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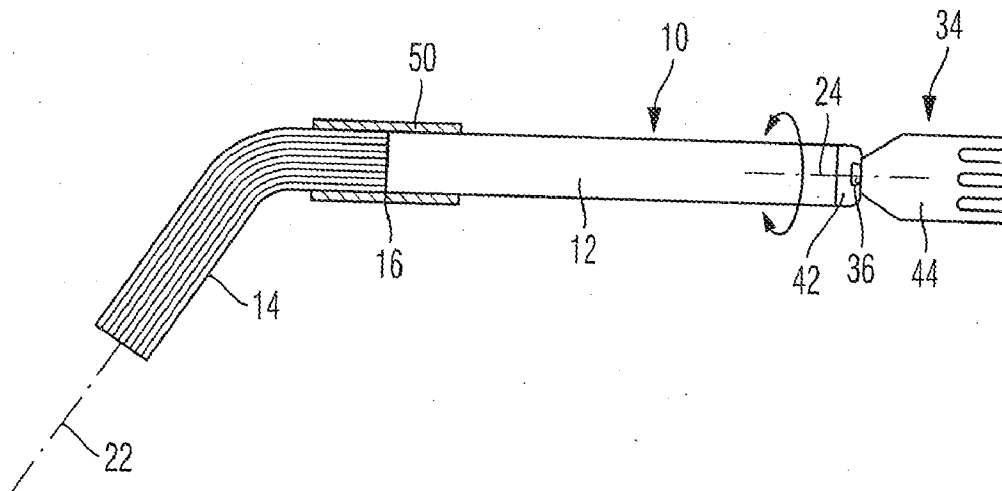
(19) **United States**(12) **Patent Application Publication**
Senn(10) **Pub. No.: US 2014/0242538 A1**(43) **Pub. Date: Aug. 28, 2014**(54) **RADIATION SOURCE AND LIGHT GUIDING
DEVICE**(71) Applicant: **Ivoclar Vivadent AG, Schaan (LI)**(72) Inventor: **Bruno Senn, Buchs (CH)**(21) Appl. No.: **14/349,416**(22) PCT Filed: **Oct. 8, 2012**(86) PCT No.: **PCT/EP2012/069832**§ 371 (c)(1),
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A61C 13/15 (2006.01)(52) **U.S. Cl.**CPC **A61C 19/004** (2013.01)USPC **433/29**(57) **ABSTRACT**

The invention relates to a radiation source, in particular a light curing device, for the polymerization of dental materials, comprising a light conductor and a light generation device which has at least two light sources, preferably semiconductor light sources, in particular light diodes, and the radiation of which is bundled by a reflector and fed into the light conductor. The light sources differ from one another with respect to their light color and/or their emission spectrum and are controllable separately for changing the light color and/or the emission spectrum and/or the spectral radiant power of the radiation emitted. The light conductor has at least one monocoresh section and one multicore section wherein the radiation emitted by the light sources is fed into a monocoresh section of the light conductor. Further, the invention relates to a light-conducting device for a radiation source or a light curing device of this kind.



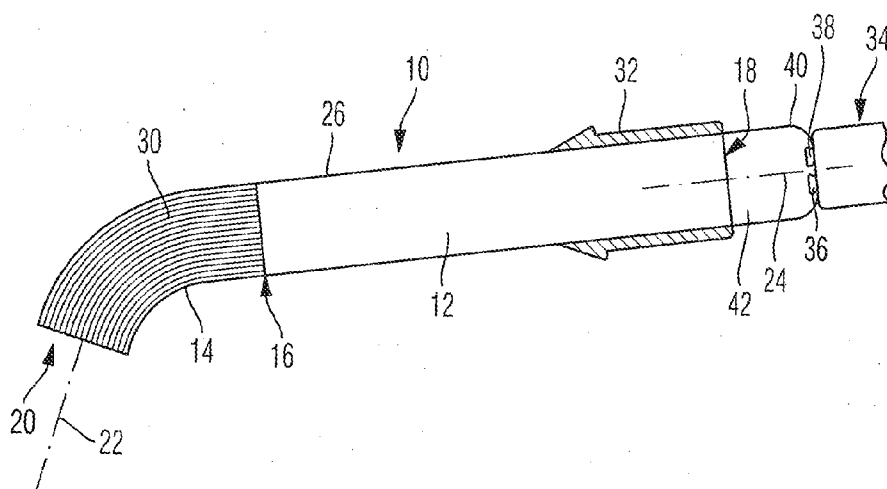


Fig. 1

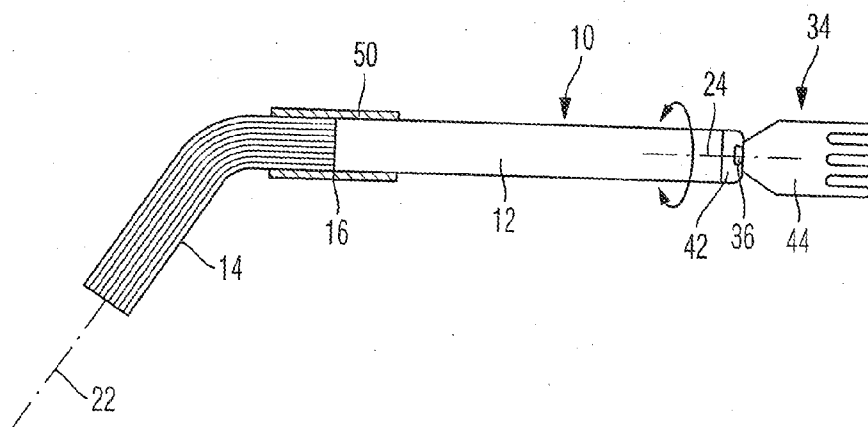


Fig. 2

RADIATION SOURCE AND LIGHT GUIDING DEVICE

[0001] The invention relates to a radiation source, preferably for medical or dental-medical use, in particular a light curing device for the polymerization of dental materials, according to the preamble of claim 1, as well as to a light conductor device for a radiation source or a light curing device of this kind, according to the preamble of claim 15.

