

CLAIMS:

1. A micro-LED comprising:
a mesa structure including a recess;
5 a semiconductor material provided in the recess, comprising a first surface adjacent the mesa substrate, a second surface opposite the first surface, and a light emission region configured to emit light in response to application of an electrical current;
wherein the second surface comprises a convex surface;
wherein light emitted by the light emission region incident on the convex
10 surface is transmitted through the convex surface if an angle of incidence to the normal of the convex surface is smaller than a critical angle, and is refracted upon transmission through the convex surface;
wherein the light emission region is located proximate the focal plane of the convex surface;
15 wherein an area of the light emission region is smaller than a cross-sectional area of the convex surface in a plane parallel to the light emission region.
2. The micro-LED of claim 1, wherein the distance from the light emission region to the focal plane of the convex surface is less than 35 % of the focal length of the
20 convex surface.
3. The micro-LED of claim 2, wherein the distance from the light emission region to the focal plane of the convex surface is preferably less than 25 %, or more preferably less than 10 %.
- 25 4. The micro-LED of claim 1, wherein the area of the light emission region is less than 20 % of the cross-sectional area of the convex surface.
5. The micro-LED of claim 4, wherein the area of the light emission region is
30 preferably less than 10 % of the cross-sectional area of the convex surface, or more preferably less than 5 % of the cross-sectional area of the convex surface.
6. The micro-LED of any preceding claim wherein the full width half maximum of light
35 emitted by the light emission region that is transmitted through the convex surface is less than 60 degrees.

7. The micro-LED of any preceding claim wherein the full width half maximum of light emitted by the light emission region that is transmitted through the convex surface is preferably less than 45 degrees, or more preferably less than 30 degrees, or still more preferably less than 25 degrees.
8. The micro-LED of claim 1, wherein a cross-section of the convex surface is circular.
9. The micro-LED of any preceding claim, wherein a radius of curvature of the convex surface is larger than the cross-sectional radius of a widest part of the convex surface.
10. The micro-LED of any preceding claim, wherein a central axis of the light emission region is aligned with respect to a central axis of the convex surface.
11. The micro-LED of claim any preceding claim, further comprising a reflective metal layer between the mesa structure and the semiconductor material.
12. The micro-LED of claim any preceding claim, wherein the light emission region is closer to the mesa structure than to the convex surface.
13. The micro-LED of any preceding claim, wherein a plurality of micro-LEDs are arranged in an array.
14. The micro-LED array of claim 13, wherein the micro-LEDs are arranged in rows and columns.
15. The micro-LED of claim 1 wherein the electrical current is applied using a first electrode adjacent to the first surface of the semiconductor material and a second electrode adjacent to the second surface of the semiconductor material.
16. The micro-LED of claim 15 wherein a central axis of the first electrode is aligned with respect to a central axis of the convex surface.

17. The micro-LED of claim 16 wherein the radius of the light emission region is defined by the radius of the first electrode.
18. The micro-LED of claim 17 wherein the area of the first electrode is less than 20 %
5 of the cross-sectional area of the convex surface.
19. The micro-LED of claim 18 wherein the area of the first electrode is preferably less than 10 % of the cross-sectional area of the convex surface, or more preferably less than 5 % of the cross-sectional area of the convex surface.
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20. The micro-LED of claim 1 wherein a cross-sectional area of the recess is larger than the area of the light emission region.
21. The micro-LED of claim 20 wherein an edge of the light emission region may be
15 more than 1 μm from an edge of the recess.