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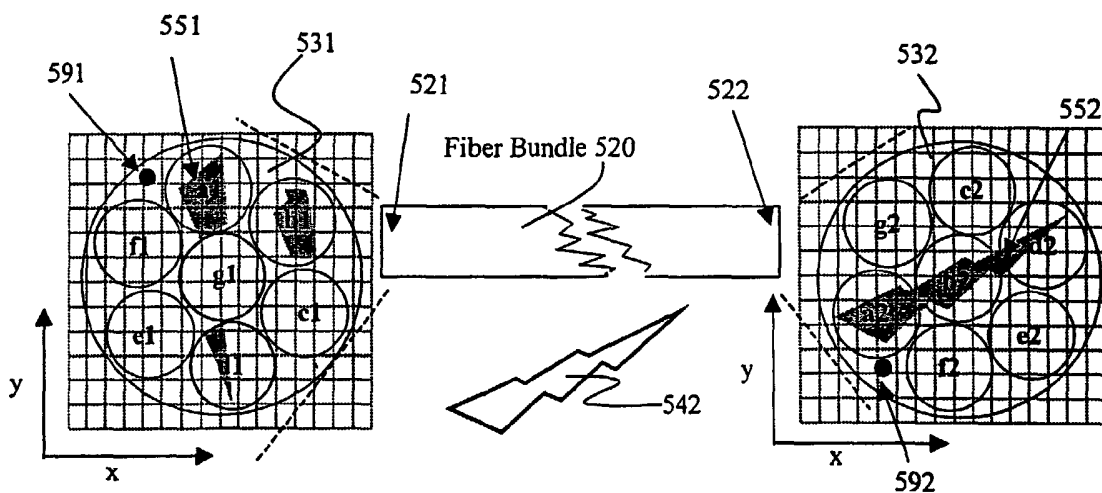
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(54) Title: NON-COHERENT FIBER OPTIC APPARATUS AND IMAGING METHOD



(57) Abstract: The present invention is a non-coherent optical fiber apparatus that may be used for imaging. Methods are described to produce geometric mapping data for an optical fiber apparatus. Images may be transmitted, reconstructed (using mapping data for the apparatus) and displayed. In addition, one or more fiber characteristics may be measured and used in conjunction with mapping data to further improve or correct the geometric, photometric or spectral content of images. The apparatus data described may be provided, by a manufacturer, for example, in raw form, or this data may be provided in a manner that is more user transparent, such as incorporating it into various image processing algorithms.

Non-coherent fiber optic apparatus and imaging method

Background of the Invention

In the field of fiber optics, rigid or flexible light transmitting fibers made of glass, plastic, polymers, or fluid-filled tubes etc. have many applications. Optical fibers can be further tailored to an application by selecting materials based on their mechanical properties such as size, shape, and flexibility and optical characteristics such as refractive index and transmission properties. Appropriately designed, optical fibers allow light to be transmitted over useful distances. Often two or more optical fibers are bundled, grouped or otherwise placed in close association to form a fiber optic bundle or conduit. Some applications of fiber optics include: delivering light to relatively inaccessible areas, such as instrument panels and body cavities, guiding laser light for medical procedures and carrying communications data. Further, in certain configurations, such as a coherent bundle, fiber optics may be used to transmit images, which is a subject of the present invention.

In the case of fiber optic endoscopes, tens of thousands of fibers may be utilized in a single device. Accordingly, within a single apparatus, for example, one fiber optic conduit may be used to deliver blue light (e.g. into the lungs) while a second fiber optic bundle may be used to return an image (e.g. an auto-fluorescence image of lung for diagnostic assessment).

When used to transmit images, existing methods place strict requirements on the geometric

relationship between individual fibers at opposite ends of a fiber optic apparatus. This geometric relationship is established and maintained during manufacturing. Typically, a core bundle of larger fibers are assembled, heated, and these fibers or cores are drawn out together, thus maintaining the side-by-side relationship of the fibers. Subsequently, both ends of these fiber bundles are cemented, fused, secured by an end sleeve or otherwise fixed.

This manufacturing process places certain limitations on the characteristics of fibers which may be used in the device. Similarly, when a substantial number of fibers are involved, imperfections in a sub-set of fibers may reduce device yield and thus increase manufacturing costs. In addition, for some applications, it may be advantageous to be able to select or mix fibers with desired properties.

Some of these manufacturing methods, concerns and limitations are further discussed in:

United States Patent No. 4011007 to Phaneuf entitled "Optical fiber bundle image conduit";

United States Patent No. 4389089, to Strack, entitled "Flexible fiber optical conduit and method of making";

United States Patent No. 6085011 to Klausmann entitled "Metal fiber end sleeve for a flexible fiber optic light guide and method for producing same";

United States Patent No. 4812400 to Washizuka entitled "Optical fiber assembly for an

endoscope”;

45 United States Patent No. 5944867 to Chesnoy, entitled “Method of manufacturing a multi-core optical fiber”;

United States Patent No. 4461841 to Harada, entitled “Acid-soluble glass composition for making flexible fiber optic bundle”.

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To provide fibers with comparable diameters and properties, rods or cores of larger glass fibers are typically heated and are drawn as a unit to the desired cross-sectional size. Similarly, individual larger cores may be fused together and the larger assemblies drawn out, together. This process is described for example in United States Patent No. 4389089 to Strack, entitled “Flexible fiber optical
55 conduit and method of making” and in United States Patent No. 4011007 to Phaneuf entitled “Optical fiber bundle image conduit”.

Hicks in United States Patent No. 3004368, issued October 17, 1961, entitled “Manufacture of fiber optical devices”, teaches: “In order to obtain an accurate reproduction of an image which is
60 transferred by a device of the above character, it is essential that the individual light-conducting fibers be arranged in identical geometric patterns at the opposite ends of the device so that each part of an image at the object end of the device will be reproduced at the image end thereof in its true location.”

65 Twenty three years later, these same limitations were echoed by Harada in United States Patent No.
4461841, issued July 24, 1984, entitled "Acid-soluble glass composition for making flexible fiber
optic bundle", in which he teaches: "When the fiber optic bundle is used as an image-transmitting
device, it is essential that the individual optical fibers be arranged in identical geometric patterns at
the opposite ends of the bundle so that each part of an image at the object end of the bundle will be
70 reproduced at the image end thereof in the same location."

