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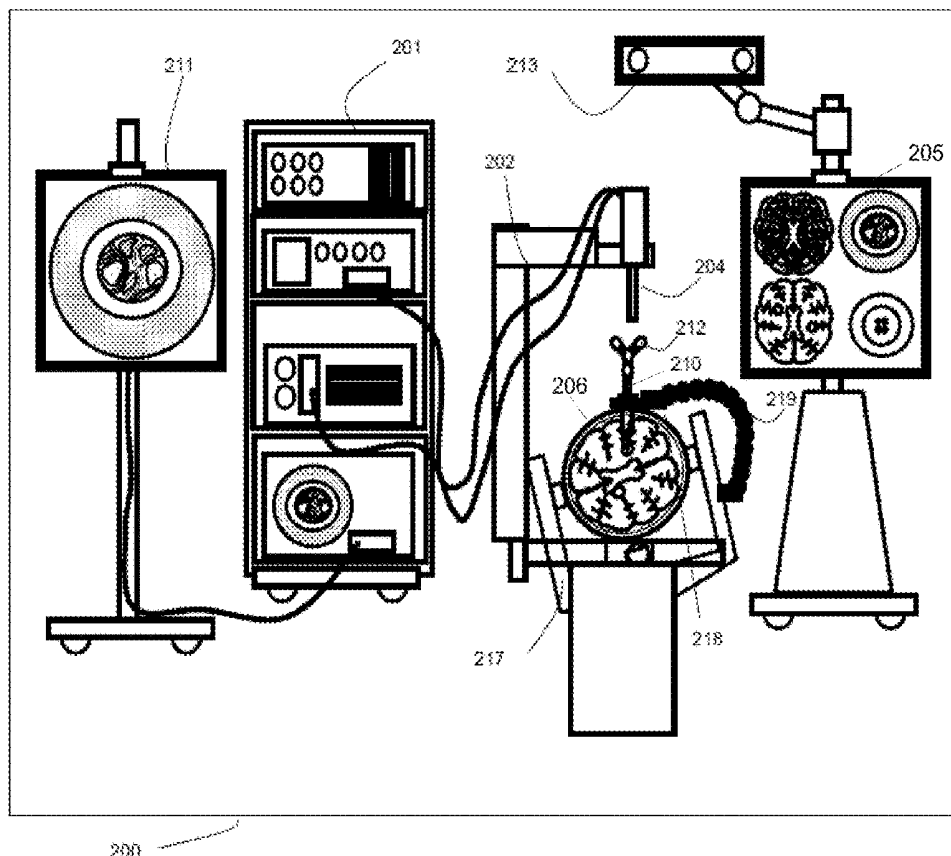
§ 371 (c)(1),

(2) Date: **Feb. 15, 2017**

(57)

**ABSTRACT**

A multispectral synchronized imaging system is provided. A multispectral light source of the system includes: blue, green and red LEDs, and one or more non-visible light sources, each being independently addressable and configured to emit, in a sequence: at least visible white light, and non-visible light in one or more given non-visible frequency ranges. The system further includes a camera and an optical filter arranged to filter light received at the camera, by: transmitting visible light from the LEDs; filter out non-visible light from the non-visible light sources; and otherwise transmit excited light emitted by a tissue sample excited by non-visible light. Images acquired by the camera are output to a display device. A control unit synchronizes acquisition of respective images at the camera for each of blue light, green light, visible white light, and excited light received at the camera, as reflected by the tissue sample.



