

ENDOSCOPE WITH PANNABLE CAMERA

Cross-References to Related Applications

The present application is a Non-Provisional Application which claims the benefit of U.S. Provisional Patent Application Serial No. 61/826,303, filed May 22, 2013 and entitled **Endoscope with Pannable Camera** (Attorney Docket No. K35); and U.S. Provisional Patent Application Serial No. 61/759,784, filed February 1, 2013 and entitled **Pannable Endoscope** (Attorney Docket No. K29), each of which is hereby incorporated herein by reference in its entirety.

BACKGROUND

Field of Disclosure

The present disclosure relates to endoscopic instruments for viewing and working in relatively inaccessible spaces; and in some aspects for operating in tight anatomical spaces within a body using an endoscope or arthroscope, or the like.

Background Information

The use of endoscopic instruments in medicine, allowing for remote viewing and operating in difficult-to-access spaces has become well-established. These instruments have also been useful in automotive, aviation, plumbing, electronics, and many other industries. In the field of medicine or veterinary practice, endoscopy or arthroscopy is often used to view or treat an anatomical region when minimal or no incisions are desired, or to avoid disturbing nearby tissues. In orthopedics, for example, the condition of a joint such as a knee or shoulder may be accessed using one or more arthroscopic instruments introduced into the joint through one or more small skin incisions. These instruments may also be used to repair various intra-articular tissues. Standard techniques of open surgery to view and repair these anatomical areas can be comparatively more time consuming, associated with greater risk and trauma to a patient, and can be associated with longer recovery time. Furthermore, anesthesia associated with open surgery may be more complicated, risky and costly. For improved field of view, an endoscope may be equipped with an actively flexible distal segment, controllable by the user at the handle end of the instrument. This may not be an effective option when the tip of the instrument is positioned in a confined space that may not accommodate the range of motion required for flexing the distal segment of an

endoscope. In medical applications, one such example would include intra-articular surgery. Generally, using an instrument with a rigid insertion shaft may be preferred if the use of an instrument with an actively flexible distal segment is impractical. A non-flexible shaft may provide improved optics or image reproduction, increased space within the instrument for additional functionality, and greater durability. However, rigid endoscopes or arthroscopes have a limited field of view and may need to be repositioned or rotated frequently to increase the field of view. Some endoscopes or arthroscopes must be physically removed from the patient to have parts swapped out in order to change the field of view. Cannula systems may facilitate this approach, but may also increase the complexity of the procedure and the size of an incision. These limitations may reduce operator efficiency, increase surgery time, and may increase the risk of iatrogenic injury. In medical and other applications, it would be advantageous for an endoscope to have an increased or variable field of view without the use of an actively flexible distal segment. It may also be advantageous to combine functions within a single conduit in order to decrease the overall diameter of the shaft of an endoscope. Additionally, current instruments are prone to degradation in function and optical quality over repeated use, cleaning and/or sterilization. An endoscope design whose manufacturing and assembly cost is low enough to economically justify its non-re-use would also be advantageous. The costs of repeated cleaning or sterilization and re-packaging would be eliminated, and it may also be easier to standardize the quality and reliability of a single-use device.

SUMMARY

An embodiment of the present disclosure comprises a variable view endoscope, useful in industrial as well as medical applications. The endoscope may comprise a proximal end and a distal insertion end opposite the proximal end. The proximal end of the endoscope may further comprise a handle. The endoscope may further include an elongated member comprising an insertion section or shaft, which may extend from the handle to the distal end. The insertion section or shaft may be configured to be rotatable about a longitudinal axis of the insertion section, relative to at least a portion of the handle. Near the distal end, an imaging device (or 'imager') may be pivotably mounted in the insertion section. The imager may be an image sensor. The imager may be disposed within a housing. The housing may comprise at least one lens through which an image is directed to the imager. The imager may have a pre-determined angular field of view, and may be configured to capture an image of the field of view. The imager may be mounted on a

pivotable assembly or camera mount. The immediate angular field of view may be rotated between a first angular position and a second angular position of the imager with respect to the long axis of the insertion section, the first and second angular positions defining the bounds of the viewable range of the imager. The immediate field of view may be varied by pivoting the imager on a mount about an axis that is approximately perpendicular or transverse to a longitudinal axis of the insertion section or shaft. The rotational axis of the camera mount may be configured to lie in a plane that roughly bisects the insertion shaft into an upper region and a lower region.

The endoscope may further comprise a pivot control structure; the pivot control structure may be configured to pivot the imager when the pivot control structure is rotated about an axis of rotation approximately perpendicular to the long axis of the insertion shaft. The pivot control structure may further comprise projections. The projections may be configured to optionally operatively engage at least one detent such that the pivot control structure may be rotated in discrete steps, each step providing an immobilizing point for the rotational position of the pivot control structure. One or more of the detents may correspond to a predefined pivotal orientation of the imager. The pivot control structure may be connected to the pivotable camera assembly by an elongate actuator, such as a pull cable or wire.

In an embodiment, the insertion shaft may extend from a handle to the insertion end of the endoscope, the insertion shaft configured to house an elongate pivot actuator that is connected on a proximal end to a control member on the handle, and connected on a distal end to a pivoting assembly. The pivoting assembly may serve as a mount for an image sensor or camera, and may include a lens assembly. The image sensor is configured to capture an image having a pre-determined angular field of view that is rotatable by longitudinal movement of the elongate pivot actuator acting on the pivoting assembly. In an embodiment, a pivoting camera assembly may be housed within a liquid carrying conduit of an endoscope insertion shaft. The camera assembly may be rotatable to an angle of between about 90 degrees and about 120 degrees of the longitudinal axis of the insertion shaft. In this position, the surface of a lens assembly may be washable by passing irrigation liquid through the insertion shaft, the irrigation liquid then passing over the surface of the lens assembly as it exits the distal end of the insertion shaft.

In an embodiment, a terminal segment of the elongate pivot actuator is constrained or re-directed to form an angle with respect to the long axis of the insertion shaft. In one example, the angle formed is within a range of about 30 degrees to about 90 degrees. A re-

directing element may be included in a distal portion of the insertion shaft, the re-directing element causing the terminal segment of the pivot actuator to form an angle with respect to the long axis of the insertion shaft. The re-directing element may be located above the axis of the pivoting assembly when the pivot actuator is connected to the pivoting assembly below its axis of rotation, whereas the re-directing element may be located below the axis of the pivoting assembly when the pivot actuator is connected to the pivoting assembly above its axis of rotation. The elongate pivot actuator may comprise a wire or cable, and a first pivot actuator may connect to the pivoting assembly on one side of its axis of rotation, while a second pivot actuator may connect to the pivoting assembly on an opposing side of the pivoting assembly. The terminal segment of a first pivot actuator may be re-directed or constrained to form an angle with respect to the long axis of the insertion shaft, whereas the terminal segment of a second pivot actuator may not be so constrained or re-directed. Alternatively, a first and second pivot actuator may both have terminal segments that are constrained or re-directed to form an angle with respect to the long axis of the insertion shaft. The re-directing element may comprise a wall in a distal portion of the insertion shaft, the wall having a notch or including a post, pulley or eyelet against which the pivot actuator may be re-directed. The re-directing element may be configured to provide an angle of the terminal segment so that the field of view of the image sensor can be rotated over a viewable range of up to 180 degrees, or optionally above 180 degrees.

The insertion section of an endoscope may also comprise a conduit, the conduit being configured to transfer fluid (liquid and/or gas) between a space in which the tip of the insertion section is positioned and a location external to the endoscope. The conduit may also be configured to carry functional components of the endoscope, including (but not limited to) a camera, camera mount, fiberoptic cable, electronic transmission cable, and mechanical pull wires or pushrods. One or more of said components may include insulation or surface features allowing the components to function in a wet environment. The endoscope may be configured to provide a sealing element that allows said functional components to extend from a handle housing to a distal area of the insertion section of the endoscope, the sealing element also inhibiting the infiltration of fluid from the conduit to at least a portion of the handle housing.

A camera assembly comprising a lens and an electronic image sensor may be positioned within a liquid carrying conduit of the insertion shaft of the endoscope, a housing of a handle assembly including a liquid port in fluid communication with the liquid carrying conduit of the insertion shaft. The camera assembly may be mounted on a pivot bearing

having an axis of rotation transverse to a longitudinal axis of the insertion shaft. The liquid carrying conduit may include one or more mechanical actuators to move the camera assembly. The liquid carrying conduit may include a communications cable connected to the image sensor, or an optical fiber bundle configured to provide illumination for the image sensor. A barrier may be positioned between the liquid carrying conduit of the insertion shaft and an internal housing of the handle assembly, the barrier configured to inhibit passage of liquid from the liquid carrying conduit to the housing of the handle assembly. The barrier may comprise a pass-through barrier that permits passage of an optical fiber bundle, mechanical actuator cable, or communications cable between the liquid carrying conduit and a housing of the handle assembly. The housing of the handle assembly may comprise a proximal housing section and a distal housing section, the distal housing section interposed between the proximal housing section and the insertion shaft. The distal housing section may comprise a pivot control apparatus to control movement of one or more pivot control cables connected to the camera assembly in the insertion shaft. The proximal housing section may enclose an electronic control board to receive image data from the camera assembly. A first pass-through barrier between the insertion shaft and the distal housing section may permit passage of the one or more pivot control cables, a pivot control cable passage in the first pass-through barrier being configured to permit unrestricted proximal and distal movement of the one or more pivot control cables over a pre-determined distance. A second pass-through barrier between the distal housing section and the proximal housing section may permit passage of a communications cable from the camera assembly to the electronic control board, a communications cable passage in the second pass-through barrier being configured to provide a liquid seal between the distal housing section and the proximal housing section of the handle assembly. The second pass-through barrier between the distal housing section and the proximal housing section may permit passage of an optical fiber bundle configured to provide illumination at a distal end of the insertion shaft, an optical fiber bundle passage in the second pass-through barrier being configured to provide a liquid seal between the distal housing section and the proximal housing section of the handle assembly. The second pass-through barrier between the distal housing section and the proximal housing section may permit passage of a liquid carrying tube configured to pass liquid to or from the distal insertion shaft through the first pass-through barrier, the second pass-through barrier, and an end of the proximal housing section.

In an embodiment, a pivoting camera assembly may be housed in the insertion end of an endoscope shaft, the pivoting camera assembly comprising a lens and an image sensor, and configured to pivot about an axis that is substantially transverse to a longitudinal axis of the shaft. A light emitter may be mounted to the camera assembly, the light emitter
5 being configured to project light into an illumination field substantially coincident with a field of view of the image sensor as the camera assembly pivots about its axis. The light emitter may be a passive light emitter, in that it conducts light that originates from a source external to the endoscope. The light emitter may be made of a light guide material, such as optical fiber material. The light emitter may include a mounting feature that cooperates
10 with a mating feature on the camera assembly to facilitate securing the light emitter on the camera assembly. A mask may be applied to one or more surfaces of the light emitter to inhibit the emission of light from said surfaces. A reflective coating may be applied to one or more surfaces of the light emitter. An emitting surface of the light emitter may be roughened to diffuse light emitted from said surface. The light emitter may have a curved
15 shape to conform to a circumferential shape of the lens. The light emitter may be formed from or fused to a number of optical fibers. Ends of the optical fibers may be disposed in one or more recesses in the camera assembly next to the lens. The light emitter may be formed from a number of individual optical fibers that have been fused together. The light emitter may comprise a transition region that incorporates a number of unfused flexible
20 optical fibers, wherein at least a portion of the transition region is nonflexible. The transition region may be attached to a portion of the camera assembly.

In an embodiment, the camera assembly may comprise a lens assembly spaced apart from an image sensor, the lens assembly and image sensor mounted on a camera housing. The camera housing may be configured to rotate about a pivot bearing having an
25 axis of rotation transverse to a longitudinal axis of an insertion shaft of the endoscope. A light emitter may be mounted on the camera housing and configured to emit light in a direction of a field of view of the image sensor. The light emitter may comprise a terminal portion of a flexible optical fiber bundle. The light emitter may comprise a solid transparent light emitting member molded from or fused to a flexible optical fiber bundle. The camera
30 housing may be configured to rotate about the pivot bearing by the action of a pull cable, the camera housing including a spooling feature providing a surface to guide a terminal portion of the pull cable, and the camera housing including a contact region to secure a distal end of the pull cable. The spooling feature may comprise a curved recess on the camera housing into which the terminal portion of the pull cable can be positioned.

In an embodiment, the camera housing may be configured to rotate by the action of a pull cable about a pivot bearing having an axis of rotation transverse to a longitudinal axis of an insertion shaft of the endoscope. The camera housing may additionally comprise a spooling feature configured to at least partially wind a terminal portion of the pull cable to a connection region on the camera housing configured to secure a distal end of the pull cable. The spooling feature may include an arcuate section and a straight section. An arc of the arcuate section may be defined by a constant radius. The radius may extend from the axis of rotation to a surface of the arcuate section. The spooling feature may be configured to wind the terminal portion of the pull cable up to about 360 degrees around the axis of rotation. The pull cable may be displaced along the longitudinal axis of the insertion section by a control structure in a handle of the endoscope. Displacement of the pull cable along the longitudinal axis of the insertion section in a first direction may be configured to cause displacement of a second pull cable along the longitudinal axis of the insertion section in a second opposite direction and vice versa. The camera housing may include an attachment point for a second pull cable. The camera housing may comprise a second spooling feature configured to at least partially wind a terminal portion of a second pull cable to a connection region on the camera housing configured to secure a distal end of the second pull cable. The second pull cable may be displaced along the longitudinal axis of the insertion section by a control member in a handle of the endoscope. The second spooling feature may be configured to wind the terminal portion of the pull cable up to about 360 degrees around the axis of rotation. The second spooling feature may include an arcuate section and a straight section. An arc of the arcuate section may be defined by a constant radius. The radius may extend from the axis of rotation to a surface of the arcuate section. The first or second spooling feature may comprise a curved recess on the camera housing into which the terminal portion of the second pull cable can be positioned.

In an embodiment, a light emitter may be formed from an optical fiber bundle comprising: a solid transparent light emitting member molded from or fused to a flexible optical fiber bundle. A transition segment of partially fused optical fibers may be formed adjacent the light emitting member at a first end and flexible optical fibers adjacent the optical fiber bundle at a second. The transition segment may comprising an inflexible molded form at the first end that maintains a fixed angular relationship with the light emitting member, wherein the light emitting member has a substantially flat emitting surface configured to emit light transmitted along the optical fiber bundle. The light emitting member may comprise acrylic or polycarbonate material. The light emitting

member may be shaped to at least partially encircle a lens assembly, the emitting surface of the member being oriented to emit light in a direction of a field of view of the lens assembly. The light emitting member may be mounted to a rotatable camera assembly, the camera assembly comprising a lens assembly opposite an image sensor, wherein the camera assembly and light emitter are configured to rotate together about a pivot shaft connected to the camera assembly.

In an embodiment, a light emitter may be formed from an optical fiber bundle by placing a section of a distal end of the fiber bundle onto a compression mold form; applying heat to the mold form or a corresponding force or plug member before, during or after placement of the section onto the mold form; moving the force or plug member into a mating relationship with the mold form; applying pressure to the section of fiber bundle; and melting the section to form a shape of the emitter determined by the shape of the mold form and corresponding force or plug member. The mold form may comprise a fiber orienting feature on which a transitional section of cable is placed, and the transitional section may be formed so as to have a fixed angular relation with respect to a face of the light emitter. The fiber orienting feature may be an incline feature. A jacket or heat sink may be applied to a region of the optical fiber bundle proximal to a transitional section. The jacket or heat sink may serve to maintain a band-like cross-sectional shape of the optical fiber bundle proximal to the transitional section during compression and heating of the distal end of the fiber bundle. A band-like cross-sectional shape of a portion of the optical fiber bundle may be maintained proximal to the transitional section during compression and heating of the distal end of the fiber bundle. The band-like cross-sectional shape may comprise placing the portion of the optical fiber bundle in a guide member. Pressure may be from a pneumatic, hydraulic, mechanical, or manual pressure source. The optical fiber bundle may comprise acrylic or polycarbonate material. The distal end of the optical fiber bundle may be wrapped around a mandrel in the mold form. Flashing may be from the light emitter after cooling. A mask or reflective coating may be applied to a surface of the light emitter. Heat may be applied with a resistive heating element. The amount of heat applied may be adjusted based on temperature feedback from a temperature sensor associated with the plug member or mold form. The light emitter may be ejected from the mold form after cooling using an ejector. The emitter may be allowed to cool such that it solidifies following which the force or plug member may be moved out of mating relationship with the mold form. At least a transitional section of the fiber bundle adjacent and proximal to the section

under pressure may be actively cooled. This may comprise blowing air across at least the transitional section of the fiber bundle.

In an embodiment, a lens assembly may be positioned relative to an image sensor in the process of assembly a camera for use in an aqueous environment, the lens assembly having an outer optical surface and an opposing optical surface facing the sensor, by: placing the lens assembly on a first surface of a plate having a pre-determined thickness, a second opposing plate surface, and an aperture into which the outer optical surface of the lens element may be inserted; inserting the lens element into the aperture so that the outer optical surface of the lens element does not extend through the full thickness of the plate, leaving a void between the outer surface of the lens assembly and a plane formed by the second surface of the plate; applying a seal between the first surface of the plate and a perimeter of the lens assembly above the first surface of the plate; adding a liquid to the void by capillary action, the liquid completely filling the void;

placing a transparent cover over the second surface of the plate; and adjusting the distance between the sensor and the optical surface of the lens assembly facing the sensor to provide an image in focus on a display screen connected to the sensor, wherein a source of the image is placed at a pre-determined distance from the second surface of the plate. The plate may comprise a glass slide. The aperture may have a diameter of about 1 mm to about 3 mm.

In an embodiment, an endoscope may have a shaft that includes a distal insertion end configured for insertion into an anatomical region of a patient. The shaft may define an interior space, the distal insertion end having an opening fluidly connecting the interior space of the shaft with an anatomical region into which the shaft is inserted. The endoscope may include an electronic image sensor within the interior space of the shaft at or near the insertion end. The image sensor may be configured in relation to the opening to have an unobstructed field of view of the anatomical region into which the shaft is inserted. The opening may be embrasured. A guard feature may be positioned over the opening, partially covering the opening. The guard feature may comprise a cage. A wall of the shaft adjacent the opening may comprise a longitudinal slit opening next to the image sensor. The width of the slit opening may increase as the slit opening extends in a direction proximal to the location of the image sensor. The image sensor may be mounted to a camera assembly. The camera assembly may be configured to pivot about a pivot axis. The opening at the distal end and the slit opening may be configured to provide the image sensor of the camera assembly an unobstructed field of view as the camera assembly pivots from about 0 degrees

to about 120 degrees with respect to a longitudinal axis of the endoscope shaft. The camera assembly may comprise a lens assembly opposite the image sensor. And the lens assembly may comprise an optically clear window spaced apart from an outer surface of the lens assembly, sealingly providing a gas or air space between the window and the outer surface of the lens assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects will become more apparent from the following detailed description of the various embodiments of the present disclosure with reference to the drawings wherein:

FIG. 1 is a representational illustration of a two-component handle design for an endoscope;

FIG. 2 shows additional features of the illustration of FIG. 1;

FIG. 3 shows an exemplary side view of an endoscope;

FIG. 4 shows a disassembled view of an example of a handle proximal section of an endoscope;

FIG. 5 shows a disassembled view of an alternate example of a handle proximal section of an endoscope;

FIG. 6 shows a top perspective view of an example of a handle distal section of an endoscope;

FIG. 7 shows an exploded view of a handle distal section and an example of a rotation sensing assembly of an endoscope;

FIG. 8 shows a partially assembled view of an exemplary endoscope;

FIG. 9 is a representational illustration of a pass-through barrier allowing utility components to pass from the handle to a conduit of an endoscope;

FIG. 10 shows an exploded view of an example of an inner sheath mount serving as a pass-through barrier;

FIG. 11 shows an exploded view of an example of a pivot control structure;

FIG. 12 shows a perspective view of an example of a sealing member ;

FIG. 13 shows a partially assembled view of an exemplary endoscope with an example of an inner sheath mount, pivot control structure, and sealing member in their assembled locations;

FIG. 14 shows a perspective view of an outer sheath mount;

FIG. 15 shows a close up partial view of an endoscope in which an inner sheath mount, inner sheath, and outer sheath are in their assembled locations;

FIG. 16 shows an example of a camera assembly mount separated from an inner sheath;

FIG. 17 shows an alternate example of a camera assembly mount as part of an inner sheath;

FIG. 18 depicts a cross-sectional view of example camera assembly mount and inner sheath of FIG. 17 taken at line 18-18 of FIG. 17;

FIG. 19 shows an example of a camera assembly, part of an outer sheath, and part of a camera assembly mount;

FIG. 20 shows an alternate example of a camera assembly, part of an outer sheath, and part of a camera assembly mount;

FIG. 21 shows an alternate example of a camera assembly, part of an outer sheath, and part of a camera assembly mount;

FIG. 22 shows a perspective view of a camera assembly;

FIG. 23 shows a side view of a camera assembly and a camera assembly mount with a wall of the camera assembly mount removed for clarity;

FIG. 24 shows a side view of an alternate exemplary camera assembly and camera assembly mount with a wall of the camera assembly mount removed for clarity;

FIG. 25 shows a side view of an alternate exemplary camera assembly and camera assembly mount with a wall of the camera assembly mount removed for clarity;

FIGS. 26-30 depict some of the possible rotational positions of an alternate camera assembly;

FIG. 31 shows an example camera assembly;

FIG. 32 shows an example camera assembly with attached optical fiber bundle and electronic flex cable;

FIG. 33 shows a top view of an exemplary camera assembly and camera assembly mount;

FIG. 34 shows a perspective view of a camera assembly and flexible optical fiber bundle or ribbon;

FIG. 35 shows a perspective view of a camera assembly having a monolithic camera housing and light emitting feature;

FIG. 36 shows a side view of the camera assembly of FIG. 35;

FIG. 37 shows an example of a flexible optical fiber bundle or ribbon;

FIG. 38 shows a side view of the flexible optical fiber ribbon of FIG. 37;

FIG. 39 shows a perspective view of an example of a light projection element;

FIG. 40 shows a perspective view of another example of a light projection element;

FIG. 41 shows a perspective view of another example of a light projection element;

FIG. 42 shows a bottom perspective view of the light projection element shown in FIG. 41;

FIG. 43 shows a cross sectional view of the light projection element shown in FIGS. 41 & 42 taken at line 43-43 of FIG. 41;

FIG. 44 shows a cross sectional view of the light projection element shown in FIGS. 41 & 42 taken at line 44-44 of FIG. 41;

FIG. 45 shows a cross sectional view of the light projection element shown in FIGS. 41 & 42 taken at line 45-45 of FIG. 41;

FIG. 46 shows a top perspective view of a camera assembly on which the light projection element of FIG. 41 is mounted;

FIG. 47 shows a top view of number of illumination fibers which are included in a flexible ribbon;

FIG. 48 shows a top view of a number of illuminations fibers of a flexible ribbon in which one end of the ribbon has been looped over itself;

FIG. 49 shows a side view of a looped end of a flexible ribbon being formed into a light projection element;

FIG. 50 shows a top view of a flexible ribbon with a fully formed light projection element;

FIG. 51 shows a representational illustration of an apparatus which may be used to form a light projection element;

FIG. 52 shows an example embodiment of an apparatus which may be used to form a light projection element;

FIG. 53 shows an example embodiment of an apparatus which may be used to form a light projection element;

FIG. 54 show an embodiment of two opposing forms which may be used to make a light projection element;

FIG. 55 shows an embodiment of an apparatus which may be used to make a light projection element;

FIG. 56 shows an embodiment of an apparatus which may be used to make a light projection element;

FIG. 57 shows an embodiment of a form which may be used to make a light projection element;

FIG. 58 shows an embodiment of a form which may be used to make a light projection element;

FIG. 59 shows an embodiment of an example apparatus which may be used to make a light projection element and a light projection element which may be made therefrom;

FIG. 60 shows a cross-sectional view of the apparatus in FIG. 59 taken at line 60-60 of FIG. 59;

FIG. 61 shows a cross sectional view of an example camera assembly taken at line 61-61 of FIG. 22;

FIG. 62 shows a cross sectional view of an example camera assembly taken at line 62-62 of FIG. 32;

FIG. 63 shows a cross-section view of an example camera assembly taken at line 62-62 of FIG. 32;

FIG. 64 shows a perspective view of an example lens assembly;

FIG. 65 shows a cross sectional view of an example lens assembly taken at line 65-65 of FIG. 64;

FIG. 66 shows a perspective view of an example lens assembly;

FIG. 67 shows a cross sectional view of an example lens assembly taken at line 67-67 of FIG. 66;

FIG. 68 shows a perspective view of an example lens assembly;

FIG. 69 shows a cross sectional view of an example lens assembly taken at line 69-69 of FIG. 68;

FIG. 70 shows a perspective view of an example lens assembly;

FIG. 71 shows a cross sectional view of an example lens assembly taken at line 71-71 of FIG. 70;

FIG. 72 shows a top down view of part of an example fixture which may be placed into a larger apparatus used for determining the proper spatial arrangement of an optical element and image sensor;

FIGS. 73-75 conceptually depict a process for enclosing an optical element in its intended working medium;

FIG. 76 conceptually depicts a process for aligning a sensor in the image plane of an optical element;

FIG. 77 depicts an example image sensor and lens assembly which are separated from one another such that the image plane of the lens assembly is not aligned with the image sensor;

FIG. 78 depicts an example image sensor which has been affixed to an example lens assembly after alignment;

FIG. 79 depicts a perspective view of an example apparatus which may be used to determine the proper spatial arrangement of an optical element and image sensor;

FIG. 80 depicts a perspective view of part of the apparatus depicted in FIG. 79;

FIGS. 81-84 depict an example process which may be used to assemble a completed fixture and place the fixture into a larger apparatus;

FIG. 85 shows a partially assembled view of an endoscope with a handle printed circuit board, power/HDMI cable, illumination fibers, and irrigation line in their assembled locations;

FIG. 86 shows a block diagram of an example image processing system; and

FIG. 87 depicts an example diagram illustrating how an image may be righted using input from a rotation sensing assembly.

