US012383127B2

(12) **United States Patent**
Benning et al.

(10) **Patent No.: US 12,383,127 B2**
(45) **Date of Patent: *Aug. 12, 2025**

(54) **ENDOSCOPIC SYSTEM FOR ENHANCED VISUALIZATION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **18/593,545**

(22) Filed: **Mar. 1, 2024**

(65) **Prior Publication Data**

US 2024/0197158 A1 Jun. 20, 2024

Related U.S. Application Data

(63) Continuation of application No. 17/668,292, filed on Feb. 9, 2022, now Pat. No. 11,944,274, which is a (Continued)

(51) **Int. Cl.**
A61B 1/06 (2006.01)
A61B 1/07 (2006.01)

(52) **U.S. Cl.**
CPC .... ***A61B 1/0655*** (2022.02); ***A61B 1/0607*** (2013.01); ***A61B 1/0638*** (2013.01); (Continued)

(58) **Field of Classification Search**
CPC .... A61B 1/04; A61B 1/05; A61B 1/06; A61B 1/00163; A61B 1/00165; A61B 1/00167; (Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,292,805 B2 * 10/2012 Vayser A61B 90/30 600/249
8,771,176 B2 * 7/2014 Hendriks A61B 18/20 600/173

(Continued)

FOREIGN PATENT DOCUMENTS

EP 2 163 185 A1 3/2010

OTHER PUBLICATIONS

PCT International Search Report and Written Opinion issued in PCT International Application No. PCT/US2011/039590, mailed Sep. 23, 2011 (13 pages).

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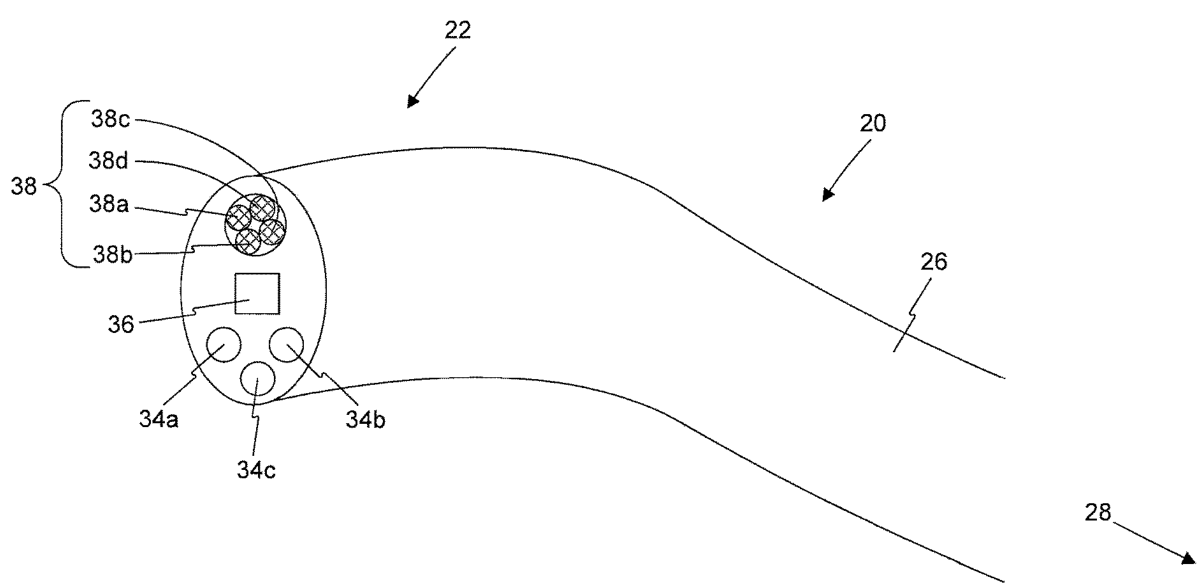
(57) **ABSTRACT**

A medical device, configured for insertion into a body, may include an elongate member extending from a proximal end to a distal end, where the distal end may be configured to be positioned inside the body. The medical device may also include an imaging device positioned at the distal end. The medical device may further include a plurality of light sources positioned at the distal end, wherein a characteristic of light delivered through a first light source may be controlled independent of the characteristic of light delivered through a second light source.

15 Claims, 5 Drawing Sheets



Related U.S. Application Data

continuation of application No. 14/972,499, filed on Dec. 17, 2015, now Pat. No. 11,278,194, which is a continuation of application No. 13/155,632, filed on Jun. 8, 2011, now Pat. No. 9,277,855.

(60) Provisional application No. 61/372,114, filed on Aug. 10, 2010.

(52) **U.S. Cl.**
CPC ***A61B 1/0676*** (2013.01); ***A61B 1/0684*** (2013.01); ***A61B 1/07*** (2013.01)

