



(11) **EP 4 037 437 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
28.08.2024 Bulletin 2024/35

(51) International Patent Classification (IPC):
H05B 45/20^(2020.01) H05B 47/105^(2020.01)

(21) Application number: **21154240.2**

(52) Cooperative Patent Classification (CPC):
H05B 45/20; H05B 47/105

(22) Date of filing: **29.01.2021**

(54) **LIGHTING SYSTEM AND METHOD FOR PROVIDING LIGHT TO AN AREA**

BELEUCHTUNGSSYSTEM UND VERFAHREN ZUR BELEUCHTUNG EINER FLÄCHE

SYSTÈME D'ÉCLAIRAGE ET PROCÉDÉ DE FOURNITURE DE LUMIÈRE SUR UNE ZONE

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(43) Date of publication of application:
03.08.2022 Bulletin 2022/31

(73) Proprietor: **Tridonic GmbH & Co KG
6851 Dornbirn (AT)**

(72) Inventors:
• **Becker, Waldemar
6850 Dornbirn (AT)**

• **Dobos, Janos
6850 Dornbirn (AT)**

(74) Representative: **Beder, Jens
Mitscherlich PartmbB
Patent- und Rechtsanwälte
Karlstraße 7
80333 München (DE)**

(56) References cited:
**DE-A1- 102008 054 050 US-B1- 10 405 399
US-B1- 9 900 960**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

[0001] The present invention relates to a lighting system and a method for providing light to an area. According to an embodiment of the invention, the lighting system corresponds to a luminaire. According to a further embodiment of the invention, the lighting system comprises two or more luminaires.

[0002] In the prior art, LED light sources (LED-LS, light emitting diode light sources) comprising one or more LEDs (light emitting diodes), such as one or more of organic LEDs, inorganic LEDs, LEDs with secondary emission etc., are well known. LED light sources are more and more used instead of more traditional light sources comprising or corresponding to filament lamps and/or gas-discharge lamps. The use of LEDs for providing light has many advantages such as reduced energy consumption, longer lifetime, lighting of variable color etc.

[0003] In particular, LED light sources configured to emit white light are used for lighting purposes. Such LED light sources may emit light of a spectrum that causes more blinding (of persons) compared to more traditional light sources in case of humid air, because the white light emitted by the LED light sources is more reflected by the humid air compared to the light emitted by a traditional light source, such as a gas discharge lamp. For example in the field of street lighting before the use of LED light sources sodium vapor lamps, such as low pressure sodium lamps, were used as light sources. A light source emitting white light (e.g. of correlated color temperature (CCT) of 6500 K) causes more blinding in case of rain or fog compared to a sodium vapor lamp. This is due to an increased light-reflection of the light emitted by the LED light source on water drops, present due to the rain or fog, compared to the light-reflection of water drops of the light emitted by a sodium vapor lamp in such a case. The terms "dazzle" and "glare" may be used as synonyms for the term "blinding".

[0004] US 10,405,399 B1 discloses a street light device that includes a light emitting module, a driving circuit, a sensing module, and a microcontroller. The light emitting module includes a first light emitting unit and a second light emitting unit. The sensing module obtains a temperature, a relative humidity, and a dust concentration. The microcontroller calculates a light attenuation rate according to the temperature, the relative humidity, and the dust concentration. The microcontroller controls the driving circuit according to the light attenuation rate to drive the first light emitting unit and the second light emitting unit, so that a color temperature ratio between the first light emitting unit and the second light emitting unit is determined according to the light attenuation rate.

[0005] DE 10 2008 054 050 A1 shows a lantern that comprises a mast and at least two light-emitting diodes fixed in or on the mast, which are adapted to emit electromagnetic radiation with a different spectrum during operation. The lantern includes a device, which is adapted to control and/or regulate the electromagnetic spectrum

and the intensity of the mixed light emitted by the light-emitting diodes as a function of at least one of the following measured variables: humidity, temperature, ambient brightness, time, visibility.

[0006] Therefore, it is an object of the present invention to provide an improved lighting system using an LED light source for providing light to an area, e.g. a street area, both in dry and wet conditions. In particular, it is an object to provide a lighting system using an LED light source for providing light to an area, for which the above-described drawbacks in case of moisture (e.g. humid air and/or wet ground) are reduced, in particular overcome.

[0007] These and other objects, which become apparent upon reading the following description, are solved by the subject-matter of the independent system claim 1 and the corresponding independent method claim. The dependent claims refer to preferred embodiments of the invention.

[0008] The terms "preferably", "in particular" and "optionally" are used herein for introducing optional features of the present invention.

[0009] According to a first aspect of the invention a lighting system for providing light to an area is provided. The system comprises at least one LED light source (LED-LS) configured to emit white light, wherein the at least one LED-LS comprises a first LED unit configured to emit the white light, and a control unit configured to control a light emission of the at least one LED-LS. The control unit is configured to control the light emission of the at least one LED-LS based on moisture information on a moisture in the area such that, in case the moisture information fulfills a condition regarding the moisture in the area, the control unit controls the at least one LED-LS to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold. The at least one LED-LS further comprises a second LED unit configured to emit light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold. The control unit is configured to control the light emission of the at least one LED-LS such that: the first LED unit emits light, in case the moisture information does not fulfill the condition, and only the second LED unit emits light, in case the moisture information fulfills the condition. The lighting system further comprises a lens unit arranged to modulate the light emitted by the second LED unit.

[0010] The lens unit comprises an improved beam geometry reducing the reflection probability of light-reflection on water drops of the light emitted by the second LED unit.

[0011] In other words, in case the moisture information fulfills the condition regarding the moisture in the area, the control unit is configured to control the light emission of white light of the at least one LED-LS such that, when the at least one LED-LS emits light (light emitting state of the at least one LED-LS), the at least one LED-LS stops emitting light of a spectrum comprising a reflection

probability of light-reflection on water drops greater than or equal to the probability threshold. That is, in case the moisture information fulfills the condition, the control unit is configured to control the light emission of the at least one LED-LS such that the control unit controls the at least one LED-LS to emit light of one or more wavelengths for which the reflection probability of light-reflection on water drops is smaller than the probability threshold.

[0012] Therefore, the lighting system may provide white light to the area in case the moisture information does not fulfill the condition. This is advantageous, because an LED-LS providing white light for illumination has a good efficiency factor with regard to the electrical energy needed for providing the lighting in the area. On the other side, in case the moisture information fulfills the condition, e.g. the air in the area comprises a certain humidity level, the lighting system may switch from providing white light to only providing light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold, for providing the lighting in the area. This is advantageous, because this reduces the blinding (of a person in the area) caused by the light emission compared to a case, in which the light emission is not changed and, thus, emission of white light is continued. Reducing the blinding increases the visibility for a person present in the area.

[0013] Emitting only light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold may decrease the efficiency factor of the light emission by the lighting system. Therefore, the control unit is configured to change the light emission of white light to light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold only in case the condition is fulfilled. Thus, in case the condition is not fulfilled, the white light with the good efficiency factor is emitted.

[0014] In the light of the above, the lighting system according to the first aspect is advantageous, because it allows reducing blinding caused by light emission of the LED-LS of the system in case the condition regarding the moisture in the area, e.g. a certain moisture level or presence of rain or fog, is fulfilled. At the same time, the lighting system allows to improve the efficiency of the light emission by allowing white light emission, in case the condition is not fulfilled (e.g. good weather, no rain, no fog).

[0015] The moisture in the area comprises the moisture of the ground in the area and the moisture of the air in the area. The term humidity is used for referring to the moisture in the air of the area. The term "moisture" is to be understood as referring to water in the form of drops (i.e. water drops) either in the air, in a substance or on a surface (e.g. the ground in the area).

[0016] In particular, the smaller the wavelength of the emitted light the higher the reflection probability of light-reflection on water drops of the emitted light.

[0017] The area may be an outdoor area, e.g. a street

area, a harbor/port area, airport area, forest area etc. Alternatively, the area may be an indoor area, e.g. indoor skiing hall, indoor pool, thermal bath etc. In particular, the area may be a combination of an outdoor and indoor area, such as a sports stadium or swimming hall, optionally with a movable roof.

[0018] The LED-LS may comprise a plurality of LEDs (light emitting diodes), such as at least one of organic LEDs, inorganic LEDs, LEDs with secondary emission etc.

[0019] The control unit may comprise or correspond to a processor, a microprocessor, a controller, a microcontroller, a field programmable gate array (FPGA), an application specific integrated circuit (ASIC) or any combination of them.

[0020] In particular, the moisture information fulfills the condition in case the moisture information informs on a humidity level greater than a humidity threshold. Alternatively or additionally, the moisture information may fulfill the condition in case the moisture information informs on precipitation and/or fog. In particular, the moisture information may fulfill the condition in case the moisture information informs on a precipitation intensity greater than an intensity threshold, i.e. on an amount of precipitation greater than a threshold amount. Alternatively or additionally, the moisture information may fulfill the condition in case the moisture information informs on a moisture level of the ground in the area greater than a moisture threshold.

[0021] Thus, the moisture information may inform on at least one of a presence of a weather condition comprising or corresponding to precipitation and/or fog; a degree of a weather condition comprising or corresponding to precipitation and/or fog; a humidity level; and a moisture level of the ground.

[0022] The humidity level may correspond to the absolute humidity in the area, i.e. the total mass of water vapor present in a given volume or mass of air. The humidity level may correspond to a relative humidity. Precipitation may comprise or correspond to rain, snow, sleet, hail etc. The moisture level may correspond to an absolute moisture level or a relative moisture level.

[0023] In particular, the lighting system comprises a weather condition sensor unit configured to detect precipitation and/or fog in the area and provide the detection result as the moisture information to the control unit. The weather condition sensor unit may comprise or correspond to a precipitation and/or fog sensor unit. Additionally or alternatively, the lighting system may comprise a humidity sensor unit configured to detect a humidity level of the humidity in the area and provide the detection result as the moisture information to the control unit. Additionally or alternatively, the lighting system may comprise a moisture sensor unit configured to detect a moisture level of the ground in the area and provide the detection result as the moisture information to the control unit. Additionally or alternatively, the lighting system may comprise a communication unit configured to receive the moisture

information, e.g. from a weather forecast station, and provide the moisture information to the control unit.

[0024] The weather condition unit may be configured to detect the presence of precipitation and/or fog in the area and optionally the degree of precipitation (i.e. amount/intensity of precipitation) and/or fog (density of fog). For implementing a weather condition sensor unit, a precipitation and/or fog sensor unit, a humidity sensor unit and a moisture sensor unit any sensors known in the art may be used.

[0025] The communication unit may be configured to communicate wirelessly and/or wire-bound for receiving the moisture information. In particular, the communication unit may be configured to communicate with a weather forecast station for receiving information on the weather condition in the area as the moisture information. The communication unit may be a part of the control unit. In particular, the wireless communication unit may be configured to communicate wirelessly using radio waves. The communication unit may be implemented by any means known in the art.

[0026] Thus, the lighting system may generate the moisture information regarding the moisture in the area by itself using at least one of a weather condition unit, precipitation and/or fog sensor unit, a humidity sensor unit and a moisture sensor unit. In this case, the control unit may be configured to determine based on the generated moisture information that the condition regarding the moisture in the area is fulfilled, e.g. presence of precipitation, the humidity level in the area is greater than a humidity threshold and/or the moisture level of the ground is greater than a moisture threshold. The control unit may react thereto, by controlling the light emission of the at least one LED light source such that the light emission is changed from a first emission state to a second emission state. In the first emission state, the at least one LED-LS emits white light, when the control unit controls the at least one LED-LS to emit light. In the second emission state, the at least one LED-LS emits only light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold.

