

CLAIMS:

1. A pixel comprising a first sub-pixel, wherein the first sub-pixel comprises:
 - 5 an LED layer comprising a light-emitting material configured to emit pump light from a light-emitting surface, the pump light having a pump wavelength;
 - a container layer having a container surface comprising a first container aperture that defines a first container volume extending through the container layer;
 - a first colour converting layer provided in the first container volume and
 - 10 configured to receive light from the light-emitting surface of the LED layer, wherein the first colour converting layer comprises a first colour converting material that is configured to absorb light at the pump wavelength and emit first converted light of a first converted wavelength;
 - a first lens provided on the container layer over the first container aperture,
 - 15 comprising an inner side adjacent to the colour converting layer and an outer side, wherein the outer side comprises a first convex surface;
 - a first reflector assembly adjacent the outer side of the first lens and conforming to the first convex surface, the first reflector assembly comprising: - a first reflector configured to reflect light at the pump wavelength and
 - 20 transmit light at the first converted wavelength; and
 - a second reflector configured to reflect light at both the pump wavelength and the first converted wavelength;
 - wherein the second reflector comprises a first sub-pixel reflector aperture and wherein the first reflector fills the first sub-pixel reflector aperture.
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2. The pixel of claim 1 further comprising a second sub-pixel, wherein the second sub-pixel comprises:
 - an LED layer comprising a light-emitting material configured to emit pump
 - light from a light-emitting surface, the pump light having the pump wavelength;
 - 30 a container layer having a container surface comprising a second container aperture that defines a second container volume extending through the container layer;
 - a second colour converting layer provided in the second container volume and configured to receive light from the light-emitting surface of the LED layer,
 - 35 wherein the second colour converting layer comprises a second colour converting

material that is configured to absorb light at the pump wavelength and emit second converted light of a second converted wavelength;

a second lens provided on the container layer over the second container aperture, comprising an inner side adjacent to the colour converting layer and an outer side, wherein the outer side comprises a second convex surface;

a second reflector assembly adjacent the outer side of the second lens and conforming to the second convex surface, the second reflector assembly comprising:

a third reflector configured to reflect light at the pump wavelength and transmit light at the second converted wavelength; and

a fourth reflector configured to reflect light at both the pump wavelength and the second converted wavelength;

wherein the fourth reflector comprises a second sub-pixel reflector aperture and wherein the third reflector fills the second sub-pixel reflector aperture.

3. The pixel of any preceding claim further comprising a third sub-pixel that emits light at the pump wavelength, wherein the third sub-pixel comprises:

an LED layer comprising a light-emitting material configured to emit pump light from a light-emitting surface, the pump light having the pump wavelength;

a container layer having a container surface comprising a third container aperture that defines a third container volume through the container layer;

a lens provided on the container layer over the third container aperture, comprising an inner side adjacent to the container layer and an outer side, wherein the outer side comprises a third convex surface;

a third reflector assembly adjacent to the outer side of the third lens and conforming to the third convex surface, the third reflector assembly comprising:

a fifth reflector configured to reflect pump light, wherein the fifth reflector comprises a third sub-pixel reflector aperture.

4. The pixel of claim 1 wherein a central axis of the first reflector and a central axis of the second reflector are aligned with a central axis of the convex surface.

5. The pixel of any preceding claim wherein one or both of the first reflector and the third reflector comprises a laminate structure.

6. The pixel of claim 5 wherein one or both of the first reflector and the third reflector comprises alternating layers of higher and lower refractive index.
7. The pixel of claim 6 wherein one or both of the first reflector and the third reflector comprises a plurality of layers of TiO_2 and SiO_2 .
8. The pixel of any preceding claim wherein one or both of the first reflector and the third reflector comprises a distributed Bragg reflector.
9. The pixel of any preceding claim wherein at least one of the second reflector, fourth reflector and fifth reflector comprises a metallic material.
10. The pixel of any preceding claim, wherein the at least one of the first container volume, second container volume and third container volume comprises reflective inner sidewalls.
11. The pixel of any preceding claim, wherein the area of at least one of the first container aperture, second container aperture and third container aperture is at least equal to the area of the light-emitting surface of the LED layer.
12. The pixel of any preceding claim, wherein an inner sidewall of at least one of the first container volume, second container volume and third container volume forms an angle relative to the normal to the light-emitting surface of the LED layer of at least 35° and no greater than 85° , or preferably no greater than 60° .
13. The pixel of claim 12, wherein at least one of the first container aperture, second container aperture and third container aperture is circular such that the corresponding container volume resembles a truncated inverted cone, or wherein at least one of the first container aperture, second container aperture or third container aperture is rectangular such that the corresponding container volume resembles a truncated inverted square pyramid.
14. The pixel of any preceding claim, wherein at least one of the first lens, second lens and third lens is hemispherical.

15. The pixel of any preceding claim, wherein at least one of the first convex surface, second convex surface and third convex surface is elliptical or parabolic.
- 5 16. The pixel of any preceding claim wherein a characteristic dimension of the lens is at least twice as large as a characteristic dimension of the aperture in the plane of the container layer.
- 10 17. The pixel of any preceding claim, further comprising a converted light reflector laminate at an interface between the LED layer and the colour converting layer.
18. The pixel of any preceding claim wherein the full-width half-maximum of the light at the converted wavelength that is transmitted through one or both of the first reflector and the third reflector is less than 60° , or preferably less than 50° .
- 15 19. The pixel of any preceding claim wherein the reflectance of one or both of the first reflector and the third reflector to light at the pump wavelength is more than 95 %, or preferably 100%.
- 20 20. The pixel of any preceding claim wherein the reflectance of one or both of the first reflector and the third reflector to light at the converted wavelength is less than 10 %, or preferably less than 5%.
- 25 21. The pixel of any preceding claim wherein the converted wavelength is longer than the pump wavelength.
22. The pixel of any preceding claim wherein one or both of the first colour converting material and the second colour converting material comprises a quantum dot material.
- 30 23. The pixel of any preceding claim, wherein the pump wavelength is blue and the first converted wavelength is a first one of a colour group comprising red and green.
- 35 24. The pixel of claim 23 when dependent upon claim 2 or any claim dependent upon claim 2 wherein the second converted wavelength is a second one of the colour group.

25. The pixel of claim 3 wherein the container volume of the third sub-pixel is filled with a translucent material.