(58) **Field of Classification Search**
CPC A61B 1/0017; A61B 1/00172; A61B 1/00174; A61B 1/00177; A61B 1/00179; A61B 1/00181; A61B 1/00183; A61B 1/00186; A61B 1/00188; A61B 1/0019
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,795,157 B1 * 8/2014 Yaron A61B 1/000094 600/117
2003/0028078 A1 * 2/2003 Glukhovsky A61B 1/0676 600/109
2003/0117491 A1 * 6/2003 Avni H04N 23/74 348/65
2003/0191368 A1 10/2003 Wang et al.
2004/0105264 A1 6/2004 Spero
2004/0186351 A1 9/2004 Imaizumi et al.
2005/0124858 A1 * 6/2005 Matsuzawa A61B 1/041 600/176
2005/0137457 A1 * 6/2005 Machida A61B 1/00082 600/116
2005/0213092 A1 9/2005 MacKinnon et al.
2005/0215911 A1 * 9/2005 Alfano A61B 1/041 600/476
2005/0219552 A1 10/2005 Ackerman et al.
2005/0228231 A1 10/2005 MacKinnon et al.
2005/0234302 A1 10/2005 MacKinnon et al.
2006/0036131 A1 * 2/2006 Glukhovsky A61B 1/0646 600/109
2006/0069314 A1 3/2006 Farr
2006/0120084 A1 6/2006 Sueoka
2006/0149129 A1 * 7/2006 Watts A61M 25/0152 600/113
2006/0173245 A1 * 8/2006 Todd A61B 1/0653 600/178
2006/0184039 A1 * 8/2006 Avni H04N 23/74 600/476
2007/0055106 A1 * 3/2007 Moriyama G02B 23/2423 600/172
2007/0059989 A1 * 3/2007 Kura A61B 1/0676 439/685
2007/0088193 A1 4/2007 Omori et al.
2007/0140582 A1 6/2007 Chen et al.
2007/0225560 A1 * 9/2007 Avni A61B 1/045 600/118
2008/0071144 A1 * 3/2008 Fein A61B 1/07 600/178
2008/0146877 A1 6/2008 Matsuzawa et al.
2008/0158343 A1 7/2008 Schechterman et al.
2008/0170846 A1 * 7/2008 Wang A61B 1/0684 396/182
2008/0183043 A1 * 7/2008 Spinnler A61B 1/0676 348/E5.029
2008/0214890 A1 * 9/2008 Motai A61B 1/018 600/107
2008/0239070 A1 10/2008 Westwick et al.
2008/0249368 A1 10/2008 Takei
2008/0262301 A1 * 10/2008 Gibbons A61M 25/0147 600/114
2008/0287742 A1 * 11/2008 St. George H04N 7/18 600/160
2009/0080184 A1 3/2009 Kobilke
2009/0149713 A1 * 6/2009 Niida A61B 1/0684 600/167
2009/0177033 A1 * 7/2009 Hendriks A61B 1/0625 600/109
2009/0225333 A1 9/2009 Bendall et al.
2009/0247881 A1 10/2009 Maeda et al.
2009/0281389 A1 * 11/2009 Iddan A61B 1/04 600/167
2009/0303319 A1 * 12/2009 Sato A61B 34/73 348/335
2009/0306474 A1 * 12/2009 Wilson A61B 1/0661 600/109
2009/0306478 A1 12/2009 Mizuyoshi
2009/0316116 A1 * 12/2009 Melville H04N 9/3129 348/742
2010/0004513 A1 1/2010 MacKinnon et al.
2010/0220179 A1 * 9/2010 Wang A61B 5/073 348/E7.085
2010/0220180 A1 * 9/2010 Lee A61B 1/00036 348/E7.085
2010/0272318 A1 * 10/2010 Cabiri A61B 1/00009 600/109
2011/0032350 A1 * 2/2011 Kikuchi A61B 1/24 348/240.99
2011/0112376 A1 * 5/2011 Vayser A61M 1/84 600/249
2011/0184243 A1 * 7/2011 Wright A61B 1/0607 600/180
2011/0205552 A1 8/2011 Bendall et al.
2011/0208004 A1 8/2011 Feingold et al.
2011/0218398 A1 * 9/2011 Tamura A61B 1/0607 600/109
2011/0218399 A1 * 9/2011 Kimoto A61B 1/041 600/109
2011/0261178 A1 * 10/2011 Lo A61B 90/361 348/E7.085
2012/0002394 A1 * 1/2012 Todd A61B 1/07 362/13
2012/0059254 A1 3/2012 Lifan et al.
2012/0092678 A1 4/2012 Babayoff
2012/0116159 A1 * 5/2012 Mizuyoshi A61B 1/0653 600/109
2012/0262560 A1 * 10/2012 Nisani A61B 1/041 348/E7.085
2013/0012794 A1 * 1/2013 Zeng A61B 1/05 600/179
2013/0020485 A1 1/2013 Jung et al.
2013/0070985 A1 3/2013 Babayoff
2013/0243284 A1 9/2013 Babayoff
2015/0373288 A1 * 12/2015 Wang H04N 9/646 348/242