DETAILED DESCRIPTION

The terms ‘endoscope’ and ‘arthroscope’ as used herein are meant to be used interchangeably and are to be given their broadest interpretation, each term denoting an instrument having an elongate section for insertion into a space that is otherwise difficult to access, for the purpose of visual inspection, diagnosis and/or treatment or repair. In the field of medicine or veterinary practice, such a space may include a body cavity, joint space, tissue plane or other body structure. The instrument may also be used in a number of non-medical (e.g., industrial) applications, in which the diameter of the insertion portion of an endoscope needs to be minimized, or in which the space within which an endoscope must operate is too confined to permit the use of an actively flexible distal segment.

A two-component handle design of an endoscope **10** is shown in **FIG. 1**. The example endoscope **10** includes a handle proximal section **16** and a handle distal section **30**. The handle proximal section **16** may be a housing. As shown, the handle distal section **30** may extend at least partially into the handle proximal section **16**. The handle distal section **30** and the handle proximal section **16** may be rotatable relative to each other. In some embodiments, a user may hold the handle proximal section **16** immobile while rotating the handle distal section **30** with a thumb or finger. The endoscope **10** may have a number of features such as, but not limited to, a rotation sensing assembly, fluid conduits, lighting, an imager or camera assembly, pivot control for the imager etc.

Additional features of the endoscope **10** are represented in **FIG. 2**. The endoscope **10** includes a handle proximal section **16** and a handle distal section **30**. In this example, at least a part of an insertion shaft or section **14** is fixed to the handle distal section **30** and moves with the handle distal section **30**. The handle distal section **30** includes a handle protuberance or fin **36** which provides a surface for a user to press against to facilitate rotating the handle distal section **30** relative to the handle proximal section **16**. In some embodiments, a user’s hand may hold the handle proximal section **16** immobile while the handle distal section **30** is rotated using one of the user’s fingers or thumb.

In some embodiments, one or both the handle proximal section **16** and the handle distal section **30** may function as a housing or provide a support structure for other components of the endoscope **10**. The endoscope **10** shown in **FIG. 2** may include a rotation sensing assembly **150**. The rotation sensing assembly **150** may track the rotation of handle distal section **30** relative to the handle proximal section **16**. In some embodiments, the rotation sensing assembly **150** may include a component which is stationary with respect to

the handle proximal section **16** and a component that is stationary with respect to the handle distal section **30**. For example, the rotation sensing assembly **150** may include a potentiometer and a keyed shaft. The potentiometer may be mounted, for example to a support member comprising the internal housing of the handle proximal section **16**. Alternatively, the handle distal section **30** may also comprise a support member for mounting one or more components of the rotation sensing assembly **150** (see for example the rotation sensor holder in **FIG. 7**). In either case, a rotational or translational component of the rotation sensing assembly is arranged to move in proportion to the degree of rotation of the handle distal section **30** relative to the handle proximal section **16**.

An exemplary embodiment of an endoscope (or, e.g., arthroscope) **10** is shown in **FIG. 3**. The endoscope **10** may be used in various endoscopic procedures, including arthroscopy, among others. As shown, the endoscope **10** includes a handle **12** and an insertion section or shaft **14**, which may comprise an elongate hollow shaft within which one or more actuation members, electrical/communications wires, lighting or light-transmitting cables and/or fluid channels may be located. As shown, in an embodiment the handle **12** may be roughly cylindrical and rounded in shape. The insertion section **14** may also be roughly cylindrical in shape and extend along a longitudinal axis. In an embodiment, the insertion section **14** may be rigid and relatively straight. In other embodiments, the insertion section **14** may be curved or angled along at least a portion of its length. In yet other embodiments, the insertion section **14** may comprise semi-rigid, malleable material permitting it to be bent and held to a desired shape. The diameter of the insertion section **14** is significantly smaller than that of the handle **12**. In some embodiments, the diameter of the insertion section **14** may be approximately 5.5 mm or smaller. The insertion section **14** of the endoscope **10** may be roughly the same length as that of the handle **12**. In alternative embodiments, the lengths and shapes of the handle **12** and insertion section **14** may differ substantially.

At least a portion of the insertion section **14** may be detachable from the handle **12**. In such embodiments, the insertion section **14** or detachable portion of the insertion section **14** may be coupled to the handle **12** by any of a variety of means including, but not limited to friction fit, snap fit, threaded coupling, bayonet mount, etc. In some embodiments, the insertion section **14** may be a disposable component and the handle **12** may be a reusable component. In embodiments in which the insertion section **14** is disposable, the insertion section **14** may be discarded after use. In other embodiments, the insertion section **14** may be sterilized after use via an autoclave, solution soaking, or other suitable sterilization

procedure. In a preferred embodiment, both the handle **12** and the insertion section **14** are disposable and may be discarded after use, obviating the need for and cost of sterilization procedures and equipment (aside from a pre-usage sterilization with ethylene oxide, radiation, or the like, during, for example, manufacture, assembly or packaging of the device). Additionally, by making both the handle **12** and insertion section **14** of the endoscope **10** disposable, there is no degradation in function or reliability resulting from repeated use and repeated cleaning. Making the entire endoscope **10** disposable has other benefits, some which will be discussed below.

Preferably, a disposable endoscope **10** may be equipped with a means to prevent its reuse, particularly if sterilization of a used instrument is likely to degrade its function. For example, the endoscope **10** may include a memory chip storing an identification code that can be recognized by an electronic processor in a base unit to which the endoscope **10** must be connected for operability and display of images. The connection may include wired communications between a controller in the base unit and a memory chip in the endoscope **10**, or, for example wireless communications using an RFID device mounted in the endoscope **10**. (Other types of wireless transmission, such as, e.g. Bluetooth or Wi-Fi, may also be used). In an embodiment, the base unit may be programmed to encode a memory device on the endoscope **10** upon first use, and may be programmed to read and identify a code signifying that the endoscope **10** has been previously used whenever the endoscope **10** is subsequently re-connected to any base unit. Upon identification of a 'used' endoscope **10**, the controller may be programmed to prevent electronic and imaging communications between the endoscope **10** and the base unit. The code and its communication may be encrypted to enhance system security. Alternatively, the endoscope **10** may include a disablement feature in its software which renders the endoscope **10** inoperable after usage.

As shown in **FIG. 3**, the handle **12** of the endoscope **10** may include a number of different features. The handle **12** may include a handle proximal section **16**. The handle proximal section **16** may be relatively smooth as shown in **FIG. 3**. The handle proximal section **16** may comprise one or more hollow sections. The handle proximal section **16** may also be contoured such that it includes a number of ergonomic attributes. In some embodiments, at least a portion of the handle proximal section **16** may not have a smooth surface and may include a knurled, ribbed, roughened, honeycombed, etc. type texture, and/or a rubberized or elastomeric surface layer to facilitate gripping the endoscope **10** during its operation. In the example embodiment, the handle proximal section **16** is formed with a number of finger grooves **18**. In some embodiments, the handle proximal section **16**

may be made of a material (e.g. rubber or other elastomer) that has a soft feel or is otherwise comfortable to hold. In some embodiments, a pistol grip-like feature (not shown) may be included as part of the handle proximal section **16**.

As shown in **FIG. 3**, the handle proximal section **16** may be divided into two separate parts. The handle proximal section **16** in **FIG. 3** includes a handle top section **20** and a handle bottom section **22**. The handle top section **20** and handle bottom section **22** of the handle proximal section **16** may be manufactured as two separate parts and coupled together by any suitable means, such as, e.g., adhesive, screws, snap-fit, etc. As shown, the handle top section **20** is smooth and contoured differently from the handle bottom section **22**. This may help a user quickly and easily determine orientation of the endoscope **10** by feel. In some embodiments the handle top section **20** and handle bottom section **22** may comprise surface materials that have a different feel (e.g., metallic vs. plastic, metallic vs. elastomeric, smooth vs. textured, etc.).

The handle **12** of the endoscope **10** may also include a handle distal section **30**. As shown in **FIG. 3**, the handle distal section **30** extends from the handle proximal section **16** toward the insertion section **14**. The handle distal section **30** may be smaller in diameter than the handle proximal section **16**. As shown, the handle distal section **30** may be longer in length than the handle proximal section **16**, but in alternate embodiments, the relative dimensions of the handle distal section **30** and handle proximal section **16** may differ.

On at least a portion of the handle distal section **30** there may be a gripping texture as shown in **FIG. 3**. In the example embodiment shown in **FIG. 3**, the grip texture is a series of spiraling ribs **32**. In other embodiments, other gripping textures, such as non-spiraling ribs, nubs, bumps, grooves, honeycomb patterning or other form of knurling or checkering, etc. may also be used. As shown, the spiraling ribs **32** in the example embodiment encircle most of the outer diameter of the handle distal section **30**. In some embodiments including a gripping texture on the handle distal section **30**, the gripping texture may not be formed as a continuous part of the handle distal section **30**. In such embodiments, the gripping texture may be a 'skin' or sleeve applied onto the handle distal section **30**. The gripping texture skin may be coupled to the handle distal section **30** by any suitable means such as, but not limited to, adhesive, snap fit, various fasteners, over-mold, etc. In some embodiments, the gripping texture skin may be made of a material different from the handle distal section **30**. The gripping texture skin, for example, may be a softer, elastomeric or rubbery, material which is more comfortable to grip/less slippery than the handle distal section **30** material.

In the example embodiment, the handle distal section **30** includes a handle raised portion **34** projecting from the top of the handle distal section **30**. In this example, the handle raised portion **34** does not project sharply up from the rest of the handle distal section **30**. Instead, the handle raised portion **34** may be constructed to gently curve up from the rest of the handle distal section **30**. In this example, the spiraling ribs **32** do not extend over and onto the top of the handle raised portion **34**. Additional features of the handle raised portion **34** will be further described below.

In one aspect, projecting from the bottom of the handle distal section **30** may be a handle fin **36**. In this example, the handle fin **36** does not project sharply away from the rest of the handle distal section **30**. Instead, the handle fin **36** may be constructed to gently curve away from the rest of the handle distal section **30** toward an inferior or dependent position of the endoscope **10**. The spiraling ribs **32** preferably do not extend over and onto the bottom of the handle fin **36**. In other embodiments, a handle fin **36** may be configured to project from the top of the handle distal section **30**, while the handle raised portion **34** may be configured to project from another aspect of the handle distal section **30**. The handle fin **36** may be disposed so as to mimic the location of an entry point for various cables, irrigation, etc. in endoscopes which may already be familiar to a physician. This may be desirable since such an entry point is often used as a surface to press against to facilitate rotation and as an orientation marker. Additional features of the handle fin **36** will be further described below.

FIG. 4 and **FIG. 5** show example embodiments of the handle top section **20** and handle bottom section **22** of the handle proximal section **16** shown in **FIG. 3**. The handle top section **20** and handle bottom section **22** are shown in an uncoupled or disassembled view. The handle proximal section **16** may be hollow and form a shell-like structure when assembled. The handle bottom section **22** may include a ledge **40** that wraps around a bottom section inner wall **42** at a distance from the top face **46** of the handle bottom section **22**. As shown, there is a curved or U-shaped cutout **44** in the handle bottom section **22** disposed at an angle substantially perpendicular to the top face **46** of the handle bottom section **22**. Two peg projections **47** may be included near the rear of the handle bottom section **22**. The peg projections **47** may extend slightly above the ledge **40** and be angled approximately perpendicular to the top face of the ledge **40**.

As shown in **FIG. 4** and **5**, a portion of the handle top section **20** may be dimensioned so that it may be overlapped by the handle bottom section **22** when the handle proximal section **16** is assembled. The overlapped section **48** may be stepped in from the

handle top section outer surface **50** as shown in **FIG. 4** and **5**. The height of the overlapped section **48** may be selected so that it is approximately equal to or slightly greater than the distance between the top of the ledge **40** of the handle bottom section **22** and the top face **46** of the handle bottom section **22**. In such embodiments, when fully assembled, the bottom face **52** (refers to orientation when assembled) of the handle top section **20** abuts the top of the ledge **40** of the handle bottom section **22**. Additionally in such embodiments, the handle top section outer surface **50** and handle bottom section outer surface **54** may be flush with each other and form a nearly continuous surface with little gap between the two. In some embodiments, there may be a small gap between the handle top section outer surface **50** and handle bottom section outer surface **54** (small gap shown in **FIG. 3**).

As shown, the handle top section **20** may include peg cutouts **59** which are shaped and disposed such that they may accept the peg projections **47** in the handle bottom section **22**. The handle top section **20** may include a curved cutout **58** at the butt or proximal portion of the handle top section **20**. As shown the curved cutout **58** may be recessed into the handle top section **20** at an angle substantially perpendicular to the bottom face **52** (refers to orientation when assembled) of the handle top section **20**. When the handle proximal section **16** is assembled, the curved or U-shaped cutout **44** of the handle bottom section **22** and the curved cutout **58** of the handle top section **20** together may form a substantially circular or ovoid handle void or opening **60** which will be further described below. It should be appreciated that the use of the terms “cutout”, “cut”, etc. herein should not be construed to imply material must be physically removed by a cutting or material removal process. In some embodiments, the curved or U-shaped cutout **44** and the curved cutout **58** may be formed during manufacture without physically removing material.

As shown in **FIG. 4** the handle bottom section **22** may include a shaft support member **63**. The shaft support member **63** in **FIG. 4** has a curved or semi-circular portion which roughly corresponds to the location of the toothed projection **62** in **FIG. 5**. The shaft support member **63** also includes a post. The post projects perpendicularly from a mid-point of the semi-circular portion, leaving approximately 90° of the semi-circular portion on each side of the post. Projecting perpendicularly from the top of the post of the shaft support member **63** toward the distal end of handle proximal section **16** is a shaft supporting section **65**. The shaft supporting section **65** may include a depression in which a portion of a sensor gear shaft **120** (see **FIG. 7**) may be seated. The post of the shaft support member **63** may be approximately the length of the radius of the semi-circular portion when the handle

proximal section **16** is fully assembled. The shaft support member **63**, toothed projection **62**, and toothed projection **64** will be further described below.

As shown in **FIG. 5**, the handle bottom section **22** may instead or optionally include a curved toothed projection **62**. The curved toothed projection **62** is complemented by a similar toothed projection **64** included on the handle top section **20**. The toothed projection **62** and toothed projection **64** may be disposed so that they are in line with one another and form an annulus or internal ring gear when the handle proximal section **16** is fully assembled.

As shown in **FIG. 4** and **5**, the face of the handle bottom section **22** opposite the curved or U-shaped cutout **44** and face of the handle distal section **20** opposite the curved cutout **58** may include semi-circular openings or voids **70**. A curved or U-shaped track **72** may be recessed into the edges of the semi-circular voids **70** along the entire arc of each semi-circular void **70** as shown in **FIG. 4** and **5**.

The example handle distal section **30** of **FIG. 3** is shown in **FIG. 6** isolated from the rest of the handle **12**. **FIG. 6** shows the handle distal section **30** from a substantially top perspective view. As shown, the spiraling ribs **32** and front handle raised section **34** detailed above are visible on handle distal section **30**. As indicated by the seam running down the vertical center plane of the handle distal section **30**, the handle distal section **30** may be constructed as two or more separate parts (**30a** and **30b** in the example embodiment) which are coupled together by any suitable means or combination of suitable means, such as, e.g., snap fit, adhesive and/or screws.

The handle distal section **30** in **FIG. 6** additionally includes a section not shown in **FIG. 3**. When the endoscope **10** is assembled, as it is in **FIG. 3**, part of the handle distal section **30** may be housed inside the handle proximal section **16**. For example, a housed handle electronics section **80** projects proximally from the external handle distal section **82** (which is visible in both **FIG. 3** and **FIG. 6**). The housed handle electronics section **80** will be further described below.

Between the housed handle electronics section **80** and the external handle distal section **82** is a small diameter span **84**. As shown, the small diameter span **84** may include a rounded groove **86** which is recessed into the outer surface of the small diameter span **84**. In some embodiments, when fully assembled, the small diameter span **84** of the handle distal section **30** may be disposed within the semi-circular voids **70** of the handle proximal section **16**. The rounded groove **86** in the small diameter span **84** and the curved or U-shaped track **72** in the semi-circular voids **70** may be in line with one another. This may allow the handle

distal section **30** and handle proximal section **16** to be rotated relative to one another as the endoscope **10** is used. Optionally, ball bearings (not shown) or other types of bearings may track along the rounded groove **86** in the small diameter span **84** of the handle distal section **30** and the U-shaped track **72** in the semi-circular voids **70** of the handle proximal section **16**. In a preferred embodiment, an o-ring (not shown) may be placed in the rounded groove **86** of the small diameter span **84** of the handle distal section **30**. The o-ring (not shown) may function as a dynamic seal between the handle proximal section **16** and handle distal section **30**. In such embodiments, the handle proximal section **16** and handle distal section **30** may be rotated relative to one another while sealing the interior of the handle proximal section **16** from liquid.

A handle fin **36** or other protuberance may serve as an orientation marker for the user as the handle proximal portion **16** and handle distal section **30** are rotated relative to one another. Orientation may be checked either visually or by feel. In some embodiments, the gripping texture on the handle fin **36** may be different than spiraling ribs **32** on the rest of the handle distal section **30** to facilitate orientation-checking by feel.

As shown in **FIG. 6**, the handle raised section **34** may include a button **90**. In some embodiments, the handle raised section **34** may include more than one button **90**, or no button at all. The button **90** may be located elsewhere on the handle distal section **30** or elsewhere on the handle **12**. In some embodiments, the handle raised section **34** may include a button **90** and one or more additional buttons **90** may be located elsewhere on the handle **12**. The button **90** may be assigned a function. In some embodiments, the button **90** may be assigned multiple functions which may be activated by various user manipulations. In some embodiments one or more of the buttons **90** may be sealed with respect to the external handle section **82** to inhibit liquid infiltration.

The button **90** may be an image capture button. In such embodiments, user depression of the button **90** may cause a photograph to be recorded by the endoscope **10**. In some embodiments, a user may double tap the button **90**, hold down the button **90**, etc. to cause the endoscope **10** to start recording video. To stop recording video, a user may double tap the button **90**, hold down the button **90**, etc. In some embodiments, a user may only be required to depress the button **90** to stop recording video. In some embodiments, a single depression of the button **90** by a user while the endoscope **10** is recording video may cause a still image to be recorded without the need to pause video recording.

The handle raised section **34** may additionally include a slide button recess **92**. As shown in **FIG. 6**, the slide button recess **92** is arranged to permit fore and aft movement of a

slide button or finger contact **98** (see **FIG. 13**) while constraining lateral movement. The slide button may be part of a pivot control or pivot control structure **100** (see, for example, **FIG. 13**) in some embodiments. In some embodiments, including the example embodiment shown in **FIG. 6**, the slide button recess **92** may be slightly curved to conform to the shape of the portion of the handle within which it resides.

As shown in **FIG. 6**, the slide button recess **92** may include a number of ridges or detents **94** that can engage with a corresponding element on the slide button to provide a series of discrete, positive stops when a user moves the slide button fore and aft. Some embodiments may not include the ridges **94**. In some embodiments, the portion of a pivot control structure **100** (see **FIG. 11**) with which a user may interface may project through a pivot control structure notch **96** (see **FIG. 13**) located in the slide button recess **92** of the handle raised section **34**. In the example embodiment in **FIG. 6**, such a portion of the pivot control structure **100** includes a finger contact **98**. As shown, the finger contact **98** may have sloped contours for ergonomic reasons. The pivot control structure **100** will be further described below.

FIG. 7 shows a more detailed illustration of an exemplary handle distal section **30** without an attached insertion section **14**. An example rotation sensing assembly **150** is also shown in **FIG. 7**. As shown, the handle distal section **30** is manufactured as two separate parts **30a** and **30b**. In the example embodiment, the two separate parts **30a** and **30b** of the handle distal section **30** include a number of screw holes **102**, which may be threaded. Screws (not shown) or other suitable fasteners may be used to couple the two separate parts **30a** and **30b** of the handle distal section **30** together. In some embodiments, the two separate parts **30a** and **30b** may be coupled together via a snap fit, ultrasonic weld, adhesive, etc.

In some embodiments one of the two separate parts **30a** and **30b** of the handle distal section **30** may include peg-like projections **104** which fit into complimentary peg accepting cavities **106** on the other of the two separate parts **30a** and **30b**. This may help to align and/or couple the two separate parts **30a** and **30b** together. In some embodiments, including the embodiment shown in **FIG. 7**, the external handle distal section **82** may be substantially hollow. In some embodiments, the hollow of the external handle distal section **82** may not be sealed against fluid. In the example embodiment shown in **FIG. 7**, a drain channel **108** may be included, for example, in the handle fin **36**. The drain channel **108** may allow any fluid which enters the hollow of the external handle distal section **82** to easily drain out. Alternate embodiments may include additional and/or different drain arrangements.

The handle distal section **30** may also include a rotation sensor holder **110** as shown in **FIG. 4**. The rotation sensor holder **110** may retain the rotation sensing assembly **150** when the endoscope **10** is fully assembled. As shown, the rotation sensing assembly **150** may include a forward gear **112**. The forward gear **112** is disposed about a forward gear shaft **114**. As shown in **FIG. 4**, a transfer gear **116** is also placed on the forward gear shaft **114**, such that rotation of the forward gear **112** causes the transfer gear **116** to rotate as well. The transfer gear **116** may mesh with a sensor shaft gear **118**, disposed on a sensor gear shaft **120**. As the forward gear **112** rotates, so will the sensor shaft gear **118** and the sensor gear shaft **120**. Use of a gear assembly may allow for placement of an attached potentiometer **122** in a location that is off-center from the central rotational axis of the handle distal section **30**, which may advantageously allow for a central placement of other internal structures (e.g., irrigation conduit, optical fiber bundle, electronic flex cable, or other electronic components).

As in the example embodiment in **FIG. 7**, the sensor gear shaft **120** may include a splined, or keyed (e.g., a D-shaped) portion. The keyed portion may operatively engage with one or more rotational potentiometers **122**. In the example embodiment in **FIG. 7**, there are two rotational potentiometers **122**. The potentiometers **122** may be mounted on or otherwise attached to a mounting element, or a part of a printed circuit board in the handle as described in reference to **FIG. 85**. The potentiometers **122** each include a keyed (e.g. D-shaped) void with which the corresponding keyed portion of the sensor gear shaft **120** mates. As the sensor gear shaft **120** rotates, the electrical resistance of the potentiometer(s) **122** will vary proportionately. Since the resistance will predictably change with the amount of rotation of the sensor gear shaft **120** the measured resistance of the potentiometer(s) **122** may be used to determine the amount of rotation that has taken place between the handle proximal section **16** and the handle distal section **30** (and by extension, the insertion section **14**).

In some embodiments, the housing of each potentiometer **122** may be mounted to elements of the housed handle electronics section **80** (or other elements attached to the handle distal section **30**), and thus immobilized relative to the handle distal section **30** (and by extension the insertion section **14**), while the shaft or rotating hub of the potentiometer **122** is connected to the handle proximal section **16**. In other embodiments, the housing of the potentiometer **122** may be immobilized relative to the handle proximal section **16**, while its shaft or rotating hub may be connected to elements of the handle distal section **30** or the handle electronics section **80**.

