A coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use, succinctly known as an illumination and laser source, capable of selectively providing illumination light and laser treatment light through a single optical fiber. The apparatus and method is especially useful during ophthalmic surgery. The present art is capable of providing the aforesaid through an optical fiber of such small size that heretofore said fiber was only useable for laser treatment light only. The present art also, with its unique optical system, allows for two illumination light outputs from a single illumination source. The apparatus utilizes a phototoxicity risk card to calibrate the system to prior art or safe illumination levels since the unique optical system provides illumination light of greater intensity than the prior art.
FIG. 2
FIG. 23

ELEMENT 1
ELEMENT 2
ELEMENT 3
ELEMENT 4

42.58
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AR VIS. AR VIS.
COAXIAL ILLUMINATED LASER ENDOSCOPIC PROBE AND ACTIVE NUMERICAL APERTURE CONTROL


BACKGROUND OF THE INVENTION

[0003] The art of the present invention relates to fiberoptic endoscopic probes for vitreoretinal surgery in general and more particularly to an apparatus and method for delivery of both broad spectrum illumination and coherent laser treatment pulses through a common optical fiber. The present invention also provides surgical illumination intensity control by providing an apparatus and method for quickly and easily providing a fiber optic illumination light output intensity reference to ophthalmic surgeons. The present invention also utilizes a unique fiber optic connector ferrule which uniquely indicates to the aforesaid apparatus source whether the fiber is designed, best suited, or desired for illumination or laser transmission light or both. Also integral to the present invention is an optical power meter, preferably for measurement of laser output power emanating from the optical fiber.

[0004] Prior art vitreoretinal surgical procedure utilizes discrete and separate optical fibers for the delivery of typically non-coherent light for illumination and coherent laser beam light for surgical treatment of tissues. Although prior art “illuminated laser probes” of various configurations have been developed, they all utilize separate optical fiber or fibers for the non-coherent illumination stream and the coherent laser delivery. The aforesaid fibers are typically arranged side by side inside of a common needle lumen. An embodiment of this prior art technology is found in U.S. Pat. No. 5,323,766, issued to Uram. This prior art technology requires a larger or more than one incision in order to introduce illumination and laser treatment light into the eye or other structure, thereby generating greater trauma to the surgical site.

[0005] Prior art devices typically utilize a laser deliver core optical fiber diameter of typically 200 to 300 microns since said diameter provides the surgical laser burn spot size most commonly desired by the surgeon. The aforesaid prior art devices have been unable to provide sufficient surgically useful illumination (non-coherent white light) power through such a small fiber, primarily due to the prior art’s inability to focus said non-coherent surgically useful light onto such a small spot size. Moreover, none of the prior art devices have combined the aforesaid surgically useful illumination and laser treatment light and transmitted through a single fiber, especially of the aforesaid small size.

[0006] The present art apparatus and method provides coaxial delivery of both broad spectrum illumination and coherent laser treatment pulses through a common optical fiber. In a preferred embodiment, the apparatus first comprises a non-coherent light source (coherent in an alternative embodiment) capable of coupling sufficient illumination light into an optical fiber with a core diameter suitable for vitreoretinal laser treatment light delivery. That is, to provide a volume of light to the surgical site which is sufficient for illumination of the surgical procedure. In a preferred embodiment said core fiber diameter is typically 200 to 300 microns since said diameter provides the surgical laser burn spot size most commonly desired by the surgeon. The aforesaid optical fiber is typically a multi-mode stepped index fiber in a preferred embodiment. Alternative embodiments may vary the size and type of the optical fiber without departing from the scope of the present art.

[0007] An object of the present invention is to utilize a light source capable of using 250 micron (or smaller) optical fibers while still providing similar surgically useful lumen output to current 750 micron fiber sources (typically 10-12 lumens). The source output aperture of the present invention in a preferred embodiment is at least 0.5 na (numerical aperture). Alternative embodiments may vary this numerical aperture without departing from the scope of the present invention. The color of the light delivered by the present invention appears white despite the light power output or intensity. Also, the output intensity is capable of reduction without significantly affecting the color, aperture, or homogeneity of the light. The output bandwidth of the aforesaid light is substantially limited to the visible spectrum, that is both UV and IR light are minimized. An option for user selectable limitations (separate from the UV and IR limitations) in the output spectrum is provided. Apparatus conformance to relevant safety standards is also provided.

[0008] Prior art illumination light sources typically require a minimum aggregate optical fiber core area equivalent to a fiber diameter of approximately 500 microns in order to deliver sufficient illuminating light to be considered useful by the surgeon. A fundamental prior art limitation with utilization of smaller light fibers for illumination is the size of the focus spot in the light source itself. In a preferred embodiment, the art of the present invention utilizes a small geometry arc lamp which is capable of focusing to an extremely small illumination spot size due to its extremely small plasma ball. This focusing attribute allows for efficient coupling of illumination light into an optical fiber of 100 to 300 micron core diameter which is typically utilized for laser treatment light delivery. Utilization of the aforesaid preferred embodiment allows for up to 40 milliwatts of illumination light to be delivered by a fiber previously considered too small to be an efficient illumination light source.

[0009] The aforesaid present art light source includes an input aperture or connector for the attachment of a laser coupling fiber. The aforesaid aperture attachment is somewhat similar to the method by which a treatment laser is attached with an ophthalmic slit lamp. That is, via a fiber optic pigtails typically equipped with a mechanical output connector such as an ex vivo laser coupling. In the preferred embodiment, dichroic optics and/or other optical path design techniques are used to coaxially couple a treatment laser beam into the illumination optical path, and into an endoscopic probe optical fiber. That is, with the aforesaid coupling arrangement (using a single fiber), the present art apparatus and
method allows a unique single and smaller optical fiber to be utilized for both illumination and laser treatment purposes. The art of the present invention further provides a new generation of vitreoretinal endoscopic instrumentation which utilizes the prior art space occupied by larger illumination fibers and is also capable of providing such in a smaller cross-sectional fiber bundle.