* cited by examiner

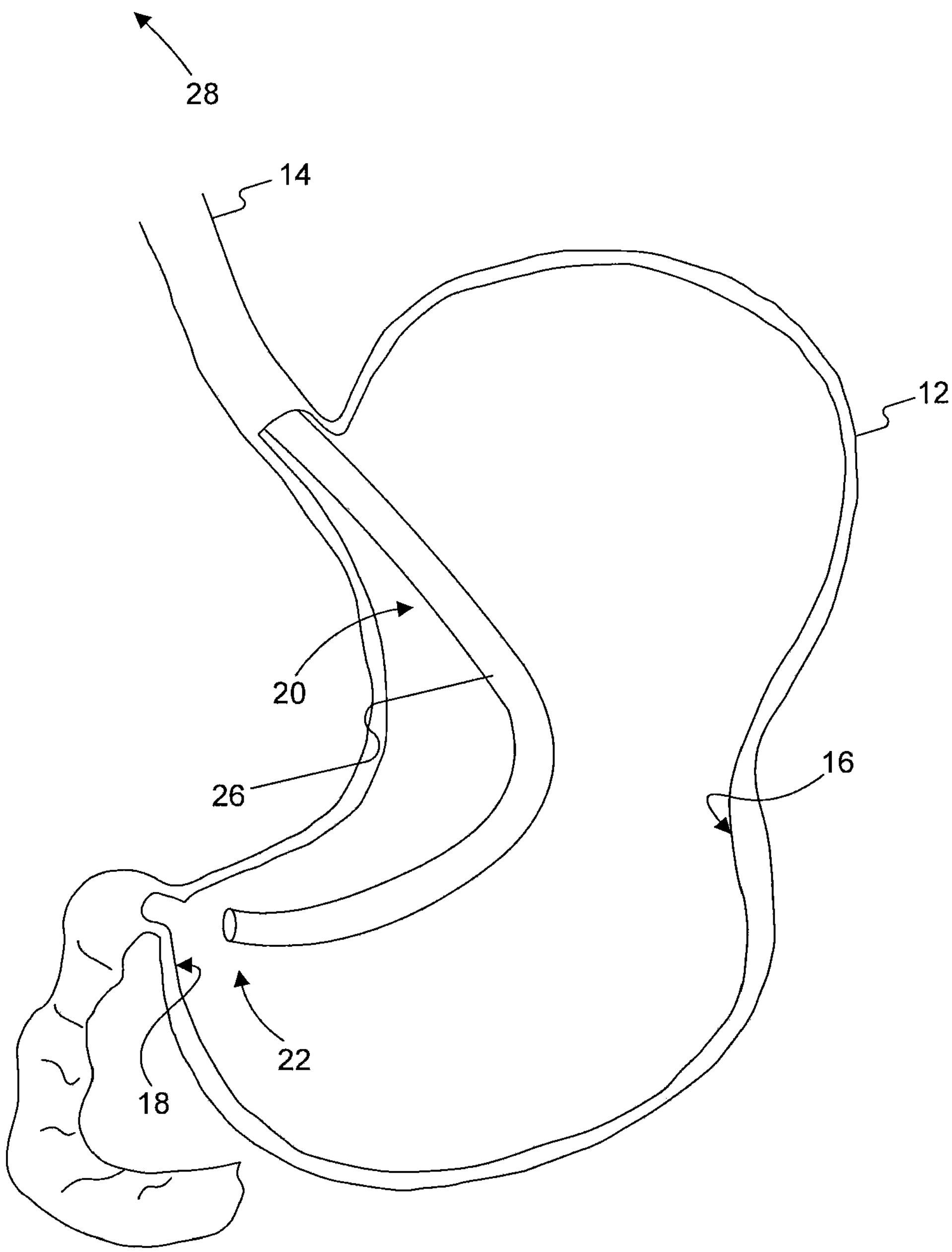


Fig. 1

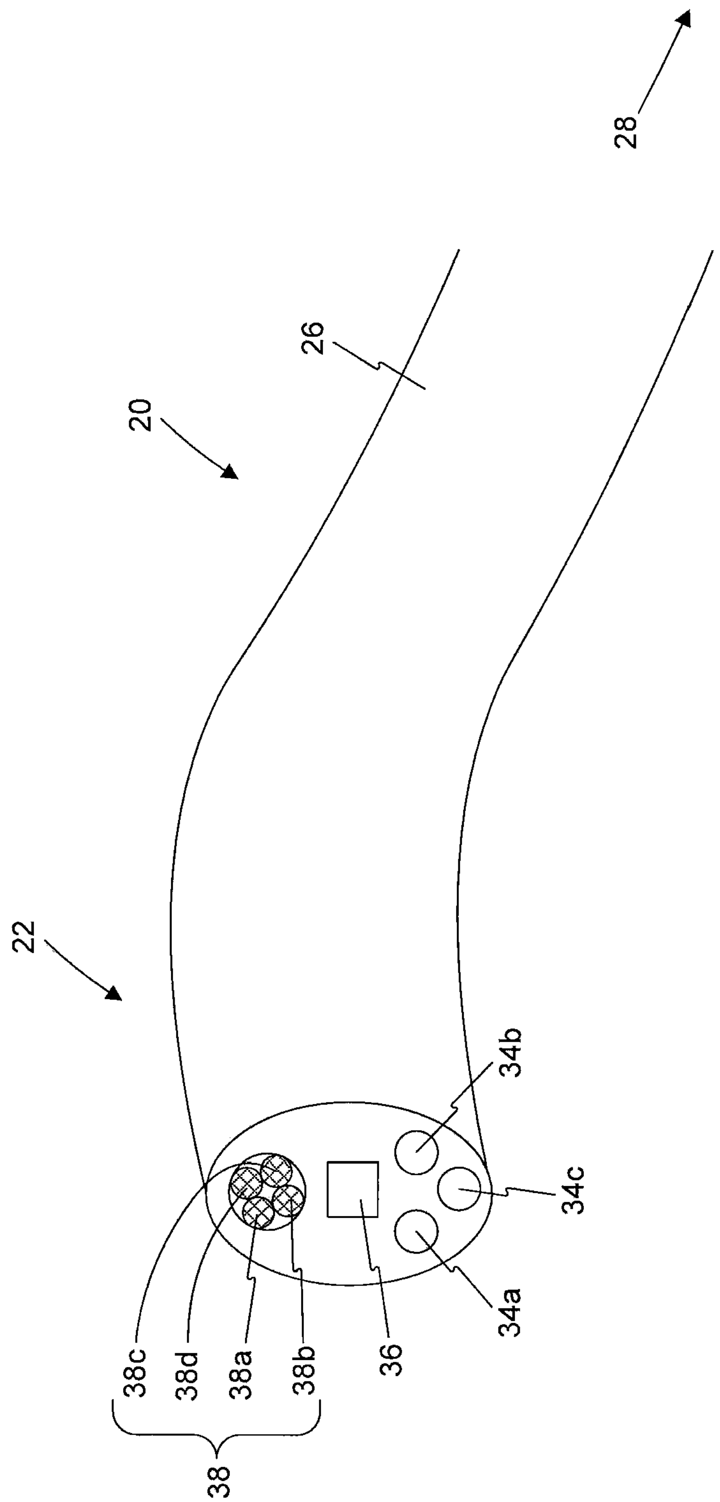


Fig. 2A

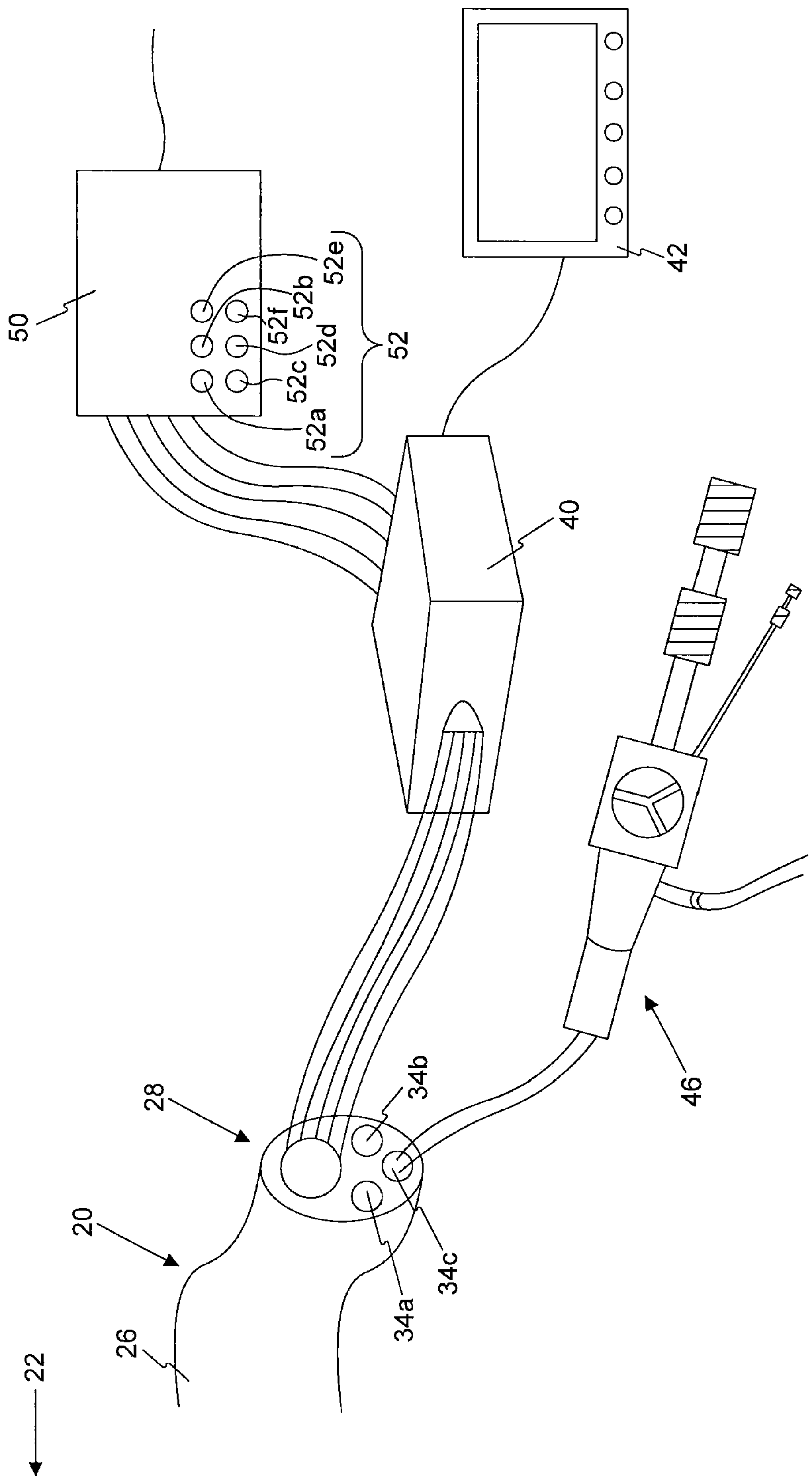


Fig. 2B

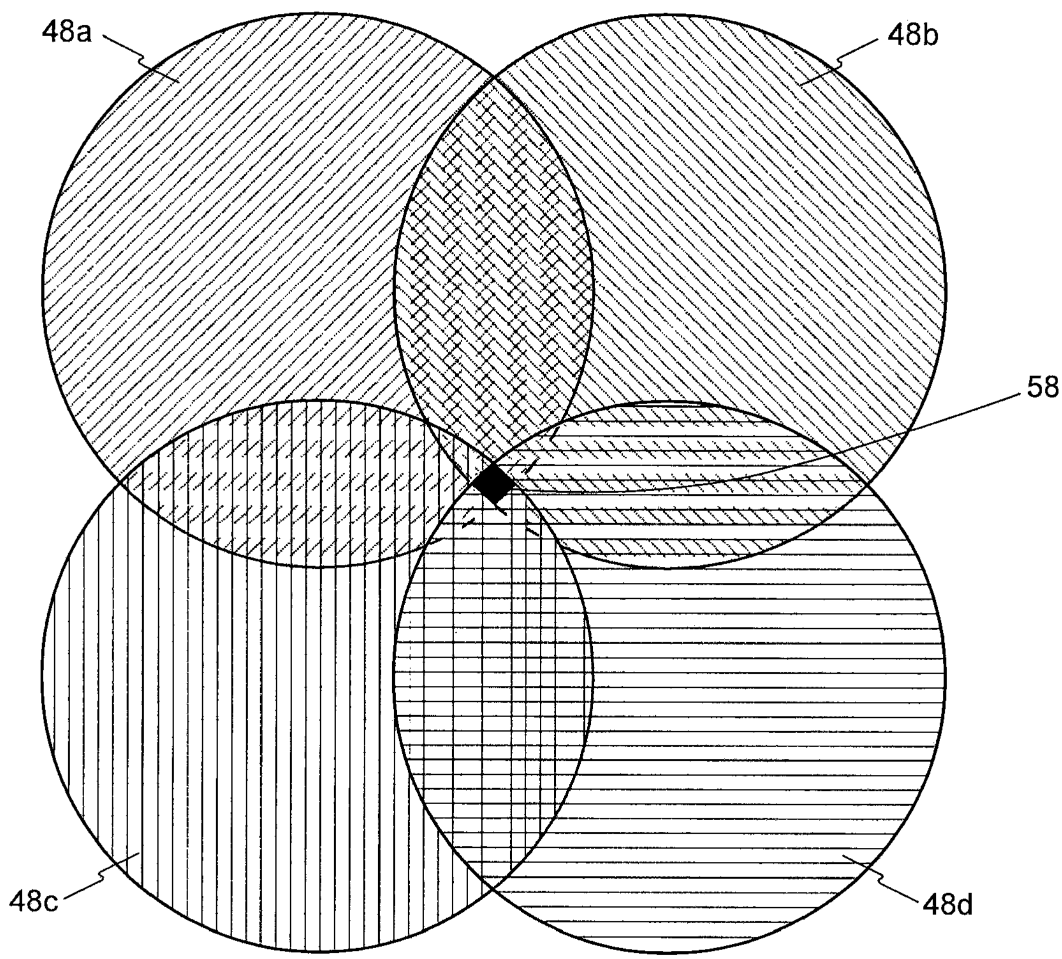


Fig. 3

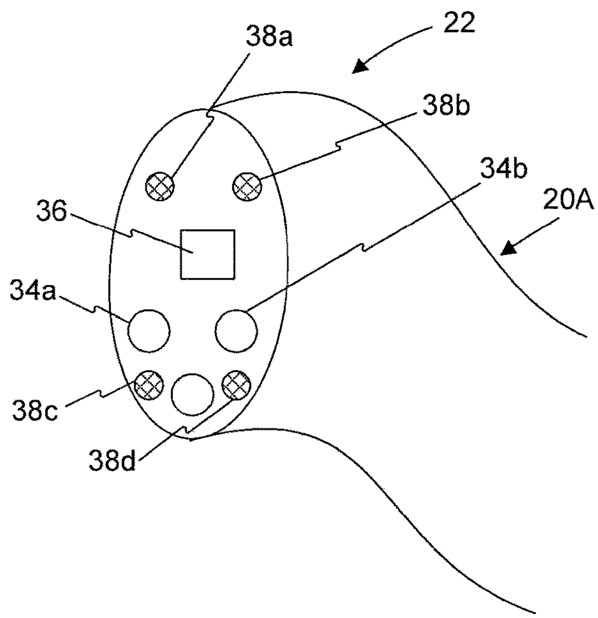


Fig. 4A

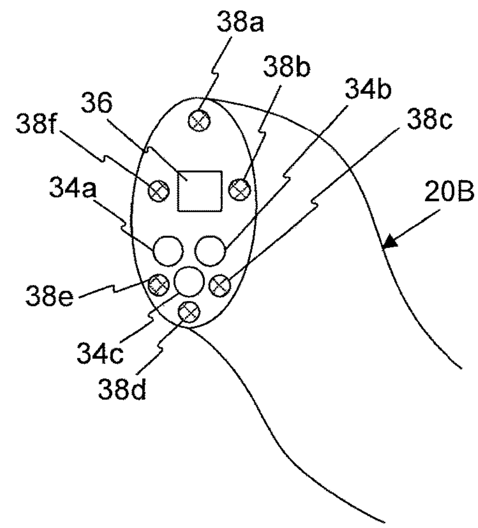


Fig. 4B

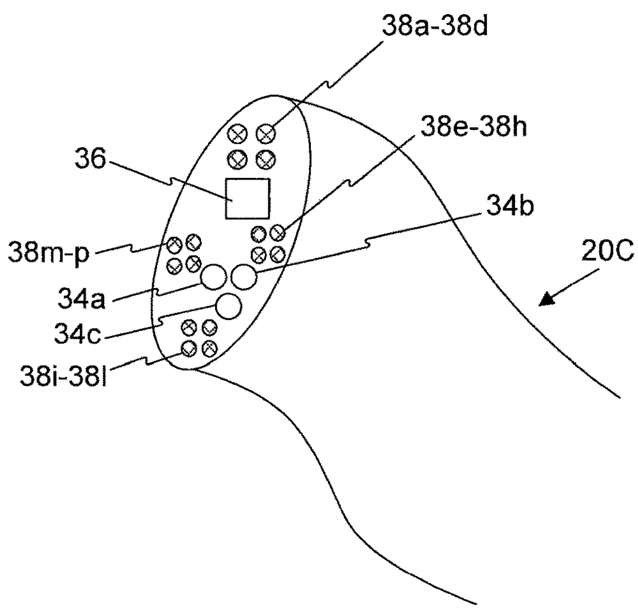


Fig. 4C

ENDOSCOPIC SYSTEM FOR ENHANCED VISUALIZATION

CROSS-REFERENCE TO RELATED APPLICATION(S)

This patent application is a continuation of and claims the benefit of priority to U.S. Nonprovisional patent application Ser. No. 17/668,292, filed on Feb. 9, 2022, which is a continuation of U.S. Nonprovisional patent application Ser. No. 14/972,499, filed on Dec. 17, 2015, now U.S. Pat. No. 11,278,194, which claims the benefit of priority to U.S. Nonprovisional application Ser. No. 13/155,632, filed on Jun. 8, 2011, now U.S. Pat. No. 9,277,855, which claims the benefit of priority to U.S. Provisional Application No. 61/372,114, filed on Aug. 10, 2010, the entirety of which is incorporated herein by reference.

