CURVED LIGHT DUCT EXTRACTION

Related Cases

This application is related to the following U.S. Patent Application filed on an even herewith, entitled RECTANGULAR LIGHT DUCT EXTRACTION ~~(Attorney Docket No. 70058US002)~~, and which is incorporated herein by reference.

Background

The long-distance transport of visible light through a building can use large mirror-lined ducts, or smaller solid fibers which exploit total internal reflection. Mirror-lined ducts include advantages of large cross-sectional area and large numerical aperture (enabling larger fluxes with less concentration), a robust and clear propagation medium (that is, air) that leads to both lower attenuation and longer lifetimes, and a potentially lower weight per unit of light flux transported.

Summary

The present disclosure describes light delivery and distribution components of a ducted lighting system having a cross-section that includes at least one curved portion, and a light source. The delivery and distribution system (that is, light duct and light duct extractor) can function effectively with any light source that is capable of delivering light which is substantially collimated about the longitudinal axis of the light duct, and which is also preferably substantially uniform over the inlet of the light duct. In one aspect, the present disclosure provides a lighting element that includes a light duct having a longitudinal axis, a reflective interior surface defining a cavity, and a curved cross-section; a plurality of voids disposed in the reflective interior surface and defining a light output surface of the curved cross-section, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis, and wherein the plurality of voids are disposed such that an areal density of voids varies across the radial output angle; and a turning film disposed adjacent the light output surface and exterior to the cavity, the turning film comprising parallel ridged microstructures, each of the parallel ridged microstructures having a vertex adjacent the exterior surface of the light duct. Light rays propagating through the light duct that intersect the plurality of voids exit the light duct radially through the plurality of voids and are redirected within a plane normal to the parallel ridged microstructures by the turning film. In yet another aspect, the present disclosure provides a lighting system that includes a light distribution duct including at least one lighting element; and at least one light source capable of injecting

light in a propagation direction parallel to the longitudinal axis, the light having a collimation half-angle less than about 30 degrees.

In another aspect, the present disclosure provides a lighting element that includes a light duct having a longitudinal axis, a reflective interior surface defining a cavity, and a cross-section having a curved light output surface; a plurality of voids disposed in the curved light output surface of the reflective interior surface, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis, and wherein the plurality of voids are disposed such that an areal density of voids varies across the radial output angle; and a turning film disposed adjacent the curved light output surface and exterior to the cavity, the turning film comprising parallel ridged microstructures, each of the parallel ridged microstructures having a vertex adjacent the exterior surface of the light duct. Light rays propagating through the light duct that intersect the plurality of voids exit the light duct radially through the plurality of voids and are redirected within a plane normal to the parallel ridged microstructures by the turning film. In yet another aspect, the present disclosure provides a lighting system that includes a light distribution duct including at least one lighting element; and at least one light source capable of injecting light in a propagation direction parallel to the longitudinal axis, the light having a collimation half-angle less than about 30 degrees.

In yet another aspect, the present disclosure provides a lighting element that includes a cylindrical light duct having a central longitudinal axis; a reflective interior surface disposed on a circumference around the longitudinal axis and defining a cavity; a plurality of voids disposed on a light output surface of the reflective interior surface, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis, and wherein the plurality of voids are disposed such that an areal density of voids varies across the radial output angle; and a turning film disposed adjacent the plurality of voids and exterior to the cavity, the turning film comprising a plurality of parallel ridged microstructures perpendicular to the longitudinal axis. Light rays propagating through the cylindrical light duct that intersect the plurality of voids exit the light duct radially through the plurality of voids and are redirected within a plane normal to the parallel ridged microstructures by the turning film. In yet another aspect, the present disclosure provides a lighting system that includes a light distribution duct including at least one lighting element; and at least one light source capable of injecting light in a propagation direction parallel to the longitudinal axis, the light having a collimation half-angle less than about 30 degrees.

The above summary is not intended to describe each disclosed embodiment or every implementation of the present disclosure. The figures and the detailed description below more particularly exemplify illustrative embodiments.