[0010] The present art accepts laser light from various surgical laser sources, mixes said laser light with illumination light, and launches both down a single fiber. Laser output aperture is minimized and the laser light is not substantially affected by the illumination dimming or other spectral output limiting. An aiming beam is visible within the illumination output pattern. Unique to the present art is a shadow appearance in the output light cone which indicates the location of laser treatment upon activation of the laser light source. Power losses through the system are also minimized. As aforesaid, the laser mixing method does not significantly affect illumination when not in use (i.e., color, aperture, or homogeneity).

[0011] Another unique feature of the present art invention is the ability to change the angular light output from an endoscopic probe coupled with the aforesaid coaxial optical fiber by actively controlling the focus characteristics of the light source. That is, prior art light sources have a fixed numerical aperture focus configuration which is typically designed to fill the full acceptance cone of the mating optical illumination fiber. The present art invention further comprises and utilizes surgeon controlled condensing optics to provide a variable focused light output from the endoscopic probe and efficient coupling into different fiber types. This is especially useful for coupling with optical fibers having different numerical aperture requirements.

[0012] Ophthalmic surgical illumination devices for use with optical fibers are found in the prior art and have been manufactured by numerous companies for years. One of many such devices is described in U.S. Pat. No. 4,757,926 issued to Scheller, et al. on Jul. 12, 1988, Entitled “Illumination System for Fiber Optic Lighting Instrument”. One of the most widely used illumination devices is the “Millenium” which is manufactured by Bausch and Lomb®. Other manufacturers are Alcon® with the “Accurus” and Grieshaber® with the “GLS150”. Due to the prevalence of the aforesaid within the marketplace, it is desirable for new and higher intensity illumination devices, such as the present art device, to provide an intensity reference indication to ophthalmic surgeons which allows them to reliably duplicate or mimic the illumination intensity of one or more of the aforesaid prior art devices. This especially true since retinal photic injury is a possible complication of the need to use bright light to clearly visualize ocular structures during delicate ophthalmic surgical procedures. The present art invention further represents a novel apparatus and method for providing the ophthalmic surgeon with graphical phototoxicity risk information in a clear and easy to understand manner. In a preferred embodiment, it is comprised of an inexpensive card that is removably attached to the control panel of a surgical light source in order to show the relationship between the output intensity of the light source and the likelihood of photic injury.

[0013] Further included with the present art apparatus is an integral optical power meter which is in a preferred embodiment, capable of measuring the laser power output emanating from the fiber optic. Alternative embodiments of said laser power meter also measure the illumination power intensity.

[0014] Accordingly, it is an object of the present invention to provide a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use which is capable of transmitting both illumination (non-coherent) and laser (coherent) treatment light through a single optical fiber of sufficiently small diameter that said fiber may be used for laser treatment, especially in eye surgical or ophthalmic applications.

[0015] Another object of the present invention is to provide a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use which provides both a surgically useful illumination (non-coherent) output and a combined laser (coherent) output.

[0016] Another object of the present invention is to provide a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use which connects with conventional laser light sources.

[0017] A further object of the present invention is to provide a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use which provides a shadow or aiming hole within the illumination light cone projection where the laser treatment is placed.

[0018] A still further object of the present invention is to provide a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use which provides an intensity reference indication to ophthalmic surgeons which allows them to reliably duplicate or mimic the illumination intensity of one or more prior art devices or allows them to understand and minimize phototoxicity risks relating to the illumination output.

[0019] A still further object of the present invention is to provide a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use which provides a unique ferrule or connector for optical fiber connection which uniquely indicates to the aforesaid apparatus source whether the optical fiber is designed, best suited, or desired for illumination or laser transmission light or both.

[0020] A still further object of the present invention is to provide a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use which minimizes trauma to the patient and surgical site.

[0021] A yet further object of the present invention is to provide a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus and method of use which has an integral power meter for measurement of laser output power.
SUMMARY OF THE INVENTION

[0023] To accomplish the foregoing and other objects of this invention there is provided a device for providing non-coherent illumination light and coherent laser treatment light through a single optical fiber of the size typically used for laser treatment only. The apparatus is especially suited for use during ophthalmic surgery.

[0024] The present art, in a preferred embodiment, utilizes a 75 watt xenon arc lamp for its high luminescence illumination (light density), greater than 6000° K color temperature, and greater than 95 color rendering index. The xenon arc lamp further provides an extremely small point light source which allows for a smaller output illumination beam diameter. Unique to the present lamp source is a mount which allows for replacement of the lamp and yet retains the location of the plasma ball of said source precisely at a predetermined location within the optical center of the apparatus.

[0025] A classic spherical reflector and two lens light collection layout is utilized rather than other lower part count layouts, such as using an elliptical reflector or a combination of a parabolic reflector and lens. Light that is incident on the reflector is reflected back to the lamp. A first achromatic lens collimates light from the source and the upside down or inverted image. A second achromatic lens is located coaxial to the first lens and focuses the light at its focal point. The optical fiber is located at the focal point of the second lens. The aforesaid reflectors are preferably spherical rather than parabolic in order to reflect illumination light in the same form as sourced from the arc lamp.

[0026] An additional separate illumination path is possible with the present art. No other conventional illumination light source incorporates multiple light paths from a single lamp. The independent nature of the two paths allow different filtering and intensity control settings to the two outputs.

[0027] Output dimming of the present art illumination is accomplished by steering the first (collimating) or penultimate lens in a fashion that does not change the lens numerical aperture or introduce shadow artifacts into the beam. A control knob allows the user to select the desired illumination level by rotating the knob.

