DISCLOSURE OF INVENTION

Thus, embodiments of the present invention ~~aims at providing~~seek to provide a lighting system capable of solving the known state-of-the-art limitations, at least in part.

An aspect of the present ~~The~~ invention provides an ~~artificial~~ lighting system for illuminating an environment with a lighting that simulates natural lighting, which comprises, a first light source configured to emit a beam of visible light, a diffused-light generator delimited by an inner surface configured to receive the light beam, and by an outer surface, said diffused-light generator being at least partially transparent to the light beam, being configured to transmit at least part of the light beam, and being further configured to emit, through the outer surface, visible diffused light, the correlated color temperature (CCT) of the transmitted light being lower than the CCT of the visible diffused light, wherein it further comprises a dark structure, which is configured to be optically coupled to the environment via the diffused-light generator, and wherein, at least one portion of the dark structure has a substantially uniform absorption coefficient in the visible range, and the dark structure is configured to provide a substantially uniform background to the first light source, and/or at least one portion of the dark structure has an absorption coefficient in the visible range at least equal to 70%, and the dark structure is configured to provide a dark background to the first light source.~~as set forth in the independent claims with advantageous possible implementations being subject of the dependent claims.~~

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, embodiments are hereby described, purely as non-limitative examples and with reference to the enclosed drawings, wherein:

- Figures 1, 2 and 7 show schematic cross-sections of embodiments of the present lighting system;

- Figure 3 shows a schematic cross-section of a possible lighting system different from the present lighting system;

- Figures 4a and 4b schematically show perspective views of light sources;

- Figures 5a, 6 and 8 schematically show perspective views of portions of the present lighting system;

- Figure 5b shows a cross-section of a reflective element comprised in the lighting system's portion shown in Figure 5a;

- Figures 9a and 10 show perspective views of light sources;

- Figure 9b shows a cross-section of a portion of the light

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CLAIMS

1. A lighting system for illuminating ~~(1)~~ an environment ~~(6)~~ with a lighting that simulates natural lighting, which comprises:

- a first light source ~~(2)~~ configured to emit a beam of visible light;

- a diffused-light generator ~~(4;68)~~ delimited by an inner surface ~~(S_1,S_2)~~ configured to receive the light beam, and by an outer surface ~~(S_e)~~, said diffused-light generator being at least partially transparent to the light beam, being configured to transmit at least part of the light beam, and being further configured to emit, through the outer surface, visible diffused light, the correlated color temperature (CCT) of the transmitted light being lower than the CCT of the visible diffused light;

~~characterized in that~~ wherein it further comprises a dark structure ~~(10,12;300;310)~~, which is configured to be optically coupled to the environment via the diffused-light generator, and wherein:

- at least one portion of the dark structure has a substantially uniform absorption coefficient in the visible range, and the dark structure is configured to provide a substantially uniform background to the first light source; and/or

- at least one portion of the dark structure has an absorption coefficient in the visible range at least equal to 70%, and the dark structure is configured to provide a dark background to the first light source.

2. The lighting system according to claim 1, wherein said at least *one portion of the dark structure* ~~(10,12;300;310)~~ *has a* substantially uniform absorption coefficient in the visible range, and the dark structure is configured to provide a substantially uniform background to the first light source; and wherein said at least one portion of the dark structure has an absorption coefficient in the

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visible range at least equal to 70%, and the dark structure is configured to provide a dark background to the first light source.

3. The lighting system according to claim 1 or 2, wherein the dark structure ~~(10,12;300;310)~~ is configured to prevent the external light from illuminating the diffused-light generator ~~(4;68)~~ from upstream.

4. The lighting system according to any of the preceding claims, wherein the dark structure ~~(10,12;300;310)~~ is configured so that, when the first light source ~~(2)~~ is on, and given a direction sheaf ~~(200)~~ with a top angle of at least 0,1 sterad, in any first point ~~(220)~~ of at least one portion of the outer surface ~~(S_e)~~, a first and a second background luminances of said first point differ from one another by no more of 50% of the first background luminance, said first and second background luminances being measured respectively in a first and a second observation directions ~~(230,240)~~, the first observation direction being parallel to any of the directions of the direction sheaf and non-parallel to any of the local dazzling directions ~~(250)~~, the second observation direction being set apart from the first observation direction by an angular distance in the range 0,3°-1° and being non-parallel to any of the local dazzling directions, said local dazzling directions being the directions which are set apart by less of 3° from any direction ~~(260)~~ under which the first light source is seen from said first point, each of said first and second background luminances being formed only by the light rays which have hit the dark structure and have never passed through the environment ~~(6)~~.