The example embodiment in **FIG. 7** includes two rotational potentiometers **122** stacked together, and offset rotationally from one another. In an alternate embodiment, the potentiometers **122** may be spaced apart from each other, but share a common rotational axis (e.g., the wipers of both potentiometers **122** are caused to move by a common shaft). This arrangement permits a controller receiving electrical resistance values from both potentiometers **122** to compute the degree of rotation of a sensor shaft (and ultimately of components at the distal end of the endoscope) with a desired accuracy through 360 degrees of rotation, thus helping to eliminate computational “blind spots” in measuring the rotation of the components at the distal shaft (e.g., a camera) of the endoscope. Any blind spot created by the position of a wiper of one potentiometer **122** at the end of its range of motion may be compensated by a wiper of a second potentiometer **122** whose position is not at the end of its range of motion. In alternative embodiments, more than two rotationally offset potentiometers **122** may be used. The rotational offset between the potentiometers **122** may be 180 degrees for computational simplicity, but other angular offsets may be used to achieve the same result, as long as the rotational offset allows any blind spot created by one potentiometer **122** to be overlapped by a functional range of another potentiometer **122**. In alternative embodiments, the gearing ratios between the forward, transfer, and sensor shaft gears **112**, **116**, **118** may vary, depending on the degree of precision desired in measuring rotation, the sensitivity of the potentiometers **122**, and other factors. In alternative embodiments, the rotation sensing assembly **150** may use belts rather than one or more of the gear assemblies. For example, the transfer gear **116** and sensor shaft gear **118** may be replaced by a belt. Other rotation to rotation arrangements known in the art may also be used. In some embodiments, the forward gear shaft **114** may include a keying feature (e.g., a D-shaped portion) which operatively engages the potentiometers **122** directly. Rotation sensors other than potentiometers **122** may also be used. Alternative embodiments may include rotation sensors such as, a rotary encoder, a rotary variable differential transformer, or other encoding devices. In embodiments using a rotary encoder, the encoder may be a gray encoder, magnetic encoder, optical encoder, etc.

In an embodiment, the sensor gear shaft **120** may not extend to the shaft bearing section of a shaft support member **63**. Rather, the rotation sensing assembly **150** may be supported by the rotation sensor holder **110**. Among other benefits, this arrangement allows for an unlimited degree of rotation of the handle distal section **30** relative to the handle proximal section **16**. Additionally, as would be appreciated by one of skill in the art, it allows for components a of rotation sensing assembly **150** to be located in an off-center

position. This may provide benefits during assembly. For example, it may simplify routing of an irrigation line **434** (see **FIG. 85**), power cable **432** (see **FIG. 85**), etc.

In other embodiments, the shaft support member **63** and potentiometers **122** may be directly connected by a shaft. A shaft splined or keyed on a distal end may extend from the shaft bearing section of the shaft support member **63** and extend through a corresponding splined or keyed (e.g., D-shaped) void in the potentiometers **122**. Since the shaft support member **63** may be fixed relative to the handle proximal section **16**, rotation of the distal handle section **30** relative to the handle proximal section **16** will vary the resistance measured by the potentiometers **122**. As mentioned above, since the resistance will predictably change with rotation of one handle section relative to the other, the resistance measurement may be used to determine the amount of rotation achieved by the handle distal section (and ultimately, the distal end of the endoscope or camera assembly **350** shown, for example, in **FIG. 19**).

In other embodiments, the rotation sensing assembly **150** may include a range finder which may be disposed on the housed handle electronics section **80** (see **FIG. 6**). The interior walls of the handle proximal section **16** (see **FIG. 4**) may include a variable-thickness or variable-height raised surface that wraps around most or all of the 360 ° of the interior wall of the handle proximal section **16**, and varies in thickness or height in a pre-determined manner along its circumferential path. As the handle proximal section **16** and handle distal section **30** rotate relative to one another, the range finder may provide a controller with a signal that varies according to the distance read by the range finder to the varying surface (either its varying thickness or height). The signal may be correlated to the thickness/height or distance measured by the range finder relative to a pre-determined base position in which the surface has a specified thickness or height and is correlated to a specified angular rotation of the handle distal section **30** relative to the handle proximal section **16**. This distance may be compared to a previous distance to thereby determine the amount of rotation that has occurred. The range finder may be any type of range finder (e.g. a mechanical position sensor, a sonic range finder, laser or other optical range finder, etc.).

In yet another alternative embodiment, an optical mouse like sensor arrangement may be used. The sensor may be mounted on one of the housed handle electronics section **80** or handle proximal section **16** and may be configured to track movement of the other of the housed handle electronics section **80** or handle proximal section **16**. In such embodiments, the amount and direction of movement sensed by the sensor may be used to determine the amount and direction of rotational displacement that has occurred. In some

embodiments, the surface tracked by the sensor may have a reference grid, number of unique indicators, pattern, markings, or other differentiating features, which allow sensor determination of rotational orientation upon start up. Other varieties of rotation sensing assemblies **150** known to those skilled in the art may also be used in various embodiments.

As shown in **FIG. 7**, the rotation sensor holder **110** of the handle distal section **30** may be shaped such that when the two separate parts **30a** and **30b** of the handle distal section **30** are coupled together, the rotation sensing assembly **150** may be captured between the two separate parts **30a** and **30b**. Each side of the rotation sensor holder **110** may include a forward gear shaft trough **124** and a sensor gear shaft trough **126**. When assembled the forward gear shaft trough **124** and the sensor gear shaft trough **126** may act as bearing surfaces respectively for the forward gear shaft **114** and the sensor gear shaft **120**. Each side of the rotation sensor holder **110** may also include a holder void **128**. The holder void **128** may be sized and shaped such that the transfer gear **116**, sensor shaft gear **118**, and potentiometers **122** may fit within the rotation sensor holder **110** when the handle distal section **30** is fully assembled.

FIG. 8 shows a partially assembled view of the handle **12** of the endoscope **10**. Only the handle bottom section **22** of the handle proximal section **16** is shown in **FIG. 8**. As shown, a part of the handle bottom section **22** of the handle proximal section **16** has been cut away. Additionally, in the embodiment shown in **FIG. 8**, the handle distal section **30** is assembled from two separate parts **30a** and **30b** (see **FIG. 7**). One of the halves (**30b**) of the handle distal section **30** has been removed in **FIG. 8** for clarity. The housed handle electronics section **80** may be located inside the handle proximal section **16**. The external handle distal section **82** extends beyond the handle proximal section **16** and is exposed to the environment.

As described above, the rotation sensing assembly **150** is disposed within the rotation sensor holder **110**. As shown, the forward gear **112** of the rotation sensing assembly **150** may mesh with the annulus gear formed by the toothed projection **62** and toothed projection **64** (best shown in **FIG. 5**). In such embodiments, when the handle **12** is fully assembled, any rotation of the handle distal section **30** in relation to handle proximal section **16** causes the forward gear **112** to rotate since it meshes with the annulus gear formed by the toothed projection **62** and the toothed projection **64**. This rotation may then be translated through the rest of the rotation sensing assembly **150** allowing the rotation to be measured by the rotation sensing assembly **150**. In a preferred embodiment, the overall gear ratio may be approximately 1:1.

Alternatively, rather than gear elements, the handle proximal section **16**, similar to that shown in **FIG. 4**, may comprise a keyed shaft or partially keyed shaft, affixed to the shaft support section **65** of the shaft support member **63**. The keyed portion of the shaft may be arranged to mate with the hub of one or more potentiometers **122**, which are held in rotation sensor holder **110**. Thus as the handle distal section **30** is rotated relative to the handle proximal section **16**, the wiper of the one or more potentiometers **122** is able to convert the relative positions of the handle distal section **30** and proximal section **16** into an electrical resistance value usable to determine rotational orientation.

Referring now to **FIG. 9**, in an embodiment, the insertion section **14** of an endoscope **10** includes a conduit **157** through which operations or functions may be performed. In industrial or medical applications, this conduit **157** may be used to pass instruments to manipulate objects at the end of the insertion section **14** (instruments such as graspers, forceps, clamps, wire baskets, dilators, knives, scissors, magnetic pickups, etc.). Fluid (gas or liquid) may also be passed to/from an external source from/to the space within which the insertion section **14** is placed. In medical applications, such a conduit **157** may be used to insufflate a body cavity with a gas, evacuate gas from a body cavity, irrigate a space with liquid, or aspirate liquid and/or suspended particulates from a space. The conduit **157** optionally may carry utility components such as light transmission, information transmission, power transmission, and mechanical control components, saving space within the insertion section **14** and helping to reduce the overall diameter of the insertion section **14**. A light transmission component may include, for example, a fiberoptic bundle, ribbon, light pipe, light projection element, and/or the like. An information transmission component may include, for example, an electrical cable bundle or ribbon connecting an imager or image sensor at the end of the insertion section **14** to an image processing unit situated in the handle **12** or external to the endoscope **10**. Such a cable may also provide power to the image sensor. Mechanical control components may include, for example, pushrods, pull wires, etc. to control the movement of an element near the end of the insertion section **14**. This may include, for example, an actively flexible distal segment of the insertion section **14** that can be actively flexed by the use of the mechanical control component(s) extending from the handle **12**. It may also include, for example, a rotatable camera or camera mount at the end of insertion section **14** that can be actively moved by the use of the mechanical control component (s) extending from the handle **12**.

In a specific embodiment, a fluid carrying conduit **157** within the insertion shaft or section **14** is configured to enclose utility components of the endoscope **10**, such as, for

example, fiberoptic bundles, communication cables and mechanical actuators. In a further embodiment, the conduit **157** may be in fluid communication with a camera assembly **350** (see, for example, **FIG. 19**) at the distal end of insertion shaft **14**. The camera assembly **350** may include a camera sensor or imager having connections to a communications cable. In this case, the camera sensor and communications cable connections, and the internal components of any associated lens assembly may be sealed against exposure to liquids present within the conduit **157**. Allowing a camera assembly **350**, lens assembly, communications cable, mechanical actuators (e.g. pull-wires) and fiberoptic cables or bundles to be exposed to a 'wet' conduit may be feasible if at least a portion of the endoscope **10** is configured to be a single use device, i.e., disposable after use in a medical procedure. Any technical challenges in adequately sterilizing intra-conduit components are thus obviated.

Some components of the endoscope **10**, particularly electronic components located within the handle section **12**, preferably should be kept dry. A barrier element **159** between the conduit **157** of the insertion section **14** and the interior of the handle **12** may allow passage of components from the handle **12** to the insertion section **14** conduit **157** (represented in **FIG. 9** by line segments **155** and referred to as pass-through components), while also inhibiting infiltration of fluid from the conduit **157** into the interior space of the handle **12**. The barrier **159** may comprise passageways (holes, slits, etc.) through which pass-through components **155**, such as the utility components described supra, may pass from the handle **12** to the conduit **157** of the insertion section **14**. The passageways may be formed to provide a relatively tight fit around the outside surface of the pass-through components **155**. In some embodiments, elastomeric gaskets, O-rings, or other similar elements may further aid in inhibiting fluid infiltration from the conduit **157** of the insertion section **14** to the interior spaces of the handle **12**. The barrier **159** may comprise a wall separating a junction region between the handle **12** and a proximal end of the insertion section **14**. The junction region may be near an area where the conduit **157** connects to a conduit port providing an external fluid connection for the conduit **157**. The barrier **159** may alternatively comprise a block through which a routing channel connects a utility hole communicating with the conduit **157** on a first side of the block with one or more features (e.g. a conduit port) on a second side of the block opposite the first side of the block, or on a third side of the block (which in some embodiments, may be roughly perpendicular to the first side of the block). Passageways for cables, ribbons, wires, pushrods or other components from the handle **12** may be formed on the second side of the block, opposite the

first side of the block and may be aligned with the utility hole of the block. The conduit **157** may be formed from a sheath (such as inner sheath **312** of **FIG. 15**) connected or attached to the handle **12** of the instrument. In some embodiments, the pass-through barrier **159** between the handle **12** and a sheath of the insertion section **14** may comprise a sheath mount, which serves to support the sheath of the insertion section **14** near its origin proximally at the handle **12**, and to attach or connect it to the handle **12**. In some embodiments, the insertion section **14** may comprise a cannula within which the sheath may be positioned. The cannula may be mounted to the handle **12** via a disconnect feature, allowing the cannula to remain in situ while the endoscope **10** – including handle **12** and sheath – can be withdrawn from a site.

A barrier **159** described in relation to **FIG. 9** is shown in **FIG. 10** and is referred to as an inner sheath mount **160**. As shown, the inner sheath mount **160** includes a distal section **161a** and a proximal section **161b**, separated in **FIG. 10** from one another to reveal the interior of the inner sheath mount **160**. As shown the distal section **161a** may include notches **162** on each side of the distal section **161a**. As shown in the example embodiment in **FIG. 10**, a portion of an interior face **164** (when assembled) of the distal section **161a** may be recessed. An irrigation or suction routing channel **166** may also be recessed into the distal section **161a** of the inner sheath mount **160**. As shown, the irrigation routing channel **166** is located within the recessed face **164**. The irrigation routing channel **166** may be in communication on a first end with a utility hole **168**. In the example embodiment, the utility hole **168** may be located substantially near the center of the distal section **161a**, within the recessed face **164** (although in other embodiments, the utility hole **168** need not be centered).

The proximal section **161b** of the inner sheath mount **160** may also include notches **170** in its right and left sides similar to the notches **162** recessed into distal section **161a**. The notches **170** may extend all the way through the proximal section **161b**. The notches **162** and **170** of the inner sheath mount **160** may be sized to accept a projection of the handle distal section **30**, which may help to hold the inner sheath mount **160** in place when the endoscope **10** is fully assembled.

The proximal section **161b** may also include a raised portion **172** of an interior face (when assembled). As shown, the raised portion **172** is of similar outer dimensions as the recessed face **164** in the distal section **161a**. When assembled, the raised portion **172** may be pressed into the recessed face **164** to couple the distal section **161a** and proximal section **161b** together. In some embodiments, glue or another suitable adhesive between the

recessed face **164** and raised portion **172** may be used to bind the proximal section **161b** to the distal section **161a**. This may also serve to create a hydraulic seal between the two components.

The proximal section **161b** may include a number of other features. As shown, the proximal section **161b** includes an irrigation or suction passage **174**. The irrigation or suction passage **174** may be situated to align with a second end of the irrigation routing channel **166** when the proximal section **161b** is mated to the distal section **161a**. When the endoscope **10** is in use, irrigation or suctioned fluid may flow between the utility hole **168** and irrigation passage **174** via the irrigation routing channel **166**.

As shown in the example embodiment in **FIG. 10**, the proximal section **161b** of the inner sheath mount **160** may include a sheath mount slit **176**. As shown, the sheath mount slit **176** may be oriented horizontally (orientation refers to that shown in **FIG. 10**) and located in the proximal section **161b** of the inner sheath mount **160**, roughly aligned with the utility hole **168**. The sheath mount slit **176** may be oriented differently in alternate embodiments. In the example embodiment in **FIG. 10**, the sheath mount slit **176** extends through the entire proximal section **161b** at an angle substantially perpendicular to the plane of the interior face (when assembled) of the proximal section **161b**.

The proximal section **161b** of the inner sheath mount **160** may also include a number of orifices **178**. In the example embodiment in **FIG. 10**, the orifices **178** are small diameter holes which extend through the entire proximal section **161b**, and can be used to allow passage of pull or push cables or wires from within the handle to the distal end of the endoscope **10**. The proximal section **161b** may also include a fiber optics passageway **179**. In the example embodiment, the orifices **178** and fiber optics passageway **179** are angled perpendicular to the interior face (when assembled) of the proximal section **161b**. In alternate embodiments, the orifices **178** and fiber optics passageway **179** may be angled differently or may have a different diameter. As shown, the orifices **178** are arranged around the sheath mount slit **176**. When the inner sheath mount **160** is fully assembled, the sheath mount slit **176** and orifices **178** are aligned with the utility hole **168** of the distal section **161a**.

In alternative embodiments, the shape, location, dimensions, etc. of some features of a pass-through barrier or inner sheath mount **160** may differ. A pass-through barrier or inner sheath mount **160** may include additional features or may omit certain features. In some embodiments, there may be a larger or smaller number of orifices **178**. In some embodiments, the orifices **178** may not be arranged in the spatial arrangement shown in

FIG. 10. There may be more than one irrigation passage **174**. In some embodiments, the inner sheath mount **160** may be associated with or include a gasket to further inhibit fluid infiltration into sensitive areas within the handle of the endoscope.

The handle electronics section **80** is configured to enclosed mechanical and electronic components that are preferably protected against fluid infiltration. The handle distal external section **82** (the pivot control housing), configured to house the pivot control structures and actuation cables for controlling movement of a camera assembly in the distal end of the endoscope shaft or insertion shaft, may be exposed to liquid with relatively minimal effect on the operation of the endoscope. Therefore, it is more important to maintain a liquid seal between the handle electronics section **80** and the handle distal external section **82**. A pass-through barrier such as sealing member **210**, shown in **FIG. 12** and **13** may be constructed to provide a tight seal (e.g. elastomeric seal) around an electronic flex cable, an optical fiber bundle, or other structures that must pass from the distal end of the endoscope to its proximal end before exiting. On the other hand, a pass-through barrier such as inner sheath mount **160**, shown in **FIG. 10** and **13**, may allow for a lesser seal, particularly as it may apply to any pull wires or cables that pass from the pivot control structure to the distal end of the endoscope shaft. Any fluid infiltration into the handle distal section **82** may be allowed to exit the housing through one or more drain holes or passages built into a dependent part of the housing, such as for example, passage **108** shown in **FIG. 7**.

In an alternate embodiment, a pass-through barrier between the handle distal section or pivot control housing **82** and the shaft of the endoscope may comprise a fully sealed structure that yet permits movement of the pull cables or actuation cables that extend from the pivot control housing to the distal end of the endoscope shaft. For example, the pass-through barrier may comprise a flexible (or floppy) diaphragm, a pleated elastomeric diaphragm, accordion-structured rubber boot, bellows structure, or otherwise displaceable diaphragm that is attached at its periphery to the housing, that forms a fluid-tight seal around any structures passing through it near its central region, and whose central region may freely move back and forth distally and proximally to permit free movement of any pivot control cables passing therethrough. With a more complete seal at this portion of the endoscope, the need for a secondary seal between the pivot control housing and the handle electronics section **80** may be reduced or eliminated.

FIG. 11 shows an example exploded view of an embodiment of a pivot control structure **100**. The pivot control structure **100** may control pivoting of a structure. The

structure may for example be a camera assembly **350** (see **FIG. 19**) at a distal end of the insertion section **14** (see **FIG. 3**). In alternate embodiments, the pivot control structure **100** may be used to instead or additionally control the flexing of a flexible section of the insertion section **14**. Some embodiments of the pivot control structure **100** may include gearing, a motor, multi-bar linkage, dials, etc. that differ from the embodiment disclosed below.

The example pivot control structure **100** in **FIG. 11** is shown in an exploded view. The finger contact **98** detailed above is shown separated from the pivot control structure **100**. As shown, the bottom face of the finger contact **98** optionally may include a number of peg projections **180**. In the example embodiment shown in **FIG. 11**, there are four peg projections **180** which are generally cylindrical in shape (number and shape of peg projections may differ). The finger contact **98** additionally includes a finger contact slot **182** situated in the under-surface of the finger contact **98**.

Below the finger contact **98**, an example embodiment of a pivoting portion **184** of the pivot control structure **100** is shown. The top of the pivoting member **184** of the pivot control structure **100** may include a slider **186**. Projecting from the center of the slider **186** is a finger contact post **188** arranged to mate with finger contact slot **182**. Optionally, finger contact peg holes **190** flank the finger contact post **188** on each side of the finger contact post **188**. When the finger contact **98** is attached to the pivot control structure **100** the finger contact slot **182** may be slid onto the finger contact post **188** on the slider **186**. Additionally, when assembled, the peg projections **180** of the finger contact **98**, if present, may be seated in the finger contact peg holes **190** of the slider **186**.

A pivot control structure **100** may interact with one or more feature of the endoscope allowing it to be locked or held in a desired orientation. As shown, the bottom face of the slider **186** of the pivoting member **184** optionally may include one or more catch bars or detent elements **192**. In other embodiments, multiple catch bars **192** may be disposed along the bottom of the slider **186**, arranged to engage with opposing raised features or ridges **94** on the handle **12**.

The catch bars or detent elements **192** may interact with the raised features or ridges **94** of the slide button recess **92** of the handle raised portion **32** described above (best shown in **FIG. 6**). As the pivot control structure **100** is displaced by the user, the spaces between ridges **94** may act as detents in which the catch bars **192** of the slider **186** may be “parked”. This helps to prevent drifting or movement of the pivot control structure **100** once a user

moves it to a desired position and releases it. It may also help to ensure that the pivot control structure **100** is not accidentally displaced during use of the instrument.

As shown, the pivoting member **184** of the pivot control structure **100** includes a curved inner shield **194**. The inner shield **194** is tiered below the slider **186**, and under the handle housing when assembled. A post **196** may span the distance between the top face of the inner shield **194** and the bottom face of the slider **186**. In some embodiments, the catch bars **192** may be located on the top of the inner shield **194**. In such embodiments, the ridges **94** described above may be located on the interior wall of the housing of the handle distal section **30** such that the ridges **94** may form detents for the catch bars **192** on the inner shield **194**. As described above, this allows the pivot control structure **100** to be “parked” in a desired position.

Extending from the bottom face of the inner shield **194** may be a pivot arm **198**. In the example embodiment, the pivot arm **198** includes two mechanical cable attachment points or holes **202**. One hole **202** is situated on one side of a pivoting shaft **204**, while the second hole **202** is situated on the other side of pivoting shaft **204**. In the illustrated embodiment, forward movement of slider **186** causes a mechanical cable connected to the lower hole **202** to be retracted proximally, while aft movement of slider **186** causes a mechanical cable connected to the upper hole **202** to be retracted proximally. In order to accommodate a relatively unimpeded passage of a fiberoptic or electrical cable from the proximal end of the handle to the distal end of the handle, the pivot arm **198** may be, for example, notched over its pivot shaft **204**, so that a passing cable may rest freely on the pivot shaft **204** (or a concentric sleeve or hub surrounding the shaft **204**). Such an arrangement would allow passage with minimal displacement laterally or vertically.

Referring now to both **FIGS. 11** and **13**, the pivot arm **198** is constructed to have a laterally displaced section **199** encompassing pivoting region **200** and pivot shaft **204**. Thus a hub or sleeve encompassing pivot shaft **204** (when assembled) is shown to serve as a bearing surface upon which a passing cable **250** may rest. A lower portion of pivot arm **198** extends downward from a location beneath the hub or sleeve of pivot shaft **204**. In some embodiments, the lower portion of pivot arm **198** optionally may be vertically aligned with the upper portion of pivot arm **198**, so that mechanical cables connected to points or holes **202** are also aligned vertically. In other embodiments, one or more cables (e.g., cable **250**) may travel around (or through) a hub of pivot shaft **204** in a variety of other ways, so that its path is minimally obstructed by the pivot arm **198** of the pivot control structure **100**.

Optionally, but in a preferred embodiment, a secondary pass-through seal provides an additional barrier between fluid that may infiltrate into the housing of the handle distal section **30** and the housing of handle proximal section **16**, in which electronics section **80** may be housed. The seal may include orifices, holes or slits through which components such as though not limited to, fiberoptic bundle, electronic cable and/or fluid conduit tubing may pass. The holes or slits may be sized to provide a snug fit over these components as they pass through the seal. In an embodiment, the secondary pass-through seal is formed from a rubber or other elastomeric material to enhance its fluid sealing characteristics.

FIG. 12 shows an example embodiment of a secondary seal, i.e. sealing member **210**. The sealing member **210** may be roughly rectangular in shape as shown in **FIG. 12**. As shown in **FIG. 12**, one end of sealing member **210** may be of a first (e.g. a rectangular) shape, while a second end of sealing member **210** may be of a second shape (e.g. have rounded edges or be rounded). This may provide an advantage during assembly to ensure that the sealing member **210** is mounted in the proper orientation. The sealing member **210** may include a number of orifices. In the example embodiment, the sealing member **210** includes a fiberoptic bundle (e.g., an illumination fiber) orifice **212**, a flex cable (i.e., electronic cable) orifice **214**, and a fluid tubing (e.g., an irrigation line) orifice **216**. In the example embodiment shown in **FIG. 12** the illumination fiber orifice **212**, flex cable orifice **214**, and irrigation line orifice **216** extend through the entire sealing member **210**. The illumination fiber orifice **212** has a relatively small diameter to match the diameter of a fiber bundle or light pipe. The flex cable orifice **214** is a slit, matching the size and shape of an electronic flex cable. The irrigation line orifice **216** is cylindrical and has a diameter larger than that of the illumination fiber orifice **212**. The illumination fiber orifice **212**, flex cable orifice **214**, and irrigation line orifice **216** extend through the sealing member **210** at an angle that is substantially perpendicular to the front face (relative to **FIG. 12**) of the sealing member **210**. In alternative embodiments, the orifices in the sealing member **210** may differ in number, size or shape. In some embodiments, the sealing member **210** may include an additional hole for wiring to the button **90**, for example.