More recently still, United States Patent No. 6205275, to Melville, entitled "Fiber-optic image
transfer assembly and method of using" among other things discusses fiber optic tapers used to
magnify or reduce images using coherent configurations.

75 United States Patent No. 4011007 to Phaneuf entitled "Optical fiber bundle image conduit"
expresses this in terms of manufacture, stating "Accordingly, after drawing the bundle to its final
dimension, opposite ends of the drawn bundle may be plotted to enclose and maintain the geometric
patterning of the individual fiber ends of the conduit."

80 More recently, in respect to multi-core optical fibers, Chesnoy in United States Patent No. 5944867
entitled "Method of manufacturing multi-core optical fiber", says "One of the main requirements
making multi-core optical fibers is that the cores must be positioned accurately relative to one
another. Such accurate positioning makes it possible to effect reliable connections, and to avoid
85 interference between signals conveyed by the various cores (crosstalk)." United States Patent No.
5222180, to Kuder, entitled "Polymer optical fibre bundle and method of making same" discusses

alternative means of configuring fiber optic devices with close-packed geometry which include fibers that are not substantially oval shaped.

90 Substantial efforts have been applied to develop methods to maintain the required fiber geometry for imaging, such as fused ends or application of an end sleeve. United States Patent No. 6085011 to Klausmann entitled "Metal Fiber end sleeve for a flexible fiber optic light guide and method for producing same", discusses final assembly and application of an end sleeve to maintain fiber alignment. In addition, Klausmann describes aspects of the process as potentially being very time
95 consuming, exacting and indicates that sometimes complete fiber alignment is difficult or not possible to achieve.

United States Patent No. 5717806, to Pileski, entitled "Bifurcated randomized fiber bundle light cable for directing light from multiple sources to a single light output"; and United States Patent No.
100 6418257, to Nash, entitled, "UVC liquid light guide" discuss various aspects of fiber optical apparatus.

United States Patent No. 6388742 to Duckett, entitled "Methods and apparatus for evaluating the performance characteristics of endoscopes" further describes means to test an endoscope.

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Means and methods cited above may be exploited to advantage for the present invention and are therefore included by reference herein.

There remains a need for a fiber optic imaging apparatus which better meets the optical, physical,
110 mechanical and manufacturing requirements, such as higher yield and/or reduced cost. It is therefore
an object of the present invention to provide a fiber optic apparatus for imaging that does not require
that the geometric relationship of fibers at respective ends, correspond. Another object of the present
invention to allow a wider range of materials and fibers that may be selected to form an imaging
bundle that may be used for imaging. It is a further object of the present invention to provide a fiber
115 optical apparatus that may be manufactured more easily, with higher yield, at lower cost or otherwise
provide advantages. It is a further object of the present invention to provide a means to improve or
correct for geometric, photometric or spectral content of images.

SUMMARY OF THE INVENTION

120 The present invention is a fiber optic imaging apparatus that does not require that the geometric
relationship of fibers at respective ends, correspond. This relaxed constraint means that cheaper
fibers or fibers with desired characteristics, fibers of various shapes, or bundles of fibers or
organizations with mixtures of fibers with diverse properties may be combined to form a new
125 apparatus. Therefore, the present invention allows a wider range of fiber selection to better meet
desired optical and/or physical characteristics such as spectral response, transmission efficiency,
flexibility, size, weight, etc. for the optical imaging apparatus.

As used herein, fiber characteristic means the physical and optical properties of optical fibers or
130 optical fiber bundles including their size, shape, flexibility, diameter, area, tapering, bandwidth, bend

radius, material composition, chromatic dispersion, cladding, cleave, coating, concentricity, core, core eccentricity, attenuation, spectral attenuation, graded index, refractive index, length, insertion loss, tensile strength, jacketing material, numerical aperture, or any other parameter that may be measured and exploited to advantage. When a plurality of fibers are considered, field of view, image quality, distortion, depth of field etc. represent additional useful characteristics.

Please note that another name for “fluid-filled tube” or “fluid-filled light guide” is “liquid light guide”.

A method of developing geometric mapping data for a fiber optic apparatus during or subsequent to manufacture is described. A method of using a fiber optic apparatus with geometric mapping data for imaging is also described. In addition, a method of measuring one or more optical fiber characteristics is described along with a method of utilizing measured fiber characteristic to further improve or correct the geometric, photometric or spectral content of images. Such data may be recorded and may be provided in electronic or other useful format or this data may be made transparent to the user by incorporating it into image processing algorithms, and supplying these.

BRIEF DESCRIPTION OF DRAWINGS

The foregoing and other objects, features, and advantages of the invention will be apparent from the following descriptions of preferred embodiments and drawing illustrating principals of the invention and its use.

In the accompanying drawings:

155 Figure 1 (Prior art) shows the existing limitations of fiber geometry and provisions necessary to use a fiber optic bundle for imaging.

Figure 2 shows the present invention as used to transmit an image or other information before additional methods are applied.

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Figure 3 shows a method to discern the geometric relationship between fibers at opposite ends of an optical fiber bundle.

Figure 4 illustrates a method to further automate the recording of fiber mapping data and fiber
165 characteristics.

Figure 5a further illustrates the present invention

Figure 5b further illustrates the process of developing and recording mapping data and fiber
170 characteristic data.

Figure 5c illustrates the application of fiber mapping and fiber characteristics for image reconstruction and processing.

175 Figure 6 illustrates a more complex fiber optic apparatus

DETAILED DESCRIPTIONS OF THE PREFERRED EMBODIMENTS

180 While the invention may be susceptible to embodiments in different forms, there is shown in the drawings, and herein will be described in detail, specific embodiments with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that as illustrated and described herein.

Figure 1 (Prior art) illustrates a fiber bundle 120 having a first (reference) end 121 and a second end 185 122 which are further shown in expanded views 131, 132, respectively. The fiber bundle illustrated has seven fibers indicated as a-g, further designated as a1-g1 at the first end and opposing ends of these fibers designated a2-g2 at the second end. Although there may be some axial rotation of the fiber bundle 120, individual fibers a1-g1, at the first end 121, seen in expanded view 131, maintain their geometric position, that is their side-by-side relationship and emerge at the second end 122 at 190 the same relative geometric position. Often, as a step in the manufacturing process for fiber optic bundles, fibers are drawn together, preserving this geometry. Then the first and second ends are fitted with an end sleeve or these ends are cemented, fused or otherwise, their geometries are fixed. Subsequently, once the ends are fixed fibers may be allowed to flex and move independently within the conduit of the fiber bundle, as desired.