[0002] The term light, as used in the description and the claims herein, does not only stand for electromagnetic radiation in the visible spectral range but also for electromagnetic radiation in the UV and near infrared range. When it is subsequently referred to the preferably deployed light diodes (or LEDs or LED chips), these terms shall also include other illuminants and radiation sources, in particular semiconductor radiation sources, emitting visible light, UV and/or near infrared light which—for reasons of better readability—shall not be listed throughout the text. Even when it is sometimes only referred to light curing devices, it is to be understood by somebody skilled in the art that the corresponding statements also apply to other radiation sources in the same manner and need to give reference to them, too.

[0003] Light curing devices of this kind have been known for a long time.

[0004] One example of the implementation of a light conductor from the 1970s can be taken from DE 23 52 670. Already at that time, flexible light conductors consisting of a single fiber have been considered to be well known. The document also proves the implementation of light-conducting liquids and of a flexible plastic hose for the supply of a light conductor to be known.

[0005] Light conductors that consist of a single fiber and that may also be referred to as a light-conducting rod, are basically comparatively stiff or rigid and are thus hard to bend. Light conductors filled with a liquid, on the other hand, are unfavorable especially in applications in the oral region as there is the danger that the patient—inadvertently—bites on the light conductor and in this manner causes a leak.

[0006] In the 1980s, but also up to now, one has typically moved on to multiple fiber light conductors; DE 297 09 785 is mentioned as an example hereof.

[0007] Multiple fiber light conductors that are also referred to as multicore light conductors, have the advantage of offering a substantially improved bending property. The dentist is thus able to impart the desired shape to the light conductor on the end side thereof in order to maintain the light emission or exit at the desired, partially deep-seated position.

[0008] By the way, the same applies to the use of light conductors for light sensors for dental cameras but also, for example, to the use of light conductors in endoscopes that require narrow radii of curvature as well.

[0009] It has already been known for a long time that with the aid of optically additive mixtures of base colors such as red, yellow and blue it is possible to generate white light. This fact is exploited by arranging LEDs of corresponding coloring closely adjacent to one another and by guiding the light emissions thereof to the light conductor.

[0010] In fact, so-called white LEDs have become known recently. These, however, are still comparatively expensive at present, and due to the light mixture the exact shade of color can be better adapted to the requirements. It is also possible to select a certain emission spectrum.

[0011] If a single LED or a single LED chip is used as the light source, light emission takes place primarily on the upper

side of the LED chip that typically has a size of approximately 1 mm². If a multicore light conductor that typically has a diameter of 6 to 13 mm, is installed in front of the LED chip, the main light emission typically only impinges on the 6 or 7 inner fibers, whereas only a very small portion of the outer optical fibers are utilized.

[0012] In order to prevent such a situation, it has become known to use a collecting lens at the light entry side end of the optical fibers. On the other hand, the additional provision of a collecting lens means two further optical boundary surfaces with the respective reflections so that the degree of efficiency decreases.

[0013] In both cases of application mentioned, one therefore gladly resorts to monocoresh light conductors or light-conducting rods, especially since the entire cross-sectional area of the light conductor can be taken by the optically effective medium in case of the monocoresh technology, in contrast to the yield losses arising from the use of multicore light conductors.

[0014] State-of-the-art light sources for medical or dental-medical use that have been typically used up to now, for instance, for the polymerization of dental materials, were constructed and designed for the emission of certain predefined emission spectra.

[0015] Contrary hereto, the invention is based on the object of producing a radiation source preferably for dental or dental-medical use, in particular a light curing device for the polymerization of dental materials, according to the preamble of claim 1, as well as a light conductor device, according to the preamble of claim 15, that, on the one hand, can be produced easily and cost-effectively and can be used universally, and, on the other hand, can be handled more ergonomically especially with medical, preferably dental applications, and whose light color and/or emission spectrum and/or spectral radiant power of the emitted radiation can be adapted to the purpose of use and case of application without the light emission or easy handling suffering any damage.

[0016] This object is inventively solved by claim 1 with respect to the radiation source and the light curing device. With respect to the light conductor device for a device of this kind the object is solved by claim 15.

[0017] Advantageous further developments emerge from the description and in particular from the subclaims. All the technical features disclosed in the description and the subclaims can be combined with each other freely according to the expertise of the respective person skilled in the art and can be jointly implemented technically in connection with the features of the independent claims 1 and 15.

[0018] Surprisingly, especially by the interaction of the reflector arrangement, which feeds the radiation directly into the light mixing element, and this light mixing element the invention achieves a very high degree of light mixing—in connection with a very simple and cost-effective design and without increasing the space requirements or the overall length—, and thus by using light sources, in particular LEDs, which differ with respect to their light color and/or their emission spectrum and which can be controlled separately from one another a corresponding device can be provided whose light color and/or emission spectrum and/or spectral radiant power of the emitted radiation can be adapted to the purpose of use and case of application without the light emission or easy handling suffering any damage.

[0019] According to the invention it is particularly favorable that due to the combination of monocoresh and multicore

light conductors, the advantages of both of them can surprisingly be achieved without the disadvantages to be expected. The bad light mixing present in the case of multicore light conductors is completely avoided, as well as the only partial light impingement that is focused on the central optical fibers. It is not necessary to use a collecting lens or any other costly light mixing device on the entry side; rather it is possible to directly feed the light radiation emitted by the one or more LED chips to the monocore light conductor. Due to the comparatively large light entry surface, the light conductor completely absorbs the light radiation and guides it forward.

[0020] The present invention makes possible to homogenize and mix the light generated in a light generation device and to distribute it across the entire cross-sectional area of the light conductor such that at the exit of the light conductor an area can be illuminated homogeneously with respect to brightness and spectral distribution. In this way, it enables an effective, simple and low-loss coupling of the emitted light, that is generated in particular by several light diodes or other semiconductor radiation sources, into the light conductor.

[0021] In a modified embodiment of the invention more than one multicore section and/or more than one monocore section are connected with one another. This is favorable for example if the light conductor is very long and comprises positions along its extension at which it must be bent heavily. At said positions multicore and further monocore sections are formed then.