As shown in the example embodiment in **FIG. 12**, the sealing member **210** may also include a number of gasketing arms **218**. In the example embodiment in **FIG. 12**, the gasketing arms **218** project away from the top and bottom faces of the sealing member **210** near the back edge of the sealing member **210**. As shown, there may be two gasketing arms **218**. In some embodiments, the gasketing arms **218** may be straight. In the example

embodiment, the gasketing arms **218** include two straight sections connected by an arcuate section which bends the gasketing arms **218** away from the sealing member **210**.

FIG. 13 shows an example embodiment of one half (**30a**) of the handle distal section **30**. As shown, the inner sheath mount **160**, pivot control structure **100** and the sealing member **210** are assembled and placed within the shown half (**30a**) of the handle distal section **30**. A flex cable **250** (e.g., flexible electronic communications/power cable) is also shown. In the example embodiment shown in **FIG. 13**, the distal section **161a** of the inner sheath mount **160** includes a sheath mounting hub **252**. The sheath mounting hub **252** extends distally along the same axis as the utility hole **168** (see **FIG. 10**). In the example embodiment, the sheath mounting hub **252** may be hollow and substantially cylindrical. The inner diameter of the sheath mounting hub **252** optionally may be approximately equal to or somewhat larger than the diameter of the utility hole **168**. In the example embodiment, a sheath mount mounting tab **254** projects superiorly from the outer surface of the sheath mounting hub **252**. The sheath mount mounting tab **254** is located next to the face of the insertion side piece **160a** from which the sheath mounting hub **252** projects. The mounting tab **254** may serve to properly orient a sheath (e.g. inner sheath **312** shown in **FIG. 15**) as it is mounted onto the sheath mounting hub **252**, and optionally may also serve as a locking member to secure a sheath to the sheath mounting hub **252** and sheath mount **160**.

In other embodiments, the sheath mount tab **254** may be disposed on the inside surface of the sheath mount hub **252**. This may be desirable because it obviates the need to nest the inner sheath mount hub **252** inside of a sheath removing a restriction in the diameter of the conduit of the sheath. Consequentially, a higher flow rate through such a conduit may be achieved. Alternatively, a sheath mount nub **254** may not be included in some embodiments. The sheath may instead be oriented and secured to a sheath mount hub **252** in any suitable fixture (not shown).

As shown the flex cable **250** extends through the inner sheath mount **160**. The flex cable **250** passes through the sheath mounting hub **252** into the distal section **161a** of the inner sheath mount **160**. The flex cable **250** is also routed through the sheath mount slit **176** of the proximal section **161b**.

The proximal section **161b** of the inner sheath mount **160** includes a fluid conduit attachment site or port **256**. The fluid conduit attachment site **256** may be a hollow, roughly cylindrical projection which extends toward the right of the page (in relation to **FIG. 13**) from the proximal section **161b** of the inner sheath mount **160**. Tubing of an irrigation line **434** (see **FIG. 85**) may be slid over the outer surface of the fluid conduit port **256**, which

optionally may be barbed to aid in retaining an installed section of tubing. As shown, the right edge of the fluid conduit port **256** may be chamfered in a manner to also facilitate ease of installation of a tubing segment to the port **256**. Additionally, as shown in **FIG. 13**, the proximal end of the fluid conduit port **256** tapers to a slightly larger diameter than the rest of the port **256** surface. This may act as a barb and help ensure that once attached, the tubing of an irrigation line **434** (see **FIG. 85**) is not easily dislodged. In an alternative embodiment, the conduit port **256** may extend and be fitted into an irrigation line orifice **216** of a sealing member **210**. The barbed portion/attachment site for an irrigation line **434** may then be placed on the sealing member **210**.

The pivot control structure **100** may be pivotally coupled into the handle distal section **30** as shown in **FIG. 13**. As shown, the pivot shaft **204** extends through the pivot shaft hole **200** in the pivot arm **198** of the pivot control structure **100**. The end of the pivot shaft **204** (or of a surrounding hub) inserted into the far wall of the handle distal section **30** may be seated in a pivot bearing **260** projecting from the inner wall of the handle distal section **30**. When fully assembled, the opposite end of the pivot shaft **204** may similarly be seated in a pivot bearing **260** projecting from the inner wall of the other half (**30b**) of the handle distal section **30**.

As shown in **FIG. 13**, the slider **186** and inner shield **194** of the pivot control structure **100** may be offset from each other by the post **196** a distance slightly larger than the thickness of the walls of the handle distal section **30**. The post **196** may extend through the pivot control structure notch **96** described above. The curvature of the slider **186** and inner shield **194** may be selected such that the slider **186** and inner shield **194** may freely move fore and aft with input from a user without interfering with the walls of the handle distal section **30** housing. The length of the pivot control structure notch **96** may determine the amount of pivotal displacement a user may create with input to the pivot control structure **100**.

In some embodiments, the walls of pivot control structure notch **96** may exert a frictional force against the post **196**. In such embodiments, this frictional force may allow the pivot control structure **100** to be “parked” in a position. In such embodiments, the walls of the pivot control structure notch **96** may be made of a high friction material such as rubber or other elastomeric material. In such embodiments, the pivot control structure **100** may not need to include the catch bars **192** or the ridges **94** described above.

The endoscope **10** may also include mechanical pivot actuators in the form of pull cables or wires, belts, or pushrods. An actuator may be any elongate member, solid, braided,

or otherwise extending from the handle of the endoscope **10** to a movable element at the distal end of the insertion section. The elongate member may be flexible or substantially rigid. The elongate member may be round (as in the example of a cable), ovoid, relatively flat, or may have any other shape or cross section. In some embodiments, the actuator may be a belt.

In an endoscope having a pannable camera or camera mount at or near the distal end of the insertion section, the pannable camera or camera mount may be rotated using pull wires or pushrods. In a pull wire embodiment, panning cables may be attached or connected to, or looped through the cable attachment holes **202**. In some embodiments, two panning cables may be attached to each cable attachment hole **202**. In a preferred embodiment both ends of a single panning cable are attached to each cable attachment hole **202** creating a loop. Alternatively, a single cable may be looped through the cable attachment hole **202** at about its midpoint, the ends of the cable then being connected distally to the rotatable camera or camera mount. The panning cables may extend from the cable attachment holes **202** in the pivot arm **198** and be routed through one or more orifices **178** in the proximal section **160b** of the inner sheath mount **160**. The panning cables may then extend through the utility hole **168** and through the conduit formed by the inner sheath, optionally alongside the length of an electronic flex cable **250** and/or fiberoptic bundle. By pivoting the pivot control structure **100**, the panning cable or cables connected to one of the cable attachment holes **202** will be pulled, while the cable(s) connected to the other attachment hole **202** will slacken. By attaching the panning cable or cables associated with one cable attachment hole **202** to one side of a pivot point and attaching the panning cable or cables associated with the other cable attachment hole **202** to the opposite side of the pivot point, the pivot control structure **100** may be used to selectively rotate a pivoting object distally in the insertion section of the endoscope. In other embodiments, a similar cabling mechanism may be used to actively flex a flexible distal segment of the insertion section.

In some embodiments, the pivot arm **198** of the pivot control structure **100** may be pivoted via gearing. In such embodiments, the finger contact **98**, finger contact post **188** (see **FIG. 11**), slider **186**, vertical post **196**, and inner shield **194** may not be necessary. At least a portion of a user input gear contained in the handle distal section **30** may project out of the handle raised section **34**. The user input gear may be rotated about a pivot axis disposed within the handle distal section **30**. This rotation may be user-initiated via, for example, a user's finger or thumb. The user input gear may mesh with a pivot shaft gear

disposed about the pivot shaft **204** for the pivot arm **198** of the pivot control structure **100**. In such embodiments, as the user input gear is rotated, the pivot shaft gear and pivot arm **198** are also caused to rotate, acting on the pivot actuators (e.g. panning, actuating or pull cables) as described above. In some embodiments, there may be an intermediary gear or any number of intermediary gears between the user input gear and the pivot shaft gear to provide any desired gear reduction to meet precision-of-movement and ergonomic requirements.

In other embodiments, the pivot arm **198** may be caused to rotate via an electric motor (e.g., brushless motor, stepper motor, etc.). Rotation via the motor may be controlled by one or more user input means such as a button **90**. In embodiments including at least one button **90**, the button **90** or buttons **90** may control the speed and direction of movement of the pivot arm **198**.

In some embodiments, the pivot shaft **204** may project to the outside of the handle distal section **30**. In such embodiments, the pivot shaft **204** (or an overlying hub or sleeve) may be directly rotated by the user. In some embodiments, the portion of the pivot shaft **204** projecting out of the handle distal section **30** may include a knob, dial, crank, etc. so that a user may easily rotate the pivot shaft **204** by grasping and rotating the knob, dial, crank, etc.

As shown in **FIG. 13**, the sealing member **210** is positioned in a gasket recess **270**. The gasket recess **270** may include gasketing arm recesses **272**. Various components may pass through the sealing member **210** as mentioned above. As shown, a flex cable **250**, connected to a printed circuit board **430a** (see, for example, **FIG. 85**) in the electronics section **80** housed in the handle proximal section **16** may pass through the flex cable orifice **214** of the sealing member **210** and extend beyond the sealing member **210** through the housing of the handle distal section **30** and sheath mount **160**, ultimately to travel distally in the insertion section of the endoscope. The irrigation line **434** (see **FIG. 85**) and fiberoptic bundle (e.g., illumination fibers **364**, see **FIG. 85**) may pass through their respective irrigation line orifice **216** and fiberoptic bundle orifice **212** and extend through the housing of the handle distal section **30** similar to the flex cable **250**.

Only one half of the gasket recess **270** is shown in **FIG. 13**. The other half of the gasket recess **270** may be located on the other, not shown half (**30b**, see **FIG. 7**, for example) of the handle distal section **30**. When fully assembled, the sealing member **210** is captured between the two halves of the gasket recesses **270**. When fully assembled the sealing member **210** may ensure that fluid which may be present in the handle distal section **30** may be inhibited from infiltrating into the handle proximal section **16**, which contains

electronics components comprising electronics section **80**. The sealing member **210** may be made of suitably compliant (e.g., elastomeric) material or other suitable gasketing material and may be pressed into the gasket recesses **270** to ensure a tight seal. In some embodiments, the sealing member **210** may be held in place using an adhesive.

FIG. 14 shows an example embodiment of an outer sheath or cannula mount **300**. An outer sheath or cannula **318** may be employed to provide additional protection to components in the distal end of the insertion section, or to allow a user to withdraw the insertion section of the endoscope while leaving the cannula **318** in situ, to allow later re-insertion of an insertion section of the endoscope. As shown, the cannula mount **300** may have a frustoconical shape, with the larger diameter section proximally forming a connector (e.g. bayonet mount) for the mounting of a cannula **318** over an inner sheath **312** (see, for example, **FIG. 15**). A cannula mount hole **302** may extend through the cannula mount **300** to merge with a cannula channel. The cannula or outer sheath mount hole **302** may be configured to accept and retain a cannula **318**. The cannula **318** may be configured to act as a sleeve over an inner sheath **312** of the insertion section.

As shown, the female bayonet mount portion **304** includes two slots **306**. The slots **306** optionally may have different dimensions to ensure proper orientation of the cannula **318** with respect to a mating (male) connector on a distal portion of the handle distal section **30**. In some embodiments, the slots **306** of the female bayonet mount portion **304** may include a serif into which the male bayonet mount portion **308** may be spring loaded using, for example, a Belleville washer. In such embodiments, a spring-loaded connection may help ensure the two pieces (cannula **318** and handle distal section **30**) are more securely locked together.

In some embodiments, an alignment feature may be included on the cannula mount **300** in order to properly orient the cannula **318** with the cannula mount **300** during assembly, and ultimately with the inner sheath **312** (see, for example, **FIG. 15**) when installed over the inner sheath **312** of the insertion section. In the example embodiment in **FIG. 10**, an outer sheath mount tab **310** may project from the inner wall of the outer sheath mount hole **302**. The outer sheath mount tab **310** may extend from a distal face of the female bayonet mount portion **304**, which may then be used to align the bayonet mount **300** with a cannula **318** having a mating slot during assembly. Alternatively, the need for such a feature may be removed by coupling the outer sheath or cannula **318** and cannula mount **300** in a suitable fixture.

FIG. 15 shows a partial cutaway view of an example embodiment of the distal face of the handle distal section **30**. An inner sheath **312** is mounted on the sheath mounting hub **252** of the inner sheath mount **160**. The inner sheath **312** includes a sheath mount notch **314**. The inner sheath mount notch **314** may be dimensioned to accept the sheath mounting tab **254** on the sheath mounting hub **252**. In such embodiments, the sheath mounting tab **254** and inner sheath mount notch **314** may ensure that the inner sheath **312** is correctly oriented on the endoscope **10**.

The inner sheath **312** (and/or the outer sheath or cannula **318**, see **FIG. 14**) may be formed from steel, any of a number of hardened plastics or other rigid, durable material. Alternatively, the inner sheath **312** or a portion thereof may be flexible, allowing the insertion section of the endoscope to bend as needed for insertion into a non-line-of-site target area. In these embodiments, a user may forgo the use of an outer sheath or cannula **318**, or the cannula **318** itself may also be constructed of a similarly flexible material.

The male bayonet mount portion **308** is also visible in the example embodiment shown in **FIG. 15**. The male bayonet mount portion **308** may include two prongs **316**. The prongs **316** may be sized to fit in the legs of the L-shape slots **306** of the female bayonet mount portion **304** referring now also to **FIG. 14**. The outer sheath **318** and cannula mount **300** may be coupled to the handle distal section **30** by aligning the prongs **316** with the slots **306**, pressing the bayonet mount over prongs **316**, and then turning the bayonet mount to lock it into position. As shown, optionally the two prongs **316** are dimensioned differently such that the outer sheath mount **300** may only have one possible orientation when coupled onto the handle distal section **30**.

Still referring now to both **FIGS. 14-15**, an outer sheath or cannula **318** may be slid over the inner sheath **312**, forming a sleeve. The inner diameter of the outer sheath **318** may be only slightly larger than the outer diameter of the inner sheath **312** to ensure a snug fit. The outer sheath **318** may include an outer sheath notch **320**. The outer sheath notch **320** may be dimensioned to accept the outer sheath mount tab **310** when the endoscope **10** is fully assembled. In some embodiments, the outer sheath **318** may be friction fit, glued or otherwise fused or attached to the wall surrounding the outer sheath mount hole **302**. The outer sheath mount tab **310** may help to ensure correct orientation of the outer sheath **318** when the endoscope **10** is fully assembled.

When the insertion section **14** (see **FIG. 3**) of the endoscope **10** is inserted into a target region, the outer sheath **318** and outer sheath mount **300** may be uncoupled from the rest of the endoscope **10** as mentioned above. This may allow the outer sheath **318** to be

used as a cannula, remaining in situ to permit the endoscope **10** to be re-introduced into the target region. If desired, the outer sheath or cannula **318** may be used as a conduit through which other instruments may be introduced into the target region. The outer sheath **318** may also function as a conduit through which fluid may be introduced or withdrawn from the target region.

A camera assembly housing **330** or distal working section is shown in **FIG. 16**, separated from a distal end of an inner sheath **312**. In this embodiment, the distal working section of an insertion section of an endoscope may be constructed separately from the inner sheath **312**, and subsequently mated to a distal end of the inner sheath **312** during assembly. In other embodiments the inner sheath **312** may be constructed as a single piece, incorporating a distal working section. In embodiments where the distal working section is constructed separately, the distal working section may be made from a material different from that of the inner sheath **312**. Additionally, it may be constructed from a number of assembled parts.

In the example embodiment in **FIG. 16**, the distal edge of the inner sheath **312** includes an inner sheath distal notch **322**. The camera assembly housing **330** may include a nested segment **332**, shaped and having an outer diameter suitable for insertion into the distal end of inner sheath **312** during assembly of the endoscope **10**. The nested segment **332** may include a nested segment tab **334** or other alignment feature. The nested segment tab **334** may be dimensioned so that it may be mated to the inner sheath distal notch **322** when the endoscope **10** is assembled. The nested segment tab **334** and inner sheath distal notch **322** may help ensure that the camera assembly housing **330** is properly oriented and aligned when the endoscope **10** is assembled.

The camera assembly housing **330** may additionally include a working segment **336**. As shown, the working segment **336** in **FIG. 16** may include a top void **338** with or without a bottom void **340**. The top void **338** and bottom void **340** may extend along most of the working segment **336** of the camera assembly mount **330**. A rounded tip **342** may be included at the distal end of the working segment **336** of the camera assembly mount **330**. As shown, the rounded tip **342** may optionally include an embrasured opening **344**. The edges of the embrasured opening **344** may be beveled, chamfered or rounded. In the example embodiment, the embrasured opening **344** is continuous with the top void **338**. In some embodiments, the top void **338** and bottom void **340** may be similarly embrasured.

A rounded tip **342**, such as the rounded tip **342** shown in **FIG. 16** may provide a number of benefits. A rounded tip **342** may facilitate the insertion of the insertion section **14**

into a target region of a patient. In some cases, this may eliminate the need for a trocar. In arthroscopic applications, the contours of the rounded tip **342** allow the endoscope **10** to be maneuvered into tight spaces within a joint. A rounded tip **342** additionally may allow a surgeon to exert pressure atraumatically on tissues within a target region. The rounded tip **342** may also serve as a guard feature for a camera assembly **350**.

As shown in **FIG. 16**, the interior walls of the working segment **336** of the camera assembly housing **330** include two camera mount pivot bearings **346**. In the example embodiment shown in **FIG. 16**, the camera pivot bearings **346** project substantially perpendicularly from the inner side walls of the camera assembly mount **330**. The camera assembly housing **330** may be made of steel, any number of hardened plastics, or any other suitably strong, rigid material.

In the example embodiment shown in **FIG. 16**, the interior walls of the working segment **336** of the camera assembly housing **330** include a number of cable guide holes **348**. In a preferred embodiment, there may only be two cable guide holes **348**. One cable guide hole **348** may be located on one side wall while another cable guide hole **348** may be located on an opposing side wall. Preferably, the cable guide holes **348** may be disposed below the camera mount pivot bearings **346**, so that the distal end of a control cable may form an angle with respect to a camera, camera mount, or camera assembly **350** (see, for example, **FIG. 23**) to which it is connected. The camera assembly housing **330** may also include one or a number of constraining features. In the example embodiment shown in **FIG. 16**, there are two restraining notches **349**. One restraining notch **349** is located on one side wall and the other restraining notch **349** is located on an opposing side wall. As shown in **FIG. 16**, the restraining notches **349** are roughly in line with the cable guide holes **348**. The cable guide holes **348** and restraining notches **349** will be described further below.

FIG. 17 depicts an embodiment of a distal working section or camera assembly housing **330** and inner sheath **312** which are constructed as a single part. Referring also to **FIG. 18C**, a cross section taken at line **18-18** of the camera assembly housing **330** is shown. In embodiments where the distal working section or camera assembly housing **330** and the inner sheath **312** are constructed as a single part, they may be made from steel. In such instances the tip shape of the inner sheath **312** and camera assembly housing **330** may be created via a rolling process. Various voids, openings, and other features, for example those described above, may then be post machined into the part. In the example embodiment in **FIG. 17**, the camera assembly housing **330** includes only the camera mount pivot bearings **346**.

It may be advantageous to create the inner sheath **312** and the camera assembly housing **330** as a single part. Among the advantages, the part may be stronger. Another advantage is that the need for a nested portion is removed. Consequently, a “choke point” in cross-sectional area at the junction of the inner sheath **312** and camera assembly housing **330** is removed. This may provide a number of benefits. Removing such a choke point allows more room for various components, such as utility components within the inner sheath **312** and camera assembly housing **330**. Moreover, removal of such a choke point allows for increased flow of irrigation fluid within the inner sheath **312** and camera assembly housing **330**. Alternatively or additionally, the overall diameter of the inner sheath **312** and camera assembly housing **330** may be decreased. The inner sheath **312** and camera assembly housing **330** may also be thickened. This helps to strengthen the part. Since thickening will strengthen the part, it may also allow an outer sheath or cannula **318** to be made thinner. A thinner outer sheath or cannula **318** in turn may allow for a larger diameter inner sheath **312** and camera assembly housing **330**. That is, without increasing the overall diameter of an insertion section **14** (comprised of an outer sheath **318**, inner sheath **312** and camera assembly housing **330**), the cross-sectional area of a conduit within the insertion section **14** may be made larger. Thickening furthermore enables the camera mount pivot bearings **346** to have a larger bearing surface allowing pressure exerted against the bearing to be spread over a larger area.

FIG. 19 shows an assembled view of the tip of the insertion section **14** (best shown in **FIG. 3**). The camera assembly housing **330**, camera assembly **350**, and outer sheath or cannula **318** are visible in **FIG. 19**. As shown, the rounded tip **342** of the camera assembly housing **330** projects past the distal end of the outer sheath or cannula **318**. A viewing notch **352** is recessed into the top of the outer sheath **318**. The camera assembly **350** may be pannable throughout the viewable range as defined by the opening created by the combination of the embrasured opening **344** and the viewing notch **352**. In some embodiments the pannable range may be approximately 180°. When panning, the camera assembly **350** may pivot on the camera pivot bearings **346** (see, for example, **FIG. 16**). Panning actuation will be described further below.

In some embodiments, the outer sheath **318** may be rotated to an insertion position (not shown) when the insertion section **14** (see **FIG. 3**) of the endoscope **10** is being inserted into the target region. In the insertion position, the viewing notch **352** may not be aligned with the embrasured opening **344** and top void **338**. This may help protect the camera assembly **350** during insertion, and in medical applications may reduce the risk of

damage to tissue upon insertion of the insertion section **14**. After insertion, the outer sheath **318** may be rotated back to a position in which the viewing notch **352** is aligned with the embrasured opening **344** and top void **338** so that the full viewable range is again available.

In some embodiments, a cap or window material may cover or be placed in the openings defining the viewing notch **352** and embrasured opening **344** to protect the camera assembly **350**. In some embodiments, the distal edge of the outer sheath **318** and the viewing notch **352** may be embrasured, rounded, beveled, etc. to help prevent damage that might result from having sharp edges.

In the example embodiment, a cap or window is not used. Such an arrangement provides a number of benefits. For example, by not using a cap or window at the tip of the insertion section **14**, the cost of the endoscope may be reduced because no expensive scratch and wear resistant materials such as sapphire, specialized glass, etc. are used. Not having a cap or window may also eliminate any undesirable reflections from the surface of the cap or window, which could otherwise affect the clarity of any image captured by a camera. Moreover, by not using a cap or window, irrigation of the target area may be conducted through the conduit of the inner sheath **312** (see **FIG. 15**) of the endoscope **10**. This enables the total diameter of the insertion section **14** to be kept small while retaining irrigation capabilities. Furthermore, irrigation flow within the inner sheath **312** may help to clear/clean any debris or material away from the camera assembly **350** and any associated lens or lenses. In one example, a user may be able to effectively irrigate the camera assembly **350** by panning the camera assembly **350** during irrigation so that the irrigation flow washes over a lens assembly **354** (see, for example, **FIG. 122**) of the camera assembly **350** and carries away the debris or unwanted material. As an added benefit, the irrigation flow may also help to cool an image sensor **380** (see, for example, **FIG. 61**) associated with the camera assembly **350**.

As shown, the embrasured opening **344** and viewing notch **352** may be dimensioned in order to protect the camera assembly **350** without the need for a cap or window. In the example embodiment in **FIG. 19**, the embrasured opening **344** and viewing notch **352** partially envelop the camera assembly **350**, which is recessed from the outer surfaces formed by the embrasured opening **344** and viewing notch **352**. Thus the embrasured opening **344** and viewing notch **352** define the edges of a guard for the camera assembly **350**. The partial envelopment helps to protect movable components of the camera assembly **350** and any associated components (e.g. control, electric, information cables, etc.) from contact with external objects either during insertion of the insertion section into

the target region, or during use of the instrument once in the target region. The embossed opening **344** and viewing notch **352** provide the camera assembly **350** an unrestricted view while exposing only a small part of the camera assembly **350** to possible damage from objects external to the insertion section (such as, e.g., a medical instrument such as a shaver). This helps to ensure that the camera assembly **350** is not damaged during insertion or during a procedure.