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Geometric position and axial rotation are further indicated and may be seen by comparing relative geometric position of all fibers in respect to a reference point, at each end. Reference point means a location, mark or marks that may be established and used to identify the geometric position of fibers at the end of an optical fiber apparatus, such as a selected fiber, scribe, connector notch, protrusion, indentation, magnetic ink spot, or any other indicator that can be exploited, accordingly. In this case fiber a1 (further designated 140a) at the first end serves as a reference point and the opposite end of this fiber, a2, designated 140b serves as a reference point for the second end. Moving from reference point 140a at the first end, fibers b1, c1, d1, e1, f1 appear in clockwise order, as illustrated, with fiber g1 (at the middle). Similarly, moving from the corresponding reference point 140b at the second end, preservation of the geometric position is illustrated with fibers appearing clockwise, as indicated, b2, c2, d2, e2, f2, with g2 in the middle. Such a geometric configuration allows fiber optic bundle to transmit an image (or other information that relies upon geometric position) and allows that information to be substantially recovered, or viewed.

To illustrate use of fiber bundle 120, for imaging, object 142 is positioned at the second end allowing an object image 152, to be substantially captured by fibers a2,g2,d2 as indicated in expanded view 132. The object image 152 is transmitted by these fibers and emerges as object image 151, in the expanded view 131, at the first end 121 of the fiber bundle 120. The described geometry shows how information content, such as object image 152, is transmitted and recovered. Clearly, this level of image detail will not be preserved in the relatively large fibers diagramed, however, the shape and position of the object are intended to illustrate the principals of image content and orientation. Alternatively, each of the fibers could be considered to be a bundle of smaller fibers in a coherent

arrangement so as to better approximate the diagram. For consistency these principals will be used in subsequent figures.

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Figure 2 illustrates a fiber optic apparatus of the present invention with a fiber bundle 220, having a first (reference) end 221 and a second end 222 which are as also shown in expanded views 231,232, respectively. Although there may be some axial rotation of the fiber bundle 220, individual fibers indicated by a1-g1 at the first end 231, do not necessarily maintain their geometric position at the second end 232 as indicated by fibers a2-g2. Note in particular that fibers designated as b2 and g2 at the second end (as seen in expanded view 232) are displaced relative to their geometric position, (illustrated as b1 and g1) relative to first end expanded view 231. To better illustrate the properties of this particular fiber bundle 220, an image 252 of object 242 at the second end of the fiber bundle 220, as diagramed, is seen to be substantially captured by fibers a2,g2,d2 in second end expanded view 232. The object image 252 is transmitted by these fibers and is seen to emerge as object image 251 at the first end of the fiber bundle 220 in fibers a1,g1,d1. However, since geometric position of the fibers in fiber bundle 220 are not preserved between the first end 221 and the second end 222, the image information is degraded. Additional figures will describe methods to measure and record geometric mapping data for an optical fiber apparatus to use such a non-coherent bundle for imaging.

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Figure 3 illustrates a fiber optic apparatus of the present invention with fiber bundle 320, having a first (reference) end 321 and a second end 322 which are shown in expanded views 331,332, respectively. Electromagnetic radiation 351 is directed into fiber (a1) at the first end. Various

240 methods of directing light into fibers are known, some of which employ lenses, light modulators, optical couplers, micro-mirror devices etc. United States patent No. 6388742 discusses testing endoscopes using a plurality of light sources to test field of view, image quality distortion, depth of field and angle of view.

245 United States Patent No. 6434302, to Fidric, entitled "Optical couplers for multimode fibers", United States Patent No. 6016376 to Ghaemi, entitled "Tapered coherent fiber bundle imaging device for near-field optical microscopy" and United States Patent No. 5864644 to DiGiovanni, entitled "Tapered fiber bundles for coupling light into and out of cladding pumped fiber devices". The prior art discussed in association with Figure 3 addresses optical coupling and other aspect of optical
250 apparatus and is therefore included herein by reference.

The fiber (a1) may be identified in any effective or convenient manner such as by designating it a color, letter, number, scribe, x-y location, geometric coordinate etc. In this instance, for example, it may be identified by its geometric position relative to a reference point, in this instance, mark 341.

255 Accordingly, electromagnetic radiation is transmitted down the fiber and emerges as 352 at the opposite end of the fiber as labeled (a2) in the second end expanded view 332. As necessary, electromagnetic radiation may be adjusted at the first end until it is seen to emerge from substantially a single fiber at the second end. The geometric position of the fiber at the second end is now recorded, in this instance, using mark 342 as a reference point. By proceeding in this manner
260 geometric mapping data may be recorded for the device. Similarly, fiber characteristics, for example, diameter, surface area, intensity or spectral properties of emerging light, for individual or

groups of fibers may be measured and recorded. A more automated method of measuring and recording the geometric mapping data will be described in association with Figure 4 with a geometric mapping with device characteristics further described, applied and illustrated in association with Figure 5 a,b,c.

Figure 4 illustrates a fiber bundle 420, of the present invention, having a first (reference) end 421 and a second end 422, shown in expanded views 431, 432, respectively. As indicated, in addition to some rotation of the fiber bundle 420, individual fibers a2-g2 at the second end 422 (seen in expanded view 432), do not necessarily correspond geometrically with their position illustrated as a1-g1 in first end expanded view 431. As illustrated, under guidance of a controller, electromagnetic radiation from source 441 is focused and scanned 451 onto desired fibers (or groups of fibers) at the first end of the fiber bundle. Fiber f1 (461) in expanded view 431, as illustrated, receives radiation. That radiation is transmitted down the fiber and emerges from the opposite end of the fiber designated as f2 in second end expanded view 432 and is detected by a detector 452, which could be for example, a CCD camera. When radiation is determined to emerge substantially from one fiber at the second end, as described in association with figures 3, geometric position may be recorded in an appropriate manner. The method and configuration of figure 4 allows mapping data to be gathered, recorded or otherwise stored, in an automated manner. The same detector 452 may be used or additional detectors (not shown) may be employed to measure fiber characteristics other than geometric position, such as fiber diameter, surface area, intensity or spectral response from the emerging radiation, etc as discussed in association with figure 3.