[0022] Whereas optical fibers typically offer a light yield that is 15% lower compared to monocore light conductors, it is inventively provided to at least divide in half these yield losses. If only the front, thus first third of the light conductor on the light exit side is formed to be multicore and the rearward two thirds of the light conductor are formed to be monocore, the yield losses are reduced from 15 to 5%.

[0023] Further it is particularly favorable that according to the invention it is prevented that an image of the LED chip is displayed by optical fibers or multicore light conductors. In the monocore light conductor section, a strong mixing is produced that in this way provides for the homogenization of light.

[0024] Nevertheless, the desired emission spectra can be provided with the realization of several

[0025] LED chips of different colors, and in fact without the need of using an additional collecting lens and further costly homogenization devices. This also particularly applies for the three light conductor chips having different colors and being typically arranged in a triangle which, for instance, have emission maxima in the red, green and blue spectral areas and which can be used to produce any desired light color by additive light mixing.

[0026] In the same way, the inventive solution can be integrated into any conventional device very cost-effectively and requiring only minimal changes to the construction. Furthermore, a very simple installation or exchange of light conductors in the medical or dental practice or, for instance, in the dental laboratory is possible. Moreover, the inventive solution is also very easy to maintain in the service workshop.

[0027] Surprisingly, in connection with the inventive light mixing device an unexpectedly high degree of homogenization with respect to the intensity distribution and the spectral emission curves across the entire exit surface of the optical fiber bundle can be achieved, in spite of the simple design and the very short overall length of the light mixing device, i.e. the very short light mixing distance within the light mixing ele-

ment—in particular in connection with the state-of-the-art reflector arrangement in the light generation device of the devices—as well as due to the repeated phase transition and boundary surface interactions between solid and air and again solid in the light path of the optical path of a device of this kind, i.e. for instance light diode/air, air/reflector, reflector/air, air/protective glass, protective glass/air, air/light mixing element, light mixing element/air, air/fiber bundle—also due to reflections at the boundary surface and resulting delay differences of different ray bundles in the optical path and their superposition. However, at the same time only very low losses of light occur with respect to the entire radiation energy produced by the light diodes until the exit end of the optical fiber bundle.

[0028] A further advantage of the inventive solution is that the use of expensive fiber bundles comprising a randomized arrangement of the individual fibers will not be necessary anymore in the future, and in this way considerable savings can be made in the production of light conductor on the one hand, and, on the other hand, mechanical problems such as twisting and squashing of the fibers do not occur anymore due to the thermal expansion in use and in autoclaving.

[0029] Furthermore, the inventive solution enables a very easy and cost-effective provision of lighting devices or light curing devices whose emitted work spectra can be synthesized by means of additive light mixing of the spectra of light diodes comprising different emission spectra by electronically controlling the different light diodes respectively. It is especially surprising that in connection with the specific construction of the inventive solution using only the simplest optical means, a very high degree of homogenization can be achieved with respect to the intensity of light and emission spectra across the entire lighting cross section and at the same time the efficiency of the transmission of light can be improved and power dissipation can be reduced.

[0030] Advantageously, the inventive light mixing device can be positioned ideally with respect to the light diodes or semiconductor light sources. In doing so, the positioning parameters can be selected such that the entry surface of the light mixing element is located “out of focus” with respect to the respective focal points of the light diodes or reflectors assigned to the semiconductor radiation sources, and is, on the one hand, illuminated most comprehensively by the bundles of entry beams and that, on the other hand, the entry angle area of the incoming radiation exploits as completely as possible the entry or acceptance cone predefined by the numerical aperture of the light entry end of the light mixing element.

[0031] As a further advantage of the inventive solution every unnecessary additional bending in the optical path of the light path is avoided. In particular, any curvatures within a (monocore) light-conducting rod can be omitted which, as has been shown, result in considerable additional light losses within the light path and worsen the degree of efficiency considerably.

[0032] Surprisingly, a further advantage of the invention is that one light mixing element of a small entire length which is in the order of magnitude of the diameter of the light mixing element is able to mix light from differently colored LED chips or semiconductor radiation sources of the different emission spectra thereof properly such that properly mixed light enters the multicore section of the light conductor and no variations in color can be detected across the light exit surface of the light conductor.

[0033] In an inventively particularly favorable manner the transition between the monocoresh and the multicore section of the light conductor can be realized maintaining the index of refraction. For this purpose, a glass-bonding adhesive or an adhesive cement can be used whose index of refraction corresponds to that of the optical material used for the light conductor.

[0034] According to a further advantageous embodiment it is provided to stiffen or reinforce the light conductor with the aid of a sleeve that especially preferably extends over the transition between the monocoresh and the multicore section. The sleeve offers the additional advantage of preventing a stiffness jump that reduces the load carrying capacity of the light conductor against shear stress due to a lateral attachment to the application location. The forces introduced are at least partially transferred by the multicore section to the more rigid monocoresh section. Nevertheless, the bending property and flexibility of the front end of the light conductor is given on a large scale, i.e. at said location at which the bending property is essential in the practical application.

[0035] The sleeve consists preferably of metal, in particular of stainless steel, and comprises a wall thickness which amounts to less than a fifth, in particular less than a fifteenth of the diameter of the light conductor. Alternatively, the sleeve can comprise a highly temperature-resistant plastic material, in particular a sulfone, etherketone or imid plastic material or plastic composite material—to which the light conductor is connected, preferably non-positively and/or in a firmly bonded manner. In this way, the required temperature resistance, mechanical strength and dimensional stability of the connection interface can be ensured on the one hand, and due to the elastic properties of the corresponding plastic materials a receptivity for thermal expansion movements and a limitation of thermal stresses can be achieved, on the other hand. At the same time, a connection interface of this kind made of such a plastic material enables the targeted use of press fits and/or preloads between the connection interface and the light mixing element on the one hand which in this case can be connected to the connection interface preferably non-positively and/or in a firmly bonded manner, and on the other hand between the connection interface and the connection component to which the connection interface can be attached free of play and securely with respect to changes in temperature using a press fit and/or preloads.