As the camera assembly **350** rotates, the distance between the camera assembly **350** and the outer sheath **318** will change. As a consequence, the amount of the outer sheath **318** which falls into the field view of the camera assembly **350** will also change. The greater the distance from the camera assembly **350** to the inner sheath **318**, the greater the amount of the outer sheath **318** which will be in the field of view of the camera assembly **350**. Thus, an optimized amount of protection while still affording the camera assembly **350** and unrestricted view may be achieved by varying the width of a viewing notch **352**.

FIG. 20 depicts an alternate assembled view of the tip of an insertion section **14** (best shown in **FIG. 3**) in which the viewing notch **352** has a varying width. The width of the viewing notch **352** varies such that the viewing notch **352** is just outside of the field of view of the camera assembly **350** in any angular orientation of the camera assembly **350**. This allows for a greater degree of envelopment of a camera assembly **350** by an outer sheath **318**.

FIG. 21 depicts another alternate embodiment of a tip of an insertion section **14** (best shown in **FIG. 3**) in which a number of openings **353** separated by bars **351** are included in place of a viewing notch **352** like that shown in **FIG. 20**. Such an arrangement may provide additional protection to a camera assembly **350**. To minimize the amount that the bars **351** obscure the field of view of the camera assembly **350**, the bars **351** may be made of a transparent material. In other embodiments the bars **351** may be made of an opaque material, for example, the same material as the outer sheath **318**.

Alternatively a cover member (not shown) which partially covers a viewing notch **352** (see **FIG. 20**) or one or more openings **353** (see **FIG. 21**) may be mounted to the distal tip of an insertion section **14** (see, for example, **FIG. 1**) Such a cover member may for example be a cage which allows a substantially clear field of view for the camera assembly **350** while providing additional protection for the camera assembly **350**. In some embodiments, the cover member may include an optically clear partial covering.

The camera assembly **350** is shown in isolation in **FIG. 22**. As shown, a flex cable **250** is coupled into the camera assembly **350** and may provide power and data

communication paths to and from the camera assembly **350**. The camera assembly **350** may be any suitable structure configured to support the camera of the endoscope **10**. In embodiments where the camera assembly **350** may be panned, the camera assembly **350** may include pivot actuator attachment features.

As shown, the camera assembly **350** may include a lens assembly **354**. As shown, the lens assembly **354** may be held in place between a camera housing top **356** and a camera housing bottom **358**. When assembled, the camera housing top **356** and camera housing bottom **358** may be coupled together by any suitable means, such as, but not limited to glue, adhesive, ultrasonic welds, press fit of cooperating features, etc. In the example embodiment in **FIG. 22**, the lens assembly **354** projects through a lens opening **360** in the camera housing top **356** such that it may have a clear view of the target anatomical area. In some embodiments, at least a portion of the lens assembly **354** may be proud of the camera housing top **356**.

The camera housing top **356** may include a number of other voids. In the exemplary embodiment shown in **FIG. 22**, the camera housing top **356** includes two elongate light projection voids **362** disposed on the right and left (relative to **FIG. 22**) flanks of the lens opening **360**, the voids **362** being designed to accommodate terminal elements of optical fibers (or optionally other light sources such as LED's) to project light onto a target area coinciding with the direction at which a camera lens or lens assembly **354** may be aimed. In the example shown, the right elongate void **362** is trapezoidal in shape while the left elongate void **362** is rhomboid in shape. In alternative embodiments, the shape of the voids **362** may differ, for example, both may be ovoid. In alternative embodiments, there may be additional voids **362**. For example, in some embodiments, there may be three voids **362** arranged in a triangular configuration around the lens opening **360**. In some embodiments there may be four voids **362** arranged in a rectangular, square, circular, or ovoid configuration around the lens opening **360**.

One or more illumination sources for the endoscope **10** may be included at least partially within the endoscope **10**. The illumination source or sources may illuminate the field of view of the camera of the camera assembly **350** regardless of its panned position. In some embodiments, the illumination source may be in the camera assembly **350**. In the example embodiment in **FIG. 22**, the illumination source is a number of optical fibers (e.g. fiberoptic fibers) **364** which may transmit light from a lighting element (not shown) external to the endoscope **10**. The optical fibers **364** may be routed and coupled into the voids **362** in the camera housing top **356**. In the example embodiment, 28 optical fibers **364** are routed

into the voids **362** of the camera housing top **356**. The number of optical fibers **364** may differ in alternate embodiments. The light emitting ends of the optical fibers **364** may be roughly flush with the top face of the camera housing top **356**. In some embodiments, other illumination sources, for example LEDs, may be used. The optical fibers **364** or other illumination source may be configured to supply any desired color or intensity of light at a pre-determined light projection angle.

As shown in the example embodiment in **FIG. 22**, the camera assembly **350** may include pivot pins **366**. The pivot pins **366** may be pivotally coupled into the pivot pin bearings **346** in the camera assembly housing **330** (see **FIG. 16**). The pivot pins **366** may project substantially perpendicularly from the long axis of the insertion section. The pivot pins **366** may allow the camera assembly **350** and optical fibers **364** (or other illumination source) to pivot in tandem with one another.

The camera assembly **350** may also include a pivot actuator attachment feature as mentioned above. In the example embodiment in **FIG. 22**, the camera assembly **350** includes a top cable attachment feature or anchor point **372** and a bottom cable attachment feature or anchor point **374**. The top cable attachment feature **372** and bottom cable attachment feature **374** will be further discussed below.

As mentioned above, the endoscope **10** may also include a pivot actuator or actuators. A pivot actuator may be an elongate member used to pull on or push the camera assembly **350** via a pivot attachment feature. In the illustrated examples, the pivot actuators are mostly pull cables or wires, but these examples should not be construed as strictly limiting pivot actuators to a cable-like structure. The elongate member may be flexible or substantially rigid. The elongate member may be round (as in the example of a cable), flat, or may have any other shape or cross section. In some embodiments, the pivot actuator may be a belt routed around a cooperating attachment feature frictionally engaged or otherwise meshed with features on the inner circumference of the belt. In a preferred embodiment, the pivot actuator may be used to only supply a pulling force. Such an arrangement allows for a smaller diameter insertion section **14** (see **FIG. 3**) because the pivot actuator does not have to be sufficiently thick or cross-sectionally strengthened, or confined within a supporting track to prevent substantial lateral displacement within the insertion section **14** in response to a pushing force against the pivot actuator. A pull-wire or pull-cable arrangement also allows a greater range of materials to be used in constructing the pivot actuator because the material only needs to have tensile strength, rather than compressive stiffness.

As shown in **FIG. 23**, panning cables may be attached to the camera assembly **350** above and below the pivot pins **366**. In the example embodiment, the panning cables are shown as relatively slack for ease of illustration. In operation one or more panning cables on one side of the pivot pins **366** would be under tension, while one or more panning cables on the other side of the pivot pins **366** would be slack. As detailed above and referring now also to **FIG. 13**, the panning cables may be attached proximally to the cable attachment holes **202** of the pivot control structure **100** (see **FIG. 13**). In some embodiments, two panning cables may be attached to each cable attachment hole **202**. The panning cables may extend from the cable attachment holes **202** in the pivot arm **198** and be routed through one or more orifices **178** in the proximal section **161b** of the inner sheath mount **160** (see **FIG. 10**). The panning cables may then extend through the utility hole **168** alongside the flex cable **250**. Since the cable attachment holes **202** are located on opposite sides of the pivot point of the pivot arm **198**, pivoting the pivot control structure **100** may cause the panning cables attached to one of the cable attachment holes **202** to slacken and panning cables attached to the other to become taut. By attaching the panning cables associated with one cable attachment hole **202** to the camera assembly **350** on one side of the pivot pins **366** and attaching the panning cables associated with the other cable attachment hole **202** to the opposite side of the pivot pins **366**, the pivot control structure **100** may be used to selectively rotate the camera assembly **350**. In some embodiments, pushing the pivot control structure **100** forward may pan the camera assembly **350** forward while pulling the pivot control structure **100** aft may pan the camera assembly **350** backward. In some embodiments, when assembled, all of the panning cables may be under tension.

In a preferred embodiment, only a single panning cable may be attached to each cable attachment hole **202** on the pivot control structure **100** pivot arm **198** (see **FIG. 13**). In such embodiments, there may be a top panning cable **368** and a bottom panning cable **370**. The top panning cable **368** and bottom panning cable **370** may extend as described above to the camera assembly **350**. The top panning cable **368** may wrap around a top cable attachment feature **372** on the camera assembly **350** and return back to the same cable attachment hole **202** on the pivot arm **198** from which it originates. The bottom panning cable **370** may wrap around a bottom cable attachment feature **374** on the camera assembly **350** and return back to the same cable attachment hole **202** from which it originates. Alternatively, the panning cable may be looped through attachment hole **202**, with both ends of the cable terminating on the cable attachment feature distally.

In the example embodiment, the top cable attachment feature **372** (best shown in **FIG. 22**) includes two holes in the camera housing top **356**. The top cable attachment feature **372** additionally includes a recess that connects the two holes. The top panning cable **368** may enter one of the holes, follow the recess, and exit the other of the two holes to return to the cable attachment hole **202** (see **FIG. 13**) in the handle. The bottom cable attachment feature **374** (best shown in **FIG. 22**) includes two attachment points or hooks which project off opposite sides of the camera housing bottom **358**. The bottom cable attachment feature **374** is on the opposite side of the pivot pins **366** than the top cable attachment feature **372**. The bottom panning cable **370** may be wrapped around one attachment point or hook of the bottom cable attachment feature **374**, strung over to the second attachment point or hook of the bottom cable attachment feature **374** and from there return to its cable attachment hole **202** on the pivot arm **198** of the handle. In alternate embodiments, the top cable attachment feature **372** and/or bottom cable attachment feature **374** may comprise, for example, eyelets, prongs, pegs, etc.

The top panning cable **368** and bottom panning cable **370** may be made from any suitable cable or wire-like material, either metallic or synthetic polymer, either braided or monofilament. The top panning cable **368** and bottom panning cable **370** may, for example, be metal or plastic strips or bands that are laterally flexible. In a preferred embodiment, the top panning cable **368** and bottom panning cable **370** are made from a material which is resistant to stretching under tension. Wrapping a single panning cable from each cable attachment hole **202** on the pivot arm **198** (see **FIG. 13**) around a pivot actuator attachment feature on the camera assembly **350** may be desirable because it ensures that the side of the panning cable running to the camera assembly **350** is under the same tension as the side of the panning cable returning from the camera assembly **350**; any stretching of some portion of the cable over time or use will have an equal effect on both halves of the cable.

In a preferred embodiment, the top panning cable **368** may be run through one of the cable guide holes **348** on each interior wall of the camera assembly mount **330**. As shown in **FIG. 23**, the top panning cable **368** is threaded through one of the cable guide holes **348** and continues extending toward the camera assembly **350** along the exterior of the camera assembly housing **330**. In some embodiments, there may be a depression or trough recessed into the exterior of the camera assembly housing **330** along the path taken by the top panning cable **368**. In such embodiments, the depression or trough may serve as a guide. The depression or trough may also help to ensure that the top panning cable **368** is roughly flush to exterior surface of the camera assembly housing **330**. This may help to ensure that

the outer sheath **318** (see **FIG. 19**) does not impinge on the top panning cable **368** to impair its movement during the use of a fully assembled endoscope **10**.

As shown in **FIG. 23**, the top panning cable **368** is strung through the constraining notch **349** as it re-enters the interior of the camera assembly housing **330**. The top panning cable **368** then runs to the top cable attachment feature **372** as describe above. On return to the cable attachment hole **202** (see **FIG. 13**), the top panning cable **368** runs from the top cable attachment feature **372** to the constraining notch **349** on the opposite wall (see **FIG. 16**) of the camera assembly housing **330**. The top panning cable **368** then runs along the exterior surface of the front wall of the camera assembly housing **330** and optionally along a depression or trough in the wall. The top panning cable **368** then re-enters the interior volume of the camera assembly housing **330** and travels back to the cable attachment hole **202** in the handle as described previously.

A terminal segment of a pivot actuator (such as a wire or cable) proximal to its connection to a pivoting assembly at the distal end of the insertion section may be constrained at a fulcrum or support point to re-direct the actuator so as to form an angle with respect to the long axis of the insertion section or shaft. For example, by running the top panning cable **368** through the cable guide holes **348** and the constraining or re-directing notches **349**, and then angling it up to the top cable attachment feature **372** on the other side of pivot pin **366**, an increased pivotal range for the pivoting camera assembly **350** may be achieved. Thus an image sensor having a pre-determined or fixed angular field of view may be rotated to allow for a rotatable field of view, so that the viewable area can be increased to a range of up to 180 degrees. In other embodiments, an image sensor may be rotated so as to achieve a viewable area that exceeds 180 degrees. As shown in **FIG. 23**, having the cable routed as described places the cable at a more acute angle of incidence to its attachment point **372**, and thus permits a greater degree of back-rotation of the camera assembly **350**.

In some embodiments, and referring now also to **FIG. 24**, the camera assembly **350** may be capable of rotating a full 180 degrees or more, because of the presence of two sets of cable guide holes **348**: a lower set of guide holes **348** to control the camera housing top section, and an upper set of guide holes **348** to control the camera housing bottom section. The degree to which the camera assembly **350** can be rotated is a function of the angle that the terminal portion of the panning cable makes with respect to the proximal portion of the panning cable or the longitudinal axis of insertion section (or endoscope shaft) **14** (see **FIG.1**). The greater the angle the terminal portion of the panning cable makes as it re-enters

the exterior of the camera assembly housing **330** in relation to the longitudinal axis of the insertion section **14**, the greater the range of motion it can induce in the camera assembly **350**. In a preferred embodiment, the re-entry surface or re-directing guide of the camera assembly housing **330** is positioned to provide for an angle of the terminal portion of the panning cable to be within a range of about 30 – 90 degrees with respect to the long axis of insertion section **14**. In other embodiments, the rotational range of motion of the camera assembly **350** may be improved while limiting the frictional resistance of the panning cable by positioning the cable re-entry surface or guide to achieve an angle of the terminal portion of the panning cable to be within a range of about 45 – 80 degrees. Such an embodiment, as described above, only requires a pulling force on either of a pair of complementary cables **368**, **370** one angled up at a distal or terminal location in insertion section **14** to attach to the top cable attachment feature **372**, and one angled down at a distal or terminal location in insertion section **14** to a corresponding bottom cable attachment feature **374**. With this arrangement, neither actuating cable is required to move laterally or transversely within most of the length of insertion section **14**, which allows the internal space within insertion section **14** to be narrower, helping to minimize its overall diameter.

In some embodiments, a constraining or re-directing notch **349** may not be used. Some embodiments may use a different type of constraint or re-directing element incorporated into a wall at the distal end of the insertion section. In some embodiments, a pulley or an eyelet may be used as a constraint. A pin, peg, post, etc. may also be used as a constraint or re-directing element. In some embodiments, a curved finger or prong may be formed in the side walls of the camera assembly housing **330**. The curved finger may extend into the interior volume of the camera assembly housing **330** such that there is a space between the interior wall of the camera assembly housing **330** and the curved finger. The top panning cable **368** may be run through this space so that it is constrained by the curved finger. In most embodiments, it may be desirable that the point of contact between the constraint and the cable has a smoothness or radius of curvature sufficient to minimize the potential for frictional damage to the panning cable during operation of the endoscope. In some cases, the constraint may be coated with a material having a low coefficient of friction such as Teflon.

In some embodiments, the bottom panning cable **370** instead of the top panning cable **368** may be constrained similarly to the preceding description to enable a greater pivotal range of the camera assembly **350** in one direction of rotation over another. As shown in **FIG. 24**, in some embodiments, both the bottom panning cable **370** and top

panning cable **368** may be constrained or redirected, allowing for even greater pivotal ranges.

In **FIG. 24**, the outer sheath **318**, camera assembly housing **330**, and camera assembly **350** are shown. There are two sets of cable guide holes **348**. One set is above the longitudinal axis of the camera assembly housing **330** and the other is below the longitudinal axis of the camera assembly housing **330**. There are also two constraining notches **349**. One of the constraining notches **349** is located above the longitudinal axis of the camera assembly housing **330** and the other is located below the longitudinal axis of the camera assembly housing **330**.

An improved mechanical advantage of the panning cables may be obtained by positioning the re-directing element (e.g. notch) on one side of (e.g., below) the pivoting axis of the camera assembly **350**, while attaching the terminal end of the panning cable to a point on the camera assembly located on the opposing side of (e.g. above) the pivoting axis of the camera assembly **350**.

As shown, the top panning cable **368** is run through one of the cable guide holes **348** below the longitudinal axis, and re-enters the camera assembly housing **330** at the constraining notch **349** below the longitudinal axis. The top panning cable **368** then redirects up to the top cable attachment feature **372** on the camera assembly **350**. In **FIG. 24**, the bottom panning cable **370** is run through a cable guide hole **348** above the longitudinal axis of the camera assembly housing **330**. The bottom panning cable **370** then re-enters the camera assembly housing **330** through the constraining notch **349** above the longitudinal axis of the camera assembly housing **330**. The bottom panning cable **370** then redirects down to the bottom cable attachment feature **374**. The top panning cable **368** and bottom panning cable **370** may wrap around a portion of the camera assembly **350** depending on where the camera assembly **350** has been pivoted to. In **FIG. 24** the bottom panning cable **370** is shown wrapping around a portion of the camera assembly **350**.

Some embodiments may make use of a belt **384** as a pivot actuator. An embodiment which includes a belt **384** as a pivot actuator is shown in **FIG. 25**. As shown, the belt **384** wraps around one of the pivot pins **366** of the camera assembly **350**. In some embodiments, the pivot pins **366** may be elongated such that a portion of at least one of the pivot pins **366** extends from the pivot bearings **346**. In such embodiments, the belt **384** may be wrapped around this portion of the pivot pins **366** as shown in **FIG. 25**. In some embodiments, the shape of the camera assembly **350** may differ such that the belt **384** may wrap around the camera assembly **350**. For example, the camera assembly **350** may be a substantially

cylindrical shape. The substantially cylindrical shape of the camera assembly **350** may be coaxial with the pivot pins **366**. In such embodiments, the belt **384** may be wrapped around the circumference of camera assembly **350**.

In some embodiments, the surface over which a belt **384** is wrapped may be recessed (e.g., V-shaped) in relation to the surfaces which flank it. This may help to keep the belt **384** in place during operation. In other embodiments, any other type of guide may be used. For example, the surface over which a belt **384** is wrapped may be flanked by two walls which keep the belt **384** in place during operation.

A belt **384** may be made of a high friction material so that the belt **384** does not slip over the surface which it wraps around as the belt **384** is driven. In some embodiments, the belt **384** may have a coarse surface, or may be toothed to aid in its ability to grip or positively engage a camera assembly pivot pin **366** (which may be geared). Use of a belt **384** may allow for a wide range of pivoting of the camera assembly **350** without the need for a pull-cable pivot actuator to be redirected laterally within the insertion section **14** to achieve an equivalent range of motion of the camera assembly **350**. This allows the insertion section **14** to be made with a smaller diameter.

In embodiments using a belt **384**, the belt **384** may be configured to be driven by displacement of the pivot control structure **100** (see **FIG. 13**). In some embodiments, the opposite end of the belt **384** from that which wraps around the camera assembly **350** or pivot pins **366** may wrap around the pivot shaft **204** of the pivot control structure **100**. In such embodiments, rotation of the pivot shaft **204** may drive the belt **384**. The portion of the pivot shaft **204** which the belt **384** wraps around may have a relatively large diameter. This may be desirable so that only a small pivotal displacement of the pivot shaft **204** is needed to drive the belt **384** a relatively large amount. In embodiments where the belt **384** includes teeth, the teeth of the belt **384** may interdigitate with a gear located on the pivot shaft **204** of the pivot control structure **100**. In such embodiments, rotation of the pivot shaft **204** and gear on the pivot shaft **204** may drive the belt **384**. As the belt **384** is driven, the movement of the belt **384** will exert a driving force on the camera assembly **350** causing the camera assembly **350** to pivot.

In yet another arrangement using one or more panning cables, a similar pivotal range may be achieved without requiring any routing of a panning cable through various features included in a camera assembly mount **330**. This may be desirable because it may allow the diameter of an insertion section **14** (see **FIG. 1**) to be made smaller. Additionally, a camera assembly mount **330** for such an embodiment would not require any fenestrations (e.g. the

cable guide holes **348** of **FIG. 16**) or re-directing elements/constraints (e.g. the constraining notch **349** of **FIG. 16**) thus simplifying manufacture of a camera assembly mount. Such an embodiment may for example use the camera assembly mount **330** and inner sheath **312** shown in the example embodiment in **FIG. 17**.

In such an embodiment, a camera assembly **350** may include one or more spooling features or surfaces **1400**. The spooling feature is configured to at least partially wind the terminal portion of a panning cable around the housing of the camera assembly. A connection or attachment point for the terminal end of the panning cable may be situated on the camera assembly housing distal to the spooling feature. The spooling feature preferably has a curved, somewhat recessed surface, which may partially or completely wrap around a portion of the camera assembly housing. Thus, in various embodiments, a panning cable may wind around the housing only partially, or in one or more complete loops around the housing. A longer spooling feature provides for a more extensive range of rotation of the camera assembly. During actuation, an associated panning cable may be wound or unwound from the spooling feature **1400**. Spooling feature **1400** may increase the pivotal range of a camera assembly **350**. Spooling feature **1400** may allow a more consistent torque to be applied to a camera assembly **350** during rotation. Spooling feature **1400** may be constructed to create a moment arm of desired or varying length. Additionally, positioning the spooling feature **1400** radially apart from the axis of rotation of the camera assembly may help a panning cable to generate rotational torque more efficiently.

The progression of **FIGS. 26-30** conceptually illustrate a camera assembly **350** including a spooling feature **1400** in a number of rotational positions. As shown, the spooling feature **1400** may include an arcuate portion and a straight portion. The arcuate portion is shaped such it has a radius of curvature which extends from the pivot axis of the camera assembly **350**. The straight portion of the spooling feature **1400** is angled such that it serves as a torque increasing feature. Additionally, the straight portion of the spooling feature **1400** allows the camera housing **355** to be made with more material (which would otherwise need to be removed to continue the arcuate section) and thus increases the structural integrity of the camera housing **355**. This may be particularly important in embodiments where the camera assembly **350** is designed to fit in a very small space and thus must be made with a very small form factor.

As shown in **FIG. 26** the top panning cable **368** may be wound around the spooling feature **1400**. A pulling force exerted by the top panning cable **368** would create a torque about the pivot axis of the camera assembly **350** causing the camera assembly **350** to rotate

in a clockwise direction. Additionally, the straight portion of the spooling feature **1400** creates a longer moment arm thus increasing the torque generated for a given amount of pulling force.

As the camera assembly **350** rotates to the position shown in **FIG. 27**, the top panning cable **368** begins to unwind from the spooling feature **1400**. As force continues to be applied and the camera assembly continues to rotate, the top panning cable **368** will continue to unwind from the spooling feature as shown in **FIG. 28**. When sufficiently unwound, the point at which the top panning cable **368** leaves the spooling feature **1400** will be located on the arcuate section of the spooling feature **1400** (as shown in both **FIG. 27** and **FIG. 28**). In an embodiment, all points on the arcuate section of the spooling feature **1400** may be located an equal distance from the pivot axis.

In an exemplary embodiment, as a pulling force continues to be exerted by the top panning cable **368**, the camera assembly **350** will continue to rotate until the top panning cable **368** no longer contacts the surface of the spooling feature **1400** as shown in **FIG. 29**. The camera assembly **350** may then continue to rotate until the pulling force of the top panning cable **368** approaches coincidence with the axis of rotation of the camera assembly. This position is depicted in **FIG. 30**. As would be understood by one skilled in the art, a panning cable may be wound around a spooling feature **1400** one or more times to increase the amount of rotation which may be created using the panning cable. The degree to which a panning cable winds around a contact surface on the camera assembly allows for a range of rotation of the camera assembly that exceeds 90 degrees. The degree of rotation of the camera assembly would then be limited only by the amount of slack and the flexibility of the attached electronic flex cable and/or the optical fiber bundle.

In an embodiment, the panning cable and spooling surface are arranged to permit the camera assembly to rotate to a position between about 90 degrees to about 120 degrees of the long axis of the distal endoscope shaft, orienting the lens surface of the camera assembly at least partially in the direction of the proximal end of the endoscope shaft. In this position, any debris or other contamination of the lens surface may be washed away by irrigation fluid traveling distally in the endoscope shaft.