5. The lighting system according to claim 4, wherein said direction sheaf ~~(200)~~ is conical and has an axis ~~(210)~~ directed along an axis direction, said axis direction being parallel to a direction ~~(260)~~ under which the first light source ~~(2)~~ is seen from at least a

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second point of said portion of the outer surface ~~(S_2)~~.

6. The lighting system according to claim 4 or 5, wherein the dark structure ~~(10;12;300;310)~~ is further configured to prevent that, when the first light source ~~(2)~~ is on, said first background luminance is greater than a threshold luminance value equal to 30% of the overall luminance of said first point ~~(220)~~ in said first observation direction ~~(230)~~, in the absence of light rays coming from the environment ~~(6)~~.

7. The lighting system according to any of the preceding claims, wherein said portion of the dark structure ~~(12;310)~~ has an area at least equal to 50% of the area of the inner surface ~~(S_1;S_3)~~.

8. The lighting system according to any of the preceding claims, wherein said portion of the dark structure ~~(310)~~ is edge-free.

9. The lighting system according to any of the preceding claims, wherein the diffused-light generator ~~(4;68)~~ is such that the CCT of the transmitted light is not greater than the CCT of the light beam.

10. The lighting system according to any of the preceding claims, wherein the diffused-light generator ~~(4;68)~~ is such that the CCT of the visible diffused light is greater than the CCT of the light beam.

11. The lighting system according to any of the preceding claims, wherein the first light source ~~(2)~~ is configured so that, on the inner surface ~~(S_1)~~, the illuminance varies between a minimum value and a maximum value, the maximum value being not greater than three times the minimum value.

12. The lighting system according to any of the preceding claims,

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wherein the diffused-light generator ~~(6; 68)~~ is arranged with respect to the first light source ~~(2)~~ so that the relation

$$|\tan(\theta_1 - \theta_e)| \leq 0{,}5 \cdot \cos(\theta_1)$$

holds true, wherein:

- θ_1 is the angle at which a first light ray of the light beam, which originates from the barycenter ~~(O'')~~ of an emitting surface ~~(S_E)~~ of the first light source, impinges on the barycenter of the inner surface; and

- θ_e is the angle at which a second light ray, which originates from the barycenter of the emitting surface of the first light source, impinges on a point of the boundary of the inner surface, said point being the point among the points of the boundary having maximum distance from the barycenter of the inner surface.

13. The lighting system according to any of claims 1-11, wherein the diffused-light generator ~~(4;68)~~ is arranged with respect to the first light source ~~(2)~~ so that the relation

$$|\tan(\theta_1 - \theta_2)| \leq X \cdot \cos(\theta_1)/L$$

holds true for at least one point of the inner surface ~~(S_2)~~ spaced apart from a barycenter ~~(O)~~ of the inner surface ~~(S_E;S_R)~~ by X, wherein:

- θ_1 is the angle at which a first light ray of the light beam, which originates from the barycenter ~~(O'')~~ of an emitting surface ~~(S_E)~~ of the first light source, impinges on the barycenter of the inner surface;

- θ_2 is the angle at which a second light ray, which originates from the barycenter of the emitting surface of the first light source, impinges on said at least one point of the inner surface; and

- L is equal to, or greater than, three meters.

14. The lighting system according to any of claims 1-11, wherein

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the diffused-light generator ~~(6; 68)~~ is arranged with respect to the first light source ~~(2)~~ so that the relation

$$\left|\tan(\theta_1 - \theta_2)\right| \leq X \cdot \cos(\theta_1)/L$$

holds true for at least one point of the inner surface ~~(S_2)~~ spaced apart from a barycenter ~~(O)~~ of the inner surface ~~(S_1;S_2)~~ by X, wherein:

- θ_1 is the angle at which a first light ray of the light beam, which originates from the barycenter ~~(O'')~~ of an emitting surface ~~(S_E)~~ of the first light source, impinges on the barycenter of the inner surface;
- θ_2 is the angle at which a second light ray, which originates from the barycenter of the emitting surface of the first light source, impinges on said at least one point of the inner surface; and
- L is equal to at least 70% of the maximum distance between any two points of the inner surface.

15. The lighting system according to any of the preceding claims, wherein the first light source ~~(2)~~ is arranged off-axis with respect to a line ~~(H)~~ perpendicular to the inner surface ~~(S_1;S_2)~~ and passing through the barycenter ~~(O)~~ of the inner surface ~~(S_1;S_2)~~.