[0036] Especially preferably a further transition occurs directly from the monocoresh section to the multicore section, i.e. without an air layer, and the index of refraction changes over the course of the transition by less than 50%, in particular by less than 20%.

[0037] Compared to the flexible monocoresh light conductor known from the publication DE-OS 23 52 670, the multicore section further has the advantage that the yield losses decrease in relation to the straight layout of the light conductor. A heavily bent multicore light conductor typically offers lower attenuation than a monocoresh light conductor curved in the same radius so that according to the invention for the straight portion of the light conductor said light conductor type (Monocoresh) having the smallest losses thereat is combined with the light conductor type (Multicore) having the smallest losses for the curved area.

[0038] It is particularly favorable if the multicore section comprises a bending or a cranked section, in particular adjacent to the light exit side end. Such a design and arrangement

considerably improves and facilitates the handling in use. Here, the light losses are kept small.

[0039] In a further particularly favorable embodiment of the invention it is provided that the monocoresh section comprises a length that at least corresponds to 5 times its diameter. It is to be understood that the length, however, is variable in both sections, for example comprises a length two times, three times, up to seven or even ten times the diameter.

[0040] The monocoresh and/or the multicore sections are conveniently formed in a conical manner, at least over a part of the lengths thereof, and in particular taper towards the end on the light exit side end. Hereby, the light conductor can be configured to be slimmer, thus improving the handling, for instance, in the mouth of a patient and/or the radiation energy, for instance, from a larger array of diodes can be concentrated on, for instance, a smaller handling surface.

[0041] In an inventively favorable manner, both the monocoresh section and the individual fibers of the multicore section consist of a core glass and a cladding glass. In a manner known per se, core glass and cladding glass strongly differ in their indices of refraction which leads to the desired total internal reflection. Such a coaxial design of the light mixing element made of two different transparent materials, preferably of two types of glass, comprising different indices of refraction can reduce radiation losses in connection with total internal reflection and achieve a better guidance of the radiation. Contrary to conventional light conductors, just like those widely used in the field of light waveguide technology, in the light mixing element mentioned here there is preferably a large difference between both indices of refraction of the core and cladding layer, which difference preferably amounts to 0.1 units. A relatively large difference of this kind between both indices of refraction enlarges the numerical aperture of the light mixing element and also allows for a “catching” of incident light beams which differ substantially from the axis of incidence of the light entry surface of the light mixing element and thus ensures an enlargement of the entry cone for the radiation of the light generation device. As a further advantage, the angular area for the total internal reflection of the radiation transmitted in the light mixing element increases and the reflection coefficient is improved considerably. Instead of glasses, other transparent inorganic materials or ceramics but also organic glasses with or without doping or transparent plastic materials can be used for core and/or cladding areas of the light mixing element.

[0042] In a further favorable embodiment, a coating is provided at the outer surface of the monocoresh or the multicore section, but also at both sections, if necessary, that prevents light from exiting and is intransparent in this respect. The coating can also be embodied so as to be metal-reflecting. Light losses within the light mixing element can be further reduced with the help of an additional reflective layer and at the same time the numerical aperture of the light mixing element can be increased considerably such that the angle of acceptance of the light entry cone of the light mixing element can be increased considerably. A further aspect is that the reflection of the light radiation transmitted within the light mixing element takes place at two boundary surfaces in this exemplary embodiment and thus every light beam transmitted reflexively within the light mixing element is separated into two respective sub-beams that are offset relative to one another, into one first sub-beam which is partially totally reflected at the boundary layer between core and cladding of the light mixing element, and into a second light beam whose

reflection occurs at the reflective outer layer of the light mixing element, thus improving the homogenization performance of the light mixing element even further.

[0043] In an advantageous embodiment of the invention it is provided that the front end of the light conductor which end is part of the multicore section is curved at a given angle, for example at an angle of 45 degrees relative to the optical axis of the light source that impinges on the light conductor. Such a design and arrangement considerably improves and facilitates the handling in use.

[0044] In a modified embodiment of the invention it is provided to configure the front end of the light conductor in a flexible manner so that it can be bent depending on the case of application, for example by 90 degrees or even more than 90 degrees. In doing so, the handling in use in specific application situations can be further improved and facilitated, for instance in areas of the oral environment of a patient which are difficult to access.

[0045] It is especially favorable in any case that in the monocore section the different colors emitted by the LED chips are mixed properly so that properly mixed light enters the multicore section, and no color variance is detectable on the light exit surface.

[0046] If the inventive adhesive between the monocore and multicore section is temperature-resistant and the adhesive and the sections have the same indices of refraction, the light conductor according to the invention is not only removable but also autoclavable. This plays a role particularly in the application within the scope of dental light conductors and endoscopes.

[0047] The mounting of the light conductor relative to the light source can be effected in any suitable manner, for example with the aid of a bushing that also enables the light conductor to be rotatable relative to the light source and to be removable. But all other design variations used between the light conductor and the light curing or lighting device, suggested heretofore in the state of the art, can be combined with the inventive solution without any problems. Thus, the connection interface between the light conductor and the light curing or lighting device can be adapted to the technical requirements in any desired way without the need for developing special solutions therefor.

[0048] According to the invention it is favorable to use the light conductor in a light curing device (or in a radiation source), wherein the light conductor is preferably twistable relative to the light curing device (or the radiation source), and is in particular supported thereon in a removable manner. This twistability enables, for instance, a dentist to adapt the point of exit and the direction of exit of the light cone from the light conductor to the localization of the tooth surface to be treated. The removability of the light conductor enables simple autoclaving thereof, independent of the light curing device (or the radiation source).

[0049] The space between the light entry end of the monocore section and the light source can be filled in any suitable manner, for example with silicone or another transparent compound whose index of refraction substantially corresponds to the index of refraction of the glass used so that only very small reflection losses arise at the media transition. It is also possible to grout the space with the transparent compound.

[0050] Even if the use of glass both for the monocore section and the multicore section of the light conductor is emphasized here, it is to be understood that any other suitable

materials, in particular a transparent plastic material, can be used for providing the light conductor.