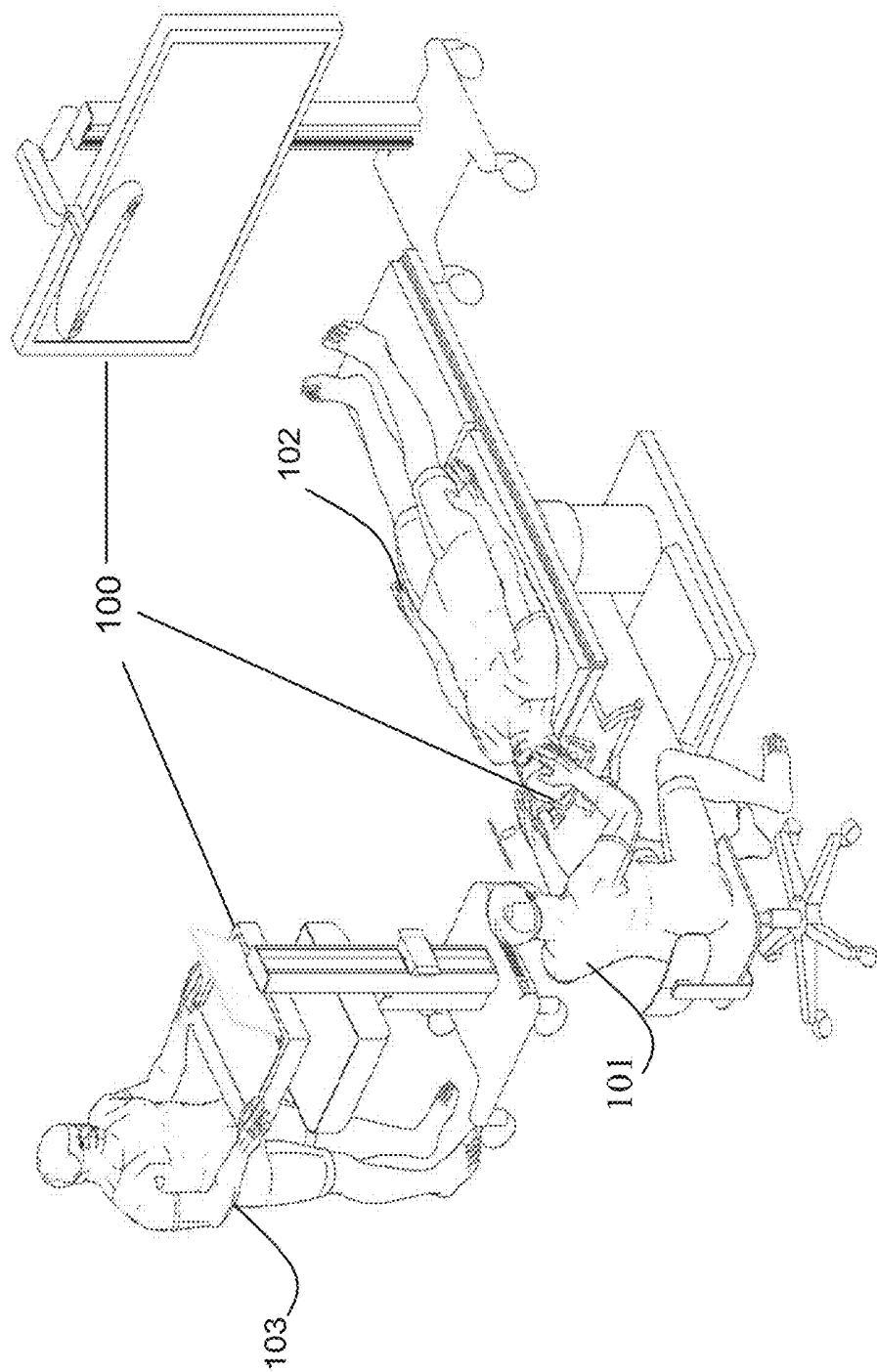


Figure 1