To rotate the camera assembly **350** from its position in **FIG. 30** to the position shown in **FIG. 30**, a pulling force may be exerted via the bottom panning cable **370**. In some embodiments, the bottom panning cable **370** may also be associated with a spooling feature. For example, the corners or edges of the camera assembly **350** around which the bottom panning cable **370** may wrap may be rounded.

FIG. 31-32 depicts a top perspective view of a specific example embodiment of a camera assembly **350** which includes a spooling feature **1400**. The camera assembly **350** includes a lens assembly **354**. The lens assembly **354** is disposed inside of a camera housing **355**. The spooling feature **1400** may be recessed into a side of the camera housing **355** as shown. The spooling feature **1400** in the example embodiment includes an arcuate portion and a straight portion. The arcuate portion of the spooling feature **1400** is shaped such it has a radius of curvature which extends from the center of the pivot pins **366** or pivot axis.

As best shown in **FIG. 31**, the wall into which the spooling feature **1400** is recessed may include a first void **1402**. The camera housing **355** may also include a second void **1404**. The second void **1404** may pass through the top face of the camera housing **355** to the bottom face of the camera housing **355**.

As shown, only a single panning cable **1406** may be used. The panning cable **1406** may extend through both the first void **1402** and the second void **1404** in the camera housing **355**. One end of the panning cable **1406** may be attached to a cable attachment hole **202** on the pivot arm **198** (see **FIG. 13**). The other end of the panning cable **1406** may be attached to the other cable attachment hole **202** on the pivot arm **198**. In some embodiments, the panning cable **1406** may be fixedly attached to the camera housing **355** at one or more points. For example, an adhesive of glue may be placed into one of the voids **1402** or **1404**. This may ensure that the panning cable **1406** does not slip or move over the surface of the camera housing **355** during actuation. Additionally, in some embodiments, the panning cable **1406** may be knotted in one or more location. For example, the panning cable **1406** may be fed through one of the voids **1402** or **1404**, knotted, and then fed through the other of the voids **1402** or **1404**. Preferably, the width of the knot may be sufficiently wide so as to not fit through either of the voids **1402** or **1404**. Such a knot may again help to keep the panning cable **1406** from slipping or moving over the surface of the camera housing **355** during actuation.

As would be appreciated by one skilled in the art, the embodiment shown in **FIG. 31-32** may easily be modified to use two panning cables. One panning cable may terminate and be fixedly attached to the camera housing **355** in or at the location of the first void **1402**. A second panning cable may terminate and be fixedly attached to the camera housing **355** in or at the location of the second void **1404**.

In other embodiments, the pivot actuator may be the rack of a rack and pinion arrangement. In such embodiments, the pivot pins **366** of the camera assembly **350** may include a toothed portion. The toothed portion of the pivot pins **366** may be the pinion gear

that interdigitates with the rack of the pivot actuator. As the rack displaces longitudinally within the insertion section **14**, this motion is translated into rotation of the camera assembly **350** via the toothed, pinion portion of the pivot pins **366**. While such an embodiment does not solely rely on a pulling force to rotate the camera assembly **350**, the pivot actuator still does not require lateral displacement of the actuator within the insertion section **14**. A push-pull rack-type actuator may nevertheless require features (e.g., rigidity, thickness) or may otherwise be constrained within a track to prevent lateral or side-to-side flexion during the application of a compressive force on the rack.

Referring now back to **FIG. 13**, the pivot control structure **100** may be capable of being “parked” in detents defined by ridges **94** in the slide button recess **92** of the handle raised portion **34**. In some embodiments, the ridges **94** may be spaced such that the detents formed by the ridges **94** may correspond with specific angular orientations of the camera assembly **350**. In some embodiments, the detents formed by the ridges **94** may be spaced such that their location corresponds to specific angular increments (e.g. 30°) of the camera assembly **350**.

As mentioned above (see **FIG. 6**), the handle distal section **30** may be rotatable relative to the handle proximal section **16**. Such rotation would also cause the longitudinal axis of the insertion section **14** to rotate as well. In turn, the camera assembly **350** may rotate with the insertion section **14**. This may allow a user to get a near-global view of the anatomical area in question with minimal to no angular repositioning of the endoscope **10**. A user may need only to pan the camera assembly **350** and rotate the handle distal section **30** relative to the handle proximal section **16** to obtain a desired field of view within an anatomical area.

Repeated contortion and bending of optical fibers such as the optical fibers **364** may lead to fracturing or failure of one or more fibers. In the instance of the optical fibers **364**, this leads to light and illumination loss which increases as more optical fibers **364** become compromised. Such bending may occur if the optical fibers **364** terminate and are attached or fused to a portion of a pivoting camera assembly **350** as described above. If the endoscope **10** is designed to be disposable, then any decrement in the integrity or performance of the optical fibers **364** may be within acceptable limits relative to the intended lifespan of the instrument. Consequently, in some embodiments the optical fibers **364** may be attached or fused to a pivotal camera assembly **350** with minimal concern for optical fiber **364** breakage and resultant light loss. A terminal illuminator, light projection element or light emitter associated with the optical fibers **364** may, in some embodiments,

be advantageously mounted to the camera assembly **350** in order to project light at whatever target or field of view a lens assembly **354** of the camera assembly **350** has been rotated or panned to. Such an arrangement helps to ensure that the field of view (shown with dashed lines in **FIG. 23-25**) for the lens assembly **354** is always illuminated by the optical fibers **364** regardless of where the in the camera assembly's **350** pannable range the camera assembly **350** has been rotated to.

In some embodiments, the illumination system may include a light guide or light pipe **375**. In some embodiments, the optical fibers **364** may comprise a light guide or light pipe **375** (see, for example, **FIG. 33**) along at least a part of the path of the illumination system. The terms “light guide” and “light pipe” are herein used interchangeably. When an optical fiber is relatively straight, light loss is relatively small because the angle of incidence of the light within the fiber is shallow enough to facilitate near total reflection within the optical fiber. Bending the optical fiber, however, may alter the angle of incidence to the point where some transmission of light out of the fiber is possible. Bends of a light pipe or guide may, however, be controlled. For this reason, use of a light guide **375** where feasible may help to minimize light loss in an illumination system comprising optical fibers **364** or may replace the optical fibers altogether. A light guide **375** may also provide a number of other benefits. For example, a light guide **375** may aid in assembly and shorten assembly time for a device. The light guide **375** may be of the types described herein or may be any suitable type light guide known to those skilled in the art.

FIG. 33 shows an example embodiment of an endoscope **10** utilizing light pipes **375**. Two larger diameter light pipes **375** may extend along one or more sections of the wall of the inner sheath **312** (see **FIG. 16**) to the camera assembly housing **330** and then bend or curve into one of the camera assembly pivot bearings **346**. The bent section of each light pipe **375** may be coated with a highly reflective material **376** in order to minimize loss of light out of the light pipe **375** as it changes direction. Any suitable highly reflective material **376** known to one skilled in the art may be used. In such embodiments, the camera assembly **350** may also have built-in camera assembly light pipes **377** that are formed in a junction with the light pipes **375** at the pivot bearings **346**. The light carried by the light pipes **375** may be transferred to the camera assembly light pipes **377** at the junction. The camera assembly light pipes **377** may extend from each of the pivot pins **366** into the camera assembly **350**. The camera assembly light pipes **377** terminate in the light projection voids **362** so that the field of view of the camera assembly **350** will be illuminated regardless of the rotational position of the camera and lens assemblies. In such an

embodiment, any bends taken by the camera assembly light pipes **377** may be coated with a highly reflective material **376** as described above. In some embodiments, the highly reflective material **376** may be included on other portions of the light pipes **375** and camera assembly light pipes **377** in addition to the bends of the light pipes **375** and camera assembly light pipes **377**.

Creating a light pipe junction coinciding with the pivoting region of the camera assembly **350** may be desirable because it avoids the bending or twisting of optical fibers **364** as the camera assembly **350** is rotated, removing the risk of damage to the optical fibers **364**. Such a design can be adapted for use in either a reusable or disposable endoscope **10**. This arrangement may also reduce the manufacturing or assembly costs of the endoscope **10**.

In another example embodiment (not shown) which uses light pipes **375**, a larger diameter light pipe **375** may extend substantially along the path of the flex cable **250**. The end of the light pipe **375** nearest the inner sheath mount **160** may form a junction with the optical fibers **364** or be arranged to draw in light from another illumination source. The end of the light pipe **375** nearest the camera assembly **350** may also form a junction with illumination fibers **364** which extend to the camera assembly **350**.

In some embodiments, the optical fibers **364** to the camera assembly **350** may be arranged to form a flexible ribbon **1000**, creating a linear array of fibers that can be terminated into a light projection element with minimal bending or bending in only one dimension (see, e.g., **FIG. 34**). Alternatively, the flexible ribbon **1000** need not be a linear array of fibers and instead may, in some embodiments, be a single, ribbon-like, flexible piece of light guide material. In some embodiments there may be two flexible ribbons **1000** each extending to one of the light projection voids **362** in the camera assembly **350**. In some embodiments, the flexible ribbons **1000** may be coated with a reflective material **376** to maximize the amount of light at the camera assembly **350**. In some embodiments, a flexible ribbon **1000** may form a junction with a light pipe.

In some embodiments, a camera housing top **356** may comprise a light piping material to serve as a light projection element or illuminator. In this case, light may be emitted from most of the camera housing top **356** and into the viewing field of the camera assembly **350**. In some embodiments, some areas of the camera housing top **356** may be blacked out or masked so that light is only emitted from a desired region or regions of the camera housing top **356**. In some embodiments, some regions of the camera housing top

356 may be coated with a highly reflective material **376** to prevent the unwanted emission of light from those areas.

FIG. 34 shows an embodiment in which the optical fibers **364** are incorporated into a flexible ribbon **1000**, which optionally may be coated in a highly reflective material **376**. As shown, the flexible ribbon **1000** extends to the camera assembly **350**. The flexible ribbon **1000** may be over-molded to, potted into, fused with or otherwise coupled to the camera assembly **350**.

In the example embodiment in **FIG. 34** the camera assembly **350** comprises a monolithic camera housing **1002**. An example monolithic camera housing **1002** without an attached flexible ribbon **1000** is shown in greater detail in **FIG. 35**. In the example embodiment, the monolithic camera housing **1002** is made from a light piping or transmitting material and functions as a light projection element. The monolithic camera housing **1002** in the example embodiment may be nearly entirely coated with a highly reflective material **376** to maximize light output from the non-coated or non-masked regions of the monolithic camera housing **1002**. A light projection or illumination surface **1004** having a shape suitable for placement adjacent a lens and image sensor assembly on the monolithic camera housing **1002** may be constructed by masking the area during application of a highly reflective material **376** (or alternatively a simple dark mask). In the example embodiment, the light projection surface **1004** has the shape of a ring. In other embodiments, the light projection surface **1004** may be crescent-shaped, semi-circular, or may have any other desired shape. Light may be emitted from the light projection surface **1004** of the monolithic camera housing **1002** to illuminate the field of view of the lens assembly **354**. As in the above-described embodiments, the field of illumination preferably pivots with the camera assembly **350**, ensuring that the field of view of the lens assembly **354** is always illuminated.

FIG. 36 shows another example embodiment of a monolithic camera housing **1002**. As shown in outline form, the monolithic camera housing **1002** includes a coupling recess **1006**. The coupling recess **1006** may allow a flexible ribbon **1000** to be suitably coupled into the monolithic camera housing **1002**. In some embodiments, the coupling recess **1006** may allow a flexible ribbon **1000** to be coupled, for example, via snap fit into the monolithic camera assembly **1002**. In some embodiments, the coupling recess **1006** may accommodate optical fibers **364** not formed in a flexible ribbon **1000**. Similar to **FIG. 35**, in **FIG. 36**, the monolithic camera housing **1002** may function as a light projecting element.

The monolithic camera housing **1002** may also be similarly coated and/or masked as the monolithic camera housing **1002** described in relation to **FIG. 35**.

FIGS. 37 and **FIG. 38** show an embodiment in which a light projection element **1005** is incorporated in an end of a flexible ribbon **1000**. The light projection element **1005** may be formed from a light piping material, which in some embodiments may be a fusion of a group of fibers into a shape suitable for projecting light from a fiberoptic bundle or flexible ribbon **1000** in a desired manner. In some embodiments, the light projection element **1005** and flexible ribbon **1000** may be two separate parts fused together (e.g., by heating or by chemical means). In other embodiments the light projection element **1005** and flexible fiberoptic ribbon **1000** may be a single molded part. In some embodiments the light projection element **1005** may be created as described in relation to **FIGS. 47-60**.

Still Referring to **FIG. 37** and **38**, the flexible ribbon **1000** may be coated with a highly reflective material **376**. The bottom and side walls of the light projection element **1005** may also be coated with a highly reflective material **376**. This may ensure that light is only emitted from the non-coated top of the light projection element **1005** and into the field of view of the lens assembly **354**. As show in **FIG. 38**, the light projection element **1005** or the flexible ribbon **1000** may include a coupling feature **1008**. The coupling feature **1008** may allow the light projection element **1005** and flexible ribbon **1000** to be coupled onto or into a camera assembly **350**. The coupling feature **1008** may be an integral part of the light projection element **1005**.

FIG. 39 and **FIG. 40** depict two example embodiments of a flexible ribbon **1000** which include light projection elements **1005**, which may be formed from a light piping material. The light projection element **1005** in **FIG. 39** has a generally ring-like shape while the light projection element **1005** in **FIG. 40** is generally crescent shaped, although other shapes may be selected as desired. In the example embodiments in **FIGS. 39** and **40** only the top surfaces of the light projection elements **1005** are left uncoated with a highly reflective material **376**.

A light projection element **1005** may comprise one or a number of textures **1010** that help to direct the light emitted from the light projection elements **1005**. In some embodiments, the texture **1010** or textures **1010** may be included to encourage light to be emitted in a diffuse manner. The texture **1010** or textures **1010** may be created, for example, during molding of the light projection element **1005**, or alternatively, the light piping material forming the light projection element **1005** may include a fill material that encourages light to be emitted from the light projection element **1005** in a diffuse manner.

FIG. 41 and **42** respectively depict top and bottom perspective views of another example embodiment of a light projection element **1005**. As shown, the light projection element **1005** is ring-like in shape. The light projection element **1005** also includes a coupling feature **1008** as shown in bottom perspective view in **FIG. 42**. The coupling feature **1008** in **FIG. 42** is an integral part of the light projection element **1005**. In the example embodiment, the coupling feature **1008** is a ledge or shelf. The ledge coupling feature **1008** may help to locate and/or align the light projection element **1005** on another component such as a camera assembly **350**. Additionally, in some embodiments, adhesive or glue may be placed along the ledge coupling feature **1008** to fix the light projection element **1005** to another component such as a camera assembly **350**. The light projection element **1005** is shown attached to an example camera assembly **350** in **FIG. 46**.

The light projection element **1005** shown in **FIGS. 41-42** does not include a highly reflective coating or material **376** (see, for example, **FIG. 37**). The need for such a highly reflective coating or material **376** may be minimized by dimensioning the light projection element **1005** to increase or maximize the total internal reflection of light entering and within the light projection element **1005** where the emission of light is not desired. This may be done by ensuring any bend or bends have a large radius in areas of the light projection element **1005** where the emission of light is undesired. Additionally, this may be done by dimensioning a light projection element **1005** such that thickness variations throughout the light projection element **1005** do not introduce changes in the angle of incidence of light within the light projection element **1005** which would make the angle of incidence less than the critical angle. It may be desirable that the thickness of the light projection element **1005** does not decrease to less than the thickness of the optical fibers or flexible ribbon to which the light projection element is attached **1005**. It may also be desirable that the surface of the light projection element **1005** be smooth in areas where the emission of light is not desired.

FIGS. 43, 44, and 45 depict a number of cross sections of the light projection element **1005** depicted in **FIGS. 41-42**. The cross sections are respectively taken at lines **43-43, 44-44, and 45-45** of **FIG. 41**. As shown, light entering the light projection element **1005** must traverse a first bend **1300** and second bend **1302** before being emitted out of the top surface of the light projection element **1005**. As shown in **FIGS. 43-45**, the light projection element **1005** may be shaped such that the radii of these bends vary depending on the plane of the light projection element **1005**. The radius of each of these bends **1300** and **1302** may be chosen so as to be as gradual as possible in the available space in a given plane. Also as

shown, the thickness of the light projection element **1005** is kept generally constant. This ensures that changes in angle incidence due to thickness variation are minimized.

The light projection element **1005** shown and described in relation to **FIGS. 41-45** is attached to an example camera assembly **350** in **FIG. 46**. As shown the light projection element **1005** is arranged such that it projects light into a primary illumination field (the surrounding area around this primary illumination field also may be illuminated due to diffusion and reflection of the emitted light) which is substantially coincident with the field of view of the lens assembly **354**.

FIGS. 47-60 detail a process and a number of example apparatuses for creating a light projection element of a desired size and shape connected to one or more optical fiber(s). Such a process may be useful in any number of applications. As indicated above, the process may be used to create a light projecting element for an endoscopic instrument or other medical apparatus. A light projecting element created via such a process may also be used in any of a variety of imaging applications. Such a process may also be useful to create light projecting elements in other articles or for other applications.

The process described in relation to **FIGS. 47-60** may be advantageous for a number of reasons. Among these reasons, the process allows a light projecting element of a desired size and shape to be constructed for little more than the material cost. It also allows for there to be no mechanical break between an optical fiber or fibers and the light projection element. This may help to avoid light loss which may otherwise be introduced at a junction. It obviates the need for time consuming routing of individual optical fibers. The process allows for easily repeatable creation of a light projection element optimized for maximum light output. Furthermore, among other advantages, the process allows a number of individual fibers to be brought to or routed to a location and then formed into the shape of the desired light projection element. Thus the final light projection element may be dimensioned such that it is larger than any restrictions in the routing pathway.

FIGS. 47-50 depict an example process of making an exemplary light projection element or emitter **2005** molded from, fused with or attached to a flexible plastic optical fiber bundle or ribbon **1000**. Particularly if molded from a flexible plastic optical fiber bundle, the light emitter comprises a solid transparent plastic light emitting member of the flexible optical fiber bundle, shaped in a pre-determined manner according to the molding forms selected to produce it. The emitter in this case may be considered a passive light emitter, in that it conducts and emits light sourced from a proximal end of the optical fiber bundle. Examples of plastic optical fiber material may include acrylic or polycarbonate,

among other materials. A flexible optical fiber ribbon **1000** is shown in **FIG. 47**. The individual optical fibers **364** comprising the flexible ribbon **1000** are shown in **FIG. 47**. One end of the flexible ribbon **1000** may be looped around until the ends of the optical fibers **364** lay back on themselves as shown in **FIG. 48**. The looped end of the flexible ribbon **1000** may then be formed and fused using, for example, compression molding, into the desired functional shape as a light projection element or light emitter **2005**. Preferably, the looping of optical fibers **364** at the end of the flexible optical fiber ribbon **1000** allows the light projection element **2005** to be formed without creating any internal voids in the formed element. Alternatively, the ends of the various optical fibers **364** may be melted into a slug of sufficient material prior to the final molding process to form the desired light projection element **2005**. Some light projection elements **2005** may not require this melting or looping so long as enough material is present to form the light projection element **2005**. The light projection element **2005** may be formed by any suitable means or combination of means such as a coining process, compression molding, stamp/die cut process, RF heating process, etc.

In some embodiments, a top form **1052a**, (see **FIG. 51**) may include a mandrel or the like to facilitate looping of the optical fibers **364**. Additionally, in some specific embodiments, optical fibers **364** may, for example, be wrapped around a mandrel on a camera assembly **350** (see, for example, **FIG. 22**) and then formed and fused into the light projection element **2005**. In such embodiments, a portion of the end product, in this case a camera assembly **350** (see, for example, **FIG. 22**), may thus act as one of the forms **1052a,b** of **FIG. 51**. In other applications, one or more of the forms **1052a,b** may be another part of an assembly of an end product. In the example embodiment depicted in **FIGS. 47-50**, the forms **1020** may comprise a force or plug member and mating mold form or cavity.

FIG. 49 illustrates a side view of a flexible optical fiber ribbon **1000** and the loop of optical fibers **364** being formed into a light projection element or emitter **2005**. As shown in the example in **FIG. 49**, the light projection element **2005** is formed through a coining/stamping process in which pressure is applied between two forms **1020**. **FIG. 50** shows a completed flexible ribbon **1000** in which the loop of optical fibers **364** has been formed and fused into a light projection element or emitter **2005**. There is no mechanical break between the flexible ribbon **1000** and the light projection element **2005**. This gives the assembly a robustness and integrity, while also allowing for the efficient transmission of light. As shown, the light projection element **2005** is shaped as a ring, although any other desired shape that places the light emitter next to the lens elements of the camera assembly

may be formed in this manner. In some embodiments, selective portions of the flexible optical fiber ribbon **1000** and/or light projection element **2005** may then be coated or masked with a highly reflective material **376** (as described, for example, in relation to **FIGS. 33-40**). In some embodiments, a texture **1010** or textures **1010** may be added to the light projection element **2005** after it has been formed. As mentioned above, the light projection element **2005** may be formed such that it includes a coupling feature **1008** (see, for example, **FIG. 38**). Additionally, in some embodiments, a fill material may be placed into one or both forms **1020** before forming the light projection element **2005**.

FIG. 51 depicts an example block diagram of an apparatus **1050** which may be used to create a light projection element or light emitter. In the example in **FIG. 51**, a light projection element may be created by fusing one or a number of optical fibers **364**. In **FIG. 51**, the fibers **364** are fused together into the desired light projection element with a combination of heat and pressure, as in, for example, compression molding. Alternatively, the fibers **364** may be fused by a chemical process (e.g. using a solvent). As shown, the apparatus **1050** includes forms **1052a, b**. The apparatus **1050** also may include a heat source **1054** in thermal communication with the forms **1052a, b**. Heat may be applied to the forms before, during and/or after the placement of the fiber bundle on the mold form. A pressure source **1056** may be included in the apparatus **1050** and may be arranged to exert pressure on one or both forms **1052a, b** and/or cause the forms **1052a, b** to be brought together. Additionally, a cooling source **1058** may be included in the apparatus **1050**.

The cooling source **1058** is configured to cool at least a transitional section of the fiber bundle adjacent to the section on the mold form. The transitional section will consequently have a distal region comprising partially merged and solidified fibers, and a more proximal region in which the individual flexible fibers are preserved. The transitional section thus has the ability optionally to maintain a fixed angular relation to the formed light emitter after cooling. Optionally, a jacket or heat sink **1059** may be placed on the optical fiber(s) **364** proximal to the transition section while a light projection element or emitter is being formed.

In operation, the heat source **1054** may be used to heat the forms **1052a** and/or **1052b**. The forms **1052a, b** may be heated to a predefined temperature. The temperature selected may depend on the optical fiber **364** material being used. The temperature used may be selected such that it is not so high as to burn the optical fiber **364** material, or in some cases any coating on the material, but sufficient to cause complete melting of the optical fiber material **364**. Additionally, the temperature selected may be sufficient to melt

the optical fiber material within the forms **1052a, b** while leaving the material near but not in the forms **1052a, b** substantially unaltered or undistorted. In an embodiment, the temperature range chosen straddles the temperature point at which the material melts. Such a temperature selection may be advantageous because it reduces the amount of time that the material remains in the apparatus **1050** to cool. In some embodiments, the temperature used may be dependent on the amount of heat energy which a cooling source **1058** and/or heat sink **1059** is capable of removing. In a specific embodiment in which the optical fiber **364** material being used is acrylic, an appropriate temperature range may be between about 270 degrees to 280 degrees Fahrenheit.

The optical fiber or fibers **364** may be placed on one of the forms **1052b**. The forms **1052a, b** may then be brought together and pressure may be exerted on the forms **1052a, b**. The heat and pressure may cause the optical fiber or fibers **364** to melt and fuse into the desired light projection element as dictated by the shape and internal features of forms **1052a, b**. In some embodiments, a fill material may also be placed in the forms **1052a, b** such that the desired light projection element is laced or impregnated with the fill material during melting and fusing.

In embodiments where the fibers **364** are fused by a chemical process, a solvent may for example be introduced to the mold form **1052b** before or after the illumination fiber or fibers **364** has been placed onto the mold form **1052b**. The forms **1052a, b** may be brought together and pressure may be exerted on the forms **1052a, b**. The action of the solvent may then cause the fiber or fibers **364** to dissolve and fuse into a shape as dictated by the forms **1052a, b**. The fiber or fibers **364** may then be allowed to set before the forms **1052a, b** are separated. In embodiments using a solvent, a cooling source **1058** and heat sink **1059** may not be necessary.