[0028] The output optical fiber connector is uniquely configured to provide the precise positioning required while reducing cost. A precise connector end is combined with an integral retention thread to reduce parts cost and assembly time. An optional groove or recess is placed on a second version of the connector to provide for sensing the difference between illumination only and laser compatible output fibers. Placement of a smooth diameter connector into the output activates a switch which will allow the laser power to be mixed. Either the lack of a connector or the groove under the switch will cause the switch to not activate and the laser power will not be mixed in.

[0029] Regarding mixing of laser treatment energy or light, laser light is delivered to the system via preferably 50 micron optical fiber or equivalent. Laser light exiting the delivery fiber is preferably collimated using a 16 mm focal length achromatic lens or equivalent. If all safety requirements are met (i.e., laser output compatible fiber inserted and selection switch for laser output activated) a steering mirror reflects the collimated laser light into the center of the illumination axis. This results in the output of the fiber having a cone of white light with a shadow in the center nearly filled with the laser aiming beam (treatment beam during treatment). That is, the laser provides an aiming beam, typically red, when not fully activated for treatment and a treatment beam, typically green, when fully activated. Without the shadow caused by the steering mirror the aiming beam would be entirely washed out or imperceptible except at very low illumination levels.

[0030] As described, unique to the present art is a coaxial laser and illumination apparatus which heretofore has not be available or utilized. Also unique to the present art is a highly efficient illumination system which utilizes spherical reflectors and associated lenses to capture a maximum light output and also provide a twin path illumination light output from a single lamp source in order to feed fibers of diameter less than 500 microns which are conventionally used for laser treatment only. Further unique to the present art is a laser steering mirror having a solenoid selectability which provides an aiming hole within the illumination path for laser placement. Still further unique to the present art is an illumination arc lamp system having an extremely small point light source which allows for an extremely small illumination focus size or numerical aperture output. Also unique to the present art is a capability of connection with existing conventional laser light sources whereby laser treatment and illumination are both provided at an output of the present art apparatus.

[0031] The present art invention also represents a novel apparatus and method for providing the ophthalmic surgeon with graphical phototoxicity risk information in a clear and easy to understand manner. In a preferred embodiment, an inexpensive card is removably attached to the control panel of the surgical light source. Preferably, the present art card is attached in close proximity to the light intensity control in order to show the relationship between the output intensity of the light source and the likelihood of photic injury. The graphical representation on the card acts as a guide for adjustment of the output intensity of the source in relationship to an accepted standard, that is such as the “Millennium” from Bausch and Lomb®. In this way the spectral and power characteristics of the various elements involved in delivering light to the eye are integrated into a single and easily manageable variable. This greatly reduces the complexity of judging the best intensity to use in a given situation.

[0032] The art of the present invention also comprises a ferrule or connector having an internal bore, preferably stepped, which is substantially parallel with the lengthwise axis of the ferrule body. The aforesaid bore allows for placement and bonding or potting of an optical fiber within and through said ferrule body. Externally, said ferrule body is also stepped in a unique form in order to optimally function as described herein.

[0033] Where provided herein, dimensions, geometrical attributes, and thread sizes are for preferred embodiment informational and enablement purposes. Alternative
embodiments may utilize a plurality of variations of the aforesaid without departing from the scope and spirit of the present invention. The art of the present invention may be manufactured from a plurality of materials, including but not limited to metals, plastics, glass, ceramics, or composites.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] Numerous other objects, features, and advantages of the invention should now become apparent upon a reading of the following detailed description taken in conjunction with the accompanying drawings, in which:

[0035] FIG. 1 is a top plan view of a preferred embodiment of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus showing illumination and laser light paths without the phototoxicity card, power meter, and ferrule connectors.

[0036] FIG. 2 is a perspective view of the arc lamp source and mount.

[0037] FIG. 3 is an assembly view of the arc lamp source and mount.

[0038] FIG. 4 is a front side plan view of the first lens mount, shaft mounted cam, and shutter with a closed position shutter shown in phantom.

[0039] FIG. 5 is a front side plan view of the steering mirror, post, bracket, ball slide, and solenoid in a non-energized extended position.

[0040] FIG. 6 front side plan view of the first output for laser and illumination light and the switch for sensing the recess in the alignment barrel.

[0041] FIG. 7 is a cross sectional view taken along line 7-7 of FIG. 6 without the switch body attached.

[0042] FIG. 8 is a side plan view of the ferrule connector without the recess for preferably laser and illumination use.

[0043] FIG. 9 is a cross sectional view taken along line 9-9 of FIG. 8.

[0044] FIG. 10 is a side plan view of the ferrule connector with the recess for preferably illumination use.

[0045] FIG. 11 is a cross sectional view taken along line 11-11 of FIG. 10.

[0046] FIG. 12 is a front side plan view of the front panel of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus housing showing the first output, illumination level control knob, phototoxicity risk card, and laser power meter display and sensor.

[0047] FIG. 13 is a right side plan view of the right panel of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus housing showing the second output, illumination level control knob, laser connector, power and laser switches, and phototoxicity risk card.

[0048] FIG. 14 is an electronic schematic diagram of the laser power meter circuitry.

[0049] FIG. 15 is an optical schematic diagram of the preferred embodiment of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus showing laser and illumination rays, reflectors, mirrors, and lenses.

[0050] FIG. 16 is an optical schematic diagram of an alternate embodiment of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus showing laser and illumination rays, reflectors, mirrors, and lenses.

[0051] FIG. 17 is an optical schematic diagram of a further alternate embodiment of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus showing laser and illumination rays, reflectors, mirrors, and lenses.

[0052] FIG. 18 is an optical schematic diagram of another alternate embodiment of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus showing laser and illumination rays, reflectors, mirrors, and lenses.