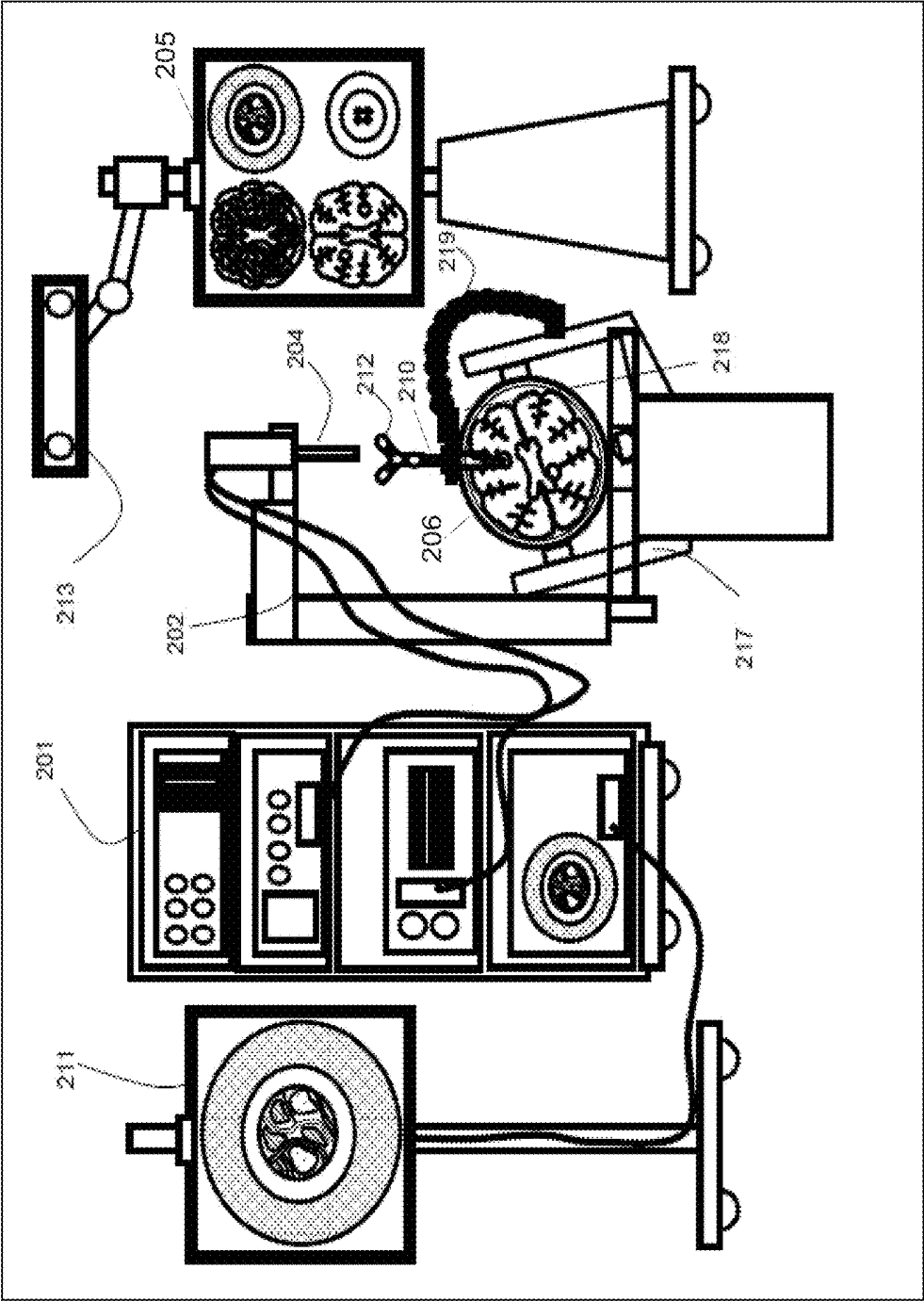


Figure 2

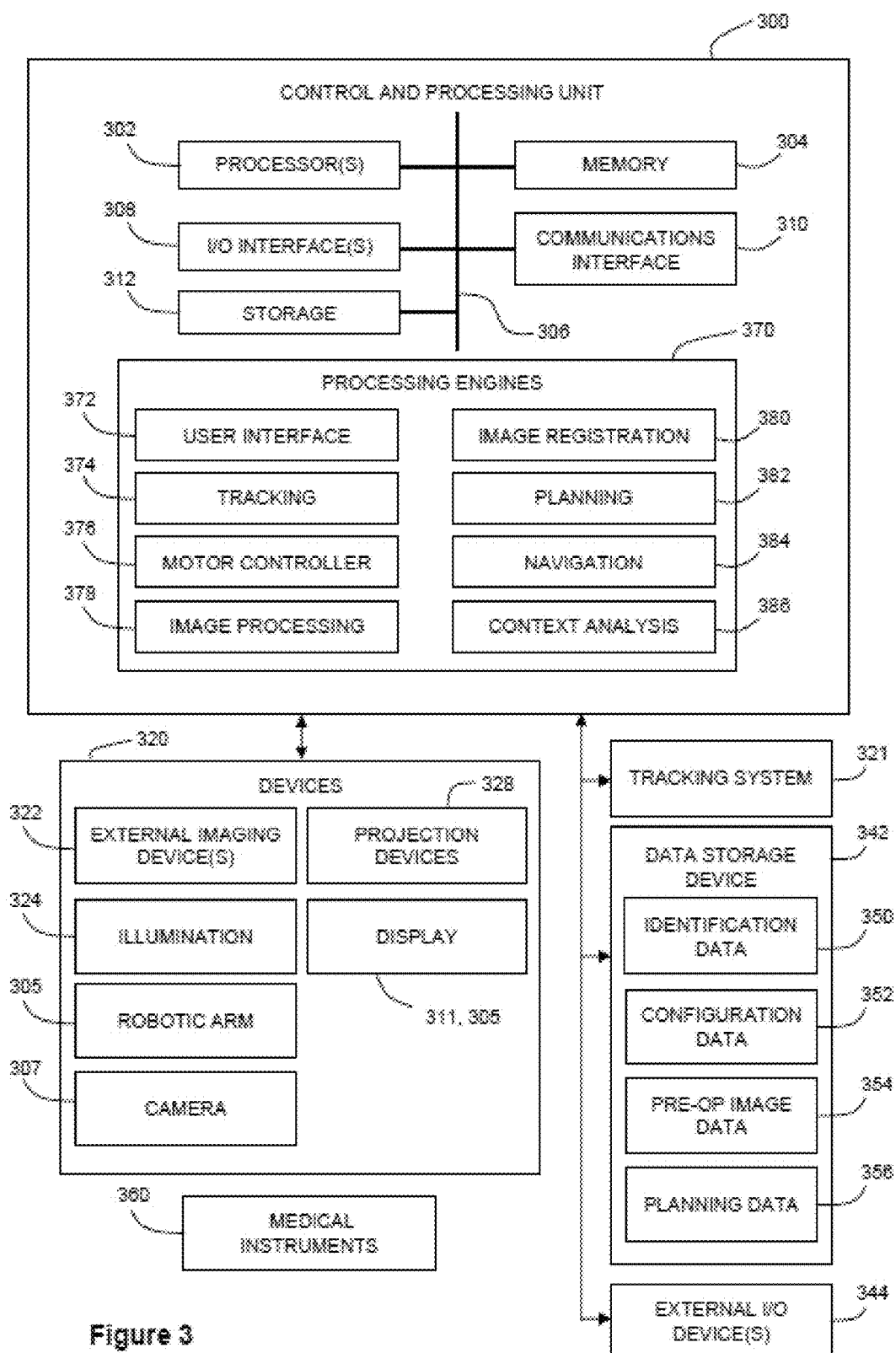