FIELD OF THE INVENTION

Embodiments of the present invention relate to an endoscopic system. In particular, exemplary embodiments of the present invention relate to endoscopes for enhanced visualization. Embodiments of the present invention also cover methods of using such devices.

BACKGROUND OF THE INVENTION

An endoscope is a flexible instrument introduced into the body for diagnostic or therapeutic purposes. Typically, these devices are inserted into the body through an opening (a natural opening or an incision), and are delivered to a work site inside the body through a body channel, such as, for example, the esophagus. Imaging devices incorporated in the endoscope allows a surgeon to see the work site from outside the body and remotely operate the endoscope to perform a desired diagnostic/therapeutic procedure at the work site. There are many different types of endoscopes in use today and embodiments of the current disclosure may be applied with any of these different types of endoscopes. In general, embodiments of the current disclosure may be applicable with any type of medical device that can be inserted into a body, and that allows a surgeon outside the body to visualize a region inside the body. For the sake of brevity, however, the novel aspects of the current disclosure will be described with reference to an endoscope.

In a typical application, a distal end of an endoscope may be inserted into the body through an opening in the body. This opening may be a natural anatomic opening, such as, for example, the mouth, rectum, vagina, etc., or an incision made on the body. The endoscope may be pushed into the body such that the distal end of the endoscope proceeds from the point of insertion to a region of interest (work site) within the body by traversing a body channel. The endoscope may include one or more lumens extending longitudinally from the proximal end to the distal end of the endoscope. These lumens may deliver various diagnostic/treatment devices to the work site to assist in the performance of the intended procedure at the work site.

Among others, these lumens may include an illumination lumen that includes an illumination source to illuminate a field of view at the work site, and an imaging lumen that includes an imaging device to capture an image of the work site and deliver the image outside the body. A diffusing lens may be used to attempt to project light evenly over the entire visualization field through the illumination lumen. Due to the differences in proximities, and other light reflecting characteristics of different locations within the field of view of the work site (such as, for example, differences in reflectivity of muscle and tissue), these different locations may appear to be illuminated differently. For instance, some of these locations may appear to be oversaturated with light while other locations may appear to be insufficiently illuminated. This variation in illumination may make visualization of the work site difficult, and may therefore be undesirable. An endoscope with a diffusing lens may, however, be limited to providing uniform light across the entire field of view. Additionally, with small bore endoscopes, the cost of implementing a diffusing lens for even distribution of light may be high. While this cost may be less of an issue with reusable endoscopes where the cost can be amortized due to repeated usage, this cost may be prohibitively high in the case of disposable endoscopes. The current disclosure is directed to systems and methods configured to enable clear visualization of a field of view within the body from outside the body.

SUMMARY OF THE INVENTION

An embodiment of the invention includes a medical device configured for insertion into a body. The medical device may include an elongate member extending from a proximal end to a distal end, where the distal end may be configured to be positioned inside the body. The medical device may also include an imaging device positioned at the distal end. The medical device may further include a plurality of light sources positioned at the distal end, wherein a characteristic of light delivered through a first light source may be controlled independent of the characteristic of light delivered through a second light source.

Various embodiments of the invention may include one or more of the following aspects: the plurality of light sources may include a plurality of fiber optic cables that terminate at the distal end; the plurality of light sources may include at least one LED; each of the plurality of light sources may be positioned at different locations at the distal end; the plurality of light sources may be configured to be illuminated by a common illumination source positioned outside the body; the characteristic of light may include at least one of an intensity, a wavelength, a polarization, a frequency, or a phase of light; the medical device may also include an illumination control system that is configured to vary the characteristic of light directed through the first light source independent of the characteristic of light directed through the second light source; the illumination control system may include controls that enable a user to manually vary the characteristic of light directed through the first light source independent of the characteristic of light directed through the second light source; the illumination control system may include an algorithm configured to automatically vary the characteristic of light directed through the first light source independent of the characteristic of light directed through the second light source; the algorithm may automatically vary the characteristic of light directed through the first light source independent of the characteristic of light directed through the second light source based on an illumination of an image captured by the imaging device; the medical device may also include an illumination control system that is configured to vary the characteristic of light based on input from one or more light sensors; and the medical device may be an endoscope.

An embodiment of the invention may also include a method of using a medical device. The method may include inserting a distal end of the medical device into a body. The medical device may extend from the distal end to a proximal end, and may include at least an imaging device and a plurality of light sources positioned at the distal end. The method may also include positioning the distal end proximate a work site within the body, and activating the imaging device to receive an image of the work site outside the body. The method may further include adjusting a characteristic of light directed through one of the light sources independent of the characteristic of light directed through other of the light sources based on the received image.

Various embodiments of the invention may include one or more of the following aspects: adjusting the characteristic of light may include varying an intensity of light directed through one of the light sources independent of the intensity of light directed through the other of the light sources; adjusting the characteristic of light may include manually adjusting the characteristic of light directed through one of the light sources independent of the characteristic of light directed through the other of the light sources; adjusting the characteristic of light may include automatically adjusting the characteristic of light directed through one of the light sources independent of the characteristic of light directed through the other of the light sources based on an illumination of the received image; and the characteristic of light may include at least one of an intensity, a wavelength, a polarization, a frequency, or a phase of light.

An embodiment of the invention may further include an endoscope. The endoscope may include an elongate body extending from a proximal end to a distal end, and an imaging device positioned at the distal end. The imaging device may be configured to direct an image of a work site proximate the distal end to a viewing device positioned proximate the proximal end. The endoscope may also include a plurality of light sources positioned at the distal end. The plurality of light sources may be configured to illuminate the work site. The endoscope may also include an illumination control system configured to vary a characteristic of light directed through one of the light sources independent of the characteristic of light directed through other of the light sources based on an illumination of the image on the viewing device.

Various embodiments of the invention may include one or more of the following aspects: the characteristic of light may include at least one of an intensity, a wavelength, a polarization, a frequency, or a phase of light; the plurality of light sources may include at least three light sources and the illumination control system may be configured to vary a characteristic of light directed through each one of the three light sources independent of the characteristic of light directed through the other two light sources; the illumination control system may be configured to automatically vary a characteristic of light directed through one of the light sources independent of the characteristic of light directed through the other of the light sources based on the illumination of the image; the plurality of light sources may include a plurality of fiber optic cables that terminate at the distal end, the plurality of light sources may be configured to be illuminated by a common illumination source positioned proximate the proximal end of the elongate body.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description, serve to explain the principles of the invention.

FIG. **1** is a schematic view of an embodiment of an endoscope performing an exemplary endoscopic procedure.

