN5 absorption spectrum, or the like. A wavelength region of light may be specified using a filter or the like, for example, as a specific wavelength region such as violet light in the wavelength region of 360 to 400 nm. Accordingly, the method can also be utilized for detailed verification of effects with a specified wavelength region or the like.

[0103] In the calculation unit of the measurement device 21, during comparison in a wavelength region, the received effective spectral irradiance may be integrated over the wavelength region to obtain a received effective irradiance (W/m²), and the reference effective spectral irradiance may similarly be integrated over the same wavelength region to obtain a reference effective irradiance (W/m²). The received effective irradiance and the reference effective irradiance thus obtained may then be compared, for example as a percentage, and evaluated.

[0104] For comparison of the integration results, an effective irradiance (W/m²) obtained by integrating the results over a specific wavelength range may be compared between, for example, the reference effective irradiance of sunlight and the received effective irradiance of a violet-light LED, and expressed as the received effective irradiance of the violet-light LED relative to the reference effective irradiance of sunlight. The results shown in Fig. 12 indicate that the effective irradiance integrated over the wavelength range of 280 to 500 nm is 57 W/m² for

sunlight and 3.3 W/m² for violet light. When the sunlight value is normalized to 100%, the violet-light LED value can be evaluated as 6%. By comparison with the value normalized to 100% for sunlight, an objective relationship between the comparison results and physical effects through OPN5 can be clarified. The received effective irradiance obtained may be compared not only with the reference effective irradiance of sunlight but also with received effective irradiance obtained from another light-source system, thereby allowing comparison among light sources.

[0105] Furthermore, in the calculation unit, it is possible to evaluate a radiation duration dependency of the light with respect to the effects on the body imparted by the absorption of light by the body through OPN5 by comparing (for example, percentage: %) a received effective dose (J/m2), obtained by multiplying the light effective irradiance (W/m2) by the radiation duration (seconds), and a received reference effective dose (J/m2), obtained by multiplying the reference effective irradiance (W/m2) by the radiation duration (seconds). It should be noted that the dose is the amount of light of exposure per day, regardless of whether the exposure duration is short (for example, in a case of being briefly exposed to strong flash of light) or the exposure time with weak light is long. On the other hand, the time of day (time frame) of exposure is not particularly limited, but in practice exposure during the daytime is more effective.

[0106] With such evaluations based on the effective irradiance and the effective dose, it is possible to quantitatively evaluate the effects on the body imparted by the absorption of light by the body through OPN5. Such a relationship is clearly defined, making it possible to, for example, evaluate what wavelength range of light, irradiance level, radiation time frame, and radiation duration are effective in relation to the physical effects of OPN5.

[0107] The measurement unit may be exemplified by, for example, a sensor 12 illustrated in Figs. 8 (A) and 8 (B), and is preferably provided on eyeglasses, an earphone, a wristwatch, a chest badge, or another article worn on the upper body; worn on the body itself by adhesion or the like; or attached to an installation near or around the body. Attachment in such a mode is selected and performed as desired on the basis of the installation form (light-source form, light-source installation position, and the like) of the light source that radiates the light, and thus is unlikely to interfere with daily life and facilitates measurement of the light spectral data received by the eyes and the body.

[0108] (Measurement of spectral data)

Spectral data of light can typically be measured using a spectrometer or an ultraviolet (UV)

meter (also called a power meter). A spectrometer can measure and obtain spectral irradiance and, when the result is integrated with respect to the wavelength, the irradiance is found. Integration is performed in a wavelength region of a specific range, making it possible to express the result as the irradiance in the wavelength region, and thus preferably use such a method. On the other hand, a UV meter can directly display the irradiance. For example, a commercially available UVA meter detects light of 320 to 400 nm and displays the irradiance in the wavelength region, which is convenient. However, from a quantitative perspective, a UV meter calibrated in accordance with the used sensor is preferred. Accordingly, a UV meter cannot measure spectral information (wavelength dependency), making application to the various spectral quantities in the present invention difficult. It should be noted that the "dose" is simply determined by multiplying the irradiance by the radiation duration (seconds).

[0109] <Setting Radiation Conditions According to Purpose>

The light radiation device according to the present invention radiates light to a person's eye to express the OPN5 gene in the retina or activate OPN5 and can thereby be useful for setting desirable radiation conditions for various diseases. Examples include conditions desirable for improvement or prevention of depression; suppression or prevention of stress; improvement or enhancement of concentration; improvement or prevention of Alzheimer's disease; improvement or prevention of dementia or cognitive impairment; suppression of myopia progression, such as suppression of axial elongation; suppression of onset of myopia; effects on choroidal thickness, cerebral blood flow, or the nervous system; and effects on other tissues, such as the testes and skin.