[0051] According to a favorable embodiment of the invention it is provided that the monocore section comprises a length that corresponds to at least 1.5 times the diameter of the monocore section.

[0052] According to a further favorable embodiment it is provided that the monocore section and/or the optical fibers of the multicore section consist of a core glass and a cladding glass. Such a coaxial design of the light mixing element made of two different transparent materials, preferably of two types of glass, comprising different indices of refraction can reduce radiation losses in connection with total internal reflection and achieve a better guidance of the radiation. Contrary to conventional light conductors, just like those widely used in the field of light waveguide technology, in the light mixing element mentioned here there is preferably a large difference between both indices of refraction of the core and cladding layer, which difference preferably amounts to 0.1 units. A relatively large difference of this kind between both indices of refraction enlarges the numerical aperture of the light mixing element and also allows for a "catching" of incident light beams which differ substantially from the axis of incidence of the light entry surface of the light mixing element and thus ensures an enlargement of the entry cone for the radiation of the light generation device. As a further advantage, the angular area for the total internal reflection of the radiation transmitted in the light mixing element increases and the reflection coefficient is improved considerably.

[0053] According to a further advantageous embodiment it is provided that there is a coating at the outer surface of the monocore and/or the multicore section which coating prevents the exit of light from the light conductor and/or reflects the light impinging thereon. Light losses within the light mixing element can be further reduced with the help of an additional reflective layer of this kind and at the same time the numerical aperture of the light mixing element can be increased considerably such that the angle of acceptance of the light entry cone of the light mixing element can be increased considerably. A further aspect is that the reflection of the light radiation transmitted within the light mixing element takes place at two boundary surfaces in this exemplary embodiment and thus every light beam transmitted reflexively within the light mixing element is separated into two respective sub-beams that are offset relative to one another, into one first sub-beam which is partially totally reflected at the boundary layer between core and cladding of the light mixing element, and into a second light beam whose reflection occurs at the reflective outer layer of the light mixing element, thus improving the homogenization performance of the light mixing element even further.

[0054] According to a further advantageous embodiment it is provided that both these sections are connected with one another at a transition with the aid of an adhesive cement and/or a glass-bonding adhesive that comprise a refraction index like glass. In this way, transfer losses due to reflections at the boundary surface can be reduced considerably because of the double rapid change of the index of refraction.

[0055] According to a further advantageous embodiment it is provided that at least the monocore section is surrounded by a sleeve.

[0056] According to a further advantageous embodiment it is provided that the sleeve at least partially extends over the transition between the monocore section and the multicore

section so that at least a portion of the multicore section that follows the monore section, is surrounded by the sleeve as well. This results in a considerable stiffening of the mechanical connectino of both light conductor sections and a transition of the flow of power across the mechanically endangered junction between the light conductor sections. The sleeve offers the additional advantage of preventing a stiffness jump that reduces the load carrying capacity of the light conductor against shear stress due to a lateral attachment to the application location. The forces introduced are at least partially transferred by the multicore section to the more rigid monore section. Nevertheless, the bending property and flexibility of the front end of the light conductor is given on a large scale, i.e. at said location at which the bending property is essential in the practical application.

[0057] According to a further advantageous embodiment it is provided that the diameter of the light conductor amounts to 6 mm to 13 mm.

[0058] According to a further advantageous embodiment it is provided that the monore and/or the multicore sections are formed in a conical manner at least over a portion of the lengths thereof. Hereby, the light conductor can be configured to be slimmer, thus improving the handling, for instance, in the mouth of a patient, and/or the radiation energy, for instance, from a larger array of diodes can be concentrated on, for instance, a smaller handling surface.

[0059] According to a further advantageous embodiment it is provided that the light entry side end is located at the monore section and that the light exit side end is located at the multicore section. In this way, on the one hand, light mixing and homogenization can be improved considerably and light losses can be minimized. On the other hand, this embodiment is advantageous with respect to the design (offset angle, crank) of the light conductor or provision with a flexible end section.

[0060] According to a further advantageous embodiment it is provided that the multicore section comprises a bending or cranked section. Such a design and arrangement considerably improves and facilitates the handling of the device in use. In doing so, light losses are kept low.

[0061] According to a further advantageous embodiment it is provided that a light exit surface of the multicore section extends at an angle of 2° to 90° relative to a light entry surface that runs perpendicular to the longitudinal extension of the monore section. Such a design and arrangement considerably improves and facilitates the handling of the device in use.

[0062] According to a further advantageous embodiment it is provided that the end on the light entry side of the monore section comprises a connection interface to a light curing device or to the radiation source) with the aid of which a polymerizable dental material can be cured. This ensures flexible coupling and decoupling of the light conductor to the light curing device (or the radiation source) wherein the light conductor can be autoclaved separate from the device.

[0063] According to a further advantageous embodiment it is provided that the connection interface is formed by a bushing that can be connected with the light curing device (or the radiation source) positively and that is fixedly connected with the end on the light entry side of the monore section. This represents an embodiment that is especially advantageous with respect to mechanics.

[0064] In an advantageous embodiment the light mixing element can be configured in a rotationally symmetric way. Constructively, this represents an especially functional solu-

tion that further comprises an adaptation, to a large extent, of the optical properties of the light mixing element with respect to the homogenization performance at a given entire length, for instance an adaptation to the geometrically optical radiation paths that are predefined with respect to the light generation device, any necessary adaptations with respect to the numerical aperture relating to the light entry end of the light mixing element and between the light mixing element and fiber bundle of the light conductor. Furthermore, it is possible to adapt the size of the light entry surface of the light mixing element to the geometry of the light generation device on the one hand, and, for instance, concentrate the energy of the light onto a fiber bundle comprising a smaller diameter, on the other hand. Furthermore, for instance curved wall sections or taperings in the cross-section of the light mixing element can influence and modify the angles of reflection of the light beams that are totally internally reflected within the light mixing element and the light homogenization within the light mixing element can be further improved by a larger number of wall reflections of the light.