[0027] For example, in case the moisture information informs on a moisture level of the ground in the area greater than a moisture threshold (e.g. wet street due to rainfall), the control unit may determine that the condition is fulfilled.

[0028] In addition or alternatively, the system may receive the moisture information regarding the moisture in the area from a weather forecast station. Thus, the control unit may already react to a received moisture information fulfilling the condition before the condition is actually fulfilled in the area. For example, in case, the communication unit receives from the weather forecast station information informing on heavy rain fall for a certain time and optionally date, e.g. on 12.05.2020 at 12.00 o'clock, and the condition corresponds to such heavy rain fall, then the control unit may determine based on the received

information from the weather forecast station that at that time and optionally date (e.g. 12.05.2020 at 12.00 o'clock), the condition regarding the moisture in the area will be fulfilled. The control unit may be configured to control the at least one LED-LS such that at that time and optionally date (12.05.2020 at 12.00 o'clock) the at least one LED-LS emits only light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold.

[0029] Optionally, the control unit may be configured to control the at least one LED-LS such that already a time period (e.g. 30 minutes) before that time and optionally date (12.05.2020 at 12.00 o'clock) the at least one LED-LS emits only light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold. Thus, the communication unit allows the control unit to react to the condition already before the condition is fulfilled.

[0030] For evaluating the moisture information received from one or more sensors of the lighting system, such as the aforementioned sensors, and/or the information received from a weather forecast station, the control unit may use one or more look-up tables and/or one or more algorithms.

[0031] The reflection probability of light-reflection on water drops may correspond to a relative scattering coefficient and the probability threshold may correspond to a threshold for the relative scattering coefficient.

[0032] In particular, the reflection probability of light-reflection on water drops may correspond to a relative Rayleigh scattering coefficient and the probability threshold may correspond to a threshold for the relative Rayleigh scattering coefficient. In other words, the relative scattering coefficient may be a relative Rayleigh scattering coefficient.

[0033] In particular, the higher the relative scattering coefficient the higher the reflection probability of light-reflection on water drops.

[0034] The first LED unit and the second LED unit each may correspond to an LED chip.

[0035] In particular, the second LED unit is configured to emit light of a spectrum comprising a relative emission intensity greater than 20% between a wavelength of 580 nm and a wavelength of 605 nm. In other words, the second LED unit may be configured to emit light of a spectrum comprising, between the wavelength of 580 nm and the wavelength of 605 nm, a relative emission intensity between 20% and 100%. That is, the relative emission intensity of the spectrum may be equal to 100% at a wavelength between the wavelength of 580 nm and the wavelength of 605 nm. Thus, the second LED unit may be configured to emit light of a spectrum comprising its main part (i.e. the main part of the spectrum) between the wavelength of 580 nm

and the wavelength of 605 nm. The second LED unit may be configured to emit light of a spectrum comprising 20% relative emission intensity at the wavelength of 580 nm and the wavelength of 605 nm. Alternatively, the second

LED unit may be configured to emit light of a spectrum comprising a relative emission intensity greater than 20% between a wavelength of 542 nm and a wavelength of 670 nm. In other words, the second LED unit may be configured to emit light of a spectrum comprising, between the wavelength of 542 nm and the wavelength of 670 nm, a relative emission intensity between 20% and 100%. That is, the relative emission intensity of the spectrum may be equal to 100% at a wavelength between the wavelength of 542 nm and the wavelength of 670 nm. Thus, the second LED unit may be configured to emit light of a spectrum comprising its main part (i.e. the main part of the spectrum) between the wavelength of 542 nm and the wavelength of 670 nm. The second LED unit may be configured to emit light of a spectrum comprising 20% relative emission intensity at the wavelength of 542 nm and the wavelength of 670 nm. The second LED unit may be configured to emit light of a spectrum between a wavelength of 565 nm and a wavelength of 620 nm or a wavelength of 527 nm and a wavelength of 685 nm.

[0036] In particular, the spectrum comprises a Gaussian spectral shape. The spectrum may be a symmetrical spectrum.

[0037] The second LED unit may be a monochromatic amber LED unit configured to emit amber light. The second LED unit may be a phosphor converted LED unit configured to emit amber light.

[0038] In particular, the first LED unit is configured to emit white light with a variable correlated color temperature (CCT) and the control unit is configured to vary the CCT of the white light.

[0039] The first LED unit may be configured to emit white light with a variable CCT between 2700 and 4000 K. Optionally, the first LED unit may be configured to emit white light with a CCT of 6500 K.

[0040] The lighting system comprises a lens unit arranged to modulate the light emitted by the second LED unit. The lens unit comprises an improved beam geometry reducing the reflection probability of light-reflection on water drops of the light emitted by the second LED unit.

[0041] For implementing the lens unit any lens known in the art may be used. The lens unit may correspond to a lens arrangement comprising a plurality of lenses.

[0042] The lens unit is arranged to reduce reflectivity of light, emitted by the second LED unit, on a wet ground in the area. That is, the lens unit may be arranged to reduce reflectivity of light, emitted by the second LED unit, on a ground in the area, wherein the moisture level of the ground is above a moisture threshold (e.g. a water level or water amount above a threshold value is present on the ground).

[0043] According to an embodiment, the lighting system is a luminaire.

[0044] The lighting system may be an outdoor luminaire, such as a street lighting luminaire, a harbor lighting luminaire, a floodlight luminaire (e.g. for a sports stadium), a spotlight luminaire (e.g. for a sports stadium), a car headlights luminaire etc.

[0045] The at least one LED-LS may correspond to at least one LED module, the luminaire may comprise a driver module for driving the at least one LED module, and the driver module may comprise the control unit. Alternatively, the control unit may be external to the driver module (i.e. not a part of the driver module).

[0046] In particular, the luminaire may comprise a housing and the at least one LED-LS (LED module), the driver module and the control unit may be arranged inside the housing. In this case, the at least one LED-LS (LED module) is arranged in the housing such that the at least one LED-LS (LED module) is configured to emit light from inside the housing via an opening and/or a transparent section of the housing to the outside of the housing.

[0047] The driver module is configured to provide the at least one LED-LS (LED module) with electrical energy. For this, the driver module may comprise an optional power factor correction (PFC) circuit, a power conversion circuit (AC/DC and/or DC/DC power conversions circuit) and/or an optional filter circuit. The power conversion circuit may comprise one or more actively switched power converters (in particular at least one actively switched DC/DC power converter and/or at least one actively switched AC/DC power converter). The control unit is configured to control the light emission of the at least one LED-LS (LED module) by controlling the electrical energy supplied by the driver module to the at least one LED-LS (LED module). In particular, in case the driver module comprises an actively switched power converter (may be referred to as active power converter), such as at least one boost converter, buck converter, flyback converter and/or resonant converter, the control unit may be configured to control switching of the actively switched power converter for controlling the electrical energy supplied to the at least one LED-LS (LED module) and, thus, the light emission by the at least one LED-LS (LED module). The higher the electrical energy (e.g. time-averaged electrical energy over a time period), in particular current (e.g. time-averaged current over a time period), supplied to the at least one LED-LS (LED module), the higher the amount of light respectively the higher the light intensity of the light emitted by the at least one LED-LS (LED module).

[0048] According to a further embodiment, the lighting system comprises two or more LED-LS and each LED-LS is a luminaire.

[0049] Each LED-LS may be an outdoor luminaire, such as a street lighting luminaire, a harbor lighting luminaire, a floodlight luminaire, a spotlight luminaire, e.g. for a sports stadium, car headlights luminaire etc.

[0050] The above description of the lighting system may be valid for each luminaire of the lighting system, in case the lighting system comprises two or more LED-LS and each LED-LS is a luminaire.

[0051] At least one of the two or more LED-LS comprises a local control unit configured to control the light emission of the respective LED-LS based on moisture information on the moisture in the area such that in case

the moisture information fulfills the condition regarding the moisture in the area, the local control unit controls the respective LED-LS to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold. In particular, each of the two or more LED-LS comprises a local control unit configured to control the light emission of the respective LED-LS based on moisture information on the moisture in the area such that in case the moisture information fulfills the condition regarding the moisture in the area, the local control unit controls the respective LED-LS to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold. In addition or alternatively, the control unit may be part of one of the two or more LED-LS and may be configured to control the light emission of the two or more LED-LS.

[0052] In the following, the two or more LED-LS of the lighting system according to the further embodiment may be referred to two or more luminaires, because each LED-LS of the lighting system according to the further embodiment is a luminaire.

[0053] The light emission by each of the two or more luminaires of the lighting system of the further embodiment may be controlled according to different alternatives in dependence of the moisture in the area. According to a first alternative, the control unit of the system may be a single central control unit that is configured to control the light emission of the two or more luminaires based on moisture information on the moisture in the area such that, in case the moisture information fulfills the condition regarding the moisture in the area, the control unit controls the two or more luminaires to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold.

[0054] According to a second alternative, the control unit of the system may be part of one of the two or more luminaires and may be configured to control the light emission of the two or more luminaires based on moisture information on the moisture in the area such that, in case the moisture information fulfills the condition regarding the moisture in the area, the control unit controls the two or more luminaires to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold.

[0055] According to a third alternative, in addition to the first alternative at least one of the two or more luminaires may comprise a local control unit configured to control the light emission of the respective luminaires based on moisture information on the moisture in the area such that in case the moisture information fulfills the condition regarding the moisture in the area, the local control unit controls the respective luminaire to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold.

[0056] According to a fourth alternative, in addition to

the first alternative each of the two or more luminaires may comprise a local control unit configured to control the light emission of the respective luminaire based on moisture information on the moisture in the area such that in case the moisture information fulfills the condition regarding the moisture in the area, the local control unit controls the respective luminaire to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold.

[0057] A fifth alternative corresponds to the third alternative, wherein the control unit of the system corresponds to the local control unit of the at least one luminaire of the two or more luminaires. A sixth alternative corresponds to the fourth alternative, wherein the control unit of the system corresponds to a local control unit of one of the two or more luminaires.

[0058] The above description with respect to the control unit of the lighting system may be valid for the local control unit of a respective luminaire.

[0059] Each LED-LS (luminaire) may comprise a communication unit for communicating, in particular wirelessly, with other devices. The other devices may comprise or correspond to the other LED-LS of the lighting system. Additionally or alternatively, other devices may correspond to mobile end devices, such as mobile phones, vehicles, local weather stations, weather forecast stations etc. For example, in case the lighting system is used for providing illumination to a street area, the communication unit of each LED-LS (luminaire) may be configured to communicate with vehicles driving on a street at the street area, mobile end devices carried by persons walking on a pedestrian at the street area and a local weather station that may be present at the street area for monitoring the weather condition at the street area. In particular, the local weather station may be configured to detect the humidity level in the street area, the moisture level of the ground in the street area (e.g. moisture level of the street) and/or the presence and optionally amount of precipitation and/or fog in the street area. Thus, the communication unit of each LED-LS (luminaire) may be configured to receive moisture information regarding the moisture at the street area from the vehicles, mobile end devices and the local weather station. The communication between each of the LED-LS (luminaires) and other devices may be wireless. The wireless communication may be based on radio waves.