[0053] FIG. 19 shows a left side plan view of the first lens mount.

[0054] FIG. 20 shows a front side plan view of the first lens mount at a full intensity position.

[0055] FIG. 21 shows a front side plan view of the first lens mount at a dimmed intensity position.

[0056] FIG. 22 shows a top plan view of an implementation of the alternate embodiments of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus as shown in the optical schematics of FIGS. 16 & 17 showing illumination and laser light paths without the phototoxicity card, power meter, and ferrule connectors.

[0057] FIG. 23 shows a side plan half cross sectional view of the preferred embodiment of the first and second lenses which correct for color, spherical aberration, and coma and have a back focus 20 mm from the apex of the last element and a numerical aperture of 0.5.

[0058] FIG. 24 shows an optical schematic of the first lens set, collimated space, dichroic hot mirror filter, and second lens set with illumination light path rays shown.

[0059] FIG. 25 shows a detailed side plan half cross sectional view with dimensional attributes of the preferred embodiment of element 1 of the lens shown in FIG. 23.

[0060] FIG. 26 shows a detailed side plan half cross sectional view with dimensional attributes of the preferred embodiment of element 2 of the lens shown in FIG. 23.

[0061] FIG. 27 shows a detailed side plan half cross sectional view with dimensional attributes of the preferred embodiment of element 3 of the lens shown in FIG. 23.

[0062] FIG. 28 shows a detailed side plan half cross sectional view with dimensional attributes of the preferred embodiment of element 4 of the lens shown in FIG. 23.

[0063] FIG. 29 shows an electrical schematic diagram of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus.

[0064] FIG. 30 shows a top perspective view in black and white photographic form of a preferred embodiment of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus showing illumination and laser light paths without the phototoxicity card, power meter, and ferrule connectors.
DETAILED DESCRIPTION

[0065] Referring now to the drawings, there is shown in the Figures both preferred and alternate embodiments of the coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus 10 also herein described as an illumination and laser source 10. There is provided a device 10 for providing non-coherent illumination light 11, 62 and coherent laser treatment light 14 through a single optical fiber 60 of the size typically used for laser treatment only in a safe, effective, and user friendly manner. The apparatus is especially suited for use during ophthalmic surgery.

[0066] The present art, in a preferred embodiment, utilizes a 75 watt xenon arc lamp 36 for its high lumiance illumination (light density), greater than 6000x K color temperature, and greater than 95 color rendering index. A unique and useful feature is the very high lumiance and small size plasma ball formed on the end of the lamp 36 cathode. If imaged correctly the plasma ball is bright enough to provide the required illumination input to a small fiber such as that used for laser treatment. The xenon arc lamp 36 further provides an extremely small point light source which allows for a smaller output illumination beam 37 diameter. Unique to the present lamp source is a mount 38 which allows for replacement of the lamp 36 and yet retains the location of the plasma ball of said source 36 precisely at a predetermined location within the optical center 35 of the apparatus.

[0067] A classic spherical reflector 40 and two lens 42, 58 light collection layout is utilized rather than other lower part count layouts, such as using an elliptical reflector or a combination of a parabolic reflector and lens. This technique allows maximum collection efficiency with a minimum of geometric aberration. The lamp 36 is located at the geometrical center 35 of the reflector 40 and at the focus (focal point) of the first lens 42. Light that is incident on the reflector 40 is reflected back to the lamp 36. This forms an upside down or inverted image of the source 36 coincidental to the source 36. The first lens 42 collimates light from the source 36 and the upside down or inverted image. The second lens 58 is located coaxial to the first lens 42 and focuses the light at its focal point. The output optical fiber 60 is located at the focal point of the second lens 58. The aforesaid reflectors 40 are preferably spherical rather than parabolic in order to reflect illumination light in the same form as sourced from the arc lamp 36.

[0068] Best form lenses 42, 58 (piano convex aspheric, facing each other) are used in the present art. It was discovered that chromatic aberrations, caused by the lenses, gave the output of the optical fiber 59, 60 either a yellow or blue cast. This is not a problem with other ophthalmic lenses because the source is many times larger than the output optical fiber. A color corrected “f 1” or possibly 0.5 numerical aperture lens set 42, 58 consisting of four elements was designed to be utilized for each lens. Each of the elements is coated with a MgF2 (magnesium fluoride) anti-reflective coating to minimize light losses, with other anti-reflective coatings or layers also utilizable. Use of the achromatic lens sets allows a high fidelity image of the illumination source 36 to be focused onto the end of the optical fiber 60, 64. That is, the multi-element lenses allow for a minimum of chromatic aberration. The aforesaid four element lens set is shown and specifically described in the Figures.