[0065] In a further advantageous embodiment the light mixing element can be configured cylindrically and preferably comprise a planar light entry and/or exit surface. This design of the light mixing element can be realized technically in an especially simple manner and thus it can be produced very cost-effectively wherein, however, a high degree of homogenization with respect to the intensity distribution and the spectral emission curves across the entire exit surface of the optical fiber bundle can be achieved surprisingly.

[0066] In a further preferred embodiment the light entry and exit surface can comprise a polished surface and/or a surface coating or other reflection-reducing coatings and/or is impingeable by an immersion means. Such a polished surface whose remaining surface roughness preferably amounts to a small fraction at most of the wavelength of light used improves the transmission properties of the light mixing element and reduces light losses considerably. Alternatively or additionally, a surface coating or other reflection-reducing coatings can be applied to the light entry and/or exit surfaces of the light mixing element. This measure can further reduce light losses when light passes through the light mixing element. As an alternative or in addition to the above mentioned measures it is also possible to apply an immersion means such as an immersion oil, for instance silicone oil, to the corresponding surfaces of the light mixing element such that the gap between the light mixing element and, for instance, the fiber bundle of the light conductor or the protective glass across light diodes or semiconductor radiation sources comprising associated reflectors is filled completely with this immersion means and thus instead of a solid-air-solid phase transition a solid-liquid-solid phase transition takes place. The index of refraction of the immersion means which is higher relative to that of air makes possible to further reduce light losses by boundary surface reflection and then again adaptations of the numerical aperture of the optical components connected to one another can be caused.

[0067] In a further preferred embodiment the light mixing element comprises at least one light-conducting core, preferably made of a core glass, comprising a first refraction index and a light-conducting cladding, preferably made of cladding glass, comprising a second refraction index, wherein the second refraction index is smaller—preferably by at least 0.1 units—than the first refraction index. Such a coaxial design of the light mixing element made of two different transparent

materials, preferably of two types of glass, comprising different indices of refraction reduces radiation losses in connection with total internal reflection and achieves a better guidance of the radiation. Contrary to conventional light conductors, just like those widely used in the field of light waveguide technology, in the light mixing element mentioned here there is preferably a large difference between both indices of refraction of the core and cladding layer, which difference preferably amounts to 0.1 units. A relatively large difference of this kind between both indices of refraction enlarges the numerical aperture of the light mixing element and also allows for a “catching” of incident light beams which differ substantially from the axis of incidence of the light entry surface of the light mixing element and thus ensures an enlargement of the entry cone for the radiation of the light generation device. As a further advantage, the angular area for the total internal reflection of the radiation transmitted in the light mixing element increases and the reflection coefficient is improved considerably. Instead of glasses, other transparent inorganic materials or ceramics but also organic glasses with or without doping or transparent plastic materials can be used for core and/or cladding areas of the light mixing element.

[0068] In a further preferred embodiment the light mixing element can comprise a reflection-enhancing coating or a reflective sleeve at its circumferential surface. Light losses within the light mixing element can be further reduced with the help of an additional reflective layer of this kind and at the same time the numerical aperture of the light mixing element can be increased considerably such that the angle of acceptance of the light entry cone of the light mixing element can be increased considerably. A further aspect is that the reflection of the light radiation transmitted within the light mixing element takes place at two boundary surfaces in this exemplary embodiment and thus every light beam transmitted reflexively within the light mixing element is separated into two respective sub-beams that are offset relative to one another, into one first sub-beam which is partially totally reflected at the boundary layer between core and cladding of the light mixing element, and into a second light beam whose reflection occurs at the reflective outer layer of the light mixing element, thus improving the homogenization performance of the light mixing element even further.

[0069] In a further preferred embodiment the diameter of the light mixing element amounts to preferably between 2 mm and 20 mm, particularly preferably between 6mm and 15 mm, in particular between 8mm and 13 mm, and the length of the light mixing element is greater than 0.5 times the diameter, in particular greater than 0.8 times the diameter, and preferably smaller than 5 times the diameter, in particular smaller than twice the diameter of the light mixing element. These dimensions represent an especially favorable constructive dimensioning with respect to the geometry of the light mixing element. In this way, an optimal mixing of light and homogenization can be achieved at minimized external dimensions. Additionally, the given diameters take account of the geometrical optical conditions with respect to the size of the light generation device and the entry diameter of the fiber bundle of the light conductor typically used in the given fields of medicine and dental medicine.

[0070] In a further preferred embodiment the light mixing device can comprise a connection interface—preferably made of a highly temperature resistant plastic material, in particular a sulfone, etherketone or imid plastic material or plastic composite material—to which the light mixing ele-

ment is connected, preferably non-positively and/or in a firmly bonded manner, wherein the connection interface is connectable to one of the two, preferably in a self-aligned manner relative to the light conductor and/or the light generation device. This represents an especially advantageous design for mounting the light mixing element within the beam path of the lighting device or the light curing device. In doing so, the connection interface can be connected to the light conductor and/or to the light generation device at or in the housing of the lighting or light curing device wherein the connection interface is preferably configured such that it adjust itself with respect to the light conductor and/or the light generation device and is thus positioned exactly within the beam path without the need for additional mounting and adjusting efforts. In this connection, the connection interface is produced at least to a large extent preferably from a highly temperature resistant plastic material, in particular a sulfone, etherketone or imid plastic material or plastic composite material. In this way, the required temperature resistance, mechanical strength and dimensional stability of the connection interface can be maintained on the one hand, and due to the elastic properties of the corresponding plastic materials a receptivity for thermal expansion movements and a limitation of thermal stresses is achieved, on the other hand. At the same time, a connection interface of this kind made of such a plastic material enables the targeted use of press fits and/or preloads between the connection interface and the light mixing element on the one hand which in this case can be connected to the connection surface preferably non-positively and/or in a firmly bonded manner, and on the other hand between the connection interface and the connection component to which the connection interface can be attached free of play and securely with respect to changes in temperature using a press fit and/or preloads.