[0060] The above is also valid with respect to a different outdoor area, such as a harbor, airport etc. For example, in case of the harbor the communication unit may be configured to communicate with ships and, thus, the communication unit of each LED-LS (luminaire) may be configured to receive moisture information regarding the moisture at the harbor area from the ships.

[0061] In particular, the first LED unit and the second LED unit form an LED module.

[0062] As described above, according to an embodiment the lighting system may be a luminaire. In this case,

the at least one LED-LS corresponds to the lighting means of that luminaire. According to a further embodiment, the lighting system may comprise at least two LED-LS, wherein each LED-LS corresponds to a luminaire. In this case, each luminaire comprises lighting means. The description of the lighting system being a luminaire according to the above-mentioned embodiment is correspondingly valid for describing each luminaire of the system according to the further embodiment.

[0063] In order to achieve the lighting system according to the present invention, some or all of the above described optional features may be combined with each other.

[0064] According to a second aspect of the invention, a method for providing light to an area is provided, wherein the method comprises the step of emitting, by at least one LED light source, LED-LS, white light wherein the at least one LED-LS comprises a first LED unit emitting the white light. The method further comprises the step of controlling, by a control unit, a light emission of the at least one LED-LS based on moisture information on a moisture in the area such that in case the moisture information fulfills a condition regarding the moisture in the area, the control unit controls the at least one LED-LS to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold. The at least one LED-LS further comprises a second LED unit emitting light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability. The control unit controls the light emission of the at least one LED-LS such that: the first LED unit emits light, in case the moisture information does not fulfill the condition, and only the second LED unit emits light, in case the moisture information fulfills the condition. A lens unit is arranged to modulate the light emitted by the second LED unit, wherein the lens unit comprises an improved beam geometry reducing the reflection probability of light-reflection on water drops of the light emitted by the second LED unit.

[0065] The method according to the second aspect of the present invention achieves the same advantages as the lighting system according to the first aspect of the invention.

[0066] The above description with regard to the lighting system according to the first aspect of the present invention is correspondingly valid for the method according to the second aspect of the present invention.

[0067] In particular, the above description of the LED-LS and control unit of the lighting system according to the first aspect of the present invention is correspondingly valid for the LED-LS and control unit used for performing the method according to the second aspect of the present invention.

[0068] In the following, the invention is described exemplarily with reference to the enclosed figures, wherein

Figure 1 (a) schematically shows a lighting system according to the first aspect of the

present invention;

Figure 1 (b) schematically shows a lighting system according to an embodiment of the present invention;

Figure 2 schematically shows a lighting system according to an embodiment of the present invention;

Figure 3 schematically shows a lighting system according to an embodiment of the present invention;

Figure 4 shows the spectrum of light that is emitted by different light sources comprising an LED light source for emitting white light at correlated color temperature (CCT) of 6500 K, a low pressure sodium lamp, a monochromatic amber LED light unit configured to emit amber light and a phosphor converted LED light unit configured to emit amber light;

Figure 5 shows an example of a relationship between a reflection probability of light-reflection on water drops and wavelength of light according to an embodiment of the invention;

Figure 6 schematically shows a lighting system according to an embodiment of the present invention.

[0069] In the Figures, corresponding elements have the same reference signs. The proportions and dimensions of the elements shown in the figures do not represent the luminaire to scale, but are merely chosen to describe the structure and function of the luminaire.

[0070] **Figure 1 (a)** schematically shows a lighting system according to the first aspect of the present invention.

[0071] As shown in Figure 1 (a), the lighting system 1 for providing light to an area comprises an LED light source (LED-LS) 2 and a control unit 3. The lighting system 1 may comprise more than one LED-LS 2. The at least one LED-LS 2 is configured to emit white light and the control unit 3 is configured to control a light emission of the at least one LED-LS 2. The control unit 3 is configured to control the light emission of the at least one LED-LS 2 based on moisture information on a moisture in the area such that, in case the moisture information fulfills a condition regarding the moisture in the area (e.g. rain present in the area), the control unit 3 controls the at least one LED-LS 2 to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold.

[0072] Therefore, the lighting system 1 of Figure 1 (a) may reduce blinding of persons present in the area that

is caused by the light emission of the at least one LED-LS 2, in case the condition regarding the moisture in the area is fulfilled (e.g. rain present in the area). Namely, the light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold is less reflected on water drops, such as rain drops, compared to light of wavelengths respectively a spectrum comprising a reflection probability of light-reflection on water drops greater than or equal to the probability threshold. Generally, the higher the reflection probability of light-reflection on water drops of a wavelength of light the more probable the light of said wavelength and, thus, the more often the light of said wavelength is reflected on water drops, such as rain drops. Reducing blinding increases the visibility of a person present in the area.

[0073] In particular, the smaller the wavelength of emitted light the higher the reflection probability of light-reflection on water drops of that emitted light.

[0074] For describing the system 1 of Figure 1 (a) in more detail, reference is made to the above description of the lighting system according to the first aspect of the present invention.

[0075] Figure 1 (b) schematically shows a lighting system according to an embodiment of the present invention. The lighting system of Figure 1 (b) corresponds to the lighting system of Figure 1 (a). Therefore, the above description of the system of Figure 1 (a) is also valid for the lighting system of Figure 1 (b) and in the following mainly additional features shown in Figure 1 (b) are described.

[0076] As shown in Figure 1 (b) the at least one LED-LS 2 comprises a first LED unit 4a configured to emit white light, and a second LED unit 4b configured to emit light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold. The control unit 3 is configured to control the light emission of the at least one LED-LS 2 such that the first LED unit 4a emits light, in case the moisture information does not fulfill the condition, and only the second LED unit 4b emits light, in case the moisture information fulfills the condition.

[0077] For a more detailed description of the first LED unit 4a and the second LED unit 4b reference is made to the above description of the first LED unit and second LED unit of the lighting system according to the first aspect of the present invention.

[0078] Figure 2 schematically shows a lighting system according to an embodiment of the present invention. The lighting system of Figure 2 corresponds to the lighting system of Figure 1 (b). Therefore, the above description of the lighting system of Figures 1 (a) and 1 (b) is also valid for the lighting system of Figure 2 and in the following mainly additional features shown in Figure 2 are described.

[0079] As shown in Figure 2 the lighting system 1 may comprise an optional weather condition sensor unit 5a configured to detect precipitation and/or fog in the area and provide the detection result as the moisture information

to the control unit 3. The optional weather condition sensor unit 5a may be a precipitation and/or fog sensor unit. Additionally or alternatively, the lighting system 1 may comprise a humidity sensor unit 5b configured to detect a humidity level of the humidity in the area and provide the detection result as the moisture information to the control unit 3.

[0080] Additionally or alternatively, the lighting system 1 may comprise a moisture sensor unit 5c configured to detect a moisture level of the ground of the area and provide the detection result as the moisture information to the control unit 3. Additionally or alternatively, the lighting system 1 may comprise a communication unit 6 configured to receive the moisture information, e.g. from a weather forecast station, and provide the moisture information to the control unit 3. The communication unit 6 may be configured for a wireless and/or wire-bound communication with outside the lighting system 1, e.g. with a weather forecast station. The wireless communication may be based on radio waves.

[0081] The lighting system 1 may comprise an optional bus (not shown in Figure 2), such as a DALI (Digital Addressable Lighting Interface) bus or DALI-2 bus, to which the control unit 3, the optional weather condition sensor unit 5a, the optional humidity sensor unit 5b, the optional moisture sensor unit 5c and the optional communication unit 6 are electrically connected allowing communication between the electrical components connected to the bus. Thus, the optional sensor units 5a, 5b, 5c and the optional communication unit 6 may provide information respectively data via the bus to the control unit 3. The control unit 3 may be configured to control electrical components, which are connected to the bus, via the bus. DALI (DALI Version 1) and DALI-2 (DALI Version 2) are industry standards that are well known in the field of lighting. Preferably, the at least one LED-LS 2 may be electrically connected to the bus. This may be in particular the case, when the lighting system 1 is a luminaire.

[0082] The lighting system 1 may comprise additional sensor units, such as a temperature sensor unit, light sensor unit, ambient light sensor unit, presence and/or movement detector unit etc., that are configured to provide information to the control unit 3 for controlling the light emission of the at least one LED-LS 2. Such additional sensor units may be connected to the optional bus of the lighting system 1.

[0083] In case the lighting system 1 is a luminaire, the control unit 3 may be part of a driver module 7 for driving the at least one LED-LS 2, as indicated in Figure 2 by a dashed box. The driver module 7 may be connected to the optional bus of the luminaire 1. The control unit 3 may alternatively be an electrical component separate to the driver module 7 that is electrically connected with the driver module 7, optionally via the optional bus. In case the lighting system 1 is a luminaire, the at least one LED-LS 2 is the lighting means of the luminaire 1 and the at least one LED-LS 2 may correspond to at least one LED module. The optional weather condition sensor unit 5a,

the optional humidity sensor unit 5b, the optional moisture sensor unit 5c, the optional communication unit 6 and/or optional additional sensor units may be connected, in particular detachably connected, to the driver module 7 for providing information respectively data to the control unit 3 for the control of the light emission of the LED-LS 2 by the control unit 3. For this, the driver module 7 may comprise one or more Zhaga interfaces (e.g. Zhaga sockets) and/or NEMA interfaces (e.g. NEMA sockets) that are well known in the art.

[0084] For a more detailed description of the optional weather condition sensor unit 5a, the optional humidity sensor unit 5b, the optional moisture sensor unit 5c and the optional communication unit 6 of the system according to Figure 2, reference is made to the above description of the optional weather condition sensor unit, the optional humidity sensor unit, the optional moisture sensor unit and the optional communication unit of the lighting system according to the first aspect of the present invention. For a more detailed description of the optional driver module 7 reference is made to the above description of the optional driver module of the lighting system according to the first aspect of the present invention.

[0085] Figure 3 schematically shows a lighting system according to an embodiment of the present invention.

[0086] The lighting system 1 of Figure 3 comprises a control unit 3 and two luminaires 2. The lighting system may comprise more than two luminaires 2. The following description with respect to two luminaires is thus only by way of example and correspondingly valid in case the lighting system comprises more than two luminaires. Each of the luminaires 2 comprises lighting means 2a, a local control unit 8, an optional weather condition sensor unit 5a, optional humidity sensor unit 5b and/or optional moisture sensor unit 5c and an optional communication unit 6. As shown in Figure 3, the lighting means 2a of each luminaire 1 comprises a first LED unit 4a configured to emit white light, and a second LED unit 4b configured to emit light of the spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold.

[0087] The above description of the lighting system of Figures 1 (a), 1 (b) and 2 is also valid for describing each of the two luminaires 2 of the system of Figure 3. In particular, the description with regard to the at least one LED-LS 2 of the system of Figures 1 (a), 1 (b) and 2 is valid for describing the lighting means 2a of each of the two luminaires 2. The above description with regard to the control unit 3 of the system of Figures 1 (a), 1 (b) and 2 is correspondingly valid for describing the local control unit 8 of each of the two luminaires 2. The description of the optional local control unit of the lighting system according to the first aspect is valid for describing the local control unit 8 of each luminaire 2.

[0088] The above description of the control unit 3 of the system of Figures 1 (a), 1 (b) and 3 is correspondingly valid for describing the control unit 3 of the system 1 of Figure 3. The control unit 3 of the system 1 of Figure 3

may be referred to as central control unit. The above description of the system of Figures 1 (a), 1(b) and 2 is correspondingly valid for the system of Figure 3.