[0069] An additional separate illumination path 62 is possible with the present art. A 0.5 system numerical aperture or “f 1” lens is the greatest practical because of limitations to the numerical aperture of available optical fibers. This equates to 60 degrees full angle. When the spherical reflector 40 is considered, an additional 60 degrees is provided from the total of 360 degrees available. Consideration of the vertical rotation around the source 36 is impractical because of shadows caused by the lamp 36 electrodes. A total of 240 degrees of horizontal rotation around the lamp 36 are left unaccounted for. Allowing for optics mounts 44 does account for some additional amount. However, at least half of the illumination output is available. This leaves room for a second light path 62 located orthogonal to the first path 11 along with the second fiber output 64. No other conventional illumination light source incorporates multiple light paths from a single lamp, that is two independent collection systems for illumination light. The independent nature of the two paths 11, 62 allow different filtering and intensity control settings to the two outputs 39, 41. Output dimming of the present art illumination system is accomplished by steering the first (collimating) or perpendi- metric lens 42 in a fashion that does not change the lens 42 numerical aperture or introduce shadow artifacts into the beam 37. The lens set mount 44 has two halves 46 and a flat spring 52. The first part 48 is attached to the optics bench 12, the second part 50 holds the lens set 42, and the spring 52 connects the two 48, 50 together on one side. Pressure on the lens mount second part 50 causes the spring 52 to deflect and the lens 42 to move in a direction generally perpendicular to the optical axis. This results in motion or movement of the image across the face of the optical fiber 60, 64 whereby the peak illumination of the beam 37 is not centered on the optical fiber 60, 64 face during dimming. Due to the aforesaid, the reduction of the output light from the fiber 60, 64 without affecting the color (i.e. color temperature) or aperture of the output is achieved. In a preferred embodiment a shaft mounted cam 54 applies the pressure to the lens mount second part 50 and spring 52. A control knob 56 is attached to the other end of the shaft 53 and allows the user to select the desired illumination level by rotating the knob 56. This method is capable of providing at least 95% reduction in output illumination intensity. In a preferred embodiment, a shutter 57 is mounted upon the shaft 53 and is rotated across the illumination beam 37 in order to fully attenuate the output illumination intensity upon full rotation of said knob 56. Alternative embodiments may utilize other methods, including but not limited to electric or electronic drives, to rotate said shaft 53 instead of said knob 56.

[0070] A dichroic “hot” mirror filter 66 is placed in the collimated space 61 between the illumination lenses 42, 58. This provides both UV and IR filtering of the light. Brackets are attached to the hot mirror 66 mount to provide a means for additional user selectable filters. Positioning of the filters is critical because this is the only area where the light 11 is generally normal to the filter surface. Location of the filter 66 on the other sides of the lenses would cause the light to have many undesirable incidence angles (between 0 and 30 degrees). Variation in the incidence angle causes dichroic reflectors or filters to have a shift in their affect. If absorption filters are used, placement outside the collimated space 61 will cause an increase in reflective losses and heating problems.
The output optical fiber connector 98 is uniquely configured to provide the precise positioning required while reducing cost. A precise connector or mating end 116 is combined with an integral retention thread 130 to reduce parts cost and assembly time. An optional groove or recess 148 is placed on a second version of the connector to provide for sensing the difference between illumination only and laser compatible output fibers. Placement of a smooth diameter connector 74 into the output activates a switch 72 which will allow the laser power to be mixed. Either the lack of a connector 98 or the groove or recess 148 under the switch 72 will cause the switch 72 to not activate and the laser power will not be mixed in.

Regarding mixing of laser treatment energy or light 14, laser light 14 is delivered to the system via a preferably 50 micron optical fiber 16 or equivalent. The connector 18 on the laser end is configured to be compatible with the laser and to provide the necessary interface to signal to the laser that a fiber is connected. The laser and light source 10 and preferably uses an SMA 905 connector or equivalent to allow repeatable connections of the laser delivery fiber 16. Laser light 14 exiting the delivery fiber is preferably collimated using a 16 mm focal length achromatic lens or equivalent 20, i.e. laser collimating lens, which can also be utilized to focus the collimated laser beam 22. The position of the fiber 16 is adjusted to be at the focal point of the lens 20. The input laser connector 18 and collimating lens 20 are located so that the collimated beam 22 is orthogonal to and intersects the center of the illumination axis 11 between the illumination lens sets 42, 58 (the collimated area for illumination light). If all safety requirements are met (i.e. laser output compatible fiber inserted and selection switch for laser output activated) a steering mirror 24 reflects the collimated laser light 22 into the center of the illumination axis 11. The steering mirror 24 is a first surface plano that is positioned at 45 degrees to the laser light 14 and is located in the center of the illumination axis 11 when laser mode is active. A unique aspect of the present invention is that the thickness of the mirror 24 is shaped to appear as a circle when viewed along the illumination axis. Due to the 45 degree surface orientation, the shape causes the mirror 24 to appear elliptical when viewed from a normal angle. The size of the mirror 24 is chosen to be sufficiently larger that the collimated laser beam 22. Placement of the steering mirror 24 in the center of the illumination axis 11 causes the light rays that would normally be there to be blocked and a shadow to appear in the center of the output light cone. The second illumination lens 58 focuses the laser light 14 reflected by the steering mirror 24 onto the end of the output fiber 60, 64. Because the length of the output optical fiber strand is relatively short, the incidence angle of light entering the input end is very nearly the same angle on the output end. This results in the output of the fiber strand having a cone of white light with a shadow in the center nearly filled with the laser aiming beam (treatment beam during treatment). That is, the laser provides an aiming beam, typically red, when not fully activated for treatment and a treatment beam, typically green, when fully activated. Without the shadow caused by the steering mirror 24 the aiming beam would be entirely washed out or imperceptible except at very low illumination levels.

Alternate embodiments may utilize more than one steering mirror 24 or place the steering mirror 24 outside of the illumination axis or illumination light path 11 and direct the laser light 14 through an aperture 158 in said spherical reflector 40 and thereafter through the arc lamp 36 plasma ball or through a dichroic reflector 160 or a reflector having an aperture 162. All of the aforesaid alternate embodiments place the laser light 14 within the collimated space 61 and utilize the second lens 58 for focus upon the output optical fiber 60. Moreover, all of the aforesaid alternate embodiments provide for a second light path 62 output as seen in the Figures.

The laser steering mirror 24 is mechanically mounted on a thin post 28 that holds it in place while minimizing the loss of illumination light 11. The post 28 is mechanically connected to a bracket 30 which is connected to a solenoid 32. The solenoid 32 causes the bracket 30 and also the steering mirror 24 to move into one of two positions. Position one is outside the collimated illumination and laser light. This position is used for no laser delivery and allows the illumination path to operate unaltered. Position two is with the steering mirror 24 located to reflect the laser light into the illumination path 11. Motion of the solenoid 32 and bracket 30 are controlled by a precision ball slide 34. Use of the slide 34 insures repeatable positioning of the mirror 24.