FIG. **2**A is an illustration of the distal end of the endoscope of FIG. **1**.

FIG. **2**B is an illustration of the proximal end of the endoscope of FIG. **1**;

FIG. **3** is an illustration of illumination coverage at a work site using the endoscope of FIG. **1**; and

FIGS. **4**A-**4**C are illustrations of different embodiments of the distal end of endoscopes of the current disclosure.

DESCRIPTION OF THE EMBODIMENTS

Reference will now be made to exemplary embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

The terms "proximal" and "distal" are used herein to refer to the relative positions of the exemplary endoscopic device **20**. When used herein, "proximal" refers to a position relatively closer to the exterior of the body or closer to the surgeon using the endoscopic device **20**. In contrast, "distal" refers to a position relatively further away from the surgeon using the endoscopic device **20** or closer to the interior of the body.

FIG. **1** depicts an exemplary endoscopic device **20** performing an exemplary medical procedure on a patient. Endoscopic device **20** may be inserted into stomach **12** through the esophagus **14**, and positioned in stomach **12** such that a distal end **22** of endoscopic device **20** may be positioned proximate a work site **18** on stomach wall **16**. A proximal end **28** (see FIG. **2**B) of endoscopic device **20** may extend out of the body of the patient and may be controlled to perform the desired operations at the distal end **22** of the endoscopic device **20**. It should be emphasized that the medical procedure illustrated in FIG. **1** is exemplary only, and that endoscopes of the current disclosure may be applied to any endoscopic application known in the art. It should also be emphasized that endoscopic device **20** of FIG. **1** can be any medical device that can be used to visualize a region inside the body from outside the body. For example, endoscopic device **20** of FIG. **1** may include any type of imaging endoscopes, guide tubes, catheters or the like without limitation.

Endoscopic device **20** may include a flexible elongate member **26** extending between the proximal end **28** and distal end **22**. During use, distal end **22** may be positioned proximate work site **18** within a body and the proximal end **28** may be positioned outside the body. Elongate member **26** may be flexible so as to enable endoscopic device **20** to bend and pass through tortuous body passages as distal end **22** of endoscopic device **20** advances to work site **18**. In some embodiments, elongate member **26** may be made of, or coated with, a polymeric or a lubricious material to enable the endoscopic device **20** to pass through body cavities with ease.

FIGS. **2**A and **2**B are schematic illustrations of distal end **22** and proximal end **28**, respectively, of endoscopic device **20**. In the discussion that follows, reference will be made to both FIGS. **2**A and **2**B. Endoscopic device **20** may include one or more lumens **34***a*, **34***b*, **34***c*, etc. extending therethrough and terminating at distal end **22**. These lumens may be configured to direct tools/instruments and the like to work site **18** from outside the body. Although these lumens are illustrated as being circular, in general, the lumens can have any cross-sectional shape. Distal end **22** of endoscopic device **20** may also include devices (**36**, **38**) that are embedded or attached thereon. These devices may be configured to perform tasks to assist in the medical procedure at work site **18**. Although not illustrated in FIG. **2**A, distal end **22** of endoscopic device **20** may also include one or more end effectors that are configured to perform specific tasks at work site **18**. These end effectors may be coupled to a distal end of an endoscopic device and may be operatively coupled to, and controlled by, an actuation device **46** (i.e. a handle) at the proximal end **28** of endoscopic device **20** (see FIG. **2**B).

One or more of the lumens **34***a*, **34***b*, **34***c* may extend from distal end **22** to proximal end **28** longitudinally along elongate member **26**. These lumens may have a constant cross-sectional shape along the entire length of elongate member **26** or may have a cross-sectional shape that changes along the length of elongate member **26**. This change in cross-sectional shape along the length may be step wise or gradual. In some embodiments, some or all lumens may be lined with a polymeric or another layer or coating to facilitate use. The lumens **34***a*, **34***b*, **34***c* may provide access to instruments and facilities that may aid in performing desired medical procedures at work site **18**. These lumens may include one or more of, among others, an irrigation lumen **34***a*, an aspiration lumen **34***b*, and a working lumen **34***c*.

The irrigation lumen **34***a* may be configured to facilitate fluid flow from proximal end **28** to distal end **22**. In some embodiments, the irrigation lumen may be attached to a source of fluid at proximal end **28** and to a nozzle (or other similar device that is configured to alter fluid flow) at distal end **22**. Aspiration lumen **34***b* may be configured to facilitate suction and/or fluid flow through it. In some embodiments, fluid may be directed from proximal end **28** to distal end **22** through irrigation lumen **34***a* to clean work site **18**. Suction may then be applied at proximal end **28** of aspiration lumen **34***b* to remove the fluid (and/or biological material) from work site **18** through the aspiration lumen. In this manner, a tissue sample may be extracted out of the body through aspiration lumen **34***b*.

The working lumen **34***c* may include a conduit that is configured to deliver an endoscopic instrument or device to work site **18**. The endoscopic instrument may include any tool that is configured to perform a desired function at work site **18** while being remotely controlled by actuation device **46** from outside the body. The endoscopic instrument may be configured as an end effector attached at the distal end of an endoscopic instrument. For instance, the endoscopic instrument may include surgical forceps attached at the distal end of links that may be manipulated from the proximal end by actuation device **46** to control the operation of the forceps at work site **18**. In general, working lumen **34***c* may have any suitable shape, size, and configuration that is configured to pass the end effector therethrough. Although only one working lumen **34***c* is illustrated in FIG. **2**A, in some embodiments, endoscopic device **20** may include multiple working lumens configured to direct a plurality of surgical tools to work site **18**.

The devices on distal end **22** of endoscopic device **20** may include an imaging device **36** and an illumination device **38**. Imaging device **36** may include a camera, imaging sensor (such as, for example, a complimentary metal-oxide semiconductor or a CMOS sensor), a light sensor, or another image receiving device (such as, for example, a fiber optic imaging device). Imaging device **36** may transmit an image signal to a monitor or other display device **42** positioned outside the body and viewable by the surgeon. The image signals may correspond to still pictures and/or transient images that display time varying images of work site **18** on the display device **42**. In some embodiments, image sensor **36** may transmit the image signals to the display device **42** wirelessly, while in other embodiments imaging device **36** may transmit the signals using wire or a cable (fiber optic or another type of cable) embedded along the length of the elongate member **26**. In some embodiments, image signals from imaging device **36** may be processed by a control device **40** before being directed to display device **42**. It is also contemplated that, in some devices, control device **40** may also direct a control signal to imaging device **36** to control various aspects of its operation. In some embodiments, in addition to, or in place of imaging device **36** fixed to distal end **22**, an imaging device may be delivered to distal end **22** through a working lumen of endoscopic device **20**.