Figure 3

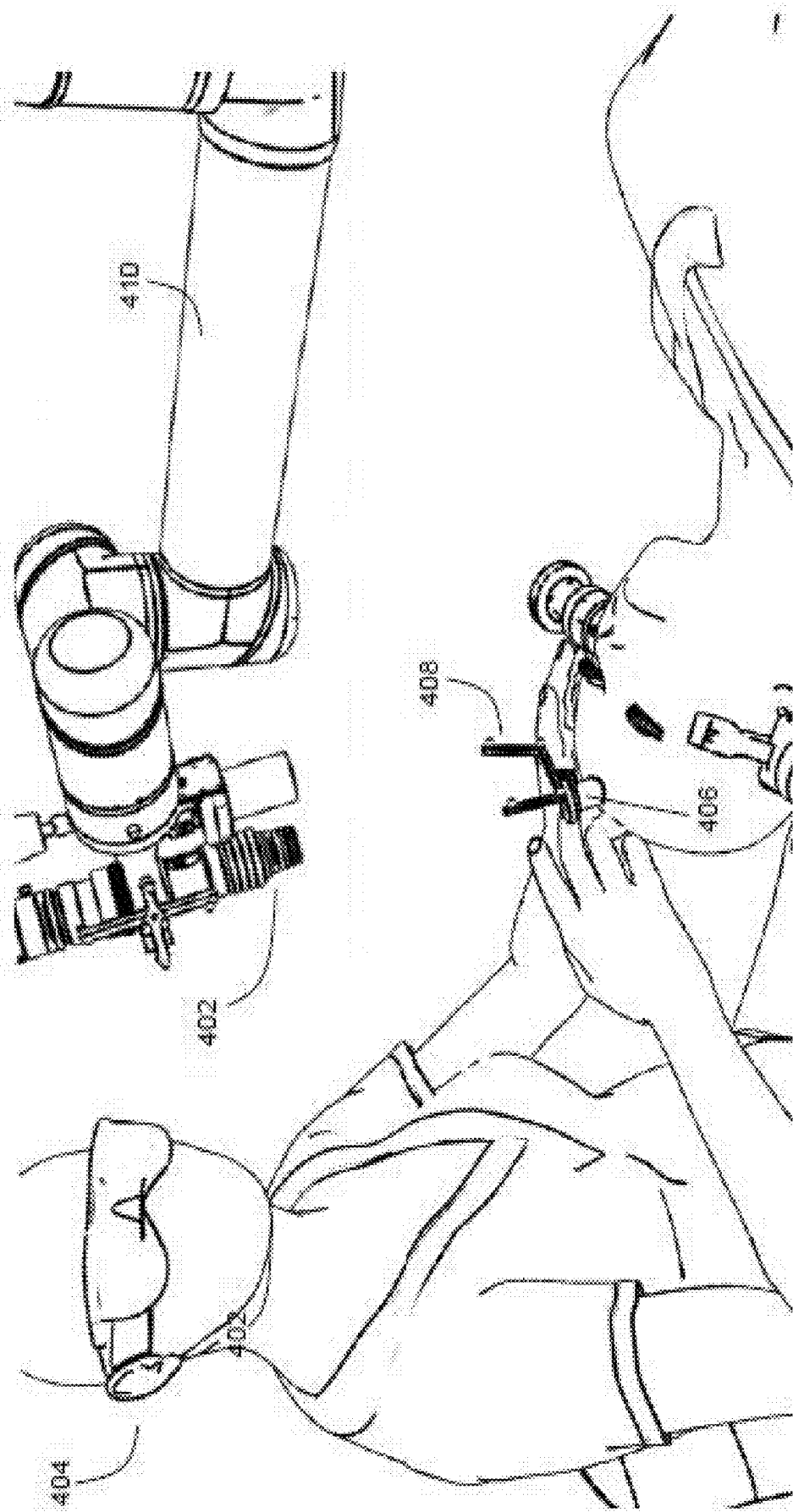