What is claimed is:

1. A lighting element, comprising:

a light duct having a longitudinal axis, a reflective interior surface defining a cavity, and a curved cross-section;

a plurality of voids disposed in the reflective interior surface and defining a light output surface of the curved cross-section, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis, and wherein the plurality of voids are disposed such that an areal density of voids varies across the radial output angle; and

a turning film disposed adjacent the light output surface and exterior to the cavity, the turning film comprising parallel ridged microstructures, each of the parallel ridged microstructures having a vertex adjacent an exterior surface of the light duct,

wherein light rays propagating through the light duct that intersect the plurality of voids exit the light duct radially through the plurality of voids and are redirected within a plane normal to the parallel ridged microstructures by the turning film.

2. The lighting element of claim 1, wherein each of the parallel ridged microstructures are orientated perpendicular to the longitudinal axis.

3. The lighting element of claim 1, wherein each of the parallel ridged microstructures are immediately adjacent the light output surface.

4. The lighting element of claim 1, wherein light rays propagate in a light duct propagation direction within a collimation half-angle of the longitudinal axis, and exit in an exit propagation direction that is different than the light duct propagation direction.

5. The lighting element of claim 1, wherein the curved cross-section comprises a circle, an oval, an ellipse, an arc, or a combination thereof.

6. The lighting element of claim 1, wherein the plurality of voids are disposed in the reflective interior surface radially, longitudinally, or in a combination thereof.

~~7. The lighting element of claim 1, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis.~~

~~8~~7. The lighting element of claim 1, wherein at least two of the plurality of voids have a different cross-sectional area.

~~9~~8. The lighting element of claim ~~7~~1, wherein the ~~plurality of voids are disposed such that an~~ areal density of voids varies ~~across the radial output angle, varies~~ parallel to the longitudinal axis~~, or varies across a combination thereof~~.

~~10~~9. The lighting element of claim 1, wherein each of the plurality of voids has a uniform cross-sectional area.

~~11~~10. The lighting element of claim 1, wherein the vertex of each of the parallel ridged microstructures have an equivalent vertex angle.

~~12~~11. The lighting element of claim 1, wherein the vertex of at least two of the parallel ridged microstructures have different vertex angles.

~~13~~12. The lighting element of claim 1, wherein the plurality of voids comprise perforations through the reflective interior surface or visible light transparent regions of the reflective interior surface.

~~14~~13. A lighting element, comprising:

a light duct having a longitudinal axis, a reflective interior surface defining a cavity, and a cross-section having a curved light output surface;

a plurality of voids disposed in the curved light output surface of the reflective interior surface, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis, and wherein the plurality of voids are disposed such that an areal density of voids varies across the radial output angle; and

a turning film disposed adjacent the curved light output surface and exterior to the cavity, the turning film comprising parallel ridged microstructures, each of the parallel ridged microstructures having a vertex adjacent an exterior surface of the light duct,

wherein light rays propagating through the light duct that intersect the plurality of voids exit the light duct radially through the plurality of voids and are redirected within a plane normal to the parallel ridged microstructures by the turning film.

~~15~~14. The lighting element of claim ~~14~~13, wherein the cross-section comprises planar portions adjacent the curved light output surface.

~~16~~15. The lighting element of claim ~~14~~13, wherein each of the parallel ridged microstructures are orientated perpendicular to the longitudinal axis.

~~17~~16. The lighting element of claim ~~14~~13, wherein each of the parallel ridged microstructures are immediately adjacent the curved light output surface.

~~18~~17. The lighting element of claim ~~14~~13, wherein the light ray propagates in a light duct propagation direction within a collimation half-angle of the longitudinal axis, and exit in an exit propagation direction that is different than the light duct propagation direction.

~~19~~18. The lighting element of claim ~~14~~13, wherein the curved light output surface comprises a portion of a circle, an oval, an ellipse, an arc, or a combination thereof.

~~20~~19. The lighting element of claim ~~14~~13, wherein the plurality of voids are disposed in the reflective interior surface radially, longitudinally, or in a combination thereof.

~~21. The lighting element of claim 14, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis.~~

~~22~~20. The lighting element of claim ~~14~~13, wherein at least two of the plurality of voids have a different cross-sectional area.