Illumination device **38** may include any device that is configured to illuminate work site **18**. Illumination device **38** may include, among others, bulbs, LEDs, one or more fiber optic cables, and light guides. In one embodiment, the illumination device may include a plurality of fiber optic cables. Other embodiments may include a collection of one or more other types of light sources. In the embodiment illustrated in FIG. **2**A, illumination device **38** is depicted as a cluster comprising four individual fiber optic cables **38***a*, **38***b*, **38***c*, and **38***d*. However, other embodiments may include a different number of fiber optic cables and a different positioning of the fiber optic cables (discussed with reference to FIGS. **4**A-**4**C). These fiber optic cables **38***a*, **38***b*, **38***c*, and **38***d* may direct light to distal end **22** from an external light source at proximal end **28** to illuminate work site **18**.

The external light source may include one or more LED, Xenon, or other light sources in an illumination control system **50**. Illumination control system **50** may be configured to control and vary a characteristic of the light directed to each of the fiber optic cables individually. This characteristic may include intensity, wavelength, polarization, frequency, phase or any other characteristic that can vary the level of illumination directed through each of the individual fiber optic cables. That is, in one embodiment, illumination control system **50** may be configured to set the intensity of light directed to fiber optic cable **38***a* at a first level, the intensity of light directed to fiber optic cable **38***b* at a second level different from the first level, the intensity of light directed to fiber optic cable **38***c* at a third level different from the first and second levels, and the intensity of light directed to fiber optic cable **38***d* at a fourth level different from the first, second, and third levels.

Illumination control system **50** may also include one or more light sources, control electronics, and associated control algorithms that operate cooperatively to modulate the amount of light directed to each of the individual fiber optic cables **38***a*, **38***b*, **38***c*, and **38***d*. In one embodiment, illumination control system **50** may include a single light source with individual lenses, irises, and/or filters to modulate the amount of light directed to each of the individual fiber optic cables **38***a*, **38***b*, **38***c*, and **38***d*. Any optical arrangement known in the art may be used to split the light from the single light source into multiple beams having different characteristics and direct each beam through the individual fiber optic cables **38***a*, **38***b*, **38***c*, and **38***d*. In other embodiments, illumination control system **50** may include multiple light sources to vary the characteristic of light input to the individual fiber optic cables **38***a*, **38***b*, **38***c*, and **38***d*. In applications involving disposable endoscopes, illumination control system **50** may form the capital equipment that may be used along with a disposable endoscope. Since the illumination control system **50** may be reused with different disposable endoscopes, the sensitivity of cost of the illumination control system **50** to the application may be low.

FIG. **3** illustrates an exemplary illumination coverage in work site **18** in an embodiment using four individual fiber optic cables. First region **48***a* may be the area illuminated by fiber optic cable **38***a*, second region **48***b* may be the area illuminated by fiber optic cable **38***b*, third region **48***c* may be the area illuminated by fiber optic cable **38***c*, and fourth region **48***d* may be the area illuminated by fiber optic cable **38***d*. The regions of overlap may be illuminated by multiple fiber optic cables and may naturally be areas of relatively high illumination. In some embodiments, distal end **22** of endoscopic device **20** may be manipulated to position an area of interest of work site **18** at a region of maximum overlap **58**. Based on an image in display device **42**, the surgeon may determine that some of the regions should be illuminated differently from other regions for good visualization of work site **18**. Illumination control system **50** may include controls **52** (such as, for example, controls **52***a*-**52***f*) to selectively vary the level of illumination in the different regions, including regions of overlap that are illuminated by multiple fiber optic cables. For instance, if an image in display device **42** indicates that the level of illumination in the first region **48***a* is too low and the level of illumination in the second region **48***b* is too high, the surgeon may manipulate the controls **52** of illumination control system **50** to increase the illumination level of first region **48***a* and decrease the illumination level of second region **48***b*.

In some embodiments, the endoscopic device **20** may include a plurality of preset illumination patterns. These preset illumination patterns may correspond to illumination patterns where the intensity (or another characteristic) of light through each fiber optic cable **38***a*-**38***d* may be optimized for a certain application or for a certain location in the body. For example, one preset pattern may correspond to an illumination pattern that is optimized for a particular endoscopic procedure (such as, for example, hemostasis of a bleeding ulcer) and another preset pattern may correspond to an illumination pattern that is optimized for another endoscopic procedure or a particular location within the body (such as, for example, the esophagus). In some embodiments, some of the preset illumination patterns may be configured to change over time. For instance, an illumination pattern may change as the distal end **22** of the endoscopic device **20** traverses a body tract for optimal visibility of different sections of the body tract. These preset illumination patterns may be selected by a user, for example, by activating a control of illumination control system **50**. The preset illumination patterns may be preset by a supplier or a user, and may be adapted to be modified as desired.

In some embodiments, illumination control system **50** may include a control algorithm to adjust the illumination of the work site automatically. This control algorithm may include software codes that analyze the image from imaging device **36** and automatically control the intensity of light in each of the fiber optic cables for optimal illumination of work site **18**. For instance, analysis of a captured image from imaging device **36** may indicate that the first region **48***a* is relatively dark and the second region **48***b* is relatively bright as compared to the other regions. Illumination control system **50** may automatically vary the intensity of light directed to each of the individual fiber optic cables in steps until a subsequent image analysis indicates that the differences in illumination of different regions is within an acceptable threshold. In some embodiments, the illumination control system **50** may be configured to "learn" from each illumination adjustment operation and improve over time. In one such embodiment, the illumination control system **50** may include a self-learning neural network or another similar algorithm. The neural network may include a training mode and a usage mode. In the training mode, illumination control system **50** may be trained to output a selected pattern of light through each fiber optic cable for a particular image pattern on imaging device **36**. In the usage mode, when this image pattern is detected in imaging device **36**, the illumination control system **50** may output the selected pattern of light through the fiber optic cables. If an image pattern on imaging device **36** does not belong to a taught list of image patterns, a characteristic of light through each fiber optic cable may be manually or automatically adjusted for optimal illumination of work site **18**, and the output pattern of light may be added to the taught list of image patterns.

FIGS. **4**A through **4**C illustrate the distal end **22** of different embodiments of endoscopic devices of the current disclosure. In endoscopic device **20**A of FIG. **4**A, four fiber optic cables **38***a*, **38***b*, **38***c*, and **38***d* are positioned at spaced locations on distal end **22**. In endoscopic device **20**B of FIG. **4**B, six fiber optic cables **38***a*, **38***b*, **38***c*, **38***d*, **38***e*, and **38***f* are positioned at spaced locations on distal end **22**. In endoscopic device **20**C of FIG. **4**C, four clusters of fiber optic cables, each cluster including four fiber optic cables, are positioned at spaced locations on distal end **22**. The positioning of the fiber optic cables in FIGS. **4**A-**4**C is only exemplary. In general, the fiber optic cables (**38***a*, **38***b*, etc.) may be positioned at any location on distal end **22** of endoscopic device **20**. In some embodiments, the fiber optic cables (**38**, **38***b*, etc.) may be positioned symmetrically about a center point of distal end **22** while in other embodiments they be positioned asymmetrically depending on the application, for example. In each of these embodiments, a characteristic of the light emitted by some or all of the individual fiber optic cables may be individually varied by illumination control system **50**. For instance, in the embodiments of FIGS. **4**A and **4**B, the intensity of the light emitted by each of the individual fiber optic cables (**38***a*, **38***b*, **38***c*, and **38***d* in the embodiment of FIGS. **4**A and **38***a*, **38***b*, **38***c*, **38***d*, **38***e*, and **38***f* in the embodiment of FIG. **4**B) may be varied individually by illumination control system **50**. And, in the embodiment of FIG. **4**C, the intensity of light emitted by each cluster of fiber optic cables (**38***a*-**38***d*, **38***e*-**38***h*, **38***i*-**38***l*, and **38***m*-**38***p*) may be varied individually.