Figure 4

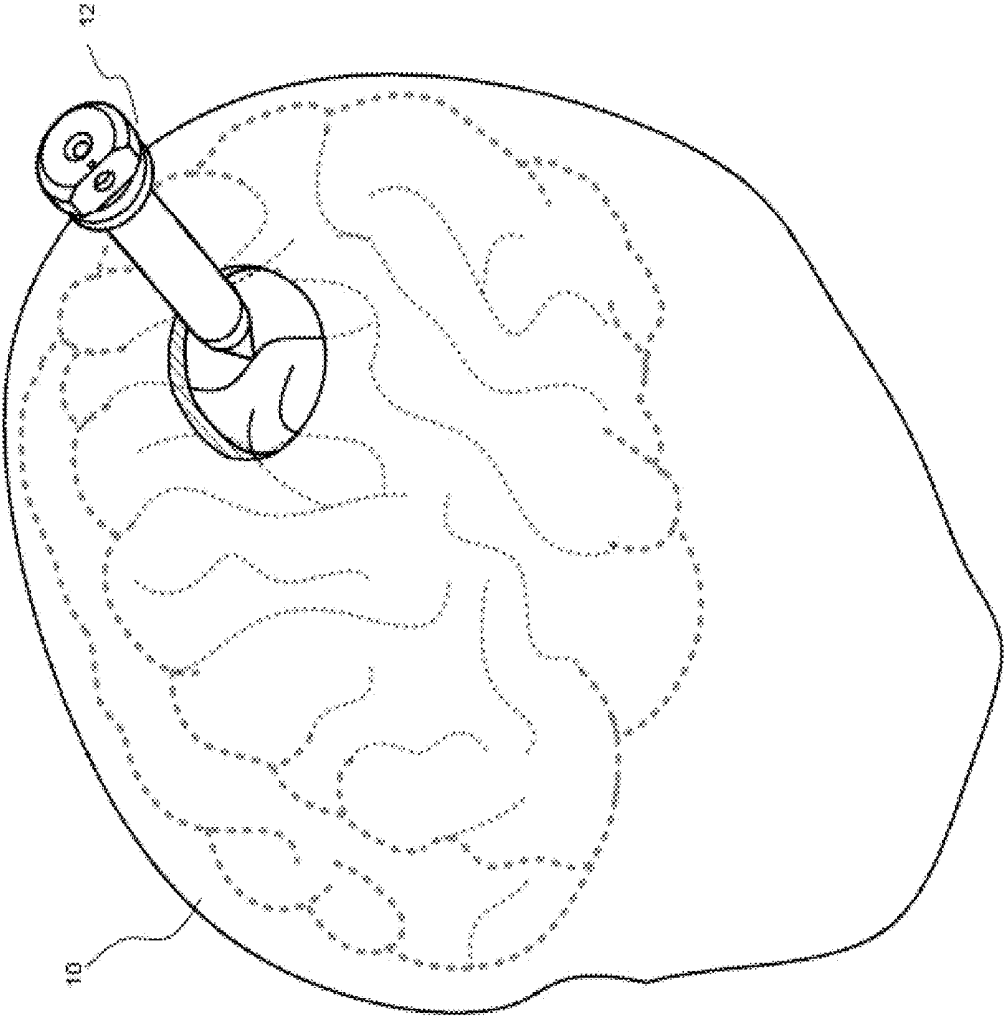


Figure 5