16. The lighting system according to any of the preceding claims, further comprising a reflective optical system ~~(20)~~ arranged inside the dark structure ~~(10)~~ and configured to convey the light beam onto the inner surface ~~(S_1;S_2)~~, said reflective optical system being such that light rays coming, in use, from the inner surface and impinging onto the reflective optical system are not reflected onto the inner surface.

17. The lighting system according to claim 16, wherein the

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reflective optical system ~~(20)~~ comprises a first mirror ~~(22)~~ of a plane type.

18. The lighting system according to claim 17, wherein said first mirror ~~(22)~~ is arranged parallel to the inner surface ~~(S_1,S_2)~~, in a manner such that the projection of the first mirror onto a plane containing the inner surface does not overlap with the inner surface.

19. The lighting system according to claim 16, wherein the reflective optical system ~~(20)~~ comprises a first mirror ~~(22;24)~~ of the converging type.

20. The lighting system according to claim 19, wherein the first mirror ~~(22)~~ is shaped as a portion of a circular paraboloid.

21. The lighting system according to claim 19, wherein the first mirror ~~(22)~~ is shaped as a portion of a parabolic cylinder.

22. The lighting system according to claim 21, wherein the reflective optical system ~~(20)~~ further comprises a second mirror ~~(24)~~ shaped as a part of a parabolic cylinder, the axes of the first and second mirrors being substantially orthogonal to each other.

23. The lighting system according to claim 22, wherein the first and second mirrors ~~(22;24)~~ are arranged so as to share a common focus, the first light source ~~(2)~~ being arranged substantially in the common focus.

24. The lighting system according to any of claims 17-23, wherein the reflective optical system ~~(20)~~ forms an optical path connecting the first light source ~~(2)~~ to the inner surface ~~(S_1,S_2)~~, the first mirror ~~(22)~~ causing a last deviation of the light path before the

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inner surface ~~(S_1,S_2)~~; and wherein a light ray connecting the barycenter ~~(O')~~ of the first mirror to the barycenter ~~(O)~~ of the inner surface *via* the reflective optical system forms an angle within 40° to 65°, both inclusively, relative to a direction perpendicular to the inner surface in the barycenter of the inner surface.

25. The lighting system according to any of claims 1-8, further comprising a reflective optical system ~~(20)~~ arranged inside the dark structure ~~(310)~~ and configured to convey the light beam onto the inner surface ~~(S_2,S_3)~~, said reflective optical system being such that light rays coming, in use, from the inner surface and impinging onto the reflective optical system are not reflected onto the inner surface; said reflective optical system comprising a first mirror ~~(22)~~ and forming an optical path connecting the first light source ~~(2)~~ to the inner surface ~~(S_1,S_3)~~, the first mirror ~~(22)~~ causing a last deviation of the optical path before the inner surface ~~(S_2,S_3)~~; and wherein the line passing through the two closest points of the inner surface ~~(S_2)~~ and the first mirror ~~(22)~~ impinges on said portion of the dark structure ~~(310)~~.

26. The lighting system according to any of the preceding claims, wherein the first light source ~~(2)~~ is formed by a plurality of light emitting devices ~~(52)~~ and a plurality of reflective concentrators ~~(54)~~, each reflective concentrator being funnel-shaped and having an input aperture ~~(IN)~~ and an output aperture ~~(OUT)~~, the area of the input aperture being smaller than the area of the output aperture, each light emitting device being optically coupled to the input aperture of a respective reflective concentrator.

27. The lighting system according to claim 26, wherein the output aperture ~~(OUT)~~ of each reflective concentrator ~~(54)~~ is shaped as a rectangle.

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28. The lighting system according to any of claims 16-25, wherein the first light source ~~(2)~~ is formed by a plurality of light emitting devices ~~(52)~~ and a plurality of reflective concentrators ~~(54)~~, each reflective concentrator being funnel-shaped and having an input aperture ~~(IN)~~ and an output aperture ~~(OUT)~~, the area of the input aperture being smaller than the area of the output aperture, each light emitting device being optically coupled to the input aperture of a respective reflective concentrator; and wherein the output apertures ~~(OUT)~~ are elongated along an elongation direction ~~(57)~~, said light beam having an axis of maximum divergence ~~(58)~~, the reflective optical system ~~(20)~~ being configured so that, in use, a bundle of light rays emanating from the barycenter ~~(O")~~ of an emitting surface ~~(S_4)~~ of the first light source ~~(2)~~ and lying in the plane of maximum divergence impinges on the inner surface ~~(S_1,S_3)~~ along a line tangent to an axis ~~(y)~~ that passes through the barycenter of the inner surface and is perpendicular to the plane of incidence of a carrier ray onto the first mirror, the carrier ray being the light ray connecting the barycenter of the emitting surface to the barycenter of the inner surface, via the reflective optical system.