Any type of fiber optic cable (plastic, glass, etc.) may be used as illumination device **38**. Although in the description above, the intensity of light directed through each fiber optic cable is described as being varied, in general, any characteristic of light that can modulate the illumination at distal end **22** may be varied by illumination control system **50**. For instance, in some embodiments, the characteristic of light that is varied by the illumination control system **50** may include a wavelength of the light directed through each fiber optic cable. Additionally, although illumination device **38** is described as being a fiber optic cable, this is not a limitation. In general, any illumination device that is capable of being individually controlled may be used as illumination device **38**. For instance, in some embodiments, LEDs may be used as illumination device **38**. In these embodiments, illumination control system **50** may control each LED individually to control a characteristic of the light emitted by each individual LED. In other embodiments, combinations of different illumination devices may be used.

In some embodiments, the illumination devices **38** at distal end **22** of endoscopic device **20** may be operatively coupled with one or more adjustable diffusing lenses or other adjustable lens membranes to selectively vary a characteristic of light emitted by each illumination device **38**. In these embodiments, a characteristic of the light emitted by each illumination device **38** may be changed by selectively activating the diffusing lens or lens membrane associated with that illumination device. The diffusing lens or lens membrane may be selectively activated by any means, such as, for example, a pressure may be applied to the lens membrane to change its optical properties, and therefore, a characteristic of light passing through the membrane. A pressure may be applied to the lens membrane by applying an electric current to the membrane.

In some embodiments, the lenses may be independently controlled to aim light at or away from a particular point, direct, focus, obscure, and/or change a characteristic of (for example, frequency, etc.) of the light. In some embodiments, a lens or another optical member associated with an illumination device may be biased to provide more (or less) illumination to a region of work site **18** illuminated by that illumination device. In some embodiments, the illumination control system **50** may vary a cant or tilt of a fiber optic cable (or another illumination device) relative to a longitudinal axis of the endoscopic device **20** to vary a characteristic of light delivered to work site **18** through that cable. The cant of the fiber optic cable may be changed by advancing or retracting wedges or other positioning mechanisms associated with that cable. In some embodiments, combinations of light sources (such as, for example, LED and fiber optic) may be used to provide illumination. In some such embodiments, different combinations of these light sources may be used to vary the level of illumination directed at a particular region. In some embodiments, one or more light sensors could be used in addition to, or as, cameras. These light sensors may assist in automatically or manually adjusting the illumination effect.

The embodiments described herein are exemplary only, and it will be apparent to those skilled in the art that various modifications and variations can be made in the disclosed systems and processes without departing from the scope of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the invention being indicated by the following claims.

What is claimed is:

1. A method of illuminating a body performed by a processor of a control device, the method comprising:

receiving an image of the body captured as the body is being illuminated by a plurality of light sources communicatively coupled to the control device;

determining an intensity of illumination at each of two regions within the body based on an analysis of the image;

determining a difference in the intensity of illumination between the two regions exceeds a threshold; and

automatically varying a lighting characteristic of at least one light source of the plurality of light sources that illuminates at least one region of the two regions in response to the difference in the intensity of illumination between the two regions exceeding the threshold to thereby change the intensity of illumination at the at least one region of the two regions.

2. The method of claim **1**, wherein each of the plurality of light sources includes a fiber optic cable or a light-emitting diode (LED).

3. The method of claim **1**, wherein the lighting characteristic includes an intensity of light emitted by the at least one light source of the plurality of light sources to illuminate the at least one region of the two regions.

4. The method of claim **1**, wherein automatically varying the lighting characteristic of the at least one light source of the plurality of light sources that illuminates the at least one region of the two regions comprises:

adjusting a lens in response to a pressure change that is caused by an electric current applied to the lens.

5. The method of claim **1**, wherein the lighting characteristic includes a first lighting characteristic, the at least one light source is a first light source of the plurality of light sources, and the at least one region of the two regions includes a first region, the method further comprising:

automatically varying a second lighting characteristic of a second light source of the plurality of light sources that illuminates a second region of the two regions in response to the difference in the intensity of illumination between the two regions exceeding the threshold to minimize the difference in the intensity of illumination between the first region and the second region.

6. The method of claim **5**, wherein the second lighting characteristic that illuminates the second region is varied independent of the first lighting characteristic that illuminates the first region.

7. The method of claim **5**, further comprising:

determining the first region is darker relative to the second region or the second region is brighter relative to the first region based on the analysis of the image.

8. The method of claim **7**, further comprising:

increasing the first lighting characteristic to brighten the first region or decreasing the second lighting characteristic to darken the second region.

9. The method of claim **1**, wherein each light source of the plurality of light sources illuminates a corresponding region of a plurality of regions, including the two regions and one or more remaining regions, within the body, and the method further comprises:

determining an intensity of illumination at each of the one or more remaining regions, of the plurality of regions, within the body based on the analysis of the image; and

determining that a difference in the intensity of illumination between at least one of the one or more remaining regions and at least one other region of the plurality of regions exceeds the threshold.

10. The method of claim **9**, further comprising:

automatically varying a corresponding lighting characteristic of a corresponding light source of the plurality of light sources that illuminates one or more of the at least one of the one or more remaining regions or the at least one other region of the plurality of regions.

11. The method of claim **1**, wherein the image of the body is received from and captured by an imaging device that includes a camera, a CMOS sensor, a light sensor, or a fiber optic imaging device.

12. The method of claim **1**, wherein the image is received from and captured by one or more imaging devices, and wherein the one or more imaging devices and the plurality of light sources are positioned at a distal end of an endoscope that is inserted inside the body at a position adjacent to the two regions.

13. The method of claim **12**, wherein the plurality of light sources are positioned at different locations at the distal end of the endoscope.

14. A method of illuminating a body performed by a processor of a control device, the method comprising:

receiving an image of the body captured as the body is being illuminated by a plurality of light sources communicatively coupled to the control device;

determining an intensity of illumination of each of a first region and a second region in the body based on an analysis of the image;

determining the intensity of illumination of the first region varies relative to the intensity of illumination of the second region by at least a threshold; and

automatically causing light emitted by one or more of the plurality of light sources that illuminate at least one of the first region or the second region to be emitted pursuant to a varied lighting characteristic until the intensity of illumination of the first region varies relative to the intensity of illumination of the second region by less than the threshold.

15. The method of claim **14**, wherein the varied lighting characteristic includes an intensity of the light.

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