[0110] Using the light radiation device according to the present invention, a radiation mode, including irradiance, radiation duration, radiation interval, irradiance-change cycle, and radiation period, can be determined so that a more effective improvement in a disease or the like is achieved. The device is particularly advantageous for setting a radiation mode for each target disease. Violet light effectively used in the light radiation device may be constant light or flickering light. Accordingly, the light radiation device can also be applied to evaluate radiation conditions for flickering light, including ON intensity, OFF intensity, radiation time cycle, peak radiation time, irradiance-change cycle, and duty ratio. Furthermore, because the light radiation device can clarify an objective relationship with the effect of expressing the OPN5 gene in the

retina or activating OPN5, the device is also desirable from a subject-centered perspective of providing an effective procedure to the subject being examined.

[0111] When effects on such diseases are evaluated, the degree, for example a percentage, of the actual received effective spectral irradiance relative to the common reference effective spectral irradiance can be evaluated in a generalized manner regardless of the measurement region or measurement time. As a result, an objective relationship with the effect of expressing the OPN5 gene in the retina or activating OPN5 can be clarified, and the device can be utilized to clarify such a relationship.

[0112] [Method for Operating Light Radiation Device]

The method for operating a light radiation device according to the present invention is a method for operating the light radiation device described above, which radiates light to a person's eye to express the OPN5 gene or activate OPN5. The method includes a light-source placement step of placing a light source that radiates light having a wavelength in a wavelength region overlapping the OPN5 absorption spectrum; a light-data comparison step of comparing, in advance or in situ, spectral data of the light obtained by receiving the light radiated from the light source placed in the light-source placement step with OPN5 absorption spectral data; and a light setting step of setting a radiation condition of the light on the basis of results obtained in the light-data comparison step to express the OPN5 gene or activate OPN5.

[0113] The method for operating the light radiation device has the same components as those described above for the light radiation device. In this operating method, the radiation condition of the light set in the light setting step may be one or two or more conditions selected from the installation position of the light source, radiation direction, wavelength range, wavelength profile, irradiance, radiation time frame, and radiation duration of the light, and the light may be light having a wavelength of 360 to 400 nm overlapping the OPN5 absorption spectrum, as described above for the light radiation device.

[0114] In this operating method, particularly in the light setting step, the radiation condition of the light radiated from the light source is set on the basis of the results obtained in the light-data comparison step to express the OPN5 gene or activate OPN5. Therefore, a setting appropriate for a radiation purpose or the like can be performed. The light setting step need not be performed by the light radiation device. In such a case, a control device connected separately by wireless or wired communication, such as a mobile communication terminal including a control computer

(for example, a smartphone) or a centralized control device, may perform the light setting step and the setting appropriate for the radiation purpose or the like. The setting in the light setting step also includes, for example, setting firmware at the manufacturing stage so that the radiation condition of the light is satisfied when use for a specific radiation purpose is known in advance.

[0115] [Light Radiation System]

Next, the light radiation system will be described. The light radiation system according to the present invention is characterized in that two or more light radiation devices according to the present invention described above are combined, or the system includes two or more light sources constituting the light radiation device according to the present invention described above.

[0116] In a light radiation system in which two or more light radiation devices having respective radiation conditions are combined, each light radiation device can be assigned a role (radiation purpose). As a result, light radiation devices assigned respective roles can be disposed at positions corresponding to behavior or behavioral patterns in a room. In a light radiation system including two or more light sources constituting a light radiation device, radiation conditions corresponding to the role of each light source can be set so that each light source performs a role (radiation purpose) for achieving a specific purpose, thereby configuring an integrated system. As a result, light set to achieve a specific purpose can be disposed at positions corresponding to behavior or behavioral patterns in a room.

[0117] (Light Sensor)

In the light radiation system, the received effective spectral irradiance actually received by the eyes is specified, and thus the substantial spectral irradiance of the light received by the eyes is measured using a light sensor. Examples of the light sensor include GaAsP photodiodes, which may be selected and applied as desired. Such a light sensor 12 may be, for example, the light sensor 12 installed on eyeglasses as illustrated in Fig. 8, a sensor 12 in the form of a chest badge, or a light sensor installed around the eyes, and is not particularly limited. A means for providing the light sensor on the eyeglasses, a means for providing the light sensor around the eyes, and the like are not particularly limited. The light sensor may be directly fixed to the eyeglasses or hooked using a hook or the like. Further, the light sensor may be fixed to an ear-hooking accessory or the like and hooked to the ear.