For convenience, rather than providing a detector at the first end, once the geometric location of a
285 fiber is known, the fiber optic bundle may be reversed to allow other useful fiber characteristics to
be measured for the first end.

Figure 5a illustrates the method of fiber mapping and its application. As discussed in association
with Figure 2, here object information 552 representing object 542 is carried by the fiber bundle, in
290 this instance substantially by fibers a2,b2,d2 at the second end 522, shown in expanded view 532.
Some information content is degraded, lost or displaced as received at the first end 521, illustrated
as 551 in the expanded view 531. The degradation in information content, in this instance is
represented by the change in geometric position of fibers b2,g2 at the second end, relative to their
position at the first (reference) end. Again, as discussed in association with previous figures,
295 geometric position may be established relative to a reference point, in this instance mark 591 and
mark 592 at respective ends of fiber bundle 520.

The x,y geometric position at the first end and second end indicated by the grid may provide, if
desired, sufficient resolution to determine the position of the fiber and allow additional fiber
300 characteristics, as defined, (e.g. area), to be measured. For example, an appropriate CCD used as
a detector as described with figures 3 and 4, combined with control over the wavelength(s) or
intensity of the light source allows characteristics of individual fibers or groups of fibers to be
measured. Various detectors and means, such as spatial light modulators, spectrometers,
photometers etc. may be combined appropriately to measure desired fiber characteristics. Additional
305 image degradation is further illustrated via the reduced area of fiber a, identified as a1 in first end

expanded view 531 and further identified by legend 551. Measurement of such a fiber characteristic and application of this data will now be further described along with application of fiber characteristic data to image processing.

310 Figure 5b shows the mapping data and a measured fiber characteristic for the fiber apparatus diagramed in figure 5a. In this example, fiber e1 has an area of 10, indicated as 561, at the first end, and area 9, indicated as 562 at the second end. Measurement of such fiber characteristics may be used to further correct, improve or otherwise be applied to advantage in processing the image. In this instance the image data transmitted in this fiber is shown smaller and is amplified (shown larger)
315 during image process as will be further described in association with figure 5c.

Geometric data mapping and measurement of desired fiber characteristics may be recorded and stored in various ways. A user could perform these functions or more typically, a manufacturer would gather this data and provide the optical fiber apparatus with this support data, providing it in
320 a useful form such as on a computer disk or making it available in electronic form that could be downloaded from the internet, for example. Similarly, this data may be abstracted in the form of image processing algorithms where geometric and any characteristic data is incorporated in a more transparent manner.

325 As describe in U.S. Pat. No. 6388742, complex fiber imaging apparatus may be assessed for performance. The present invention, using geometric and fiber characteristic data would allow a given device to be programmed to meet or match a 'bench-mark' or reference device. Such

matching could be performed with the aid of computers and various detectors and light sources. The result would be a batch of devices with substantially similar characteristics. Medical, industrial and other fields of use would benefit accordingly. Tapered fiber bundles provide an example of devices, which are currently relatively complex and expensive to manufacture.

Figure 5c shows a camera sensor (514) capturing image information having principal components 524a, 524b and 524c from one end 504 of an optical fiber apparatus of the present invention. Raw image data from camera sensor 514 is transferred to computer memory 544 and the image data is represented in this domain by components 534a, 534b and 534c. Some data loss through fiber 'a' (shown smaller in Fig. 5a, marked 515) is further indicated in the capture of the object image component 534a – transmission characteristics for this fiber, having been measured and represented in the mapping data as described in association with figure 5b. Raw image data in computer memory 544 is now processed using mapping and characteristic data for the apparatus. Display of the processed image data 556 is shown on computer display 555. As illustrated, image component 534a is corrected based on measured fiber characteristics stored in conjunction with the geometric mapping data. Measuring such fiber characteristics and applying them appropriately with mapping data allows further geometric, photometric or spectral processing to be applied to images. The image is reconstructed from the fiber geometry stored in the mapping data. Finally, as illustrated the reconstructed image data is rotated, in this instance to recover the orientation of the original object 542 of figure 5a. Additionally, fiber characteristics may be further applied, for example to correct for photometric loss or spectral changes. Accordingly, substantial portions of the image could be color corrected for display.

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Figure 6 illustrates a fiber optic apparatus 620 of the present invention having a first end 621 seen in first end expanded view 631, has various components which are separated at the second end 622, as shown in second end expanded view 632. In this instance two separate sources of electromagnetic radiation, 643, 644 are used during the mapping process as previously described in association with figures 3,4,5. A non-round fiber bundle 645 has all of its fibers illuminated simultaneously during mapping. Fiber L1 as illustrated represents a fluid filled light guide which could be used, for example, to illuminate the instrument panel of a measurement device. Fibers A1,B1,C1 at the first end, emerge at the second end as A2,B2,C2. The fibers are separated and positioned so as to read a DNA micro-array from microscope slide 642. Fiber designated M1 at the first end emerges and has its second end M2 and that end is further shown coated with a fluorescent tagged monoclonal antibody thus forming a bio-probe for a specific protein. As previously described desired fiber characteristics and geometric information are stored for the apparatus and may be used accordingly.

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While a preferred embodiment of the present invention is shown and described, it is envisioned that those skilled in the art may devise various modifications of the present invention without departing from the spirit and scope of the appended claims.

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We claim:

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1. A fiber optic mapping apparatus comprising

a plurality of optic fibers,

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each of said fibers having a first end and a second end,

wherein said fibers have positions at said first end, and positions at said second end,

and

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wherein said position of at least one of said fibers at said first end is known and said position of said at least one of said fibers at said second end is unknown,

means for transmitting electromagnetic radiation into said first end of said at least one of said fibers,

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means for detecting said electromagnetic radiation at said second end of said at least one of said fibers,

means for recording said position of said at least one of said fibers at said second end.

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2. The apparatus of claim 1, further comprising means for providing said recorded position of said at least one of said fibers at said second end.
3. The apparatus of claim 1, further comprising at least one additional fiber optic bundle,
395 comprising at least one optic fiber, associated with the said fiber optic bundle.
4. The apparatus of claim 1, further comprising means for measuring at least one characteristic of said at least one of said fibers at said first end.
- 400 5. The apparatus of claim 4, wherein said means for recording further records the measurement of said at least one characteristic.
6. The apparatus of claim 5, further comprising means for providing said measurement of said at least one characteristic.
- 405 7. The apparatus of claim 4, further comprising means for selecting at least one of said fibers based on said measured at least one characteristic.
8. The apparatus of claim 4, further comprising means for measuring at least one characteristic
410 of said at least one of said fibers at said second end.