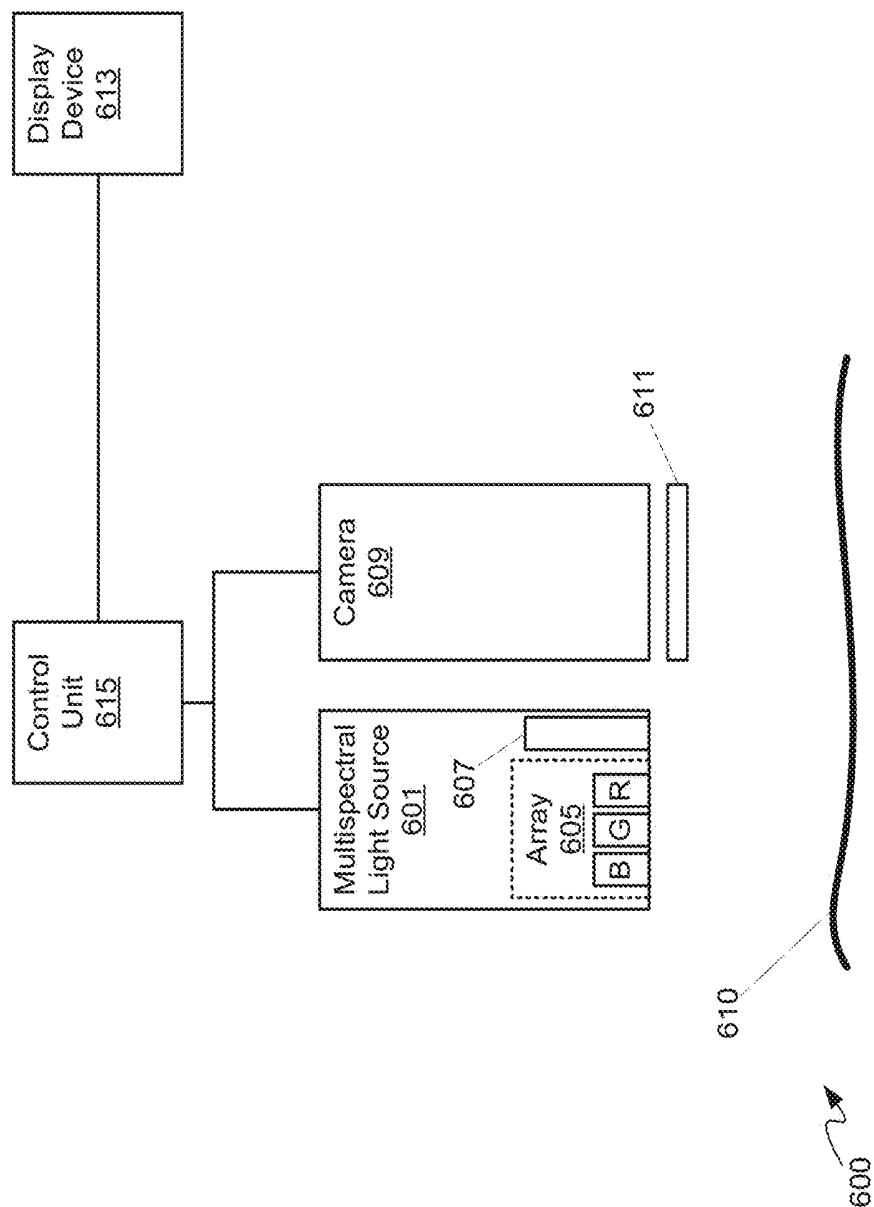


Figure 6

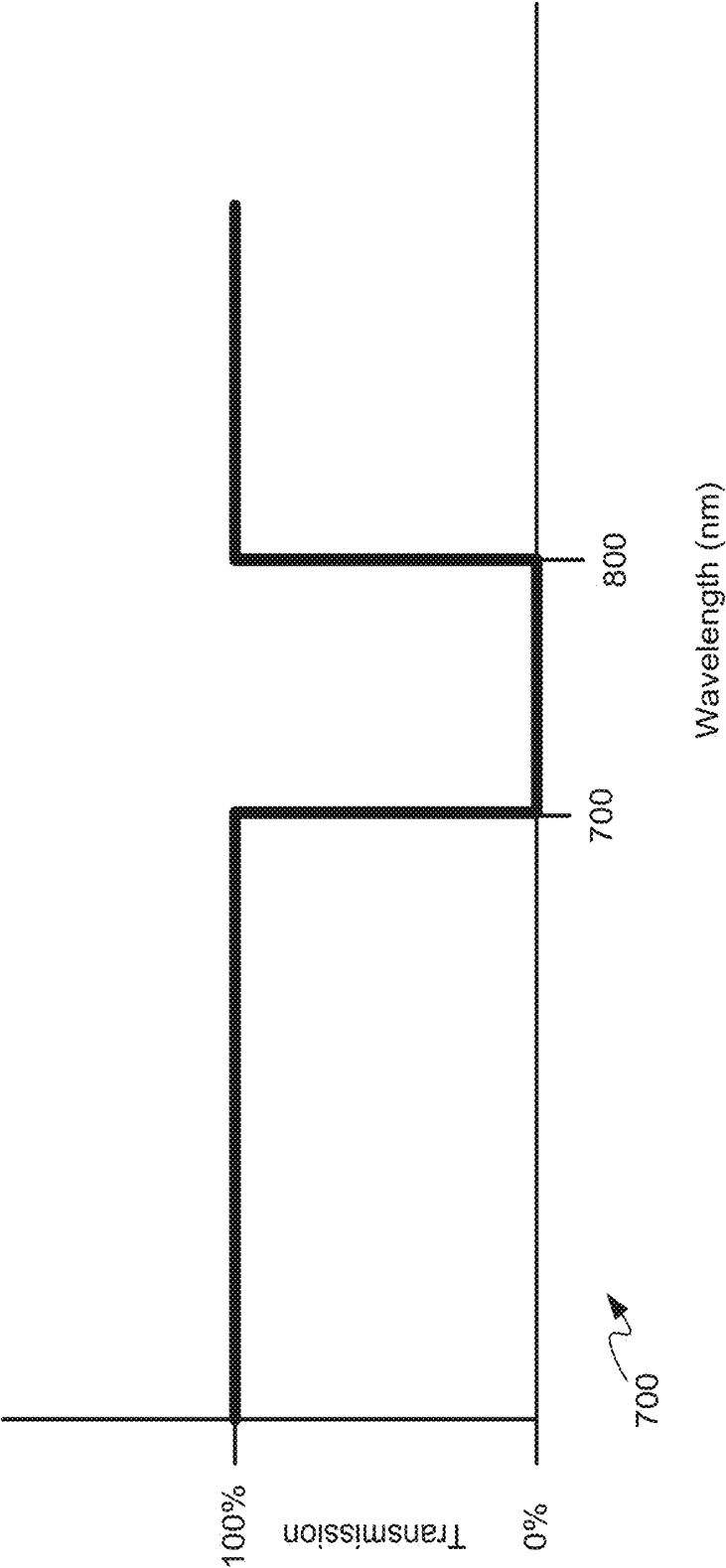