[0089] The communication unit 6 of each luminaire 2 may be configured to communicate with other devices. For example, the communication unit 6 of one luminaire 2 may be configured to communicate with the communication unit 6 of another luminaire 2. The communication unit 6 of each luminaire 2 may be configured to communicate with the central control unit 3. The communication unit 6 of each luminaire 2 may be configured for a wireless communication. The wireless communication may be based on radio waves.

[0090] The system 1 may comprise an optional weather condition sensor unit, an optional humidity sensor unit, an optional moisture sensor unit and/or an optional communication unit arranged outside the luminaires 2 (not shown in Figure 3), which are configured to provide information to the control unit 3. This information is in particular moisture information regarding the moisture of the area for which the system 1 comprising the two luminaires 2 provides light. In addition or alternatively, the control unit 3 may receive the moisture information from at least one, in particular each, of the two luminaires 2 (in particular optional sensor units 5a, 5b, 5c of the respective luminaire 2). The communication unit (arranged outside the luminaires 2) may be configured to receive information from outside the system 1, in particular from a weather forecast station, and provide the received information to the control unit 3. The communication unit may be part of the control unit 3. In this case, the control unit 3 may use the communication unit for communicating, in particular wirelessly, with the two luminaires 2. The control unit 3 is configured to control the light emission of the two luminaires 2 based on the information received from the optional weather condition sensor unit, the optional humidity sensor unit, the optional moisture sensor unit and/or the optional communication unit that are arranged outside the luminaires 2. In this case, at least one luminaire 2, in particular each luminaire 2, may optionally not comprise the optional sensor units 5a, 5b, 5c. The communication unit 6 of at least one luminaire 2, in particular of each luminaire, may optionally be configured for only communicating with the control unit 3 (central control unit).

[0091] Optionally, the system 3 may not comprise the central communication unit 3 or the central communication unit 3 may correspond to the local control unit 8 of one of the luminaires 2.

[0092] Therefore, the control unit 3 (being a central control unit as shown in Figure 3 or corresponding to a local control unit 8 of one of the luminaires 2) may be configured to control the light emission of the two luminaires 2 based on moisture information on a moisture in the area (that is illuminated by the lighting system 1 of Figure 3) such that, in case the moisture information fulfills a condition regarding the moisture in the area, the control unit controls the two luminaires 2 to emit only light

of a spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold. The control unit 3 may receive the moisture information from at least one, in particular each, of the two luminaires 2 (in particular optional sensor units 5a, 5b, 5c of the respective luminaire 2) and/or one or more additional sensor units and/or an additional communication unit 6 that are arranged outside the luminaires, as described above. In addition or alternatively, the control unit 3 may receive the moisture information from electrical devices, such as mobile end devices of a person walking in the area.

[0093] Alternatively or additionally, the local control unit 8 of at least one, in particular of each, of the two luminaires 2 is configured to control the light emission of the respective luminaire 2 based on moisture information on the moisture in the area (that is illuminated by the lighting system 1 of Figure 3) such that in case the moisture information fulfills the condition regarding the moisture in the area, the local control unit 8 controls the respective luminaire 2 to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold. The local control unit 8 may receive the moisture information from at least one of

- one or more own optional sensor units 5a, 5b, 5c and/or a own optional communication unit 6;
- at least one other luminaire 2;
- one or more optional additional sensor units and/or an optional additional communication unit 6 that are arranged outside the luminaires, as described above; and
- electrical devices, such as mobile end devices of a person walking in the area.

[0094] Figure 4 shows the spectrum of light that is emitted by different light sources comprising an LED light source for emitting white light at correlated color temperature (CCT) of 6500 K, a low pressure sodium lamp, a monochromatic amber LED light unit configured to emit amber light and a phosphor converted LED light unit configured to emit amber light. The phosphor converted LED light unit configured to emit amber light may be referred to as phosphor converted amber LED light unit.

[0095] Curve C1 of Figure 4 shows the spectrum of light emitted by an LED light source for emitting white light at correlated color temperature (CCT) of 6500 K. Curve C2 of Figure 4 shows the spectrum of light emitted by a monochromatic amber LED light unit configured to emit amber light. Curve C3 of Figure 4 shows the spectrum of a phosphor converted LED light unit configured to emit amber light. Curve C4 of Figure 4 shows the spectrum of a low pressure sodium light unit, which is an example of a sodium vapor lamp light unit. Curve C5 of Figure 4 shows a luminosity function indicating the average spectral sensitivity of human visual perception of brightness for different wavelengths. The luminosity

function may be referred to as luminous efficiency function or as V-Lambda-Curve. Curve C6 of Figure 4 shows the reflection probability of light-reflection on water drops of light for different wavelengths.

[0096] The horizontal axis (x-axis) of the graph of Figure 4 corresponds to the wavelength in nanometers (nm). For curves C1, C2, C3 and C4, the vertical axis (y-axis) of the graph of Figure 4 corresponds to the relative emission intensity. For curve C5, the vertical axis of the graph of Figure 4 corresponds to the average spectral sensitivity of human visual perception of brightness. For curve C6, the vertical axis of the graph of Figure 4 corresponds to the reflection probability of light-reflection on water drops respectively the scattering probability of light-scattering (normalized to a wavelength of 460 nm).

[0097] The reflection probability of light-reflection on water drops and the scattering probability of light-scattering on water drops are direct proportional. That is, the higher the reflection probability of light-reflection on water drops the higher the scattering probability of light-scattering on water drops and vice versa. Therefore, the embodiments of the present invention may alternatively use, instead of the reflection probability of light-reflection on water drops, the scattering probability of light-scattering on water drops as a value for controlling light emission of the at least one LED-LS by the control unit of the lighting system. In other words, the control unit may be configured to control the light emission of the at least one LED-LS based on moisture information on the moisture at an area such that, in case the moisture information fulfills a condition regarding the moisture in the area, the control unit controls the at least one LED-LS to emit only light of a spectrum comprising a scattering probability of light-scattering on water drops smaller than a probability threshold.

[0098] As indicated by Figure 4, the spectrum of the LED light source for emitting white light (cf. curve C1) may comprise its 20% (0.2) relative emission intensity at about 430 nm (nanometers) and about 670 nm. The spectrum of the monochromatic amber LED light unit (cf. curve C2) may comprise its 20% (0.2) relative emission intensity at 580 nm and 605 nm. The spectrum of the phosphor converted LED light unit configured to emit amber light (cf. curve C3) may comprise its 20% (0.2) relative emission intensity at 542 nm and 670 nm.

[0099] As indicated by curve C6, the smaller the wavelength of the emitted light the higher the reflection probability of light-reflection on water drops of the emitted light. That is, when the wavelength of the emitted light is increased, the reflection probability of light-reflection on water drops of the emitted light decreases and vice versa. For example, the reflection probability of light-reflection is greater for the peak wavelength of the spectrum of the white light shown by curve C1 than for the peak wavelength of the spectrum of the monochromatic amber LED light unit shown by curve C2. The peak wavelength of a spectrum corresponds to the wavelength at which the relative emission intensity of the spectrum is 100% (1).

The reflection probability of light-reflection is similar, in particular the same, for the peak wavelength of the spectrum of the monochromatic amber LED light unit shown by curve C2 and the peak wavelength of the spectrum of the phosphor converted LED light unit configured to emit amber light shown by curve C3.

[0100] As shown in Figure 4, the spectrum of the low pressure sodium light unit (cf. curve C4) is best with regard to the reflection-probability of light-reflection on water drops of the emitted light compared to the spectrum of the monochromatic amber LED light unit and the spectrum of the phosphor converted LED light unit configured to emit amber light. Namely, the width of the spectrum of the low pressure sodium light unit is smallest. Moreover, the spectrum of the monochromatic amber LED light unit is better with regard to the reflection-probability of light-reflection on water drops of the emitted light compared to the spectrum of the phosphor converted LED light unit configured to emit amber light. Namely, the width of the spectrum of the monochromatic amber LED light unit (cf. curve C2) is smaller than the width of the spectrum of the phosphor converted LED light unit (cf. curve C3). Nevertheless, as shown by curve C5, indicating the average spectral sensitivity of human visual perception of brightness for different wavelengths, although the spectrum of the phosphor converted LED light unit is wider than the spectrum of the monochromatic amber LED light unit and the low pressure sodium light unit, the phosphor converted amber LED light unit may be used for implementing the at least one LED-LS of the lighting system, in particular the second LED unit of the at least one LED-LS.

[0101] Therefore, the at least one LED-LS of the lighting system according to the present invention preferably comprises or corresponds to a monochromatic amber LED light unit configured to emit amber light or a phosphor converted LED light unit configured to emit amber light. In particular, the second LED unit of the at least one LED-LS of the lighting system may be a monochromatic amber LED light unit configured to emit amber light or a phosphor converted LED light unit configured to emit amber light.

[0102] Figure 5 shows an example of a relationship between a reflection probability of light-reflection on water drops of light and the wavelength of light according to an embodiment of the invention.

[0103] According to Figure 5, the reflection probability of light-reflection on water drops of emitted light is indicated by a relative scattering coefficient. Therefore, the greater the relative scattering coefficient of a wavelength of light, the greater the reflection probability of light-reflection on water drops of light at that wavelength. The relative scattering coefficient is in particular a relative Raleigh scattering coefficient.

[0104] Figure 5 indicates an example of a possible probability threshold in terms of a threshold T1 for the relative scattering coefficient. For example, it is assumed that the at least one LED-LS of the lighting system is

configured to emit white light of e.g. a CCT of 6500 K and, thus, light of a spectrum between 430 nm and 670 nm, in particular between 430 nm and 650 nm or 415 nm and 665 nm. It is further assumed that the threshold T1 corresponds to the value of the relative scattering coefficient for the wavelength equaling to 540 nm (indicated by the dashed line in Figure 5). According to that assumptions, the control unit of the lighting system is configured to control the light emission of the at least one LED-LS such that, in case the moisture information fulfills the condition regarding the moisture in the area, the control unit controls the at least one LED-LS to emit only light of a spectrum comprising wavelengths greater than 540 nm. Namely, when the control unit controls the at least one LED-LS to emit only light of a spectrum comprising wavelengths greater than 540 nm, then the control unit controls the at least one LED-LS to emit only light of a spectrum comprising a reflection probability of light reflection on water drops smaller than the probability threshold indicated by the threshold T1. For this the at least one LED-LS may comprise or correspond to a monochromatic amber LED light unit configured to emit amber light or a phosphor converted LED light unit configured to emit amber light.

[0105] A monochromatic amber LED light unit may be configured to emit light of a spectrum comprising a relative emission intensity greater than 20% between a wavelength of 580 nm and a wavelength of 605 nm. A monochromatic amber LED light unit may be configured to emit light of a spectrum comprising 20% relative emission intensity at a wavelength of 580 nm and a wavelength of 605 nm. Alternatively, a monochromatic amber LED light unit may be configured to emit light of a spectrum between a wavelength of 565 nm and a wavelength of 620 nm.