~~23~~21. The lighting element of claim ~~21~~13, wherein the plurality of voids are disposed such that an areal density of voids varies ~~across the radial output angle, varies~~ parallel to the longitudinal axis~~, or varies across a combination thereof~~.

~~24~~22. The lighting element of claim ~~14~~13, wherein each of the plurality of voids has a uniform cross-sectional area.

~~25~~23. The lighting element of claim ~~14~~13, wherein the vertex of each of the parallel ridged microstructures have an equivalent vertex angle.

~~26~~24. The lighting element of claim ~~14~~13, wherein the vertex of at least two of the parallel ridged microstructures have different vertex angles.

~~27~~25. The lighting element of claim ~~14~~13, wherein the plurality of voids comprise perforations through the reflective interior surface or visible light transparent regions of the reflective interior surface.

~~28~~26. A lighting element, comprising:

a cylindrical light duct having a longitudinal axis and a circular cross-section;

a reflective interior surface disposed on a circumference around the longitudinal axis and defining a cavity;

a plurality of voids disposed on a light output surface of the reflective interior surface, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis, and wherein the plurality of voids are disposed such that an areal density of voids varies across the radial output angle; and

a turning film disposed adjacent the plurality of voids and exterior to the cavity, the turning film comprising a plurality of parallel ridged microstructures perpendicular to the longitudinal axis,

wherein light rays propagating through the cylindrical light duct that intersect the plurality of voids exit the light duct radially through the plurality of voids and are redirected within a plane normal to the parallel ridged microstructures by the turning film.

~~29~~27. The lighting element of claim ~~28~~26, wherein each of the parallel ridged microstructures are orientated perpendicular to the longitudinal axis.

~~30~~28. The lighting element of claim ~~28~~26, wherein each of the parallel ridged microstructures are immediately adjacent the light output surface.

~~31~~29. The lighting element of claim ~~28~~26, wherein light rays propagate in a light duct propagation direction within a collimation half-angle of the longitudinal axis, and exit in an exit propagation direction that is different than the light duct propagation direction.

~~32~~30. The lighting element of claim ~~28~~26, wherein the plurality of voids are disposed in the reflective interior surface radially, longitudinally, or in a combination thereof.

~~33. The lighting element of claim 28, wherein the plurality of voids are disposed within a radial output angle measured around the longitudinal axis.~~

~~34~~31. The lighting element of claim ~~28~~26, wherein at least two of the plurality of voids have a different cross-sectional area.

~~35~~32. The lighting element of claim ~~33~~26, wherein the plurality of voids are disposed such that an areal density of voids ~~varies across the radial output angle,~~ varies parallel to the longitudinal axis~~, or varies across a combination thereof~~.

~~36~~33. The lighting element of claim ~~28~~26, wherein each of the plurality of voids has a uniform cross-sectional area.

~~37~~34. The lighting element of claim ~~28~~26, wherein the vertex of each of the parallel ridged microstructures have an equivalent vertex angle.

~~38~~35. The lighting element of claim ~~28~~26, wherein the vertex of at least two of the parallel ridged microstructures have different vertex angles.

~~39~~36. The lighting element of claim ~~28~~26, wherein the plurality of voids comprise perforations through the reflective interior surface or visible light transparent regions of the reflective interior surface.

~~40~~37. The lighting element of claim 1, claim ~~14~~13, or claim ~~28~~26, wherein the plurality of voids comprise shapes selected from arcs, circles, ellipses, ovals, triangles, rectangles, pentagons, X-shapes, zig-zags, stripes, slashes, stars, and combinations thereof.

~~41~~38. A lighting system, comprising:

a light distribution duct including at least one lighting element of claim 1, claim ~~14~~13, or claim ~~28~~26; and

at least one light source capable of injecting light in a propagation direction parallel to the longitudinal axis, the light having a collimation half-angle less than about 30 degrees.

~~42~~39. The lighting system of claim ~~41~~38, further comprising a second light source configured to inject a second light into the light distribution duct within a collimation half-angle less than 30 degrees of the longitudinal axis.

~~43~~40. The lighting system of claim ~~42~~39, wherein at least one of the light source or the second light source comprises a solar light source.

~~44~~41. The lighting system of claim ~~43~~40, wherein the solar light source comprises a solar concentrator.