[0071] In a further preferred embodiment the light entry and/or light exit surfaces of the light mixing element can be formed in an aplanar manner. Thus, it is, for instance, possible to configure the respective surfaces of the light mixing element in a slightly wavelike or undulated manner, for instance like the concentric, circular waves that arise in a water surface after a stone's throw. As a result of such a surface design, incoming and outgoing light beams—in contrast to a planar surface—are deflected slightly in an alternating manner in the radial direction of the light mixing element and are spread across a larger angular area, thus considerably increasing the light mixing effect of the light mixing element. A similar effect could be achieved with a faceted surface design or with a Fresnel cut of the respective surfaces of the light mixing element at the front side. Furthermore, it is also possible to configure the respective surfaces of the light mixing element convexly or concavely, in order to thus increase the angles of acceptance for the light entry cone or undertake adaptations with respect to the numerical entry and/or exit aperture and in this way to, for instance, limit the divergence of the exit beam from the light mixing element and adapt it to the numerical aperture of the fiber bundle.

[0072] In a further preferred embodiment the light mixing device can be provided and configured for retrofitting a lighting device or a light curing device, and is mountable between the light conductor and the housing of the light generation device or the light curing device—preferably in a bushing. This creates the possibility of retrofitting existing lighting devices or light curing devices which are being used with the

advantageous inventive light mixing device and thus improve their efficiency and retrofit them with the inventive advantages.

[0073] Further advantages, details and features emerge from the following description of two exemplary embodiments of the invention in conjunction with the drawing, in which:

[0074] FIG. 1 shows a schematic sectional view through an embodiment of a light conductor according to the invention; and

[0075] FIG. 2 shows a schematic sectional view through a further embodiment of a light conductor according to the invention.

[0076] The light conductor 10 illustrated in FIG. 1 comprises a monore section 12 and a multicore section 14. Both sections 12 and 14 have the same outer diameter and merge with one another in a flush manner at a transition 16. The monore section 12 is located adjacent to a light entry side end 18 of the light conductor 10, and the multicore section 14 is located adjacent to a light exit side end 20 of the light conductor.

[0077] The monore section extends in a straight manner and in the illustrated embodiment takes up a length of about three quarters of the length of the light conductor. The multicore section 14 takes up the last, i.e. the front quarter of the light conductor and is curved adjacent to the end 20, and in fact by about an angle of 60 degrees.

[0078] A light exit axis 22 correspondingly extends at an angle of approximately 60 degrees relative to a light entry axis 24.

[0079] Both the monore section 12 and the multicore section 14 comprise at the outside thereof a cladding 26 (not shown in detail) that is formed like a coating and that reflects light radiation impinging thereon from inside back inwards.

[0080] The monore section is formed as a massive, rod-shaped light-conducting rod that is surrounded by the cladding 26. In contrast to that, the multicore section 14 consists of a plurality of light-conducting or optical fibers 30, for example 100 to 500 individual light-conducting fibers, as schematically indicated in FIG. 1. In the illustrated embodiment the multicore section 14, too, is formed in a rigid manner.

[0081] At the transition 16, both sections 12 and 14 are connected with one another with the aid of a glass-bonding adhesive. The light-conducting rod of the monore section, the light-conducting or optical fibers 30 of the multicore section 14, and the glass-bonding adhesive (not shown) have the same indexes of refraction, respectively, so that reflections at the phase boundaries are avoided, if possible.

[0082] The monore section 12 comprises at its light entry side end 18 a plug-in sleeve 32. Via said plug-in sleeve 32, the light conductor 10 is supported in a plug-in manner at a corresponding socket of a light curing device, which socket is formed in a manner known per se and is not illustrated here.

[0083] The light entry into the light entry side end 18 takes place via a light source 34 that comprises a plurality of individual LED chips, some of which are illustrated in FIG. 1, namely chips 36 and 38. The light exit of the light source 34 is bundled in a manner known per se by means of a reflector 40. The space 42 between the light source 34 and the end 18 is filled with silicone or another compound whose index of refraction approximates that of glass.

[0084] The chips 36 and 38 are installed on a cooling element 44 that dissipates the heat generated thereat.

[0085] The chips 36 and 38 comprise different emission maxima and preferably can be controlled separately.

[0086] When all LED-chips of the light source 34 are switched on, the space 42 is filled with light of different colors. In the monore section 12 there is a good light mixing in any case so that white light is fed into the optical fibers 30.

[0087] FIG. 2 illustrates a further embodiment of the inventive light conductor. In contrast to the embodiment according to FIG. 1, the multicore section 14 is configured so as to be flexible in this example. In the exemplary embodiment illustrated, the optical light exit axis 22 extends at an angle of approximately 45 degrees relative to the light entry axis 24; it is to be understood, however, that any other position, and even a redirection of nearly 180 degrees, is possible as well.

[0088] In this exemplary embodiment, the transition 16 is surrounded by a sleeve 50 that serves to stiffen the transition and that prevents the adhesive cement provided at the transition from failing due to a strong mechanical load.

[0089] As can be seen in FIG. 2, the light-conducting rod may be rotated as a whole by means of the light conductors 10; this is also possible in the case of the embodiment according to FIG. 1. In the embodiment according to FIG. 2 only one single chip 36 is provided as a light source 34, said chip being centrally installed on the cooling element 44. The space 42 is quite small which is already favorable due to the fact that silicone typically produces higher light losses than glass. In this respect, the space 42 according to FIG. 1 is illustrated in an exaggeratedly long manner; in practice, the length of the space 42 amounts to, for example, one third or less of the diameter of the light conductor 10.

[0090] According to FIG. 1, the diameter of the light conductor amounts to 12 mm and according to FIGS. 2 to 5 mm, whereas it is to be understood that the diameter of the light conductor may take any suitable values without departing from the scope of the invention. This also applies to the length distribution between the monore and multicore section.

[0091] For example, the monore section alone may be at least eight times longer than its diameter. In the embodiment according to FIG. 2, the length of the multicore section 14 amounts to approximately two fifth of the total length of the light conductor 10, and that of the monore section correspondingly amounts to three fifth.