In some embodiments, a cooling source **1058** may be used to remove heat energy from portions of the optical fiber or fibers **364** where melting/fusing is not desired (e.g. near the heated forms **1052a, b** or at the transition area between the light projecting element and the unaltered fiber or fibers). A heat sink **1059** (e.g. a metallic sleeve placed around the fiber bundle or ribbon) may also or additionally be employed to the same end.

The forms **1052a, b** may then be allowed to cool. Once the forms **1052a, b** have sufficiently cooled, they may be separated and the optical fibers **364** and fused light projection element or emitter may be removed. In some embodiments, a cooling source **1058** may be used to speed cooling of the forms **1052a, b**. Cooling the forms **1052a, b** allows the melted optical fibers **364** to solidify and fuse into the shape of light projection

element. Preferably, the forms **1052a, b** are cooled until the optical fiber **364** material is no longer hot enough to flow. In some embodiments, the apparatus **1050** may include an ejector (not shown) which may eject the light projection element once the forms **1052a, b** are separated. After ejection, any flashing on the light projection element may then be removed.

The forms **1052a, b** may be constructed of metal or other suitable heat-stable material. The shape of the desired light projection element may be cut, milled, recessed, etc. into the forms **1052a, b**. As described above in relation to **FIGS. 39** and **40**, the light projection element may include surface texturing over the illumination surfaces **1010** and/or features such as coupling features **1008**. Such texturing and features may be included as part of the shape which is cut, milled, recessed, etc. into the forms **1052a, b**.

In some embodiments, the heat source **1054** may be electric. In some embodiments, the forms **1052a, b** may include resistive heating elements therein. In some embodiments, the heat source **1054** may be one or more heat rods in thermal communication with the forms **1052a, b**. Any other suitable heating element may also be used. Additionally, a thermocouple (not shown) or temperature sensor may be used to provide temperature feedback to ensure that the forms **1052a, b** are maintained at the desired temperature. The heat output of the heat source **1054** may be adjusted based upon readings from the temperature sensor.

The pressure source **1056** may be any suitable pressure source. In various embodiments, the pressure source **1056** may be a manual pressure source, mechanical or electromechanical pressure source, pneumatic pressure source, hydraulic pressure source, etc.

The cooling source **1058** may be any suitable cooling source. In various embodiments, the cooling source **1058** may be a fan, compressor or the like connected to a conduit to direct cooling air to flow around a desired portion of the optical fiber or fibers **364**. In some embodiments, the cooling source **1058** may be a liquid cooling source, for example, a water jacket surrounding the optical fiber or fibers **364**.

The heat sink **1059** may be made of any suitable material and may take any suitable shape or form. Preferably, the heat sink **1059** is made of a material with a higher melting temperature than the optical fiber material or operating temperature of the apparatus **1050**. In some embodiments, a jacket or heat sink **1059** may also serve additional purposes. For example, the heat sink **1059** may also function as a guide member which serves to constrain the optical fiber(s) **364** in a desired orientation (e.g. a flat ribbon) while the light projection

element is being formed. In some embodiments where a heat sink **1059** may not be necessary, a guide member may still be included. Such a guide member may not require the heat dissipating properties of a heat sink **1059**.

Referring now to **FIGS. 52** and **53** a specific example of an apparatus **1050** which may be used to create a light projection element is depicted. As shown, the apparatus **1050** is similar to that shown in **FIG. 51**. The apparatus **1050** includes a stationary element **1060** and a moving or force element **1062**. The apparatus **1050** additionally may include guides **1064** which precisely constrain the movement of the moving element **1062**. In the example embodiment shown in **FIG. 52**, the guides **1064** are rails. A form **1052a** or **1052b** is included on both the stationary element **1060** (e.g. a mold cavity) and the moving element **1062** (e.g. a force or plug member). The forms **1052a, b** are disposed on opposing surfaces of the stationary element **1060** and the moving element **1062**. When the moving element **1062** is brought together with the stationary element **1060** (see **FIG. 53**) in the presence of an appropriate amount of heat and pressure, the forms **1052a, b** cooperate to melt the optical fiber material and form a light projection element from one or more optical fibers placed in the apparatus **1050**. A close up perspective view of the form (or mold cavity) **1052b** of the stationary element **1060** and the form (or force/plug member) **1052a** of the moving element **1062** is depicted in **FIG. 54**.

Once the stationary element **1060** and the moving element **1062** are brought together, pressure from a pressure source **1056** (see **FIG. 51**) may be exerted on the optical fiber(s) via the forms **1052a, b** to aid in formation of the light projection element or light emitter. As mentioned above, the forms **1052a, b** (and in some embodiments, stationary element **1060** and moving element **1062** to which they are attached) may be heated as mentioned above. The heat may also aid in the formation of the light projection element.

The apparatus **1050** shown in **FIG. 52** additionally includes a coupling element **1066**. The coupling element **1066** allows the moving element **1062** to be attached to a pressure source **1056** (see **FIG. 51**). To facilitate such coupling, the coupling element in **FIG. 52** includes a threaded shaft **1068**. In some embodiments, the threaded shaft **1068** may be threaded into a ram element (not shown) of a pressure source **1056**.

FIG. 55 and **FIG. 56** depict another example embodiment of an apparatus **1050** which may be used to create a light projection element. As shown, the apparatus **1050** is similar to that shown in **FIGS. 52-53**. The apparatus **1050** includes a stationary element **1060** and a moveable element **1062**. As in **FIGS. 52** and **53** guides **1064**, and a coupling element **1066** including a threaded shaft **1068** are also included. Also as in **FIGS. 52** and

53, a form **1052a** or **1052b** is included on both the stationary element **1060** and the moving element **1062**. The forms **1052a, b** are disposed on opposing surfaces of the stationary element **1060** and the moving element **1062**. When the moving element **1062** is brought together with the stationary element **1060** (see **FIG. 56**), the forms **1052a, b** cooperate to form a light projection element from one or more optical fibers placed in the apparatus **1050**. The forms **1052a, b** included on the stationary element **1060** and the moving element **1062** in **FIGS. 55-56** differ from those shown in **FIGS. 52-53**. A close up perspective view of the form **1052b** of the stationary element **1060** and the form **1052a** of the moving element **1062** in **FIGS. 55-56** are respectively depicted in **FIG. 57** and **FIG. 58**.

A close up perspective view of the form **1052b** of the stationary element **1060** and the form **1052a** of the moving element **1062** of **FIGS. 55-56** are shown in **FIG. 59**. Also shown in **FIG. 59** is an example light projection element **2005** which would result from use of the shown forms **1052a, b**. The example light projection element **2005** in **FIG. 59** is similar to that shown and described in relation to **FIGS. 41-46**.

As shown, a transition span or region **1072** is shown in **FIG. 59** (and also **FIGS. 41-46**). The transition span **1072** is located between the light projection element **2005** and the individual optical fibers **364**. A transition span **1072** may be created as a result of high heat in the area surrounding the light projection element **2005** dissipating as the element **2005** transitions to the more proximal optical fiber bundle. It may be desirable to produce as small a transition span **1072** as possible since the transition span **1072** may be brittle and relatively less pliant. As mentioned above, this may be accomplished through use of a heat sink **1059** (see, for example, **FIG. 51**) and/or a cooling source **1058** (see, for example, **FIG. 51**). In applications where the light projection element or emitter **2005** is to be placed on a pivoting or rotating assembly (e.g. the camera assembly **350** shown in **FIG. 32**) it may be desirable that such a span be fixedly attached to the assembly. This may ensure that the transition span **1072** is not subjected to excessive stress or bending. Instead, the stress and bending would then be applied to the more pliant, individual optical fibers **364** further away from the light projection element **2005** which are left substantially unaltered during the formation of the light projection element **2005**.

Referring now also to **FIG. 60**, a cross-section of the apparatus **1050** and light projection element **2005** taken at line **60-60** of **FIG. 59** is shown. One or more of the forms **1052a, b** may include a fiber orienting feature. As shown, the mold form **1052b** of the stationary element **1060** includes a fiber orienting incline feature **1070**. Such an incline feature **1070** may be advantageous for a number of reasons. For example, an incline feature

1070 may help to ensure the optical fibers **364** transition into the light projection element or emitter **2005** in a desired arrangement, angle, orientation, etc. with respect to an illumination face of the formed light emitter. In the example embodiment, the incline feature **1070** serves to keep the optical fibers **364** in a substantially flat ribbon like arrangement. Additionally, the incline feature **1070** serves to constrain the optical fibers **364** such that they transition to the light projection element **2005** at a desired angle. At least part of the resulting transition section of the fiber bundle has been exposed to sufficient heat and/or pressure to solidify into a non-flexible material upon cooling.

FIG. 61 shows a cross sectional view of an exemplary camera assembly including a lens assembly **354** taken at the cross-sectional plane represented by line **61-61** of **FIG. 22**. The lens assembly **354** is shown housed between the camera housing top **356** and camera housing bottom **358** as in **FIG. 22**. As shown, the lens assembly **354** is positioned to project an image onto the plane of an image sensor **380**. The type of image sensor **380** may include, for example, a CCD image sensor, CMOS image sensor, etc. Preferably, the image sensor **380** may be housed in a sealed section of the camera assembly **350** to guard against fluid exposure. In a disposable endoscope, a less costly process may be used to seal the image sensor against fluid exposure (e.g., using a clear epoxy compound), because the assembly would not then be designed to withstand the rigors of sterilization and reuse.

As shown in **FIG. 61** the image sensor **380** may be electrically coupled to a flex board **381** of the flex cable **250**. In some embodiments, a conformal coating material may be used to give added protection against moisture, and optionally may be constructed to support the joints of a ball grid array mounting for the image sensor **380**. The flex cable **250** may provide power to the image sensor **380**, as well as the means of conveyance of data and/or commands from/to the image sensor **380**. In some embodiments, a stiffener **382** may be included in the camera assembly **350**. In the example embodiment shown in **FIG. 61**, a stiffener **382** is positioned to strengthen the structure on which the image sensor **380** is supported, which may help to protect the physical integrity of the image sensor **380**. The stiffener **382** may comprise, for example, a thin aluminum backing (which in an exemplary embodiment may be about 0.002 inch thick).

The camera assembly **350** may also include one or a number of fiber guides **384**. In the example shown in **FIG. 61**, a fiber guide **384** is coupled to the bottom face of the camera housing bottom **358**. The example fiber guide **384** includes a guide trough **386**. The back wall of the guide trough **386** of the fiber guide **384** may be seen projecting toward the bottom of the page in **FIG. 61**. The fiber guide **384** may also be or include a number of

directing notches or channels **388** which in the example fiber guide **384** shown in **FIG. 61** are recessed into the back wall of the guide trough **386**. In some embodiments, including the exemplary embodiment in **FIG. 61**, directing notches or channels **388** may be formed in one or both of the camera housing top **356** and camera housing bottom **358**. The fiber guide **384** may help to route the illumination fibers **364** during assembly of the endoscope **10**. The fiber guide **384** may also act to keep the illumination fibers **364** in place during operation of the endoscope **10**. The location, shape, number, size, etc. of the fiber guides **384** may vary depending on the specific configuration of the endoscope **10**. In some embodiments, glue, epoxy or another suitable adhesive or agent may be used in addition to the fiber guides **384** to help keep the illumination fibers **364** in the desired location. In some cases, for example, in which light guides or light projection element (as shown, e.g., in **FIG. 33-40** or as shown in **FIG. 62**) are used, fiber guides **384** may not be used in an assembly.

FIG. 62 depicts a cross section of the camera assembly **350** depicted in **FIG. 32** taken at line **62-62** of **FIG. 32**. As shown, a lens assembly **354** is shown in place in the camera housing **355**. An image sensor **380** is also shown in place within the camera housing **355**. The lens assembly is positioned to project an image to the image sensor **380**. As above, the image sensor **380** may be any type of image sensor (e.g. CCD, CMOS, etc.) and may be sealed against fluid exposure. Also as above, the image sensor **380** is coupled onto a flex board **381** attached to a flex cable **250**. The camera assembly **350** shown in **FIG. 62** does not include a fiber guide **384** (see **FIG. 61**). Instead a light projection element or light emitter **2005** is in place on the camera assembly **350** in **FIG. 62**.

As shown, the flex cable **250** is doubled back upon itself in the example embodiment. This may be accomplished by bending the flex cable **250** and then maintaining the bend by applying glue or another fixative to the affected areas of the flex cable **250**. Double-looping the flex cable **250** below the camera assembly **350** may be advantageous in embodiments in which the camera assembly **350** is enclosed in a confined space. For example, confining the camera assembly **350** to the space within an inner sheath **312** as shown in **FIG. 20** may limit the amount of flex cable **250** available for bending. The flex cable **250** may then have to bend over an undesirably small radius in certain rotation positions of the camera assembly **350**. Such a small bend radius can be detrimental to a flex cable **250** especially if it occurs repeatedly. This problem becomes more of an issue as the diameter of the inner sheath **312** decreases. By arranging the flex cable **250** to double back upon itself, however, a greater length of flex cable **250** is available for repeated bending upon rotation of the camera assembly **350** and a larger minimum bend radius may be

obtained. Thus, this may allow the inner sheath **312** to then be made with a smaller diameter without concern for the integrity of the flex cable **250** due to the repeated bending and unbending over a small radius.

Both the flex cable **250** and the optical fibers **364** leading the light projection element **2005** exhibit some resistance to bending. Additionally, both can exert a restoring spring force when bent. This resistance to bending may increase the camera assembly's **350** resistance to rotation. As shown in **FIG. 63**, the flex cable **250** and the optical fibers **364** may be angled toward one another. Such an arrangement may leverage the stiffness of the flex cable **250** against the optical fibers **364** or vice versa to assist in rotating camera assembly **350**. To best illustrate this concept, the flex cable **250** is not doubled back upon itself in **FIG. 63**.

FIG. 64 depicts an example embodiment of a lens assembly **354**. The lens assembly **354** is shown in isolation in **FIG. 64**. It may be installed in/on a camera assembly **350** (see **FIG. 61**) during assembly of the endoscope **10**. As shown, the lens assembly **354** includes an objective lens **400**. The objective lens **400** may be seated in a lens housing **402**. The lens housing **402** may be made of a rigid material such as aluminum, steel or a hardened polymer or plastic compound. In an embodiment, the lens housing **402** may be cylindrical, or may have an ovoid or otherwise shaped cross-section to accommodate the shape of the lens or lenses being used. In the example embodiment shown in **FIG. 64** the lens housing **402** may have a flange section at its base to facilitate its installation in a camera housing or camera assembly **350**. The lens housing **402** is configured to enclose the lens or lenses of a lens assembly **354**. In the example embodiment, a lens enclosure **404** extends through the entire lens housing **402**. The objective lens **400** of the lens assembly **354** is disposed mostly within the lens enclosure **404**. In some embodiments, glue, epoxy or another suitable adhesive may be used to couple and seal the objective lens **400** into the lens housing **402**. In some embodiments, the adhesive may be added where the objective lens **400** contacts the lens enclosure **404**.

FIG. 65 shows a cross sectional view of a lens assembly **354** in a plane defined by line **65-65** shown in **FIG. 64**. As in **FIG. 64**, the objective lens **400** is disposed within the lens enclosure **404** of the lens housing **402** in **FIG. 65**. A disc **406** is also shown in **FIG. 65**. The disc **406**, which may be constructed from a thin metal or plastic, is located within the lens enclosure **404** between the objective lens **400** and a second lens **408** of the lens assembly **354**. As shown in **FIG. 65**, the disc **406** includes a central aperture **410**. The aperture **410** size may vary depending on the optical arrangement of the lenses in relation to

the camera sensing element. In some embodiments, glue, epoxy or another suitable adhesive may be used to couple and seal the second lens **408** into the lens housing **402**

In some embodiments, a focusing element may be included in the lens assembly **354**. In the example embodiment depicted in **FIG. 65**, the lens assembly **354** does not include a focusing element. The lens assembly **354** may be arranged to project an image of objects at a distance between approximately 9mm and 50mm in focus onto the plane of the image sensor **380** (see **FIG. 61**). In the example embodiment shown in **FIG. 65**, the immediate field of view (the field of view visible at any one time) of the lens assembly **354** is approximately 75°, although alternate embodiments may provide larger or smaller immediate fields of view.

In alternative embodiments, the lens assembly **354** may include a focusing element (not shown) capable of moving the objective lens **400**, second lens **408**, or both the objective lens **400** and second lens **408** in order to bring various anatomical objects into focus without the need to reposition the endoscope **10**.

Any of a variety of suitable focusing elements may be used. For example, in some embodiments, Nitinol wires may be used to adjust the focus of the lens assembly **354**. The Nitinol wires may be selectively heated and cooled to move a lens in a lens assembly **354** to bring an object into focus. In some embodiments, one Nitinol wire or set of Nitinol wires may be used to pull the lenses apart and another Nitinol wire or set of Nitinol wires may be used to bring the lenses closer together.

In some embodiments, an electro-active polymer (such as, e.g., an ionic electro-active polymer) may be used as an actuator to bring a desired object into focus. An ionic electro-active polymer may be advantageous in medical applications because it only requires a small voltage for actuation.

In some embodiments, the lens assembly **354** may be constructed to be bi-stable, so that a focusing element may be capable of focusing on either a close depth of field or a more distant depth of field. A user may operate the focusing element in a binary manner to select which depth of field is desired or appropriate. A button such as button **90** described above, may be used to adjust the focus of the endoscope **10**.

FIG. 66 depicts an example embodiment of a lens assembly **354**. The lens assembly **354** is shown in isolation in **FIG. 66**. It may be installed on a camera assembly **350** (see **FIG. 61**) during assembly of the endoscope **10**. As shown, the lens assembly **354** includes an objective lens **400**. The objective lens **400** may be seated in a lens housing **402**. The lens housing **402** may be made of a rigid material such as aluminum, steel or a hardened polymer

or plastic compound. In an embodiment, the lens housing **402** may be cylindrical, or may have an ovoid or otherwise shaped cross-section to accommodate the shape of the lens or lenses being used. In the example embodiment shown in **FIG. 66** the lens housing **402** may have a flange section at its base to facilitate its installation in a camera housing or camera assembly **350**. The lens housing **402** may include a lens enclosure **404** configured to enclose the lenses of a lens assembly **354**. The objective lens **400** of the lens assembly **354** is disposed such that it is not proud of the top of the lens housing **402**. This may help to shelter the objective lens **400** from contact with medical instruments (e.g. a shaver) during use of the endoscope **10**. In some embodiments, glue, epoxy or another suitable adhesive may be used to couple and seal the objective lens **400** into the lens housing **402**. In some embodiments, the lenses, including the objective lens **400**, may be compression fit into the lens housing **402**.

FIG. 67 shows a cross sectional view of a lens assembly **354** in a plane defined by line **67-67** shown in **FIG. 66**. As in **FIG. 66**, the objective lens **400** is disposed within the lens enclosure **404** of the lens housing **402** in **FIG. 23**. A disc **406** is also shown in **FIG. 67**. The disc **406**, which may be constructed from a thin metal or plastic, is located within the lens enclosure **404** between the objective lens **400** and second lens **408** and a third lens **409** of the lens assembly **354**. As shown in **FIG. 67**, the disc **406** includes a central aperture **410**. The aperture **410** size may vary depending on the optical arrangement of the lenses in relation to the camera sensing element.

The lens assembly **354** is arranged to project an image of objects at a distance between approximately 4mm and 50mm in focus onto the plane of the image sensor **380** (see **FIG. 61**). In the example embodiment shown in **FIG. 67**, the immediate field of view (the field of view visible at any one time) of the lens assembly **354** is approximately 75°, although alternate embodiments may provide larger or smaller immediate fields of view.

FIG. 68 depicts another example embodiment of a lens assembly **354**. The lens assembly **354** is shown in isolation in **FIG. 68**. It may be installed on a camera assembly **350** (see, for example, **FIG. 61**) during assembly of the endoscope **10**. As shown, the lens assembly **354** includes an objective lens **400**. The objective lens **400** may be seated in a lens housing **402**. The lens housing **402** may be made of a rigid material such as aluminum, steel or a hardened polymer or plastic compound. In an embodiment, the lens housing **402** may be cylindrical, or may have an ovoid or otherwise shaped cross-section to accommodate the shape of the lens or lenses being used. In the example embodiment shown in **FIG. 268** the lens housing **402** may have a flange section at its base to facilitate its installation in a

camera housing or camera assembly **350**. Other portions of the lens housing **402** may also be shaped to facilitate its installation into a camera housing or camera assembly **350**. The lens housing **402** may include a lens enclosure **404** configured to enclose the lenses of a lens assembly **354**. The objective lens **400** of the lens assembly **354** is disposed such that it is not proud of the top of the lens housing **402**. This may help to shelter the objective lens **400** from contact with medical instruments (e.g. a shaver) during use of the endoscope **10**. In some embodiments, glue, epoxy or another suitable adhesive may be used to couple and seal the objective lens **400** into the lens housing **402**.

FIG. 69 shows a cross sectional view of a lens assembly **354** in a plane defined by line **69-69** shown in **FIG. 68**. As in **FIG. 68**, the objective lens **400** is disposed within the lens enclosure **404** of the lens housing **402** in **FIG. 69**. A disc **406** is also shown in **FIG. 69**. The disc **406**, which may be constructed from a thin metal or plastic, is located within the lens enclosure **404** between the objective lens **400** and second lens **408** and a third lens **409** of the lens assembly **354**. As shown in **FIG. 69**, the disc **406** includes a central aperture **410**. The aperture **410** size may vary depending on the optical arrangement of the lenses in relation to the camera sensing element.

As shown in **FIG. 69**, the outer diameter of each lens **400**, **408**, and **409** in a lens assembly **354** may be made to have substantially equal diameters. Having equal outer diameters on the lenses **400**, **408**, and **409** will cause the lenses **400**, **408**, and **409** to self center as the lenses **400**, **408**, and **409** are placed in the lens enclosure **404**. This may help in assembly of and cut down on assembly time for a lens assembly **354**. Such a self centering design may be particularly desirable in lens assemblies **354** in which precise lens alignment is needed.

FIG. 70 depicts another example of embodiment of a lens assembly **354**. The lens assembly **354** is shown in isolation in **FIG. 70**. It may be installed on a camera assembly **350** (see, for example, **FIG. 61**) during assembly of the endoscope **10**. As shown, the lens assembly **354** includes a window **411**. The window **411** may be seated in a lens housing **402**. The lens housing **402** may be made of a rigid material such as aluminum, steel or a hardened polymer or plastic compound. In an embodiment, the lens housing **402** may be cylindrical, or may have an ovoid or otherwise shaped cross-section to accommodate the shape of the lens or lenses being used. In the example embodiment shown in **FIG. 70** the lens housing **402** may have a flange section at its base to facilitate its installation in a camera housing or camera assembly **350**. Other portions of the lens housing **402** may also be shaped to facilitate its installation into a camera housing or camera assembly **350**. The

lens housing **402** may include a lens enclosure **404** configured to enclose the lenses of a lens assembly **354**. The window **411** of the lens assembly **354** is disposed such that it is substantially flush with the top of the lens housing **402**. In some embodiments, glue, epoxy or another suitable adhesive may be used to couple and seal the window **411** into the lens housing **402**. Preferably, the window **411** may be coupled to the lens housing **402** such that a fluid seal is created between internal components in a lens housing **402** and the outside environment.

FIG. 71 shows a cross sectional view of a lens assembly **354** in a plane defined by line **71-71** shown in **FIG. 70**. As in **FIG. 70**, the window **411** is flush with the top of the lens housing **402**. The lens assembly **354** includes an objective lens **400**. The objective lens **400** is disposed within the lens enclosure **404** of the lens housing **402** in **FIG. 71**. A disc **406** is also shown in **FIG. 71**. The disc **406**, which may be constructed from a thin metal or plastic, is located within the lens enclosure **404** between the objective lens **400** and second lens **408** and a third lens **409** of the lens assembly **354**. As shown in **FIG. 71**, the disc **406** includes a central aperture **410**. The aperture **410** size may vary depending on the optical arrangement of the lenses in relation to the camera sensing element. Similar to the lens assembly **354** shown in **FIG. 69**, the lenses **400**, **408**, and **409** of the lens assembly **354** in **FIG. 71** are of equal outer diameters. As described above, this may aid in assembly and alignment of the lenses **400**, **408**, and **409**.

The lens assembly **354** shown in **FIG. 71** additionally includes a sealed space **412**. The sealed space **412** exists between the internal face of the window **411** and the surface of the objective lens **400**. This sealed space **412** may be filled with a medium in which the lenses **400**, **408**, and **409** of the lens assembly **354** are designed to operate in (e.g. air). The window **411** may thus, form a “goggle” which allows the lens assembly **354** to operate in any medium. For, example, if the lenses **400**, **408**, and **409** are designed to be used in air, the sealed space **412** may be filled with air. The lens assembly **354** may then be placed into another medium, for example, a liquid (e.g. water) and remain in proper focus. Preferably the window **411** is shaped such that it does not distort the image transmitted through the lenses **400**, **408**, and **409** of the lens assembly **354**.