Figure 7

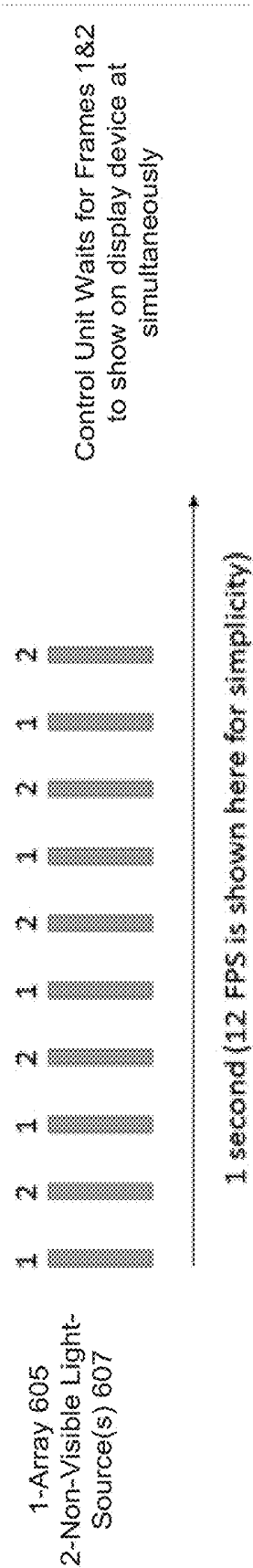