[0106] A phosphor converted amber LED light unit may be configured to emit light of a spectrum comprising a relative emission intensity greater than 20% between a wavelength of 542 nm and a wavelength of 670 nm. A phosphor converted amber LED light unit may be configured to emit light of a spectrum comprising 20% relative emission intensity at a wavelength of 542 nm and a wavelength of 670 nm. Alternatively, a phosphor converted amber LED light unit may be configured to emit light of a spectrum between a wavelength of 527 nm and a wavelength of 685 nm. For this alternative, the threshold T1 may be moved to the relative scattering coefficient at a wavelength of e.g. 525 nm. As can be seen from Figure 5, the relative scattering coefficient is only slightly greater for the wavelength 525 nm compared to the wavelength 540 nm. Thus, in this case the reflection probability of light-reflection on water drops of the emitted light may be still acceptable for reducing blinding.

[0107] Figure 6 schematically shows a lighting system according to an embodiment of the present invention.

[0108] In particular, Figure 6 shows an example of an embodiment according to which the lighting system comprises three or more street luminaires L1, L2, L3 for light-

ing a street. The above description of the lighting system of the first aspect and Figures 1 (a), 1 (b), 2 and 3 is correspondingly valid for the lighting system of Figure 6, wherein the three street luminaires L1, L2, L3 correspond to three LED-LS of the system. The above description of the lighting system of the first aspect and Figures 1 (a), 1 (b), 2 and 3 is correspondingly valid for each of the luminaires L1, L2, L3, wherein the respective luminaire corresponds to the lighting system. In the following description reference is made to only three luminaires L1, L2, L3 (shown in Figure 6). This is also valid in case the lighting system comprises less or more luminaires.

[0109] As shown in Figure 6, each of the luminaires L1, L2, L3 is configured to wirelessly receive information, in particular moisture information regarding the moisture of the street area, from a local weather station 61, a mobile end device of a person 62 present at the street area, a vehicle 63 driving at the street area and the other luminaires.

[0110] The moisture information regarding moisture of the street area may be locally generated by the lighting system. For example, the moisture information may be generated by one or more sensors of at least one of the luminaires L1, L2, L3 and/or by one or more sensors of the lighting system arranged extern to the luminaires L1, L2, L3. The locally generated moisture information may be provided to each of the luminaires L1, L2, L3 from either one or more other luminaires L3 and/or an optional central control unit of the lighting system. Thus, the moisture information may be provided within the lighting network comprising the three luminaires L1, L2, L3.

[0111] Alternatively or additionally, the moisture information may be provided from outside the lighting system, in particular from a data network. For example, the moisture information may be provided to an optional central control unit of the lighting system and/or to at least one of the luminaires L1, L2, L3, in particular each of the luminaires L1, L2, L3, from a weather forecast station.

[0112] The above description is not limited to a street area and thus, street luminaires, but is also valid for any area to be illuminated by a lighting system, wherein the lighting system may comprise any type of luminaire or may correspond to any type of luminaire.

Claims

1. A lighting system (1) for providing light to an area, wherein

- the system (1) comprises:
- at least one LED light source (2), LED-LS, configured to emit white light, wherein the at least one LED-LS (2) comprises a first LED unit (4a) configured to emit the white light, and
- a control unit (3) configured to control the light emission of the at least one LED-LS (2) based on moisture information on moisture in the area

such that: in case the moisture information fulfills a condition regarding the moisture in the area, the control unit (3) controls the at least one LED-LS (2) to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold,

- the at least one LED-LS (2) comprises a second LED unit (4b) configured to emit light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold,
- the control unit (3) is configured to control the light emission of the at least one LED-LS (2) such that: the first LED unit (4a) emits light, in case the moisture information does not fulfill the condition, and only the second LED unit (4b) emits light, in case the moisture information fulfills the condition,

characterised in that

the lighting system (1) further comprises a lens unit arranged to modulate the light emitted by the second LED unit (4b), wherein the lens unit comprises an improved beam geometry reducing the reflection probability of light-reflection on water drops of the light emitted by the second LED unit (4b).

2. The lighting system (1) according to claim 1, wherein the moisture information fulfills

the condition in case the moisture information informs on at least one of a humidity level greater than a humidity threshold, precipitation and/or fog, and a moisture level of the ground in the area greater than a moisture threshold.

3. The lighting system (1) according to claim 1 or 2, wherein the lighting system (1) comprises at least one of

a weather condition sensor unit (5a), in particular a precipitation and/or fog sensor unit, configured to detect precipitation and/or fog in the area and provide the detection result as the moisture information to the control unit (3);

a humidity sensor unit (5b) configured to detect a humidity level of the humidity in the area and provide the detection result as the moisture information to the control unit (3); a moisture sensor (5c) unit configured to detect a moisture level of the ground in the area and provide the detection result as the moisture information to the control unit,

a communication unit (6) configured to receive the moisture information, in particular from a

- weather forecast station, and provide the moisture information to the control unit (3).
4. The lighting system (1) according to any one of the previous claims, wherein the reflection probability of light-reflection on water drops corresponds to a relative scattering coefficient and the probability threshold corresponds to a threshold (T1) for the relative scattering coefficient.
 5. The lighting system (1) according to any one of the previous claims, wherein the first LED unit (4a) and the second LED unit (4b) each correspond to an LED chip.
 6. The lighting system (1) according to any one of the previous claims, wherein
 - the second LED unit (4b) is configured to emit light of a spectrum comprising a relative emission intensity greater than 20% between a wavelength of 580 nm and a wavelength of 605 nm or a wavelength of 542 nm and a wavelength of 670 nm; or
 - light of a spectrum between a wavelength of 565 nm and a wavelength of 620 nm or a wavelength of 527 nm and a wavelength of 685 nm.
 7. The lighting system (1) according to any one of the previous claims 1-5 wherein
 - the second LED unit (4b) is a monochromatic amber LED unit configured to emit amber light, or
 - the second LED unit (4b) is a phosphor converted LED unit configured to emit amber light.
 8. The lighting system (1) according to any one of the previous claims 1-5 wherein the first LED unit (4a) is configured to emit white light with a variable correlated color temperature, CCT, and the control unit (3) is configured to vary the CCT of the white light.
 9. The lighting system (1) according to any one of the previous claims, wherein the lighting system is a luminaire.
 10. The lighting system (1) according to claim 9, wherein
 - the at least one LED-LS (2) corresponds to at least one LED module,
 - the luminaire (1) comprises a driver module (7) for driving the at least one LED module, and
 - the driver module (7) comprises the control unit (3).
 11. The lighting system (1) according to any one of claims 1 to 8, wherein the lighting system (1) comprises two or more LED-LS (2) and each LED-LS (2) is a luminaire.
 12. The lighting system (1) according to claim 11, wherein
 - at least one, in particular each, of the two or more LED-LS (2) comprises a local control unit (8) configured to control the light emission of the respective LED-LS (2) based on moisture information on the moisture in the area such that:
 - in case the moisture information fulfills the condition regarding the moisture in the area, the local control unit controls the respective LED-LS (2) to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold; and/or
 - the control unit (3) is part of one of the two or more LED-LS (2) and is configured to control the light emission of the two or more LED-LS (2).
 13. The lighting system (1) according to claim 11 or 12, wherein each LED-LS (2) comprises a communication unit for communicating, in particular wirelessly, with other devices, in particular other LED-LS (2) of the lighting system (1).
 14. The lighting system according to any one of claim 11 to 13 when depending on claim 5, wherein the first LED unit (4a) and the second LED unit (4b) form an LED module.
 15. A method for providing light to an area, wherein the method comprises the steps
 - emitting, by at least one LED light source (2), LED-LS, white light, wherein the at least one LED-LS (2) comprises a first LED unit (4a) emitting the white light,
 - controlling, by a control unit (3), a light emission of the at least one LED-LS (2) based on moisture information on a moisture in the area such that:
 - in case the moisture information fulfills a condition regarding the moisture in the area, the control unit (3) controls the at least one LED-LS (2) to emit only light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than a probability threshold, wherein
 - the at least one LED-LS (2) further comprises a second LED unit (4b) emitting light of a spectrum comprising a reflection probability of light-reflection on water drops smaller than the probability threshold,

- controlling the light emission of the at least one LED-LS (2) such that:

the first LED unit (4a) emits light, in case the moisture information does not fulfill the condition, and
 only the second LED unit (4b) emits light, in case the moisture information fulfills the condition,
 the method being **characterised by** comprising the step of
 modulating the light emitted by the second LED unit (4b), wherein the lens unit comprises an improved beam geometry reducing the reflection probability of light-reflection on water drops of the light emitted by the second LED unit (4b).

Patentansprüche

1. Beleuchtungssystem (1) zum Bereitstellen von Licht an einen Bereich, wobei

- das System (1), umfasst:
- mindestens eine LED-Lichtquelle (2), LED-LS, die konfiguriert ist, um weißes Licht zu emittieren, wobei die mindestens eine LED-LS (2) eine erste LED-Einheit (4a) umfasst, die konfiguriert ist, um das weiße Licht zu emittieren, und
- eine Steuereinheit (3), die konfiguriert ist, um die Lichtemission der mindestens einen LED-LS (2) basierend auf Feuchteinformationen über Feuchte in dem Bereich derart zu steuern, dass: falls die Feuchteinformationen eine Bedingung bezüglich der Feuchte in dem Bereich erfüllen, die Steuereinheit (3) die mindestens eine LED-LS (2) steuert, um nur Licht eines Spektrums, umfassend eine Reflexionswahrscheinlichkeit von Lichtreflexion an Wassertropfen, die kleiner als ein Wahrscheinlichkeitsschwellenwert ist, zu emittieren,
- die mindestens eine LED-LS (2) eine zweite LED-Einheit (4b) umfasst, die konfiguriert ist, um Licht eines Spektrums, umfassend eine Reflexionswahrscheinlichkeit von Lichtreflexion an Wassertropfen, die kleiner als der Wahrscheinlichkeitsschwellenwert ist, zu emittieren,
- die Steuereinheit (3) konfiguriert ist, um die Lichtemission der mindestens einen LED-LS (2) derart zu steuern, dass: die erste LED-Einheit (4a) Licht emittiert, falls die Feuchteinformationen die Bedingung nicht erfüllen, und nur die zweite LED-Einheit (4b) Licht emittiert, falls die Feuchteinformationen die Bedingung erfüllen,

dadurch gekennzeichnet, dass

das Beleuchtungssystem (1) ferner eine Linseneinheit umfasst, die angeordnet ist, um das Licht zu modulieren, das durch die zweite LED-Einheit (4b) emittiert wird, wobei die Linseneinheit eine verbesserte Strahlgeometrie umfasst, die die Reflexionswahrscheinlichkeit von Lichtreflexion an Wassertropfen des Lichts verringert, das durch die zweite LED-Einheit (4b) emittiert wird.

2. Beleuchtungssystem (1) nach Anspruch 1, wobei die Feuchteinformationen die Bedingung erfüllen, falls die Feuchteinformationen über mindestens eines von einem Feuchtigkeitsgehalt informiert, der größer als ein Feuchtigkeitschwellenwert, Niederschlag und/oder Nebel ist, und ein Feuchtegehalt des Bodens in dem Bereich größer als der Feuchteschwellenwert ist.