9. The apparatus of claim 8, wherein said means for recording further records the measurement of said at least one characteristic of said at least one of said fibers.

415 10. The apparatus of claim 9, further comprising means for providing said measurement of said at least one characteristic.

11. The apparatus of claim 8, further comprising means for selecting at least one of said fibers based on said measured at least one characteristic.

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12. The apparatus of claim 1, wherein said plurality of optic fibers is grouped in a tapered bundle.

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13. The apparatus of claim 1, further comprising means for identifying said at least one of said fibers at said first end based on at least one of the following: color, letter, number, scribe, x-y location, geometric coordinate, axial coordinate, Cartesian coordinate, position relative to a reference point.

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14. An apparatus for transmitting image information, comprising
a plurality of optic fibers forming a fiber optic bundle having a first end and a second end,

wherein said fibers have positions at said first end, and positions at said second end,
and

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wherein said position of said at least one of said fibers at said first end is known and
said position of said at least one of said fibers at said second end is unknown,

means for identifying said at least one of said fibers at said first end,

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means for detecting said position of said at least one of said fibers at said second end,

means for recording said position of said at least one of said fibers at said second end,

445

means for transmitting information encoded as optical signals into said first end of said
fibers,

means for receiving said optical signals from said second end of said fibers, and

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means for using said recorded position of said at least one of said fibers at said second end
to decode said received optical signals into said transmitted information.

15. The apparatus of claim 14, further comprising means for providing said recorded position
of said at least one of said fibers at said second end.

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16. The apparatus of claim 14, further comprising at least one additional fiber optic bundle, comprising at least one optic fiber, associated with the said fiber optic bundle.

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17. The apparatus of claim 14, further comprising means for measuring at least one characteristic of said at least one of said fibers at said first end.

18. The apparatus of claim 17, further comprising means for recording the said at least one characteristic of said at least one of said fibers.

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19. The apparatus of claim 18, further comprising means for providing the said at least one characteristic.

20. The apparatus of claim 17, further comprising means for selecting fibers based on the said at least one characteristic.

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21. The apparatus of claim 14, further comprising means for measuring at least one characteristic of said at least one of said fibers at said second end.

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22. The apparatus of claim 21, further comprising means for recording said at least one characteristic of said at least one of said fibers.

23. The apparatus of claim 22, further comprising means for providing said at least one characteristic.
- 480 24. The apparatus of claim 21, further comprising means for selecting fibers based on said at least one characteristic.
25. The apparatus of claim 14, wherein said fiber optic bundle is tapered.
- 485 26. The apparatus of claim 14, wherein said means for identifying is based on at least one of the following: color, letter, number, scribe, x-y location, geometric coordinate, axial coordinate, Cartesian coordinate, position relative to a reference point.
27. An apparatus for transmitting information, comprising
- 490 a plurality of optic fibers forming a fiber optic bundle having a first end and a second end,
- wherein said fibers have a first end position and a second end position,
- 495 means for mapping said first end position,
- means for mapping said second end positions,

means for measuring a characteristic of each of said fibers,

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means for transmitting image information comprising optical signals into said second end,

means for receiving said optical signals at said first end,

505

means for using said mapped first end positions and said second end positions to decode said received optical signals, and

means for improving said image information by using said measured characteristic.

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28. An apparatus for measuring a characteristic of optical fibers, comprising

means for identifying the geometric position of said fibers,

means for measuring at least one characteristic of each of said fibers, and

515

means for recording said at least one characteristic.

29. A fiber optic mapping method comprising

520 grouping a plurality of optic fibers to form a fiber optic bundle having a first end and
a second end,

 wherein said fibers have positions at said first end, and positions at said
second end, and

525

 wherein the position of at least one of said fibers at said first end is known
and the position of said at least one of said fibers at said second end is
unknown,

530

 identifying said at least one of said fibers at said first end,

 detecting said position of said at least one of said fibers at said second end, and

 recording the position of said at least one of said fibers at said second end.

535

30. The method of claim 29, further comprising providing said recorded position of said at least
one of said fibers at said second end.

31. The method of claim 29, wherein at least one additional fiber optic bundle, comprising at
least one optic fiber, is associated with the said fiber optic bundle.

540

32. The method of claim 29, further comprising measuring at least one characteristic of said at least one of said fibers at said first end.

545 33. The method of claim 32, further comprising recording said at least one characteristic of said at least one of said fibers.

34. The method of claim 33, further comprising providing said at least one characteristic.

550 35. The method of claim 32, further comprising selecting at least one of said fibers based on said at least one characteristic.

36. The method of claim 29, further comprising measuring at least one characteristic of said at least one of said fibers at said second end.

555

37. The method of claim 36, further comprising recording said at least one characteristic of said at least one of said fibers.

38. The method of claim 37, further comprising providing said at least one characteristic.

560

39. The method of claim 36, further comprising selecting at least one of said fibers based on said at least one characteristic.

40. The method of claim 29, further comprising grouping said plurality of optic fibers to form
565 a tapered fiber optic bundle.

41. The method of claim 29, further comprising identifying said at least one of said fibers at said
first end based on at least one of the following: color, letter, number, scribe, x-y location,
geometric coordinate, axial coordinate, Cartesian coordinate, position relative to a reference
570 point.

42. A method of transmitting fiber optic information, comprising

grouping a plurality of optic fibers to form a fiber optic bundle having a first end and
575 a second end,

wherein said fibers have positions at said first end, and positions at said
second end, and

580 wherein the position of said at least one of said fibers at said first end is
known and the position of said at least one of said fibers at said second end
is unknown,

identifying said at least one of said fibers at said first end,

585

detecting said position of said at least one of said fibers at said second end,

recording said detected position of said at least one of said fibers at said second end

590 transmitting information encoded as optical signals into said first end of said fibers

receiving said optical signals from said second end of said fibers, and

using said recorded position of said at least one of said fibers at said second end to

595 decode said received optical signals into said transmitted information.

43. The method of claim 42, further comprising providing said recorded position of said at least one of said fibers at said second end.