[0118] (Installation Form of Light Source and Control of Light)
In the light radiation system, the installation form of the light source (including an arrangement form in a case in which a diffusing plate or a reflecting plate is provided as necessary) and the control of the light delivered to the eyes are important. Through the installation form of the light source and the control of the light described below, it is possible to control the light that reaches the eyes to express the OPN5 gene or activate OPN5. Modes of the control of the light include a control means related to the radiation conditions of the light and a control means for the directionality of the light.
[0119] For the "control means related to the radiation conditions of the light," for example, the light emitted from the one or two or more light sources is preferably controlled by one or two or more means selected from setting or changing the wavelength range, setting or changing the irradiance, setting or changing the time frame, and setting or changing the radiation duration.
[0120] Regarding "setting or changing the wavelength range," "setting a specific wavelength range" refers to setting the wavelength range of the light radiated from the light source. Examples include a means such as providing a light source that emits light having a wavelength within a specific wavelength range, or providing a filter that transmits a specific wavelength range in front of the light source to emit light having a wavelength within the specific wavelength range. Further, "changing a specific wavelength range" refers to changing the wavelength range of the light radiated from the light source. Examples include a means such as separately providing light sources that emit light having wavelengths within different wavelength ranges and changing the light source by switching between the light sources, or switching to another filter, in front of the light source, that transmits a specific wavelength range to transmit light having a wavelength within a different wavelength range.
[0121] "Setting or changing the irradiance" refers to setting or changing the irradiance of the light emitted from the light source to a desired value. Such setting or changing of the irradiance is preferably performed in accordance with the level of received effective spectral irradiance received by the eye. When sufficient received effective spectral irradiance has been received from the perspective of the light effect of OPN5 evaluated on the basis of the evaluation method of the present invention, radiation may be stopped or the irradiance may be decreased. On the other hand, when insufficient received effective spectral irradiance has been received from that perspective, the irradiance may be increased. Specifically, when a violet-light LED light source

emitting violet light having a wavelength of 360 to 400 nm is used, the lower and upper limits of irradiance reaching the eye are not particularly limited. The lower limit may be preferably 0.05 W/m² (5 μW/cm²), more preferably 0.10 W/m², and even more preferably 0.2 W/m². The upper limit may be preferably 50 W/m² (5,000 μW/cm²), more preferably 20 W/m², and even more preferably 10 W/m². An actual irradiance range may be obtained by combining any of the above-described lower and upper limits, and the irradiance is preferably set or changed as desired within such a range.

[0122] "Setting or changing the time frame" refers to setting or changing the time frame of emitting the light from the light source as desired. The setting or the changing of the time frame is preferably performed in accordance with the time frame in which the light is to be radiated from the perspective of the light effect of OPN5 evaluated on the basis of the evaluation method of the present invention. Specifically, for example, in a case of the evening following sunset, the light within the range of the OPN5 absorption spectrum cannot be obtained from the sun outdoors and thus, in the time frame of the evening following sunset, a setting or a change of radiating light indoors is desirably not performed from the perspective of not disrupting a circadian rhythm. Further, the time frame can be set as desired, and thus may be a regular or an intermittent time frame.

[0123] "Setting or changing the radiation duration" refers to setting or changing the radiation duration of emitting the light from the light source as desired. The setting or the changing of the radiation duration is preferably performed in accordance with a length of the radiation duration of the light from the light effect of OPN5 evaluated on the basis of the evaluation method of the present invention. Specifically, for example, the light may be radiated intermittently or discontinuously, for example. It should be noted that, in the case of setting or changing the radiation duration, the radiant intensity is preferably also set in conjunction thereto.