3. Beleuchtungssystem (1) nach Anspruch 1 oder 2, wobei das Beleuchtungssystem (1) mindestens eine von einer Wetterbedingungssensoreinheit (5a) umfasst, insbesondere eine Niederschlags- und/oder Nebelsensoreinheit, die konfiguriert ist, um Niederschlag und/oder Nebel in dem Bereich zu erfassen und das Erfassungsergebnis als die Feuchteinformationen an die Steuereinheit (3) bereitzustellen;

eine Feuchtigkeitsensoreinheit (5b), die konfiguriert ist, um einen Feuchtigkeitsgehalt der Feuchtigkeit in dem Bereich zu erfassen und das Erfassungsergebnis als die Feuchteinformationen an die Steuereinheit (3) bereitzustellen;
 eine Einheit des Feuchtesensors (5c), die konfiguriert ist, um einen Feuchtegehalt des Bodens in dem Bereich zu erfassen und das Erfassungsergebnis als die Feuchteinformationen an die Steuereinheit bereitzustellen, eine Kommunikationseinheit (6), die konfiguriert ist, um die Feuchteinformationen zu empfangen, insbesondere von einer Wettervorhersagestation, und die Feuchteinformationen an die Steuereinheit (3) bereitzustellen.

4. Beleuchtungssystem (1) nach einem der vorstehenden Ansprüche, wobei die Reflexionswahrscheinlichkeit von Lichtreflexion an Wassertropfen einem relativen Streukoeffizienten entspricht und der Wahrscheinlichkeitsschwellenwert einem Schwellenwert (T_1) für den relativen Streukoeffizienten entspricht.

5. Beleuchtungssystem (1) nach einem der vorstehenden Ansprüche, wobei die erste LED-Einheit (4a) und die zweite LED-Einheit (4b) jeweils einem LED-Chip entsprechen.

6. Beleuchtungssystem (1) nach einem der vorstehen-

den Ansprüche, wobei

die zweite LED-Einheit (4b) konfiguriert ist, um Licht eines Spektrums, umfassend eine relative Emissionsintensität von mehr als 20 % zwischen einer Wellenlänge von 580 nm und einer Wellenlänge von 605 nm oder einer Wellenlänge von 542 nm und einer Wellenlänge von 670 nm; oder
Licht eines Spektrums zwischen einer Wellenlänge von 565 nm und einer Wellenlänge von 620 nm oder einer Wellenlänge von 527 nm und einer Wellenlänge von 685 nm, zu emittieren.

7. Beleuchtungssystem (1) nach einem der vorstehenden Ansprüche 1 bis 5, wobei

die zweite LED-Einheit (4b) eine monochromatische bernsteinfarbene LED-Einheit ist, die konfiguriert ist, um bernsteinfarbenes Licht zu emittieren, oder
die zweite LED-Einheit (4b) eine leuchtstoffkonvertierte LED-Einheit ist, die konfiguriert ist, um bernsteinfarbenes Licht zu emittieren.

8. Beleuchtungssystem (1) nach einem der vorstehenden Ansprüche 1 bis 5, wobei die erste LED-Einheit (4a) konfiguriert ist, um weißes Licht mit einer variablen korrelierten Farbtemperatur, CCT, zu emittieren, und die Steuereinheit (3) konfiguriert ist, um die CCT des weißen Lichts zu variieren.

9. Beleuchtungssystem (1) nach einem der vorstehenden Ansprüche, wobei das Beleuchtungssystem eine Leuchte ist.

10. Beleuchtungssystem (1) nach Anspruch 9, wobei
die mindestens eine LED-LS (2) mindestens einem LED-Modul entspricht,
die Leuchte (1) ein Treibermodul (7) zum Treiben des mindestens einen LED-Moduls umfasst, und
das Treibermodul (7) die Steuereinheit (3) umfasst.

11. Beleuchtungssystem (1) nach einem der Ansprüche 1 bis 8, wobei das Beleuchtungssystem zwei oder mehr LED-LS (2) umfasst und jede LED-LS (2) eine Leuchte ist.

12. Beleuchtungssystem (1) nach Anspruch 11, wobei mindestens eine, insbesondere jede, der zwei oder mehr LED-LS (2) eine lokale Steuereinheit (8) umfasst, die konfiguriert ist, um die Lichtemission der jeweiligen LED-LS (2) basierend auf Feuchteinformationen über die Feuchte in der Umgebung derart zu steuern, dass:

falls die Feuchteinformationen die Bedingung bezüglich der Feuchte in dem Bereich erfüllen, die lokale Steuereinheit die jeweiligen LED-LS (2) steuert, um nur Licht eines Spektrums, umfassend eine Reflexionswahrscheinlichkeit von Lichtreflexion an Wassertropfen zu emittieren, die kleiner als der Wahrscheinlichkeitsschwellenwert ist; und/oder
die Steuereinheit (3) Teil von einer der zwei oder mehr LED-LS (2) ist und konfiguriert ist, um die Lichtemission der zwei oder mehr LED-LS (2) zu steuern.

13. Beleuchtungssystem (1) nach Anspruch 11 oder 12, wobei jede LED-LS (2) eine Kommunikationseinheit zum Kommunizieren, insbesondere drahtlos, mit anderen Vorrichtungen, insbesondere anderen LED-LS (2) des Beleuchtungssystems (1), umfasst.

14. Beleuchtungssystem nach einem der Ansprüche 11 bis 13, wenn sie von Anspruch 5 abhängen, wobei die erste LED-Einheit (4a) und die zweite LED-Einheit (4b) ein LED-Modul ausbilden.

15. Verfahren zum Bereitstellen von Licht an einen Bereich, wobei das Verfahren die folgenden Schritte umfasst

- Emittieren, durch mindestens eine LED-Lichtquelle (2), LED-LS, von weißem Licht, wobei die mindestens eine LED-LS (2) eine erste LED-Einheit (4a) umfasst, die das weiße Licht emittiert,
- Steuern, durch eine Steuereinheit (3), einer Lichtemission der mindestens einen LED-LS (2) basierend auf Feuchteinformationen über eine Feuchte in dem Bereich, derart, dass:

falls die Feuchteinformationen eine Bedingung bezüglich der Feuchte in dem Bereich erfüllen, die Steuereinheit (3) die mindestens eine LED-LS (2) steuert, um nur Licht eines Spektrums, umfassend eine Reflexionswahrscheinlichkeit von Lichtreflexion an Wassertropfen zu emittieren, die kleiner als ein Wahrscheinlichkeitsschwellenwert ist, zu emittieren,
wobei

- die mindestens eine LED-LS (2) ferner eine zweite LED-Einheit (4b) umfasst, die Licht eines Spektrums, umfassend eine Reflexionswahrscheinlichkeit von Lichtreflexion an Wassertropfen emittiert, die kleiner als der Wahrscheinlichkeitsschwellenwert ist,
- Steuern der Lichtemission der mindestens einen LED-LS (2) derart, dass:

die erste LED-Einheit (4a) Licht emittiert, falls die Feuchteinformationen die Bedingung nicht erfüllen, und nur die zweite LED-Einheit (4b) Licht emittiert, falls die Feuchteinformationen die Bedingung erfüllen, wobei das Verfahren **dadurch gekennzeichnet ist, dass** es den Schritt des Modulierens des Lichts umfasst, das durch die zweite LED-Einheit (4b) emittiert wird, wobei die Linseneinheit eine verbesserte Strahlgeometrie umfasst, die die Reflexionswahrscheinlichkeit von Lichtreflexion an Wassertropfen des Lichts verringert, das durch die zweite LED-Einheit (4b) emittiert wird.

Revendications

1. Système d'éclairage (1) permettant de fournir de la lumière à une zone, dans lequel

- le système (1) comprend :
- au moins une source de lumière LED (2), LED-LS, configurée pour émettre une lumière blanche, dans lequel l'au moins une LED-LS (2) comprend une première unité LED (4a) configurée pour émettre la lumière blanche, et
- une unité de commande (3) configurée pour contrôler l'émission de lumière de l'au moins une LED-LS (2) sur la base d'informations relatives à l'humidité sur l'humidité dans la zone de sorte que : si les informations relatives à l'humidité remplissent une condition concernant l'humidité dans la zone, l'unité de commande (3) commande l'au moins une LED-LS (2) pour émettre uniquement de la lumière d'un spectre comprenant une probabilité de réflexion de la de réflexion de lumière sur des gouttes d'eau inférieure à un seuil de probabilité,
- l'au moins une LED-LS (2) comprend une seconde unité LED (4b) configurée pour émettre de la lumière d'un spectre comprenant une probabilité de réflexion de la réflexion de la lumière sur des gouttes d'eau inférieure au seuil de probabilité,
- l'unité de commande (3) est configurée pour contrôler l'émission de lumière de l'au moins une LED-LS (2) de telle sorte que : la première unité LED (4a) émet de la lumière, si les informations relatives à l'humidité ne remplissent pas la condition, et que seule la seconde unité LED (4b) émet de la lumière, si les informations relatives à l'humidité remplissent la condition,

caractérisé en ce que

le système d'éclairage (1) comprend en outre

une unité de lentille agencée pour moduler la lumière émise par la seconde unité LED (4b), dans lequel l'unité de lentille comprend une géométrie de faisceau améliorée réduisant la probabilité de réflexion de la réflexion de lumière sur des gouttes d'eau de la lumière émise par la seconde unité LED (4b).

2. Système d'éclairage (1) selon la revendication 1, dans lequel les informations relatives à l'humidité remplissent la condition si les informations relatives à l'humidité renseignent sur au moins l'un parmi un niveau d'humidité supérieur à un seuil d'humidité, des précipitations et/ou du brouillard, et un niveau d'humidité du sol dans la zone supérieur à un seuil d'humidité.

3. Système d'éclairage (1) selon la revendication 1 ou 2, dans lequel le système d'éclairage (1) comprend au moins une parmi

une unité de détection des conditions météorologiques (5a), en particulier une unité de détection des précipitations et/ou du brouillard, configurée pour détecter les précipitations et/ou le brouillard dans la zone et fournir le résultat de la détection sous forme d'informations relatives à l'humidité à l'unité de commande (3) ;
une unité de détection de l'humidité (5b) configurée pour détecter un niveau d'humidité de l'humidité dans la zone et fournir le résultat de détection sous forme d'informations relatives à l'humidité à l'unité de commande (3) ;
une unité de détection de l'humidité (5c) configurée pour détecter un niveau d'humidité du sol dans la zone et fournir le résultat de détection sous forme d'informations relatives à l'humidité à l'unité de commande, une unité de communication (6) configurée pour recevoir les informations relatives à l'humidité, en particulier d'une station de prévision météorologique, et fournir les informations relatives à l'humidité à l'unité de commande (3).

4. Système d'éclairage (1) selon l'une quelconque des revendications précédentes, dans lequel la probabilité de réflexion de la réflexion de lumière sur les gouttes d'eau correspond à un coefficient de diffusion relatif et le seuil de probabilité correspond à un seuil (T_1) pour le coefficient de diffusion relatif.

5. Système d'éclairage (1) selon l'une quelconque des revendications précédentes, dans lequel la première unité LED (4a) et la seconde unité LED (4b) correspondent chacune à une puce LED.

6. Système d'éclairage (1) selon l'une quelconque des

revendications précédentes, dans lequel

la seconde unité LED (4b) est configurée pour émettre de la lumière d'un spectre comprenant une intensité d'émission relative supérieure à 20 % entre une longueur d'onde de 580 nm et une longueur d'onde de 605 nm ou une longueur d'onde de 542 nm et une longueur d'onde de 670 nm ; ou la lumière d'un spectre compris entre une longueur d'onde de 565 nm et une longueur d'onde de 620 nm ou une longueur d'onde de 527 nm et une longueur d'onde de 685 nm.