600 44. The method of claim 42, further comprising associating at least one additional fiber optic bundle, comprising at least one optic fiber, with the said fiber optic bundle.

45. The method of claim 42, further comprising measuring at least one characteristic of said at least one of said fibers at said first end.

605

46. The method of claim 45, further comprising recording said at least one characteristic of said at least one of said fibers.

47. The method of claim 46, further comprising providing said at least one characteristic.
- 610
48. The method of claim 45, further comprising selecting at least one of said fibers based on said at least one characteristic.
49. The method of claim 42, further comprising measuring at least one characteristic of said at
- 615 least one of said fibers at said second end.
50. The method of claim 49, further comprising recording said at least one characteristic of said at least one of said fibers.
- 620 51. The method of claim 50, further comprising providing said at least one characteristic.
52. The method of claim 49, further comprising selecting at least one of said fibers based on said at least one characteristic.
- 625 53. The method of claim 42, further comprising grouping said plurality of optic fibers to form a tapered optic bundle.
54. The method of claim 42, further comprising identifying said at least one of said fibers at said first end based on at least one of the following: color, letter, number, scribe, x-y location,

630 geometric coordinate, axial coordinate, Cartesian coordinate, position relative to a reference
point.

55. A method of transmitting information, comprising

635 grouping a plurality of optic fibers to form a fiber optic bundle having a first end and a
second end,

 wherein said fibers have a first end position and a second end position,

640 mapping said first end position,

 mapping said second end positions,

 measuring a characteristic of each of said fibers,

645 transmitting image information comprising optical signals into said second end,

 receiving said optical signals at said first end,

650 using said mapped first end positions and said second end positions to decode said received
optical signals, and

improving said image information by using said measured characteristic.

56. A method of measuring a characteristic of optical fibers, comprising

655

identifying the geometric position of said fibers,

measuring at least one characteristic of each of said fibers, and

660

recording said at least one characteristic.

Figure 1
(Prior art)