[0124] Regarding the "control means for the directionality of the light," to ensure that light emitted from the one or two or more light sources is directed toward the eyes, the directionality of the light is preferably set by one or two or more means selected from: installing or changing the light source (including installing or changing the light source when a diffusing plate or a reflecting plate is provided as necessary); setting or changing the angle of the light emitted from the light source; when a diffusing material that diffuses the light is provided, the diffusion angle of the diffusing material and installation or change of the light source using the diffusing

material; and, when a reflecting material that reflects the light is provided, setting the reflection angle of the reflecting material and installation or change of the light source using the reflecting material. This mode constitutes a control means for the directionality of the light.
"Directionality" is an important factor from the perspective of the light effects of OPN5. For example, in the case of deskwork, it is particularly desirable that the light source be provided ahead in the visual line so as to radiate light toward the eyes. Further, as illustrated in Fig. 7, it is preferable that the direction of the light can be changed automatically or manually from "D" to "D′."

[0125] Regarding "installing or changing the light source," "setting or changing the angle of the light emitted from the light source," "installing or changing the diffusing material that diffuses the light," and "installing or changing the reflecting material that reflects the light," in each case, it is preferable that the relevant component be installed in advance so that the light is directed toward the eyes, or be installed so that the direction of the light can be changed to a desired direction.

[0126] Such a light radiation system is a system for effectively achieving the light effect of expression of the OPN5 gene or activation of OPN5, and is desirable for evaluating, for example, suppression of myopia progression, such as suppression of axial elongation; suppression of onset of myopia; effects on choroidal thickness, cerebral blood flow, or the nervous system; and effects on other tissues, such as the testes and skin.

DESCRIPTION OF REFERENCE SIGNS

[0127] 10: light source
11: reflecting material
12: sensor
D, D′: direction of light
21: light radiation device
22: measurement unit
23: calculation unit
24: memory
25: display unit

CLAIMS

What is claimed is:

1. A light radiation device configured to radiate light to an eye to express the OPN5 gene or activate OPN5, the light radiation device comprising:

a light source configured to radiate light having a wavelength in a wavelength region overlapping an absorption spectrum of OPN5,

wherein a radiation condition of the light radiated from the light source is set to express the OPN5 gene or activate OPN5.

2. The light radiation device according to claim 1, wherein the radiation condition is set on the basis of results obtained by comparing, in advance or in situ, spectral data of the light obtained by receiving the light radiated from the light source with absorption spectral data of OPN5.

3. The light radiation device according to claim 1, wherein a spectrum of the light obtained by receiving the light radiated from the light source is set so that a maximum value of a received effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of a spectral irradiance ($W/m^2/nm$) of the light in a wavelength region of 280 to 500 nm and a relative absorbance of the absorption spectral data of OPN5, is 0.2% or more of a maximum value of a reference effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of a spectral irradiance ($W/m^2/nm$) of a sunlight spectrum defined by AM1.5G and the relative absorbance of the absorption spectral data of OPN5.

4. The light radiation device according to any one of claims 1 to 3, wherein the radiation condition is one or two or more selected from a radiation direction of the light, a wavelength range of the light, a wavelength profile of the light, an irradiance of the light, a radiation time frame of the light, and a radiation duration of the light.

5. The light radiation device according to claim 1 or 2, wherein the radiation condition of the light is set by a light setting unit provided together with the light source or provided separately from the light source.

6. The light radiation device according to any one of claims 1 to 3, wherein the radiation condition of the light is set, on the basis of the comparison results, in accordance with a

predetermined degree of expression of the OPN5 gene or a predetermined degree of activation of OPN5.

7. The light radiation device according to any one of claims 1 to 3, wherein the light is light having a wavelength of 360 to 400 nm overlapping the absorption spectrum of OPN5.

8. The light radiation device according to any one of claims 1 to 3, wherein the light source is disposed at a position selected from a position where the light is radiated directly toward the eye, a position in a field of view, a position in a visual line direction, a position where the light is radiated to the eye as diffused light diffused by a diffusing material, and a position where the light is radiated to the eye as reflected light reflected by a reflecting material.

9. The light radiation device according to any one of claims 1 to 3, wherein (i) when the light source is provided at a position where the light is radiated directly toward the eye, an irradiance of the light is set in accordance with a distance and/or an angle from the light source to a person; (ii) when the light source is provided at a position in the field of view or in the visual line direction, the irradiance of the light is set in accordance with a distance and/or an angle from the light source to the person; (iii) when the light source is provided at a position where the light is radiated to the eye as diffused light diffused by the diffusing material, the irradiance of the light is set in accordance with a distance from the light source and the diffusing material to the person, and/or a diffusion angle and a transmittance of the diffusing material; and (iv) when the light source is provided at a position where the light is radiated to the eye as reflected light reflected by the reflecting material, the irradiance of the light is set in accordance with a distance from the light source and the reflecting material to the person, and/or a reflectance of the reflecting material.

