The non-circular core fiber 302 further includes the enclosed open cavity 358, which is sandwiched between the cladding 352 and the covering 360. The covering 360 has a circular geometry.

[0031] In one exemplary embodiment of the device 300 and referring to FIGS. 9 and 14, the fiber core 350 of the non-circular core fiber 302 is constructed out of poly (methyl methacrylate) ("PMMA") with a hexagonal geometry in a circumscribed ø660 µm diameter circle. The fiber core 350 is clad by the cladding 352 with an interior surface geometry 356 that has the same hexagonal geometry as the fiber core 350. However, the exterior surface geometry 354 of the cladding 352 is circular. The cladding 352 is constructed of a silicone with an ø740 µm OD. The lead-in fiber 304 of the device 300 has a 200 µm OD glass core and a 230 µm OD cladding. The length of the non-circular core fiber 302 is 30 cm. During operation, the core optical fiber 302 is filled with laser light having an angular distribution of a NA of 0.22. It should be noted that other embodiments could include different materials for both the core and cladding, including utilizing various transparent or translucent glasses and polymers. If the total length of the diffuser is short, then absorbance is not of primary concern, but the materials should not be opaque at the wavelengths of interest. For example, if the diffuser is to be used to provide UV illumination then a silica core light guide is appropriate, whereas use of mid wave IR light would encourage the use of a fluorite or silver halide glass. A wide range of injection moldable polymer materials are appropriate for visible and near IR applications, including but not limited to PMMA, poly carbonate (PC) and polystyrene (PS). Various castable materials including epoxies and silicones are also of interest. In all cases, care should be utilized to ensure the materials could handle the required amount of optical power without ill effects, such as melting or crazing.

[0032] FIG. 27 shows a map of the irradiance at the vertical cross-section (shown as "316" in FIG. 9) through the fiber core 350 taken just before the diffusing proximal end 310. The light source used is a 690 nm laser with 0.125 Watt launch power and this power was adjusted until the irradiance measured at

cross-sectional view of a square shaped non-circular core fiber 302 with the projected path of similar propagating rays. The skew ray 370 still propagates without crossing the central axis of the fiber core 350, but now its path is such that its energy can at some locations be found near the edges of the fiber core 350 while in other locations it can be found closer the center of the fiber core 350. A meridional ray 372 that starts on the central axis of the fiber core 350 can have a path that samples much of the area of the fiber core 350 without ever crossing the axis again. These two examples demonstrate how introducing a large set of rays with a range of different launch angles into a non-circular core fiber 302 can yield a “top hat” core irradiance distribution after a short propagation length that corresponds to only a few internal reflections.

[0034] Our study indicates that replacing the non-circular core fiber 302 shown in FIG. 14 with any of the above-discussed different embodiments of the non-circular core fiber 302 would still allow the device 300 to provide the desired “top hat” core irradiance distribution (e.g., FIGS. 13-18). For example, the fiber core 350 of FIG. 13 is same as the fiber core 350 shown in FIG. 14. They both are constructed out of PMMA with a hexagonal geometry in a circumscribed ø660 µm diameter circle.

The non-circular core fiber 302 of FIG. 13 differs from the core fiber of FIG. 14 because the cladding 352 of FIG. 13 has a hexagonal geometry. The cladding 352 of FIG. 13 is constructed of a fluorinated polymer in a circumscribed ø740 um diameter circle.

[0035] In another exemplary embodiment and referring to FIG. 15, the fiber core 350 has the same geometry and dimensions as the fiber core of FIG. 14 except that it is constructed out of polystyrene instead of PMMA. However, the non-circular core fiber 302 of FIG. 15 does not have the cladding 352. Instead, it (302) further includes the enclosed open cavity 358 and the covering 360. The covering 360 is constructed of a translucent Pebax® resin with an ø1000 µm OD and an ø900 µm inner diameter (“ID”). In this exemplary embodiment, the trapped air contained in open cavity 358 acts as a cladding to ensure the light is

and are clocked at 60º relative to the pair 361). Please note that while the embodiments discussed herein use 60º increments, other predetermined patterns such may also be suitable such as, without limitations, 45º, 72º, 90º, 120º, 180º increments.

[0043] Each scattering feature 362 can be created by a suitable art-disclosed laser. For example, a focused, mode-locked 532 nm 10 pico-second laser pulse at 1.5 Watts average power can create the features 362 shown in FIG. 10, which are comprised of three cylinders, each approximately 27 μm in diameter and 270 μm in length oriented around the central axis of the fiber core 350 at 60º increments. In another example, a series of 520 nm 400 femto-second laser pulses at 2.0 Watts average power focused through an objective lens with a numerical aperture of 0.4 can create the features 362 shown in FIG. 43 (discussed in more details below), each feature a sphere approximately 40 um in diameter centered around the central axis of the fiber core 350 at increments of 60º. Please note that while the embodiments discussed herein use 60º increments, other degree increments are also suitable such as 45º, 72º, 90º, 120º, 180º, etc.

[0044] The scattering characteristics of each of the features 362 are varied by material, geometry and processing. The proportion of light scattered per length or per feature 362 must increase as the density of light per length in the light diffusing section 308 decreases due to light being scattered out of the non-circular core fiber 302. This can be achieved by changing the number of features 362 per unit length or the size of the features 362 as a function of length. Depending on the amount of return light acceptable, linear increase in size may suffice but a non-linear increase in size vs length may be preferred. In another exemplary embodiment, the number of features 362 per unit length may increase while the size of the features 362 as a function of length may decrease. It should be noted that it is also possible for one skilled in the art to change the processing parameters in order to change the amount of scattering per feature 362.