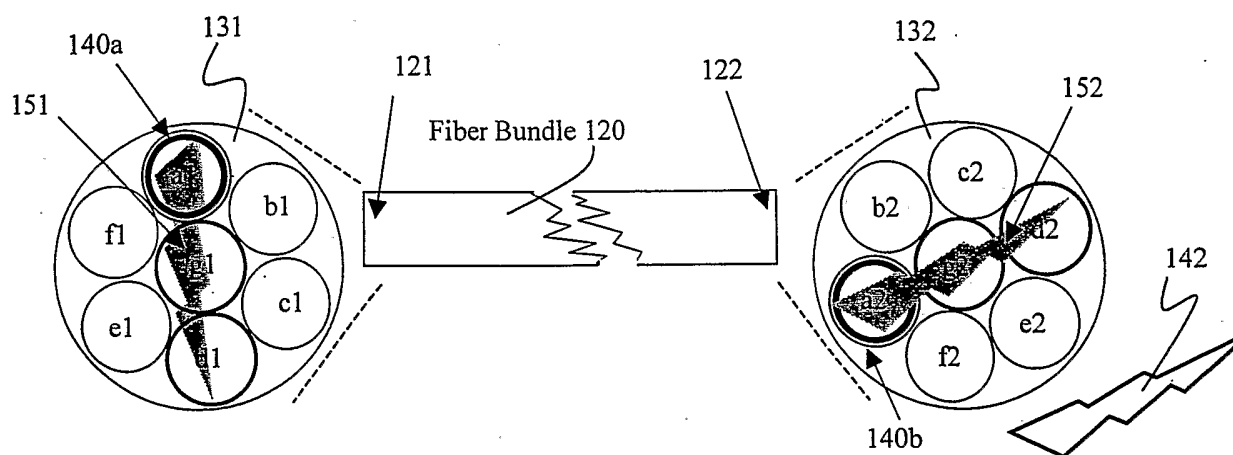


Figure 2

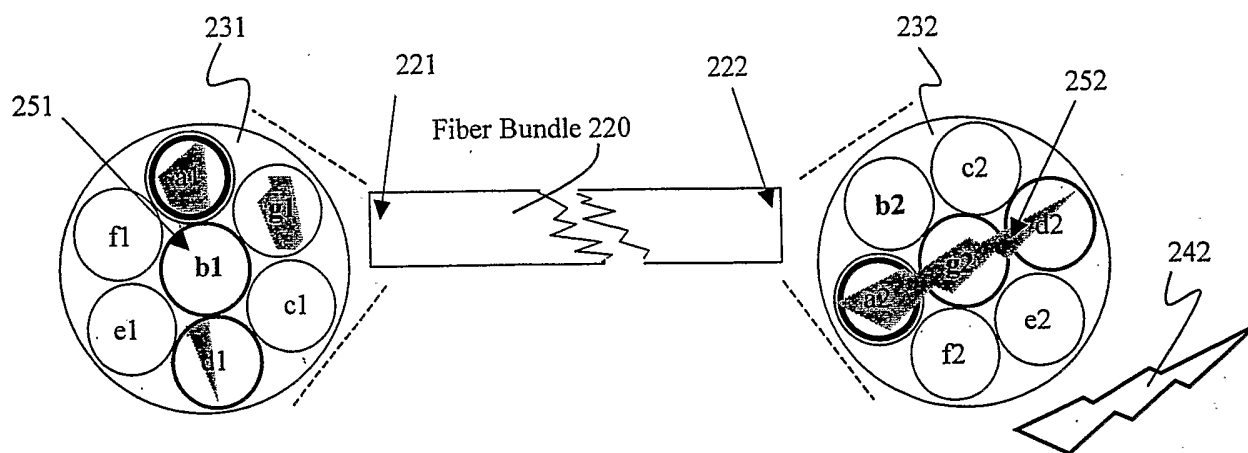


Figure 3

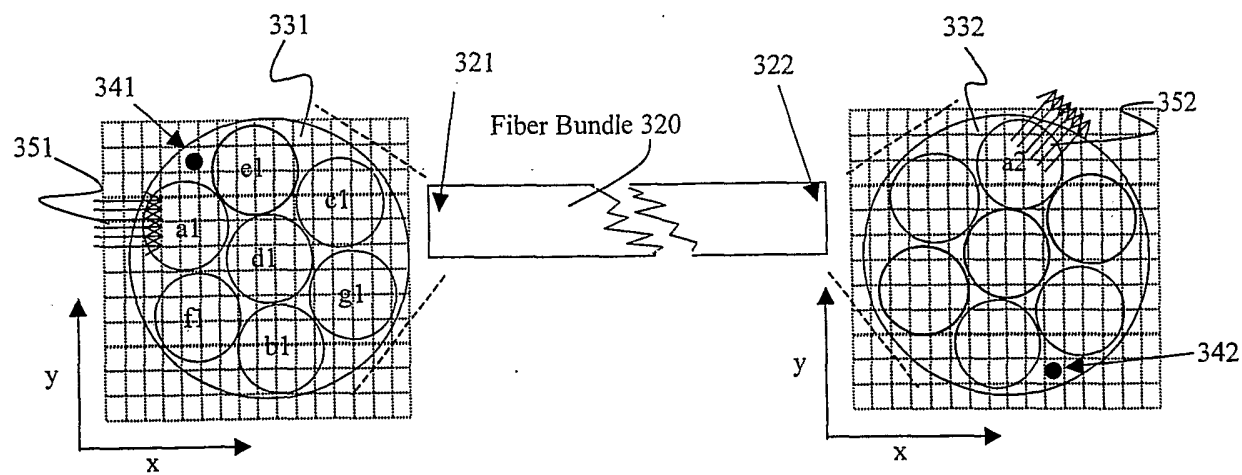


Figure 4

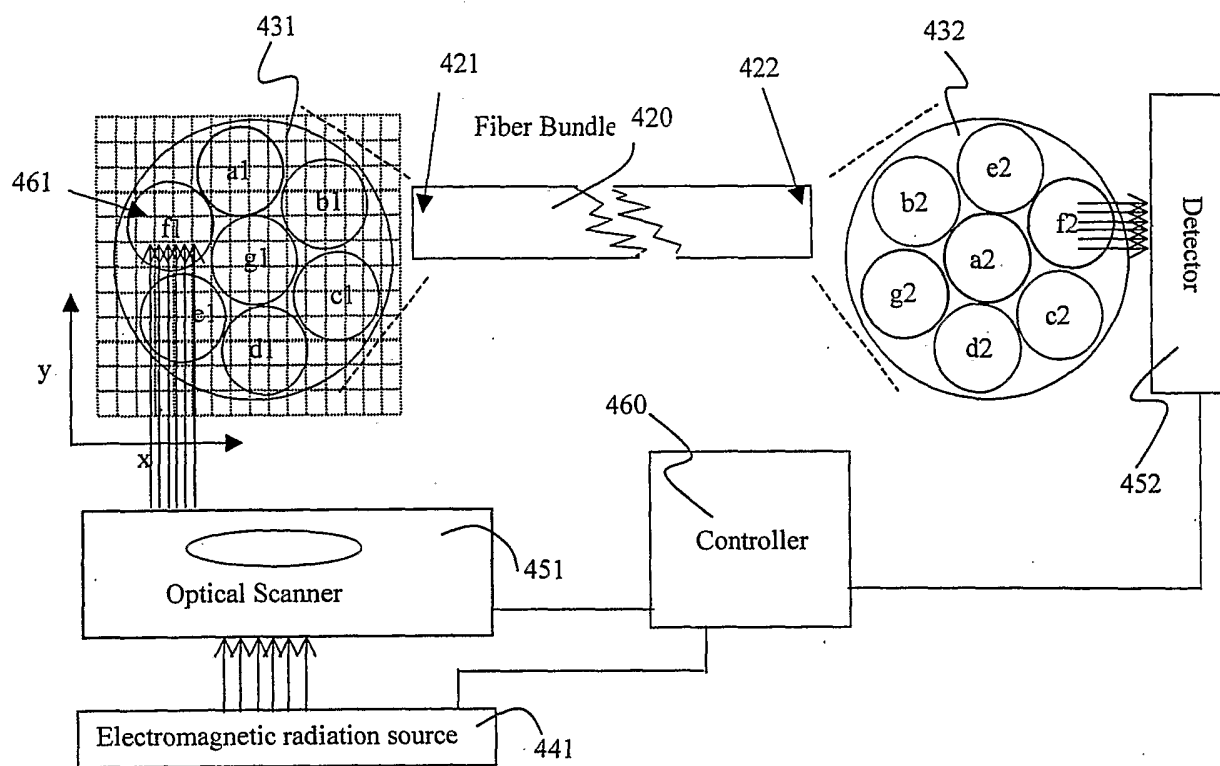


Figure 5a

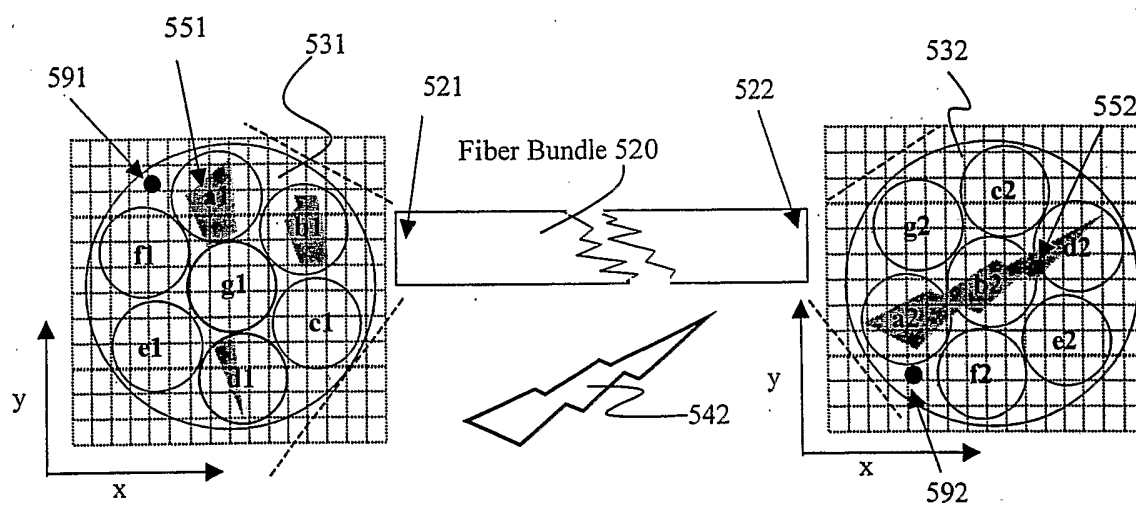


Figure 5b

First end (reference)	x	y	area	Second end	x	y	area
Reference indicator	5	10		Reference indicator	5	3	
a1	8	10	10	a2	4	5	10
b1	13	8	10	b2	9	7	10
c1	13	5	10	c2	10	10	10
d1	9	3	10	d2	13	8	10
e1	5	4	10	e2	13	4	9
f1	4	7	10	f2	8	3	10
g1	9	6	10	g2	5	8	10