As described, unique to the present art is a coaxial laser and illumination path apparatus 10 which heretofore has not been available or utilized. Also unique to the present art is a highly efficient illumination system which utilizes spherical reflectors 40 and associated lenses 42, 58 to capture a maximum light output and also provide a twin path illumination light output from a single lamp source in order to feed fibers of diameter less than 500 microns. Further unique to the present art is a laser or steering mirror 24 having a solenoid 32 selectability which provides an aiming hole within the illumination path 11 for laser placement. Still further unique to the present art is an illumination arc lamp 36 system having an extremely small point light source 36 which allows for an extremely small illumination focus size or numerical aperture output. Also unique to the present art is an arc lamp 36 mount 30 which precisely and interchangeably places the plasma ball of the arc lamp 36 at the focus or optical center 35 of the optics system. Also unique to the present art is a unique dimming mechanism which moves the focal point of an output dimming or first lens 42 in order to provide dimming without introducing artifacts, chromatic aberrations, or change of color temperature. Also unique to the present art is a capability of connection with existing conventional laser light sources whereby laser treatment and illumination are both provided at an output of the present art apparatus 10. The optical system of the present apparatus 10 is uniquely capable of accepting the input cone angles of the illumination 33 and laser light 15 placed at the output optical fiber 60 and substantially reproducing said cone angles at the output of the optical fiber, typically where the endoscopic probe is located, with any aberrations caused by the optical fiber itself.

Further alternate embodiments of the present art apparatus 10 may utilize parabolic reflectors instead of spherical reflectors in order to collimate the illumination source 36. This technique would eliminate the need for the first collimating lens 42 and allow transmission of the laser beam 22 through an aperture within the parabolic reflector or via a steering mirror 24 within the collimated space 61. Still further alternate embodiments may utilize an elliptical reflector having two focal points whereby the illumination
source 36 is placed at the first focal point and the output fiber 60 is placed at the second focal point with the laser beam 22 introduced through an aperture within the elliptical reflector or via a steering mirror 24 between the illumination source 36 and the output fiber 60. This latter alternate embodiment requires focusing the laser beam 22 onto the output fiber 60 via a lens placed within the laser beam path 22 prior to the output fiber 60 yet allows elimination of both the first collimating lens 42 and the second focusing lens 58.

In a preferred embodiment, onto the face of the card is printed a circular shaped scale 84 that has different color bands 86 representing the phototoxicity risk at a given intensity level, for example green, yellow, and red. The control knob 56 has an indication line that points to the current output intensity level and concurrent phototoxicity risk associated with the probe being used. Unique to the present art is the ability of the card 76 to indicate output intensity at the optical fiber output. The card 76 is meant to be disposed of after a single use and replaced with a new one provided with each optical fiber instrument. In this manner the output of the light source 10 is recalibrated each time it is used. The calibrated unit type may vary with different instrument styles to provide the surgeon with the most pertinent information possible.

As aforesaid the card 76 provides a known point of reference relative to the prior art illumination devices. For example, if the surgeon maintains the knob 56 indicator line within the green color band, he or she will understand that the light intensity output is within the safe intensity of the prior art illuminators such as the “Millennium” from Bausch and Lomb®. This control phenomena is especially useful when utilizing more powerful illumination sources 10 such as described herein. That is, the surgeon must have a prior art point of reference when utilizing more powerful and modern illumination systems such as the present art. The art of the present invention may further provide several bands which do not provide a reference to the prior art but instead indicate phototoxicity levels or light intensity levels directly to the surgeon.

Unique to the present art is the ability of the manufacturer of the optical fiber to provide a phototoxicity risk card 76 which accounts for attenuation and spectral absorption within the optical fiber provided with said card 76. Thus for example, if an optical fiber is highly attenuating, the card may indicate that the surgeon must turn the intensity control knob 56 to a higher level in order to obtain an equivalency to one or more of the aforesaid prior art illuminators or to achieve a desired photo-illumination output.

The art of the present invention also comprises a ferrule or connector 98 having an internal bore 102, preferably stepped 104, which is substantially parallel with the lengthwise axis 100 of the ferrule body 98. The aforesaid bore 102 allows for placement and boning or potting of an optical fiber within and through said ferrule body 98. Externally, said ferrule body 98 is also stepped 112, 148 in a unique form in order to optimally function as described herein.

In a preferred embodiment, the ferrule body 98 has an external end 114 and a mating end 116 and externally comprises a substantially cylindrical head 118 of a first diameter 120 having a first end 122 and a second end 123, said first end 122 co-located with said external end 114. Said ferrule body 98 further externally comprises a lip 124 of greater diameter than said head 118 and having a first side 126 and a second side 128 with said first side 126 mounted with said second end 123 of said head 118. A threaded portion 130 of preferably smaller diameter than said head 118 is attached with and extends from said lip 124 second side 128. In a preferred embodiment, said threaded portion 130 first comprises an 8-32 UNC thread with a first end 132
and second end 134, said first end 132 connected with said second side 128 of said lip 124. Also in a preferred embodiment, said threaded portion 130 has a groove 136 of approximately 0.030 inch at said first end 132 with approximately 0.090 inch of said thread 130 thereafter following and another approximately 0.030 inch groove 136 following said thread 130 at said second end 134. Externally the ferrule body 98 also has an alignment barrel 138 having a first 140 and second 142 end following said threaded portion 130, said first end 140 attached with said threaded portion 130. The second end 142 of said alignment barrel 138 is collocated with said mating end 116 of said ferrule body 98. Also, said second end 142 of said alignment barrel 138 contains an orifice 144 of substantially equivalent or slightly greater diameter as the optical fiber mounted within said stepped bore 102. Said orifice 144 is interconnected with said internal stepped bore 102. In an embodiment of the present art, said orifice is approximately 0.011 inch in diameter and 0.025 inch in length. Also in a preferred embodiment, said alignment barrel 138 has a chamfer 146 at the circumference of said second end 142. Preferably said chamfer 146 is of approximately 45 degree angle and 0.015 inch in length. Alternative embodiments may utilize chambers of different angles or shapes or forego use of a chamfer altogether.