Claims

1. A frontal light diffusing device for delivering a predetermined optical irradiance value to a targeted treatment area comprising a non-circular core fiber section having a proximal end, a distal end, an optical axis, and a non-circular fiber core; and a lens component having a lens; wherein

   a) the lens component is physically attached to the distal end of the non-circular core fiber section;

   b) the non-circular fiber core has a latitudinal, cross sectional shape of a regular polygon; and

   c) when the front light diffusing device is in light communication to a light source;

      i) the light source provides and transmits light rays to the frontal light diffusing device;

      ii) the light rays, having respective angles relating to the optical axis of the non-circular fiber section, enter the proximate end of the non-circular core fiber section and propagate internally within the non-circular fiber core while preserving the respective angles thereby achieving a “top hat” core irradiance distribution;

      iii) the light rays exit the distal end of the non-circular core fiber section in a mixed “top hat” spatial irradiance distribution;

      iv) the lens receives the light rays exiting the distal end of the non-circular core fiber section and projects the light rays onto the targeted treatment area located at a predetermined standoff distance from the lens resulting in the targeted treatment area receiving a targeted “top hat” spatial irradiance distribution with less than +/- 20% of the predetermined optical irradiance value; and

v) the physical attachment of the lens component to the distal end of the non-circular core fiber section is designed to reduce transmission loss during transmission of the light rays from the distal end of the non-circular core fiber to the lens.

2. The light diffusing device of Claim 1 further comprising a cylindrical optical fiber section having a proximal end and a distal end, wherein:

i. the proximal end of the cylindrical optical fiber section is in light communication with the light source, and the distal end of the cylindrical optical fiber section is in light communication with the proximal end of the non-circular core fiber section.

3. The light diffusing device of Claim 2 wherein the cylindrical optical fiber section and the non-circular core fiber section are connected via a fiber optic connector.

4. The light diffusing device of Claim 2 wherein the cylindrical optical fiber section and the non-circular core fiber section are connected via fusion bonding.

5. The light diffusing device of Claim 2 wherein the cylindrical optical fiber section and the non-circular core fiber section are connected via glue.

6. The light diffusing device of Claim 1 wherein latitudinal, cross sectional shape of the non-circular fiber core of the non-circular core section is

selected from the group consisting of hexagon, square, triangle, and octagon.

7. The light diffusing device of Claim 1 wherein the lens is a GRIN lens.

8. The light diffusing device of Claim 1 wherein latitudinal, cross sectional shape of the non-circular fiber core of the non-circular core section is a hexagon.

9. The light diffusing device of Claim 1 wherein latitudinal, cross sectional shape of the non-circular fiber core of the non-circular core section is a square.

10. The light diffusing device of Claim 1 wherein the non-circular fiber core of the non-circular core section has a helical or twisted shape.

11. The light diffusing device of Claim 1 wherein the non-circular core fiber section further comprises a covering, a cladding, and an enclosed open cavity located between, and created by, the covering and the cladding; wherein the cladding encloses the non-circular fiber core of the non-circular core fiber section.

12. The light diffusing device of Claim 11 wherein the cladding has an exterior, latitudinal, cross sectional shape that is different than the cladding's interior, latitudinal, cross sectional shape.

13. The light diffusing device of Claim 12 wherein the exterior, latitudinal, cross sectional shape of the cladding is circular, and the interior, latitudinal, cross sectional shape is same as the latitudinal, cross sectional, shape of the non-circular fiber core.

14. The light diffusing device of Claim 1 wherein the targeted “top hat” spatial irradiance distribution i) has an average (“I_0”) optical irradiance; and ii) is defined as variation of the spatial emitted irradiance at the targeted treatment area from the light diffusing device is less than +/- 20% of the average (“I_0”) optical irradiance.

15. The light diffusing device of Claim 1 wherein the targeted “top hat” spatial irradiance distribution i) has an average (“I_0”) optical irradiance; and ii) is defined as variation of the spatial emitted irradiance at the targeted treatment area from the light diffusing device is less than +/- 15% of the average (“I_0”) optical irradiance.

16. The light diffusing device of Claim 1 wherein the targeted “top hat” spatial irradiance distribution i) has an average (“I_0”) optical irradiance; and ii) is defined as variation of the spatial emitted irradiance at the targeted treatment area from the light diffusing device is less than +/- 10% of the average (“I_0”) optical irradiance.

17. A frontal light diffusing device for delivering a predetermined optical irradiance value to a targeted treatment area comprising a non-circular core

fiber section having a proximal end, a distal end, an optical axis, and a non-circular fiber core; and a collimation lens assembly; wherein

a) the collimation lens assembly is physically attached to the distal end of the non-circular core fiber section;

b) the non-circular fiber core has a latitudinal, cross sectional shape of a regular polygon; and

c) when the front light diffusing device is in light communication to a light source;

   i) the light source provides and transmits light rays to the frontal light diffusing device;

   ii) the light rays, having respective angles relating to the optical axis of the non-circular fiber section, enter the proximate end of the non-circular core fiber section and propagate internally within the non-circular fiber core while preserving the respective angles thereby achieving a “top hat” core irradiance distribution;

   iii) the light rays exit the distal end of the non-circular core fiber section in a mixed “top hat” spatial irradiance distribution;

   iv) the collimation lens assembly having a variable aperture that blocks portions of light rays exiting from the distal end of the non-circular core fiber section thereby allowing only a central portion of the light rays to exit through the variable aperture and to project onto the targeted treatment area resulting in the targeted treatment area receiving a targeted “top hat” spatial irradiance distribution with less than +/- 20% difference in irradiance between in near field, far field, and distance between the near field and the far field.