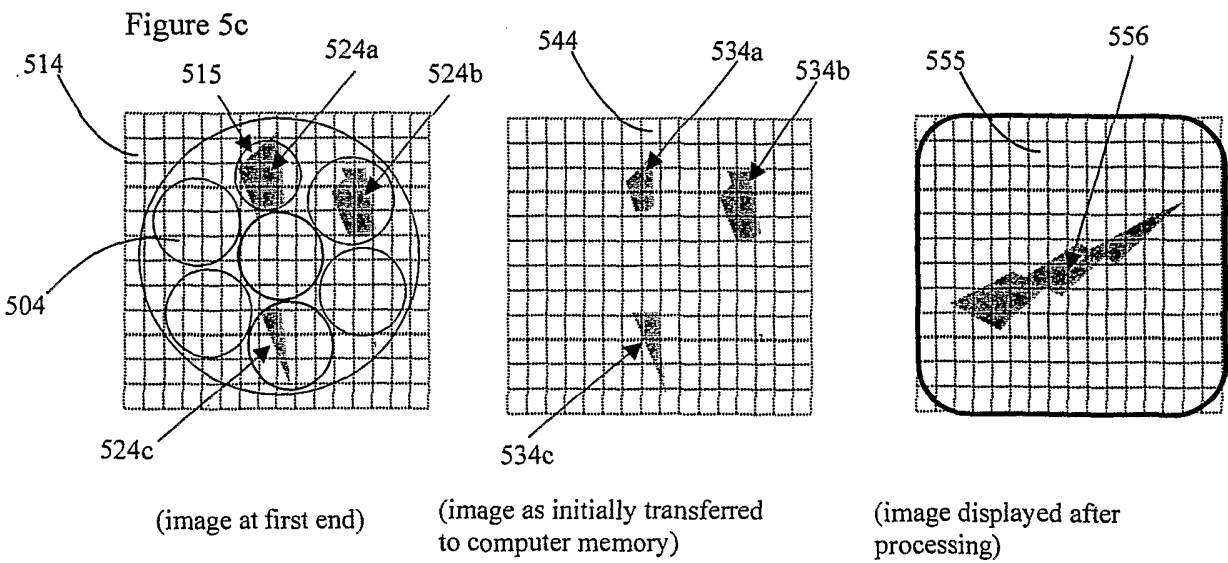
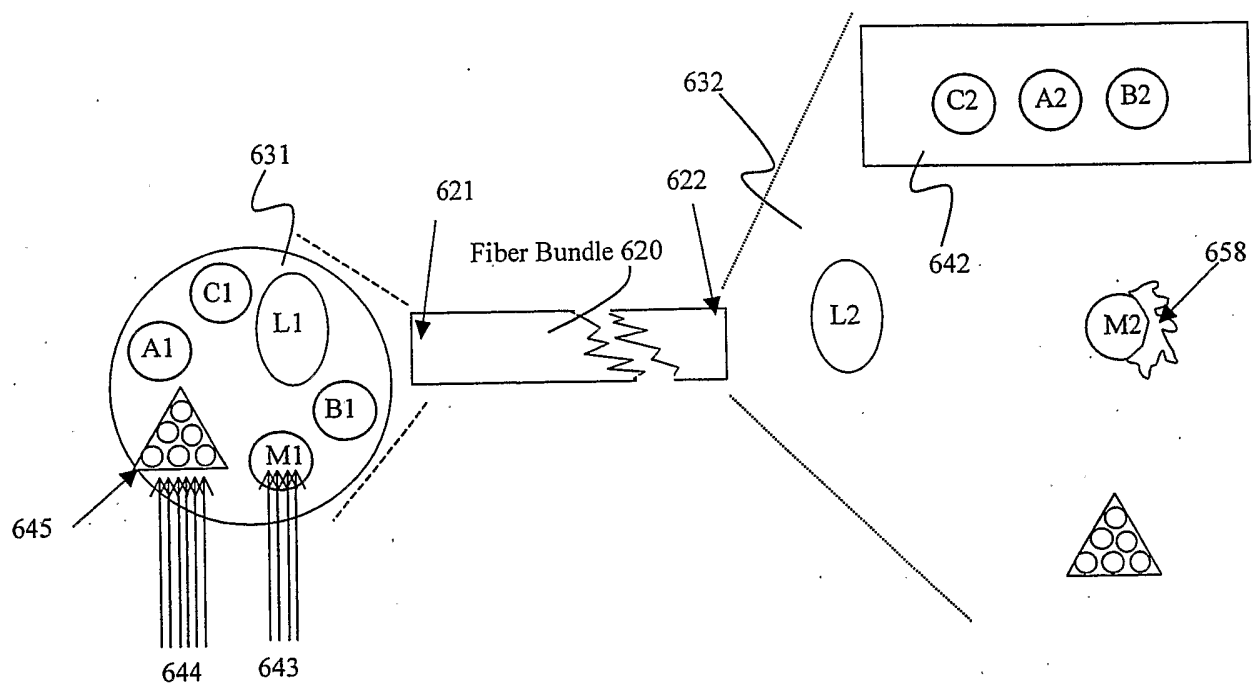


Figure 6



INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 03/01263

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/04 G02B6/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 553 184 A (EIKELMANN ECKARD ET AL) 3 September 1996 (1996-09-03) column 2, line 30 -column 6, line 46; figures 1,2 ---	1,14, 27-29, 42,55,56
X	US 4 760 421 A (MARGOLIN GEORGE D) 26 July 1988 (1988-07-26)	1-3, 12-16, 25-31, 42-44, 53-56
Y	column 2, line 5 -column 4, line 25; figures 1,4,8-14 column 5, line 18 -column 6, line 53 column 9, line 49 -column 10, line 13 --- -/--	4-11, 17-24, 32-38, 45-52



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 03/01263

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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