[0092] All details and values of the embodiment described are only to be understood as being exemplary and can thus be amended within the scope of protection of the claims. Even if the invention is described here in conjunction with the use in a dental light curing device, it is to be understood that the basic ideas of the invention are also used advantageously in other apparatuses requiring light conductors, in particular in medical devices such as endoscopes or other light sources, for instance, for medical research, the use in a laboratory or industrial purposes.

1. A radiation source for the polymerization of dental materials, comprising

a light generation device, and
a light conductor,

the light generation device having at least two light sources, the radiation of which is bundled by a reflector and fed into the light conductor,

wherein the light sources differ from one another with respect to their light color and/or their emission spectrum, in that the different light sources are controllable

separately for changing the light color and/or the emission spectrum and/or the spectral radiant power of the radiation emitted, and

wherein the light conductor has a monocoresh section and a multicore section, the monocoresh section being disposed closer to the light sources than the multicore section, and wherein the radiation bundled by the reflector is transmitted directly to the monocoresh section.

2. The radiation source according to claim 1, wherein the monocoresh section comprises a length that corresponds to at least 1.5 times the diameter of the monocoresh section.

3. The radiation source according to claim 1, wherein the monocoresh section and/or optical fibers of the multicore section comprise a core glass and a cladding glass.

4. The radiation source according to claim 1, wherein there is a coating at the outer surface of the monocoresh and/or on the multicore section, which coating prevents the exit of light from the light conductor thereat and/or reflects light impinging thereon.

5. The radiation source according claim 1, wherein both monocoresh and multicore sections are connected with one another at a transition with the aid of an adhesive cement and/or a glass-bonding adhesive that comprises and/or comprise a refraction index similar to glass.

6. The radiation source according to claim 5, wherein a sleeve is disposed at an outer circumference of the monocoresh section.

7. The radiation source according to claim 6, wherein the sleeve at least extends over the transition between the monocoresh section and the multicore section, and wherein in that a subsection of the multicore section adjacent to the monocoresh section is surrounded by the sleeve.

8. The radiation source according to claim 1, wherein the diameter of the light conductor amounts to 6 mm to 13 mm.

9. The radiation source according to claim 1, wherein the monocoresh and/or the multicore section are formed in a conical manner, only over a portion of the lengths thereof.

10. The radiation source according to claim 1, wherein a light entry side end of the light conductor is located at the monocoresh section and a light exit side end is located at the multicore section.

11. The radiation source according to claim 1, wherein the multicore section comprises a bending or a cranked section.

12. The radiation source according to claim 1, wherein a light exit surface of the multicore section extends at an angle of 2° to 90° relative to a light entry surface that runs perpendicular to the longitudinal extension of the monocoresh section.

13. The radiation source according to claim 1, wherein a light entry side end of the monocoresh section comprises a connection interface to the light sources of the light curing device with the aid of which a polymerizable dental material can be cured.

14. The radiation source according to claim 13, wherein the connection interface is formed by a bushing that can be connected with the light curing device positively and that is fixedly connected with the light entry side end of the monocoresh section.

15. A light conductor device for a medical or dental-medical radiation source, for a light curing device for the polymerization of dental masses, comprising

a bar-shaped monocoresh light mixing element made of at least one transparent material,
a multicore light conductor,

a connection interface that is connectable to a housing of the light source or the light curing device,

the light mixing element being connected to the light conductor in a firmly bonded and light-conducting manner, and

wherein the light mixing element and the light conductor are received in the connection interface in a firmly bonded, hermetically sealed manner and capable of compensating for expansion such that the light conductor device is autoclaveable.

16. The light conductor device according to claim 15, wherein the light mixing element is formed in a rotationally symmetric manner.

17. The light conductor device according to claim 15, wherein the light mixing element is formed cylindrically and comprises a planar light entry and/or exit surface.

18. The light conductor device according to claim 15, wherein the light entry and/or exit surface comprises a polished surface and/or a surface coating or reflection-reducing coating and/or is impingeable by an immersion means.

19. The light conductor device according to claim 15, wherein the light mixing element comprises a light-conducting core, made of a core glass, comprising a first refraction index and a light-conducting cladding, made of a cladding glass, comprising a second refraction index, the second refraction index being lower than the first refraction index.

20. The light conductor device according to claim 15, wherein the light mixing element comprises a reflection enhancing coating or a reflective sleeve at a circumferential surface of the light mixing element.

21. The light conductor device according to claim 15, wherein the diameter of the light mixing element is between 2 mm and 20 mm, and wherein the length of the light mixing element is greater than 0.5 times the diameter and smaller than 5 times the diameter of the light mixing element.

22. The light conductor device according to claim 15, wherein the light conductor device comprises a connection interface to which the light conductor is connected, the connection interface being connectable to the housing in a self-aligned manner relative to the light generation device.

23. The light conductor device according to claim 17, wherein at least one of the light entry and/or light exit surfaces of the light mixing element is formed in a planar manner.

24. The light conductor device according to claim 15, wherein the light conductor device is provided and configured for retrofitting a lighting device or a light curing device.

25. The radiation source of claim 1, wherein it is a light curing device and wherein the at least two light sources are semiconductor light sources.

26. The radiation source of claim 25, wherein semiconductor light sources comprise light diodes.

27. The light conductor device according to claim 15, wherein the at least one transparent material comprises glass.

28. The light conductor device according to claim 15, wherein the light conductor device is autoclaveable after it is disconnected from the housing.

29. The light conductor device according to claim 19, wherein the second refraction index is 0.05 to 0.2 units lower than the first refraction index.

30. The light conductor device according to claim 21, wherein the diameter of the light mixing element is between 6 mm and 15 mm, and wherein the length of the light mixing element is greater than 0.8 times the diameter and smaller than twice the diameter of the light mixing element.

31. The light conductor device according to claim **21**, wherein the diameter of the light mixing element is between 8 mm and 13 mm.

32. The light conductor device according to claim **22**, wherein the connection interface is made of a highly temperature resistant plastic material and wherein the connection interface comprises a non-positive connection and/or a firmly bonded connection.

33. The light conductor device according to claim **32**, wherein the highly temperature resistant plastic material comprises a sulfone, etherketone or imid plastic material or plastic composite material.

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