29. The lighting system according to claim 28, wherein the reflective optical system ~~(20)~~ is configured so that the carrier ray lies in a single plane, and wherein the first light source ~~(2)~~ is arranged so that said axis of maximum divergence is perpendicular to said single plane.

30. The lighting system according to any of claims 26-29, wherein the first light source ~~(2)~~ further comprises a mask ~~(60)~~ having a circular or elliptical overall aperture ~~(62)~~, said mask being coplanar with said output apertures ~~(OUT)~~, said mask being suitable for blocking light coming from portions of the output apertures which are

arranged around said overall aperture.

31. The lighting system according to any of the preceding claims, wherein the diffused-light generator comprises a first diffuser ~~(4)~~ configured to substantially not absorb light in the visible range and to diffuse more efficiently the short-wavelengths components in respect to the long-wavelength components of the light beam, said diffuser being configured to diffuse light rays with wavelength equal to 450nm at least 1.2 times more efficiently than light rays with wavelength equal to 650nm.

32. The lighting system according to claim 31, wherein the first diffuser ~~(4)~~ comprises a matrix of a first material wherein first particles of a second material are dispersed, said first and second materials having, respectively, a first and a second refractive indexes, said first particles having equivalent diameters such that the product of said equivalent diameters times the first refractive index is in the range 5 nm-350 nm.

33. The lighting system according to claim 32, wherein the first light source ~~(2)~~ and the density of the particle distribution across the first diffuser ~~(4)~~ are such that the product between the density and the illuminance provided by the first light source, when in use, on the first diffuser is substantially constant on the first diffuser.

34. The lighting system according to any of claims 31-33, wherein said first diffuser ~~(4)~~ has a panel shape, at least one of said inner and outer surfaces ~~(S_1, S_2)~~ being formed by the first diffuser.

35. The lighting system according to any of the preceding claims, wherein the diffused-light generator comprises a second light source ~~(68)~~ configured to emit at least a portion of said visible diffused

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light independently from the first light source ~~(2)~~.

36. The lighting system according to claim 35, wherein the second light source ~~(68)~~ comprises:

- a second diffuser ~~(64)~~ shaped as a light-guiding panel and configured to be edge-lit; and

- an illuminator ~~(66)~~ for edge lighting the second diffuser ~~(64)~~.

37. The lighting system according to claim 36, wherein the CCT of at least one of the first light source ~~(2)~~ and the illuminator ~~(66)~~ is variable in a controllable manner.

38. The lighting system according to any of claims 35-37, wherein the second light source ~~(68)~~ comprises an OLED.

39. The lighting system according to any of the preceding claims, wherein the diffused-light generator ~~(4;68)~~ has an elongated shape.

40. The lighting system according to any of the preceding claims, further comprising an optical reference arranged downstream the diffused-light generator ~~(4;68)~~ and formed by a reflecting surface ~~(320)~~, a portion of said reflecting surface being delimited by a corresponding edge portion and being configured so that:

- said portion of said reflecting surface and said edge portion are lit by light generated by the first light source ~~(2)~~ and transmitted by the diffused-light generator; and

- the shortest of the optical paths connecting the first light source to said portion of said reflecting surface has a length equal to at least 70% of the maximum distance between any two points of said portion of said reflecting surface.

41. The lighting system according to any of claims 1-39, further

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comprising an optical reference arranged downstream the diffused-light generator ~~(4;68)~~ and formed by a diaphragm ~~(350)~~ delimiting an aperture between environments, a portion of said aperture between environments being delimited by a corresponding edge portion and being configured so that:

- said portion of said aperture between environments and said edge portion are lit by light generated by the first light source ~~(2)~~ and transmitted by the diffused-light generator; and

- the shortest of the optical paths connecting the first light source to said portion of said aperture between environments has a length equal to at least 70% of the maximum distance between any two points of said portion of said aperture between environments.

42. A building comprising the lighting system ~~(1)~~ according to any of the preceding claims and a wall ~~(P2)~~ of said environment ~~(6)~~, wherein said wall forms a cavity ~~(8)~~, the diffused-light generator ~~(4;68)~~ extending inside the cavity ~~(8)~~.