[0084] The alignment barrel 138 of the present art is uniquely shaped within the embodiments to indicate whether laser light or illumination light should be applied to the optical fiber. In a preferred embodiment of the laser ferrule, the alignment barrel is of uniform diameter, approximately 0.118 diameter, which indicates to the source that laser light or energy is desired. In a first alternative embodiment or illumination ferrule, the alignment barrel contains a recess 148 located approximately 0.075 inch from said barrel 138 second end 142 and extending approximately 0.268 inch from said second end 142. When utilized, the illumination and laser source 10 detects this recess and determines that illumination light and not laser light is desired. Further alternative embodiments may utilize the aforesaid recess 148 for laser light and the uniform barrel diameter for illumination light.

[0085] Internally said stepped bore 102 first comprises a first larger bore substantially within said head portion which is of approximately 0.008 inch diameter and extends substantially the length of said head. A second intermediate bore of approximately 0.063 inch diameter extends from said first larger bore to said orifice 144 within said threaded portion 130 and said alignment barrel 138. Also in a preferred embodiment, the orifice 144 length is approximately 0.025 inch. Alternative embodiments may utilize first and second bores and orifices having a plurality of diameter and length sizes provided that the diameter portions are smaller than the ferrule external portions within which each is located.

[0086] When assembled with an optical fiber, the optical fiber extends through said bore 102 and orifice 144 and terminates substantially flush with said ferrule body 98 mating end 116 or second end 142 of said alignment barrel 138. Preferably said optical fiber is held within said bore 102 via potting or adhesive compounds surrounding said fiber and attaching with said bore 102 of the ferrule 98.

[0087] In a preferred embodiment, the external head 118 diameter is approximately 0.234 inch with a length of approximately 0.375 inch. The lip 124 external diameter is approximately 0.312 inch with a thickness of approximately 0.025 inch. Also, said alignment barrel 138 is approximately 0.118 inch in diameter and 0.380 inch in length.

[0088] Where provided, dimensions, geometrical attributes, and thread sizes are for preferred embodiment informational and enablement purposes. Alternative embodiments may utilize a plurality of variations of the aforesaid without departing from the scope and spirit of the present invention. This is especially true as relating to said head 118, lip 124, and threaded portion 130. Said lip 124 may be integrated as part of the head 118 or removed completely. Also, the position, location, and type of threaded portion 130 may vary. Said threaded portion 130 may not utilize said grooves 136, utilize grooves of a shorter or longer length, or have said head 118 and lip 124 diameters sized substantially the same as or smaller than the outside diameter of said threads 130. The art of the present invention may be manufactured from a plurality of materials, including but not limited to metals, plastics, ceramics, or composites.

[0089] Unique to the present invention is the integral inclusion of a laser power meter 150 having a sensor 152, a power display 154, and associated control circuitry 156. The power meter 150 allows a surgeon to place the endoscopic fiber optic probe onto said sensor 152, energize the laser through the illumination and laser source 10 and measure the laser power output as seen on said display 154. Inclusion of the aforesaid is especially useful due to variations in optical fibers or to account for attenuation through the illumination and laser source 10. By utilizing the power meter 150, the surgeon has complete knowledge of the laser power transmitted to the surgical site. Alternative embodiments may utilize said power meter 150 for measurement of the output illumination 37 intensity as well as the laser light 14 power.

[0090] In operation, the surgeon connects a laser light source via optical fiber to the input laser connector 18 on the apparatus 10. The surgeon thereafter connects a ferrule connector 98 with an integral optical fiber connector with an endoscopic probe at the first output 39 or for illumination only at said second output 64. If said ferrule connector 98 at said first output 39 does not have the aforesaid recess 148, the apparatus 10 will allow the steering mirror 24 to position within the illumination light path 11 and further allow transmission of laser light. If the surgeon desires to measure laser power output, he or she places the output end of the endoscopic probe onto said sensor 152 and upon full laser activation, reads the laser power output on the display 154. If the apparatus 10 is powered, the surgeon proceeds to illuminate the tissues of concern with a cone of white illumination light having a shadow where the laser beam will be placed and a typically red laser aiming beam within said shadow. Upon full activation of laser power, a typically green treatment laser beam replaces said typically red aiming beam to treat the tissues of concern. All of the aforesaid illumination and treatment may be achieved with a single incision and through a single optical fiber of smaller diameter than prior art sources.

[0091] Those skilled in the art will appreciate that a coaxial illuminated laser endoscopic probe and active numerical aperture control apparatus 10 (illumination and laser source) and method of use such has been shown and
described. The apparatus and method of use allows for simultaneous transmission of illumination and laser treatment light through a single optical fiber of a size which is typically utilized for laser treatment light only. The apparatus and method further provides control of the angular light output from the endoscopic probe attached with said optical fiber. The apparatus also provides for distinct and separate illumination without utilization of the treatment laser while providing complete intensity control of said illumination. Those skilled in the art will appreciate that a medical light intensity photoxicity control or risk card 76 has also been shown and described for use with the present art. Said photoxicity risk card 76 is especially useful for quick and easy determination of illumination intensity output from a specific type of optical fiber or higher power source such as the present art. Those skilled in the art will appreciate that a photon illumination and laser ferrule connector 98 has also been shown and described. Said ferrule 98 is especially useful for quick and positive connection of an optical fiber to a laser or illumination source 10 as herein described and further allows said source 10 to distinguish the optical fiber type or use, that is for illumination or medical laser application. The present art device is useful during surgery and especially ophthalmic surgery. Also, those skilled in the art will appreciate the integral inclusion of a laser optical fiber output power meter.