7. Système d'éclairage (1) selon l'une quelconque des revendications 1 à 5 précédentes, dans lequel

la seconde unité LED (4b) est une unité LED ambrée monochromatique configurée pour émettre une lumière ambrée, ou la seconde unité LED (4b) est une unité LED convertie au phosphore configurée pour émettre une lumière ambrée.

8. Système d'éclairage (1) selon l'une quelconque des revendications 1 à 5 précédentes, dans lequel la première unité LED (4a) est configurée pour émettre une lumière blanche avec une température de couleur corrélée variable, CCT, et l'unité de commande (3) est configurée pour faire varier la CCT de la lumière blanche.

9. Système d'éclairage (1) selon l'une quelconque des revendications précédentes, dans lequel le système d'éclairage est un luminaire.

10. Système d'éclairage (1) selon la revendication 9, dans lequel

l'au moins une LED-LS (2) correspond à au moins un module LED, le luminaire (1) comprend un module de pilotage (7) pour piloter l'au moins un module LED, et le module de pilotage (7) comprend l'unité de commande (3).

11. Système d'éclairage (1) selon l'une quelconque des revendications 1 à 8, dans lequel le système d'éclairage (1) comprend deux ou plusieurs LED-LS (2) et chaque LED-LS (2) est un luminaire.

12. Système d'éclairage (1) selon la revendication 11, dans lequel au moins une, en particulier chacune, des deux ou plusieurs LED-LS (2) comprend une unité de commande locale (8) configurée pour commander l'émission de lumière des LED-LS (2) respectives sur la base d'informations relatives à l'humidité sur

l'humidité dans la zone, de telle sorte que :

si les informations relatives à l'humidité remplissent la condition relative à l'humidité dans la zone, l'unité de commande locale commande la LED-LS (2) respective pour qu'elle n'émette que de la lumière d'un spectre comprenant une probabilité de réflexion de la réflexion de lumière sur des gouttes d'eau inférieure au seuil de probabilité ; et/ou l'unité de commande (3) fait partie de l'une des deux ou plusieurs LED-LS (2) et est configurée pour commander l'émission de lumière des deux ou plusieurs LED-LS (2).

13. Système d'éclairage (1) selon la revendication 11 ou 12, dans lequel chaque LED-LS (2) comprend une unité de communication pour communiquer, en particulier sans fil, avec d'autres dispositifs, en particulier d'autres LED-LS (2) du système d'éclairage (1).

14. Système d'éclairage selon l'une quelconque des revendications 11 à 13 lorsqu'il dépend de la revendication 5, dans lequel la première unité LED (4a) et la seconde unité LED (4b) forment un module LED.

15. Procédé de fourniture de lumière à une zone, dans lequel le procédé comprend les étapes consistant à

- émettre, par au moins une source de lumière LED (2), LED-LS, de la lumière blanche, dans lequel l'au moins une LED-LS (2) comprend une première unité LED (4a) émettant la lumière blanche, - commander, par une unité de commande (3), une émission lumineuse de l'au moins une LED-LS (2) sur la base d'informations relatives à l'humidité sur une humidité dans la zone, de telle sorte que :

si les informations relatives à l'humidité remplissent une condition concernant l'humidité dans la zone, l'unité de commande (3) commande l'au moins une LED-LS (2) pour qu'elle n'émette que de la lumière d'un spectre comprenant une probabilité de réflexion de la réflexion de lumière sur des gouttes d'eau inférieure à un seuil de probabilité, dans lequel

- l'au moins une LED-LS (2) comprend en outre une seconde unité LED (4b) émettant une lumière d'un spectre comprenant une probabilité de réflexion de la réflexion de lumière sur les gouttes d'eau inférieure au seuil de probabilité, - commander l'émission de lumière de l'au moins une LED-LS (2) de telle sorte que :

la première unité LED (4a) émet de la lumière, si les informations relatives à l'humidité ne remplissent pas la condition, et seule la seconde unité LED (4b) émet de la lumière, si les informations relatives à l'humidité remplissent la condition, le procédé étant **caractérisé en ce qu'il** comprend l'étape consistant à moduler la lumière émise par la seconde unité LED (4b), dans lequel l'unité de lentille comprend une géométrie de faisceau améliorée réduisant la probabilité de réflexion de la réflexion de lumière sur des gouttes d'eau de la lumière émise par la seconde unité LED (4b).

5

10

15

20

25

30

35

40

45

50

55

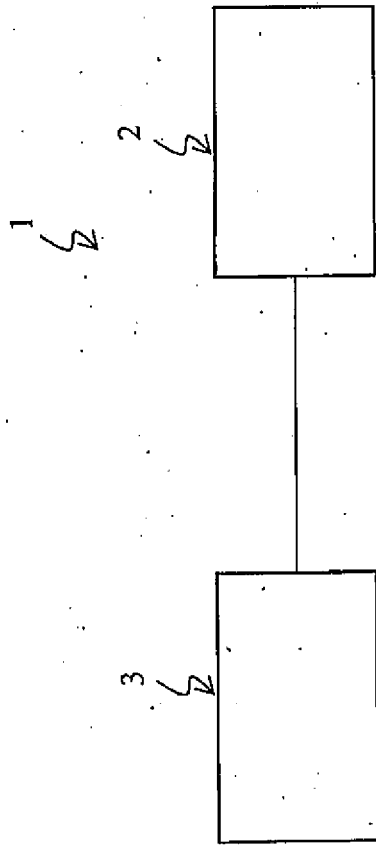
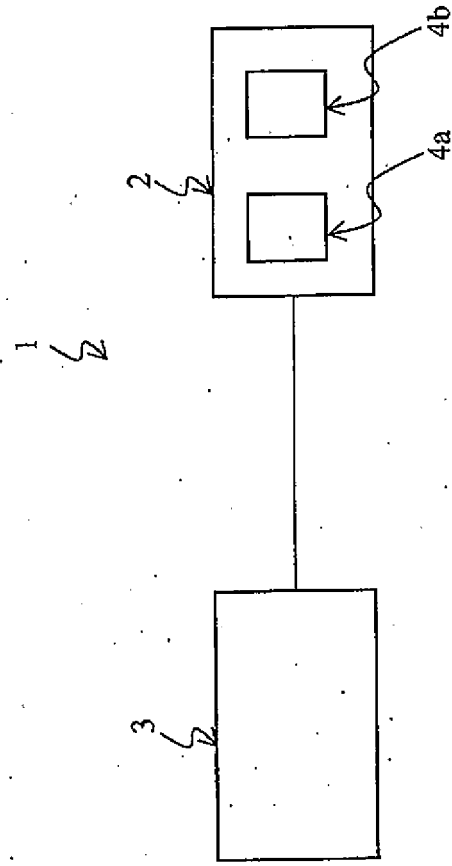


Figure 1 (a)



Figur 1 (b)