FIG. 72-84 depict an example process and apparatus for determining the proper spatial arrangement of a lens or lens assembly and an image sensor (or other desired destination or imaging surface, e.g. a film plate or holder for a piece of film) associated with the lens or lens assembly. Such a spatial arrangement is key to ensuring that the image received by the image sensor is in focus. The apparatus and process may allow the

determination of the focal length of a lens or lens assembly and may allow determination of the image plane of a lens or lens assembly. For illustrative example, focal length for a single lens may be determined as follows :

$$1/f_{lens} = (n_{lens} - n_{incident}) * (1/R_1 - 1/R_2)$$

Where: n =index of refraction

R1 and R2 = respectively the radii of the curvature of the entrance and exit of the lens.

As indicated by the formula, such a process and apparatus may be necessary in scenarios where the shape of the lens or lenses are not precisely known. Also as indicated, since the lens or lens assembly must be in contact with the medium it is intended to be used in, such determinations may become complicated in applications where the lens or lens assembly is designed for use in a liquid environment. Specifically, the process and apparatus depicted in **FIGS. 72-84** may be advantageously used for lenses or lens assemblies which are designed for use in a liquid environment or liquid working medium.

The process may involve fixing the lens or lens assembly within a fixture included as part of the apparatus. The process may then involve introducing an amount of the liquid medium into the fixture such that the liquid medium abuts the lens or lens assembly. The liquid medium may then be enclosed such that it is retained against the lens or lens assembly and no air bubbles are present. The process takes advantage of the small size of the lens assembly being focused to use capillary action to introduce the liquid medium, effectively eliminating the trapping of air between the liquid medium and the surface of the lens. For example, liquid introduction by capillary action may be used for lens assemblies having diameters of about 1mm to about 3mm in diameter. Additionally, the liquid medium may be enclosed and retained by a transparent plate that creates no lensing effect on the image transmitted through the lens or lens assembly. The imaging surface may then be adjusted until it is substantially on the image plane of the lens or lens assembly in the fixture.

FIG. 72 depicts a top down view of part of an example fixture which may be placed into a larger apparatus used for determining the proper spatial arrangement. A plate or block **602** is shown in **FIG. 72**. The plate **602** may be made of any suitable material, such as glass (e.g., glass microscope slide). Preferably, the plate **602** is of a material which will not degrade, dissolve, or become otherwise compromised when it comes into contact with the liquid which the lens or lens assembly is designed to work in. The plate **602** may be made of a dark material or may include at least one darkened region.

The plate **602** has a defined thickness and includes an aperture or a void **604**. The aperture **604** extends through the entirety of the plate **602**. The aperture **604** is sized and shaped to accept a lens or lens assembly. As shown, a gasket **606** may also be include. The gasket **606** may surround the void **604**. The gasket **606** may, for example, be an o-ring. Other embodiments may use any other suitable gasket **606**.

The progression of block diagrams in **FIGS. 73-75** conceptually depict an example process which may be used to assemble a completed fixture **600** (shown in **FIG. 75**). The process depicted in **FIGS. 73-75** encloses a lens or the objective lens of a lens assembly **354** in a wet environment or liquid working medium. For illustrative purposes, **FIGS. 73-75** depict a number of cross-sectional views taken at line **73-73** of **FIG. 72**.

As shown in **FIG. 73**, the lens or lens assembly **354** may be introduced into the aperture or void such that its outer surface or an outer lens element is situated within the interior volume of the void **604**. In this example, an inner surface of the lens is defined to be that surface of the lens assembly or element that faces the sensor, and an outer surface or an outer lens element is defined to be that surface of the lens assembly or element that faces the plate or its aperture/void. Optionally, the void **604** is chamfered or countersunk such that it widens as it extends toward the bottom face of the plate **602**. Once the lens or lens assembly **354** has been introduced, the gasket **606** may create a fluid impermeable seal between the lens or lens assembly **354** and the top of plate **602**. The gasket **606** may also serve to hold the lens or lens assembly **354** in place.

A volume of liquid or working medium **608** may then be inserted into that portion of the void **604** not occupied by the lens. The volume of liquid **608** inserted is preferably greater than the air volume in the void **604**. The liquid **608** introduced may be of the type in which the lens or lens assembly **354** is designed to function, such as, e.g. water or saline solution. The aperture or void **604** is sufficiently small that liquid can move to fill the void via capillary action of the liquid along the surfaces of the outer lens and contiguous surfaces of the plate defining the void. Using this method, the migration of the liquid into the void completely displaces any air, thus forming a completely air-free environment in the interface between the liquid and the surface of the lens within the void. Thus any distortions created by air against the surface of the lens during the alignment of the lens with the sensor can be eliminated. The liquid **608** shown in **FIG. 74** has sufficient surface tension that a droplet may hang from the void **604** against the force of gravity. For liquids with differing surface tensions, the plate **602** may be flipped over such that gravity is not an issue when the liquid **608** is placed in the void **604**. As shown, the liquid **608** wets or

contacts the lens or objective lens of a camera assembly **354**. Also as shown, it is ideally desirable that the liquid **608** includes no air bubbles.

Referring now to **FIG. 75**, once liquid **608** has been introduced, a second plate **610** such as a plastic or glass cover slip may be placed against a surface of the first plate **602**. This may be similar to wet mounting a microscope slide. As shown, the second plate **610** encloses the liquid **608** in the void **604**. The second plate **610** may be held against the first plate **602** by surface tension of the liquid **608**. In other embodiments, the second plate **610** may be actively held in place. Such embodiments may be desirable in instances where the lens or lens assembly **354** is designed for use in a liquid with a lesser degree of surface tension.

The second plate **610** preferably is made from a material which is optically clear at the desired wavelengths (e.g. transparent for visual optical purposes). Additionally, it may be desirable that the second plate **610** be made from a material which will not degrade, dissolve, or become otherwise compromised when it comes into contact with the liquid which the lens or lens assembly **354** is designed to work in. The second plate **610** may also be planar as shown in **FIG. 75**. This may be desirable to ensure that no lensing effect is created by the second plate **610**.

Once the working medium has been enclosed such that it is retained against the lens or lens assembly **354**, the fixture **600** may be completed. Determinations of the focal length or image plane may then be made as described and shown in relation to **FIG. 76**. A reference object **612** may be placed in the field of view of the lens or lens assembly **354** at a desired distance from the lens assembly **354**. The desired distance may be the intended distance from the subject to the lens or lens assembly **354** during usage of the lens assembly **354**. The reference object **612** may be any suitable reference. Various embodiments may, for example, use a reference grid, cross hairs, checkerboard, dot arrangement, image, etc. In **FIG. 76**, the reference object **612** is conceptually illustrated as a solid line. Light from the reference object **612** may be transmitted through the lens or lens assembly **354**. An image **614** of the reference object **612** will be in focus at the image plane of the lens or lens assembly **354**.

An image sensor **616** is also shown in **FIG. 76**. An image sensor **616** may be adjusted until its imaging surface is approximately in line with the image plane or acceptably within the depth of focus of the lens or lens assembly **354**. While moving the image sensor **616**, a user may monitor the image captured by the image sensor **616** on a display **618** until the image is in acceptable or crisp focus. In alternate embodiments, an

image sensor **616** may remain stationary while the fixture **600** and reference object **612** are moved relative to the image sensor **616**.

In some embodiments, the focusing process may not be a manual process. In such embodiments, adjustment of an image sensor **616** may be executed by a computer which, for example, moves the image sensor **616** to the image plane using an auto-focusing algorithm. In one such example, a passive auto focus system using contrast detection may be used. In such an embodiment, the image sensor **616** may be adjusted until a point of maximum intensity difference between adjacent pixels is found.

Once the imaging surface of the image sensor **616** is approximately aligned with the image plane of the lens or lens assembly **354**, the image sensor **616** and lens or lens assembly **354** may be secured in fixed spatial relation to one another. This may be done by any suitable method.

In a specific embodiment, shown in **FIG. 77** and **78** the image sensor **616** may be secured in fixed spatial relation to a lens assembly **354** by glue, adhesive or another suitable agent. As shown in **FIG. 77**, the lens assembly **354** and the image sensor **616** are shown separated from one another. As described above, the distance between the lens assembly **354** and the image sensor **616** may be varied until the desired focus is achieved. Once the appropriate distance is determined, the two may then be secured together as depicted in **FIG. 78**. As shown, there is a small space between the lens assembly **354** and the image sensor **616**. A bead of glue **1180** has been applied between the flange of the lens assembly and the image sensor **616**. This bead of glue **1180** serves to secure the image sensor **616** to the lens assembly **354** at the appropriate distance from the lens assembly **354**.

FIG. 79 depicts a specific example apparatus **1200** for determining the proper spatial arrangement of a lens or lens assembly and an image sensor (or other desired destination or imaging surface, e.g. a film plate or holder for a piece of film) associated with the lens or lens assembly. As shown, the apparatus **1200** includes an image sensor mount **1202**. An image sensor (not shown in **FIG. 79**) may be mounted to the image sensor mount **1202**. The apparatus **1200** also includes a fixture holder **1204**. The fixture holder **1204** may hold a fixture **600**. The fixture **600** may be assembled following a process such as that shown and described in relation to **FIGS. 72-75**. The fixture holder **1204** may also be configured to hold a reference object **612**. A close up view of the fixture holder **1204** is shown and described in **FIG. 80**.

The apparatus **1200** also includes spatial adjusters **1206** configured to adjust the spatial locations of the image sensor mount **1202** and the fixture holder **1204** relative to one

another. In the example embodiment shown in **FIG. 79**, the spatial adjusters **1206** are micrometer adjusters. In other embodiments, other varieties of spatial adjusters **1206** may be used. In some embodiments, spatial adjusters **1206** may only be included for one of the image sensor mount **1202** or the fixture holder **1204**. A user may adjust the spatial orientation of the image sensor holder **1202** and fixture holder **1204** relative to one another using the spatial adjusters **1206**. As described in relation to **FIG. 76**, this may be done until the imaging surface of the image sensor is approximately in line with the image plane of the lens or lens assembly.

FIG. 80 depicts a close up view of the fixture holder **1204** shown in **FIG. 79**. As shown, the fixture holder **1204** includes a recess **1230** in its top face. This recess **1230** may help retain and properly orient a fixture on the fixture holder **1204**. Also shown are two alignment features **1232**. The alignment features **1232** may help to properly orient a fixture on the fixture holder **1204**.

In the example embodiment in **FIG. 80**, the fixture holder **1204** includes a void **1234**. The void **1234** may be sized and shaped to allow a clear field of view for a lens or lens assembly included in an assembled fixture placed on the fixture holder **1204**. A number of slots **1236** are also included in the fixture holder **1204**. A reference object may be inserted into any of the desired slots **1236**. The slots **1236** are disposed such that a reference object may be placed at predetermined distances from a fixture in place on the fixture holder **1204**.

The progression of **FIGS. 81-82** depict an example process which may be used to assemble a completed fixture **600** (shown in **FIG. 82**) and place the fixture **600** into a larger apparatus such as the apparatus **1050** shown in **FIG. 79**. **FIG. 81** depicts a front view of a plate **602**. A lens assembly **354** is also shown in **FIG. 81**. As shown, the lens assembly **354** includes a flange which sits on top of the gasket **606**. The flange may be helpful in creating a fluid seal with the gasket **606**. The flange may cooperate with the gasket **606**, such that the gasket **606** acts as a stop which helps to position the lens assembly **354** such that it protrudes a desired depth into the plate **602**.

FIG. 82 depicts a bottom perspective view of the plate **602**. As shown, a small portion of the lens assembly **354** is also visible protruding into the void **604** in the plate **602**. An amount of liquid or working medium **608** is also shown being placed into the void **604**. In the example in **FIG. 82**, the liquid **608** is introduced via a syringe **1220** and hypodermic needle **1222**. The liquid **608** may be inserted into the void **604** using any other suitable means such as a dropper, pipette, etc.

It may be desirable that the liquid be introduced such that it first contacts a side wall of the void **604**. The volume of liquid may then be increased such that the liquid wicks around the lens assembly **354** before filling the center of the void **604** and eventually forming a droplet as shown in **FIG. 82**. This wicking may help to minimize the trapping of air bubbles within the void **604**. It may also help to ensure that the lens assembly **354** is not damaged, for example by the hypodermic needle **1222** during the introduction of the liquid.

Once liquid **608** has been introduced, a second plate **610** may be brought into contact with a surface of the first plate **602** similar to wet mounting a microscope slide. The second plate **610** encloses the liquid **608** in the void **604**. **FIG. 83** depicts a front view of the plate **602**, as it is being placed onto a fixture holder **1204**. The fixture holder **1204** depicted is the same as the example fixture holder shown in **FIGS. 79-80**. A second plate **610** is in place on the fixture holder **1204**. As shown, the recess **1230** is sized to accept and locate the second plate **610**. Referring now also to **FIG. 84**, the first plate **602** may be brought into contact with the second plate **610** to complete assembly of the fixture **600**. The alignment features **1232** may serve to properly locate the first plate **602** on the fixture holder **1204**.

FIG. 85 shows another example embodiment of the endoscope **10**. Only an inner sheath **312** is shown in **FIG. 85**. Additionally, the bottom section **22** of the handle proximal section **16**, and half (**30a**) of the handle distal section **30** are visible. As shown, the endoscope **10** includes a handle-enclosed printed circuit board **430a** (also referred to herein as handle PCB **430a**). A power/HDMI cable **432**, optical fibers **364**, and irrigation line **434** are also shown. **FIG. 85** shows example routing pathways for the power/HDMI cable **432**, optical fibers **364**, and irrigation line **434**. As shown, the power/HDMI cable **432**, optical fibers **364**, and irrigation line **434** enter the endoscope **10** through an opening **60** at the rear or butt of the handle proximal section **16**. This entry point may be more advantageous than a handle side-entry point because it reduces the potential of various cords and cables to get tangled as the insertion section is rotated relative to the handle proximal section **16**.

In some embodiments, the power/HDMI cable **432**, optical fibers **364**, and irrigation line **434** may enter the endoscope **10** at an angle with respect to the rear handle opening **60**. Such an arrangement would afford an ergonomic benefit to the user by allowing the user to grasp a greater portion of the rear portion of the handle proximal section **16**.

As shown, the power/HDMI cable **432**, optical fibers **364**, and irrigation line **434** extend over a portion of the handle PCB **430a** after entering the handle proximal section **16**. The power/HDMI cable **432** plugs into a power/HDMI connector **430b** on the handle PCB **430a**. The power/HDMI cable **432** may provide power to the endoscope **10**. Image data may

pass to the handle PCB **430a** via the flex cable **250**. The power/HDMI cable **432** may transmit visual data collected by the endoscope **10** to an external graphical user interface display (not shown). The optical fibers **364** and irrigation line **434** extend under the handle PCB **430a** and follow the pathways previously described. In embodiments in which the endoscope **10** is disposable, the power/HDMI cable **432**, optical fibers **364**, and irrigation line **434** may all be included as disposable components to ensure sterility or save on the costs of re-use.

A control wire **91** for button **90** is also shown in **FIG. 85**. As shown, the control wire **91** passes through an orifice in the sealing member **210**. The control wire **91** is in communication with the handle PCB **430a**. Also as shown in **FIG. 85** the handle PCB **430a** includes a handle PCB flex cable **430e**. The handle PCB flex cable **430e** connects to a handle PCB portion **430f**, permitting PCB portion **430f** to be oriented at an angle (e.g., perpendicular) to the rest of the handle PCB **430a**. When assembled, the flex attached handle PCB portion **430f** may be disposed between the two potentiometers **122** of the example rotation sensing assembly **150** (see **FIG. 7**).

In some embodiments, the handle PCB **430a** may include an image or graphic processing unit **430c**. Preferably, however, the image processing unit **430c** may be located external to the endoscope **10**. The image processing unit **430b** may function as an electronic righting mechanism for the endoscope **10**. The image processing unit **430c** may receive the image captured by the image sensor **380** which is sent from the image sensor **380** to the handle PCB **430a** via the flex cable **250**. In a preferred embodiment, the image captured by the image sensor **380** is then transmitted to the image processing unit **430c** external to the endoscope **10** via the power/HDMI cable **432**. The image processing unit **430c** may also receive a signal from the rotation sensing assembly **150**. In some embodiments, an analog to digital converter **430d** may be included on the handle PCB **430a** to convert the signal from the rotation sensing assembly **150**. The image processing unit **430c** may use the signal from the rotation sensing assembly **150** to electronically “right” the image to a desired orientation. In some embodiments, image may be rotated by the image processing unit **430c** so that the image is displayed as if it were captured from the user’s point of view. In some embodiments, the image processing unit **430c** may also correct for the effects of lens distortion.

Unless the orientation of an image displayed on a graphical user interface is first corrected, the displayed image may be disorienting to the user. By defining a direction according to the user’s point of view, the image processing unit **430c** may use data from the

rotation sensing assembly **150** to automatically rotate images so that images correspond with the user's point of view.

FIG. 86 shows an example block diagram of an imaging system. As shown, the imaging system includes an image sensor **380** that captures an image. The image captured by the image sensor **380** may be passed via a camera serial interface **450** (for example a MIPI camera serial interface) to an image processing unit **452**. The image processing unit **452** (IPU) may then move image frames to other hardware components in the imaging system. Other hardware components may include, but are not limited to, a memory device and a graphical processing unit **430c** (GPU). The graphical processing unit **430c** may correct any distortion caused by the lens assembly **354**.

In some embodiments, the graphical processing unit **430c** may correct this distortion by representing the image as a texture on a surface that has been loaded into the graphical processing unit **430c**. This may cause the image to be adjusted or stretched in a manner which corrects and/or removes the distortion introduced by the lens assembly **354**. In embodiments where the image is righted, the graphical processing unit **430c** may then rotate the corrected image via input from a rotation sensing assembly **150** (see, for example, **FIG. 7**). For example, the measurement from a rotation sensing assembly **150** may be passed to the graphical processing unit **430c** through an analog to digital converter **430d** (see, for example, **FIG. 85**). The signal from the analog to digital converter **430d** may then be used to rotate the image to its righted orientation. In some embodiments, a user may be able to toggle image righting, distortion correction, and/or various other image manipulations which may be performed on or off. Image righting will be further described later in the specification in relation to **FIG. 87**.

The processed image from the image processing unit **430c** may then be displayed on a graphical user interface or display **454**. In some embodiments, the processed image from the image processing unit **430c** may be stored in a memory. In such embodiments, a user may capture images to be stored in memory for later recall by triggering a button **90**, for example. Some embodiments may include a video processing unit **456** which may encode the frames from the image sensor **380** into a recordable video format. In such embodiments, encoded video may then be stored in memory. A user may command the endoscope to initiate and stop video capture via interaction with a button such as button **90** as described above.

In some embodiments, the image processing unit **430c** may also subject a captured image to exposure feedback analysis. In specific embodiments, an image histogram may be

created from all the pixels of the image. The image histogram may then be used to tune the image or tune the exposure of subsequent images received by the image chip or sensor **380**. Such further processing by the image processing unit **430c** may help to reduce blown-out white areas of the image or underexposed dark areas of the image. Other means of tuning an image or images, such as, for example, tone mapping, etc. may also be used.

FIG. 87 depicts an example diagram illustrating how an image may be righted using input from a rotation sensing assembly **150** (see, for example, **FIG. 87**). As shown, a first block **2100** and a second block **2102** are depicted. Within each block **2100**, **2102** is an endoscope **10** having a field of view **2104**. The field of view **2104** of the endoscope **10** in the first block **2100** is oriented approximately 180 degrees from the endoscope **10** in the second block **2102**. This may be accomplished by rotating the distal end of the endoscope **10** relative to the proximal end of the endoscope **10**. In conventional endoscopes **10**, during rotation of the distal section relative to the proximal section, the image sensor does not rotate because the image sensor is housed in the proximal section. Thus, the endoscopes **10** shown in the first block **2100** and second block **2102** would both capture image **2106**.

In the various embodiments described herein where the image sensor **380** rotates with the distal end of the endoscope **2106**, this would not be the case. The endoscope **10** shown in the first block **2100** would capture image **2106**, while the same endoscope **10** rotated to the position shown in the second block **2102** would capture image **2108**. This is so because as the image sensor rotates with the distal end of the endoscope **10**, the image sensor will be caused to be upside-down. In this position, for example, the top of the image sensor will pick up what one accustomed to a conventional endoscope **10** would expect to be the bottom of the image.

In order to obviate the need for a user to acclimate to this, the image may be rotated in proportion to the degree of rotation of the distal end of the endoscope **10**. Thus the image may always be displayed in a way which would be expected by a user accustomed to conventional endoscopes **10**. This may prevent any possible confusion which may be caused by a rotating image sensor. It may also facilitate user adoption of such an endoscope **10**.

The illustrations provided by the drawings should be viewed as non-limiting examples of the inventions disclosed by this specification. The present disclosure is intended to embrace any alternatives, modifications and variances that may nevertheless encompass the novel features of the inventions disclosed herein.

The embodiments shown in the drawings are presented only to demonstrate certain examples of the disclosure. And the drawings are to be used only for illustrative purposes;

as such, the size of some of the elements may be exaggerated and not drawn to a particular scale. Additionally, elements shown within the drawings that have the same reference numbers may be identical elements or may represent similar or analogous elements, depending on the context.

Where the term "comprising" is used in the present description and claims, it does not exclude other elements or steps. Where an indefinite or definite article is used when referring to a singular noun, e.g. "a" "an" or "the", this includes a plural of that noun unless otherwise specifically stated. Hence, the term "comprising" should not be interpreted as being restricted to the items listed thereafter; it does not exclude other elements or steps, and so the scope of the expression "a device comprising items A and B" should not be limited to devices consisting only of components A and B. This expression signifies that, with respect to the present disclosure, the only relevant components of the device are A and B.

Furthermore, the terms "first", "second", "third" and the like, whether used in the description or in the claims, are intended to distinguish between similar elements and not necessarily to describe a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances (unless clearly stated otherwise) and that the embodiments of the disclosure described herein are capable of operation in other sequences and/or arrangements than are described or illustrated herein.

CLAIMS

1. An endoscope having a proximal handle assembly and a distal insertion shaft; the insertion shaft having a distal portion that includes a camera assembly; the insertion shaft comprising a liquid carrying conduit;
 - the camera assembly comprising an electronic image sensor;
 - the proximal handle assembly comprising a proximal housing and a distal housing;
 - the distal housing and the insertion shaft connected together and rotatable together relative to the proximal housing;
 - the liquid carrying conduit including a wired connection extending from the camera assembly to a printed circuit board attached to the distal housing, the wired connection being exposed to any liquids carried by the conduit; wherein
 - the proximal housing of the handle assembly comprises a liquid passageway in fluid communication with the liquid carrying conduit of the insertion shaft.
2. The endoscope of claim 1, wherein the wired connection comprises a communications cable.
3. The endoscope of claim 1, wherein the wired connection provides electrical power to the camera assembly.
4. The endoscope of claim 1, wherein the wired connection comprises a flex cable.
5. The endoscope of claim 1, wherein the camera assembly comprises a lens mounted over the electronic image sensor.
6. The endoscope of claim 1, wherein the camera assembly comprises a camera mount configured to rotate about an axis transverse to a longitudinal axis of the insertion shaft.
7. The endoscope of claim 6, wherein the camera mount is configured to rotate about an axis transverse to a longitudinal axis of the distal portion of the liquid carrying conduit.

8. The endoscope of claim 6, wherein the liquid carrying conduit includes one or more mechanical actuation cables extending from the distal housing to the camera mount, and wherein the insertion shaft is configured so that the one or more mechanical actuation cables are exposed to any liquids that flow within the liquid carrying conduit.
9. The endoscope of claim 1, further comprising a fiberoptic bundle extending from the camera assembly through the proximal handle assembly, and exiting from the proximal handle assembly, wherein the insertion shaft is configured so that the fiberoptic bundle is exposed to any liquids that flow within the liquid carrying conduit.
10. The endoscope of claim 1, wherein the proximal housing is configured to enclose the printed circuit board, and wherein the distal housing, printed circuit board, wired connection and camera housing are configured to rotate together relative to the proximal housing.
11. The endoscope of claim 1, further comprising a barrier positioned between the liquid carrying conduit of the insertion shaft and an internal space of the distal housing, the barrier configured to inhibit passage of liquid from the liquid carrying conduit into the distal housing of the handle assembly.
12. The endoscope of claim 11, wherein the barrier comprises a pass-through barrier that permits passage of an optical fiber bundle, mechanical actuation cable, or communications cable between the liquid carrying conduit and the distal housing of the handle assembly.