[0092] Having described the invention in detail, those skilled in the art will appreciate that modifications may be made of the invention without departing from its spirit. Therefore, it is not intended that the scope of the invention be limited to the specific embodiments illustrated and described. Rather it is intended that the scope of this invention be determined by the appended claims and their equivalents.

What is claimed is:

1. A ferrule connector for use with an illumination or laser source comprising:
   a ferrule body having an internal bore having an optical fiber; and
   a head; and
   a threaded portion attached with and following said head; and
   an alignment barrel attached with and following said threaded portion; and
   a mating end opposite said threaded portion; and
   an orifice in said mating end of substantially equivalent or greater diameter than said optical fiber.
2. The ferrule connector for use with an illumination or laser source as set forth in claim 1 further comprising:
   a recess within said alignment barrel whereby said optical fiber may be distinguished for use with a laser light source, an illumination light source, or both.
3. The ferrule connector for use with an illumination or laser source as set forth in claim 1 whereby:
   said threaded portion is an 8-32 UNC thread.
4. The ferrule connector for use with an illumination or laser source as set forth in claim 2 whereby:
   said threaded portion is an 8-32 UNC thread.
5. A ferrule connector for use with an illumination or laser source comprising:
   a connector body having an external end, a mating end, an internal bore which is substantially parallel with a lengthwise axis of the connector body, and an externally stepped form; and
   an optical fiber mounted within said bore; and
   a head of a first diameter having a first end and a second end, said first end co-located with said external end; and
   a threaded portion of a smaller diameter than said head attached with said head; and
   an alignment barrel having a circumference, a first end, and a second end, said first end of said alignment barrel attached with said threaded portion and said second end of said alignment barrel substantially co-located with said mating end of said body; and
   said second end of said alignment barrel having an orifice of substantially equivalent or slightly greater diameter as said optical fiber mounted within said bore and interconnected with said bore and said optical fiber terminated substantially flush with said second end of said alignment barrel; and
   said connector body with said alignment barrel capable of providing a quick and positive connection of said optical fiber to a laser source or an illumination source.
6. The ferrule connector for use with an illumination or laser source as set forth in claim 5 further comprising:
   a lip on said body of a greater diameter than said head and having a first side and a second side with at least a portion of said first side substantially mounted with said second end of said head and said threaded portion substantially attached with and extending from at least a portion of said lip second side.
7. The ferrule connector for use with an illumination or laser source as set forth in claim 5 further comprising:
   a recess within said circumference of said alignment barrel; and
   said recess indicating to said source whether said optical fiber is designed, best suited, or desired for an illumination light or a laser transmission light.
8. The ferrule connector for use with an illumination or laser source as set forth in claim further comprising:
   a recess within said circumference of said alignment barrel; and
   said recess indicating to said source whether said optical fiber is designed, best suited, or desired for an illumination light or a laser transmission light.
9. The ferrule connector for use with an illumination or laser source as set forth in claim whereby:
   said alignment barrel has one or more steps within said circumference; and
   one or more of said steps indicating to said source whether said optical fiber is designed, best suited, or desired for an illumination light or a laser transmission light.
10. The ferrule connector for use with an illumination or laser source as set forth in claim whereby:
said alignment barrel has one or more steps within said circumference; and
one or more of said steps indicating to said source whether
said optical fiber is designed, best suited, or desired for
an illumination light or a laser transmission light.
11. The ferrule connector for use with an illumination or
laser source as set forth in claim 5 whereby:
said threaded portion is an 8-32 UNC thread.
12. The ferrule connector for use with an illumination or
laser source as set forth in claim 6 whereby:
said threaded portion is an 8-32 UNC thread.
13. The ferrule connector for use with an illumination or
laser source as set forth in claim 6 whereby:
said threaded portion is an 8-32 UNC thread.
14. The ferrule connector for use with an illumination or
laser source as set forth in claim 6 whereby:
said threaded portion is an 8-32 UNC thread.
15. The ferrule connector for use with an illumination or
laser source as set forth in claim 6 whereby:
said threaded portion is an 8-32 UNC thread.
16. The ferrule connector for use with an illumination or
laser source as set forth in claim 10 whereby:
said threaded portion is an 8-32 UNC thread.
17. The ferrule connector for use with an illumination or
laser source as set forth in claim 5 whereby:
said internal bore comprises one or more bores of a larger
diameter than said orifice; and
a potting or an adhesive compound within one or more of
said bores of larger diameter whereby said optical fiber
is attached with said internal bore.
18. The ferrule connector for use with an illumination or
laser source as set forth in claim 7 whereby:
said internal bore comprises one or more bores of a larger
diameter than said orifice; and
a potting or an adhesive compound within one or more of
said bores of larger diameter whereby said optical fiber
is attached with said internal bore.
19. The ferrule connector for use with an illumination or
laser source as set forth in claim 9 whereby:
said internal bore comprises one or more bores of a larger
diameter than said orifice; and
a potting or an adhesive compound within one or more of
said bores of larger diameter whereby said optical fiber
is attached with said internal bore.
20. The ferrule connector for use with an illumination or
laser source as set forth in claim 11 whereby:
said internal bore comprises one or more bores of a larger
diameter than said orifice; and
a potting or an adhesive compound within one or more of
said bores of larger diameter whereby said optical fiber
is attached with said internal bore.

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