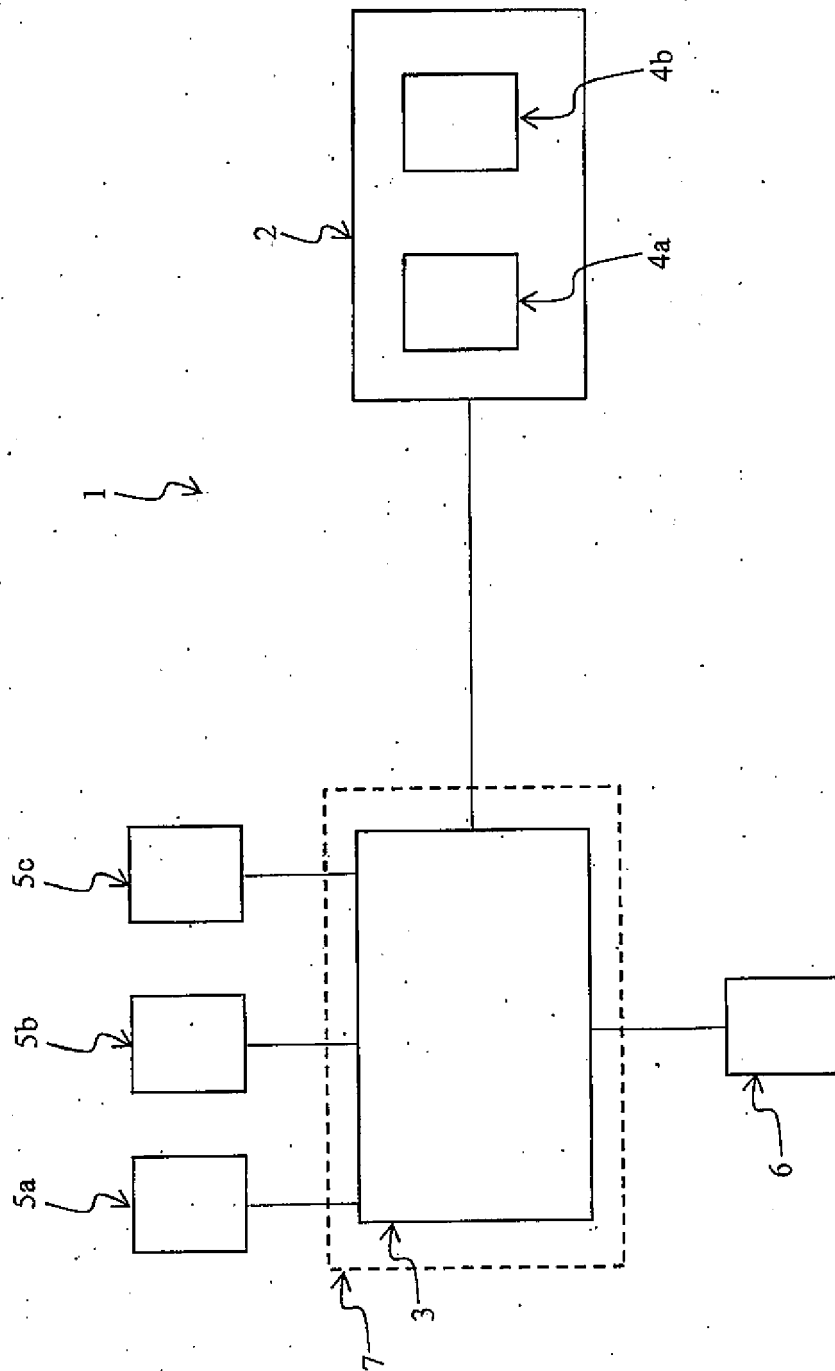


Figure 2

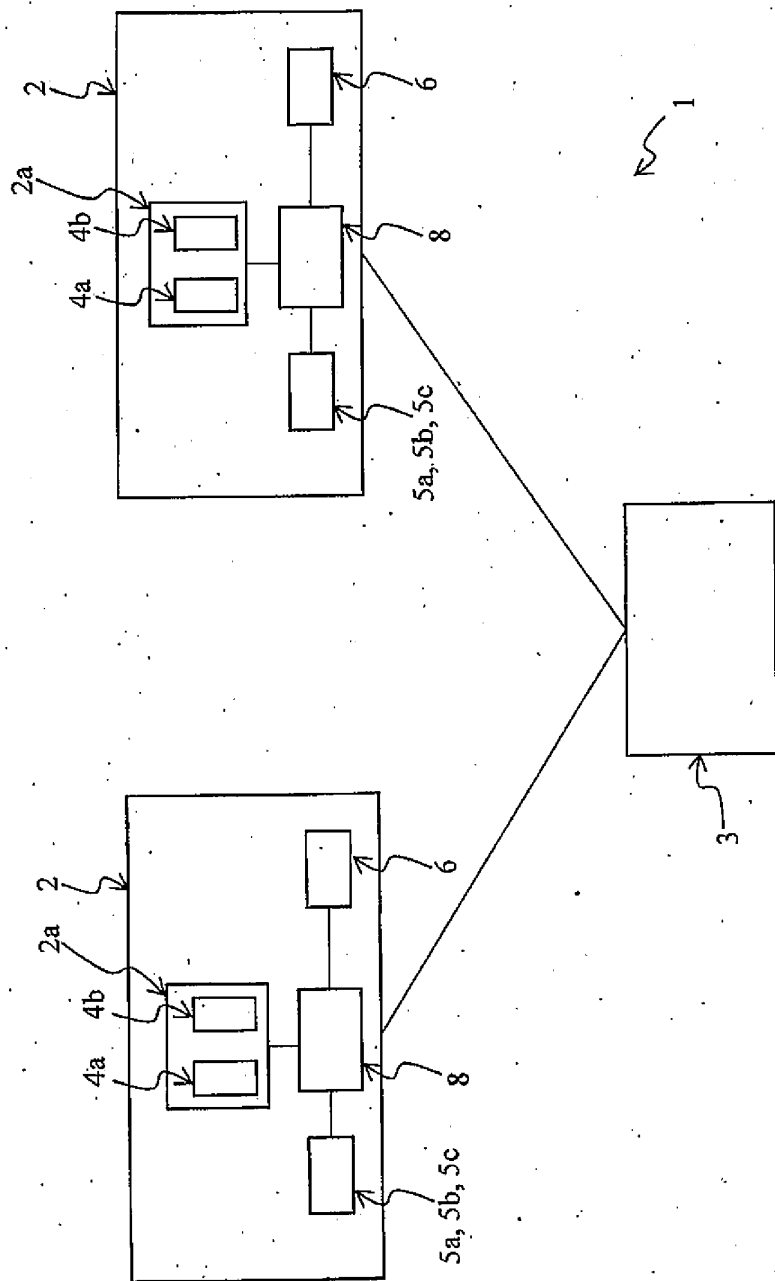


Figure 3

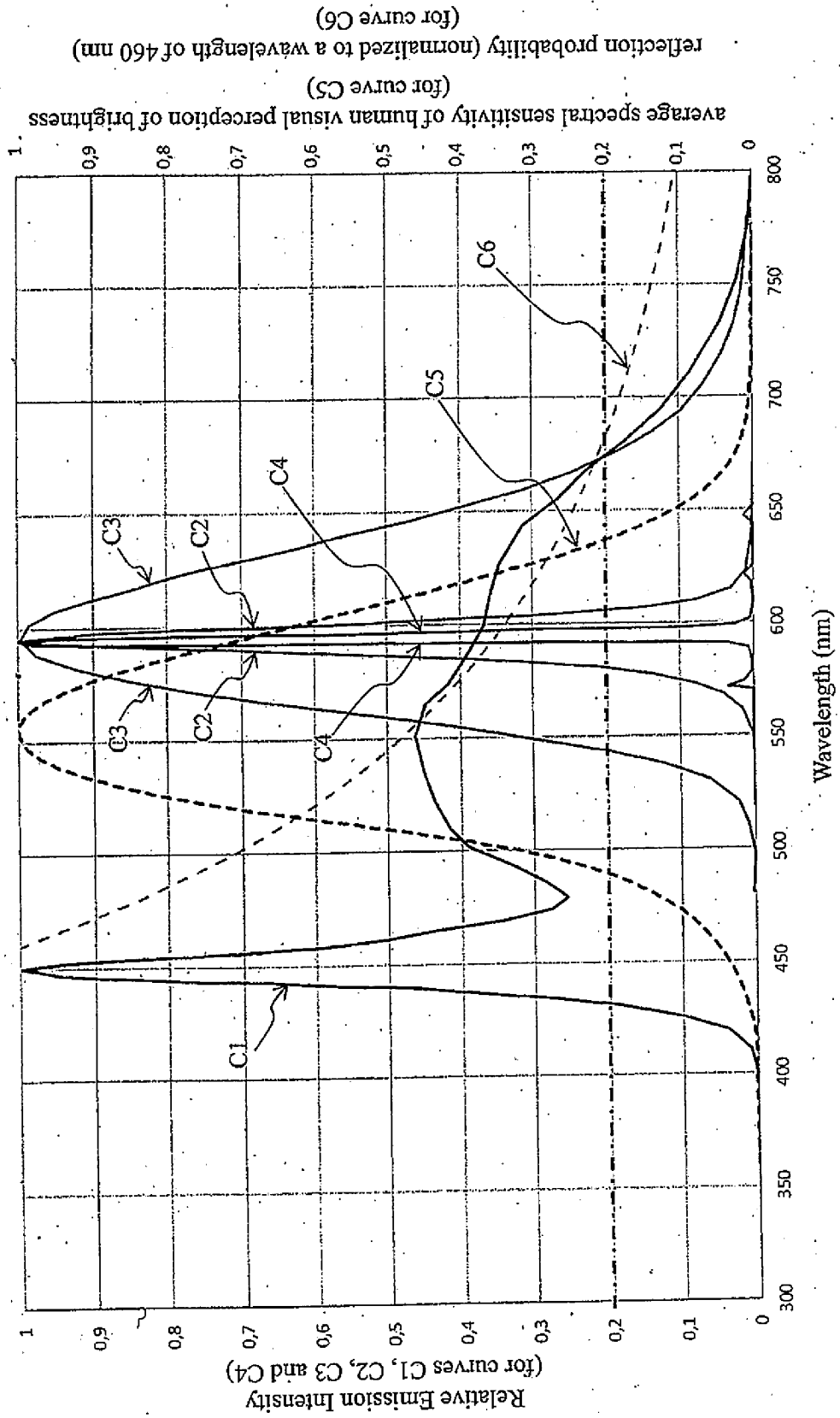


Figure 4

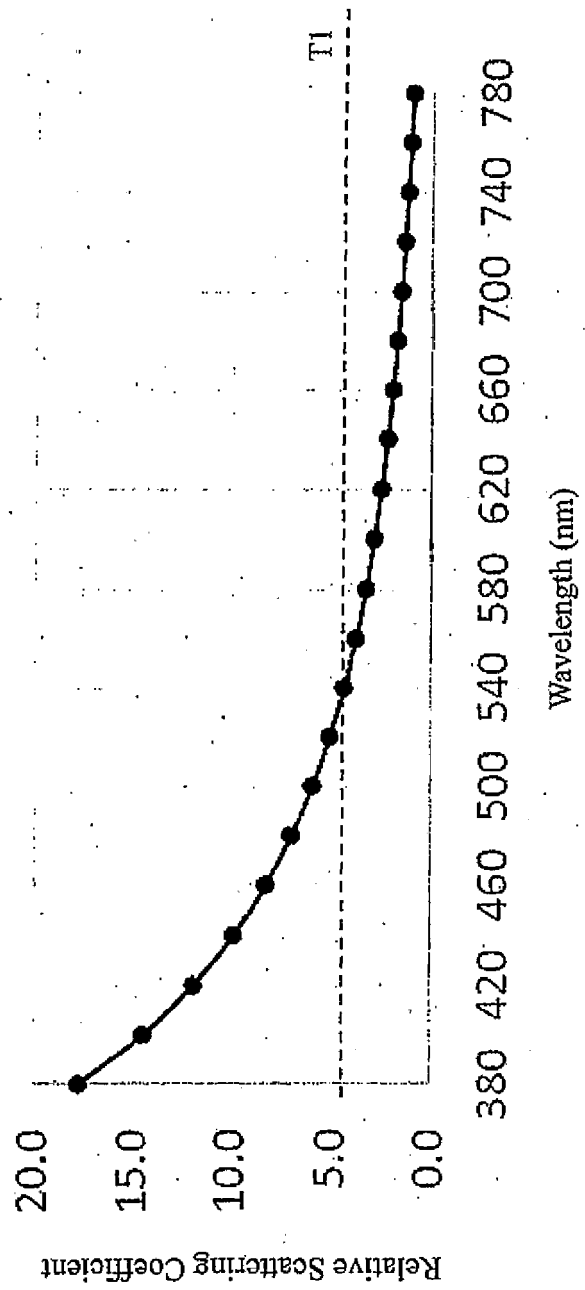


Figure 5

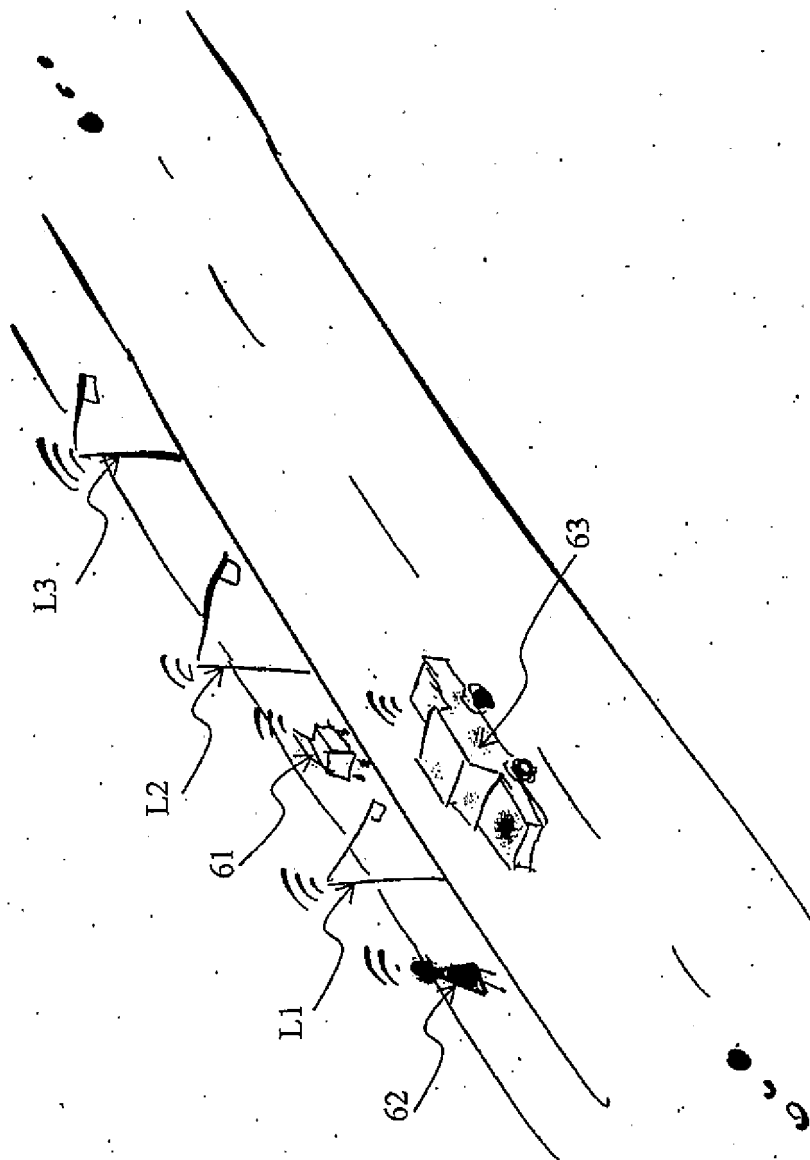


Figure 6

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 10405399 B1 [0004]
- DE 102008054050 A1 [0005]