10. The light radiation device according to any one of claims 1 to 3, wherein the light source is selected from: a structure-attached light source attached to a floor, including underfoot, a wall, a ceiling (including by suspension therefrom), or another structure; an installation-attached light source attached to a desk, a table, a partition, a shelf, a desktop member, a personal computer, a display, a PC keyboard, a television, an audio device, or another device or installation; a built-in or attached light source of a portable personal computer, a tablet, a smartphone, or another mobile terminal; a body-accessory-attached light source attached to, or detachably mounted by an attachment on, a vision correcting aid, eye

protective equipment, face protective equipment, a neck-hanging accessory, an ear-hooking accessory, head-mounted equipment, or another body accessory; and a functional-device-attached light source attached to a functional device for augmented reality, virtual reality, or mixed reality, including goggles, a headset, or another functional device.

11. The light radiation device according to any one of claims 1 to 3, wherein an orientation or position of the light source is set manually or automatically.

12. The light radiation device according to claim 1 or 2, wherein a received effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of a spectral irradiance ($W/m^2/nm$) of each wavelength in a wavelength region of 280 to 500 nm of a spectrum of received light and a relative absorbance of absorption spectral data of OPN5, is compared with and evaluated against a reference effective spectral irradiance ($W/m^2/nm$), calculated as a product, on a per-wavelength basis, of a spectral irradiance ($W/m^2/nm$) of an absorption spectrum of sunlight defined by AM1.5G and a relative absorbance of the absorption spectrum of OPN5.

13. The light radiation device according to claim 12, wherein the received effective spectral irradiance is set to 0.2% or more of the reference effective spectral irradiance.

14. The light radiation device according to claim 12, wherein, during the comparison, the received effective spectral irradiance ($W/m^2/nm$) is integrated over a wavelength region to be compared to obtain a received effective irradiance (W/m^2), the reference effective spectral irradiance ($W/m^2/nm$) is similarly integrated over the same wavelength region to obtain a reference effective irradiance (W/m^2), and the received effective irradiance and the reference effective irradiance thus obtained are compared.

15. The light radiation device according to claim 14, wherein the received effective irradiance is set to 0.2% or more of the reference effective irradiance.

16. The light radiation device according to claim 14, wherein a received effective dose (J/m^2), obtained by multiplying the received effective irradiance (W/m^2) by a radiation duration (seconds), is compared with a received reference effective dose (J/m^2), obtained by multiplying the reference effective irradiance (W/m^2) by the radiation duration (seconds).

17. The light radiation device according to claim 16, wherein the received effective dose is set to 0.2% or more of the received reference effective dose.

18. The light radiation device according to claim 1 or 2, wherein measurement for the comparison is performed by a measurement unit, and the measurement unit, on the basis of a form of the light source that radiates the light, is provided on eyeglasses, an earphone, a wristwatch, a chest badge, or another article worn on a body, is worn on the body itself, or is attached to an installation near or around the body.

19. The light radiation device according to any one of claims 1 to 3, wherein the light is flickering light and/or constant light, and respective radiation conditions for the flickering light and/or the constant light are set on the basis of results obtained by comparing, in advance or in situ, spectral data of the radiated light with absorption spectral data of OPN5.

20. A light radiation system, wherein two or more light radiation devices according to any one of claims 1 to 19 are combined, or two or more light sources constituting a light radiation device according to any one of claims 1 to 19 are provided.

21. A method for operating a light radiation device configured to radiate light to an eye to express the OPN5 gene or activate OPN5, the method comprising:

placing a light source configured to radiate light having a wavelength in a wavelength region overlapping an absorption spectrum of OPN5;

comparing, in advance or in situ, spectral data of the light obtained by receiving the light radiated from the placed light source with absorption spectral data of OPN5; and

setting a radiation condition of the light on the basis of results obtained by the comparing to express the OPN5 gene or activate OPN5.

22. The method according to claim 21, wherein the radiation condition of the light set in the setting is one or two or more conditions selected from an installation position of the light source, a radiation direction of the light, a wavelength range of the light, a wavelength profile of the light, an irradiance of the light, a radiation time frame of the light, and a radiation duration of the light.

23. The method according to claim 21 or 22, wherein the light is light having a wavelength of 360 to 400 nm overlapping the absorption spectrum of OPN5.