Figure 8

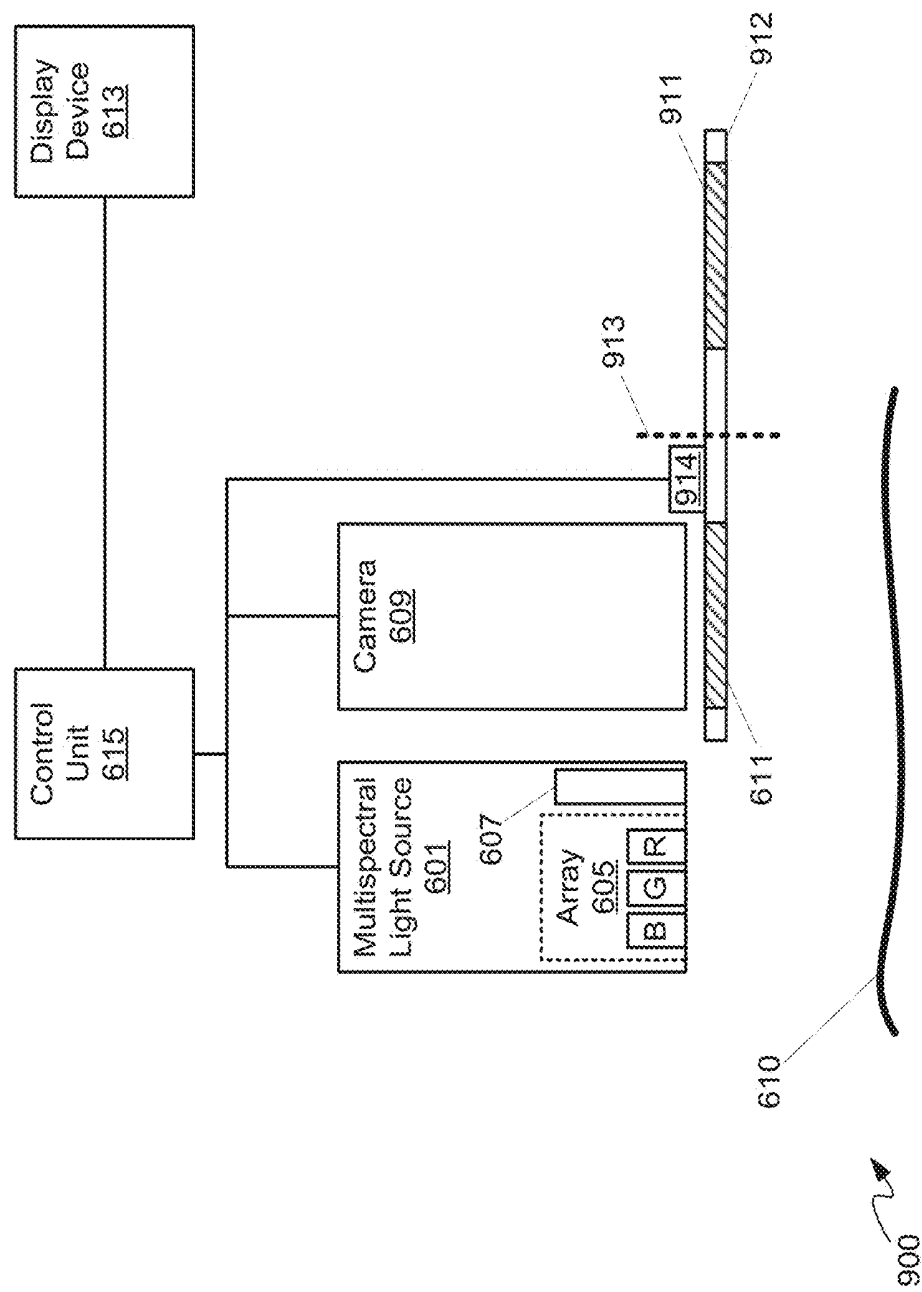


Figure 9

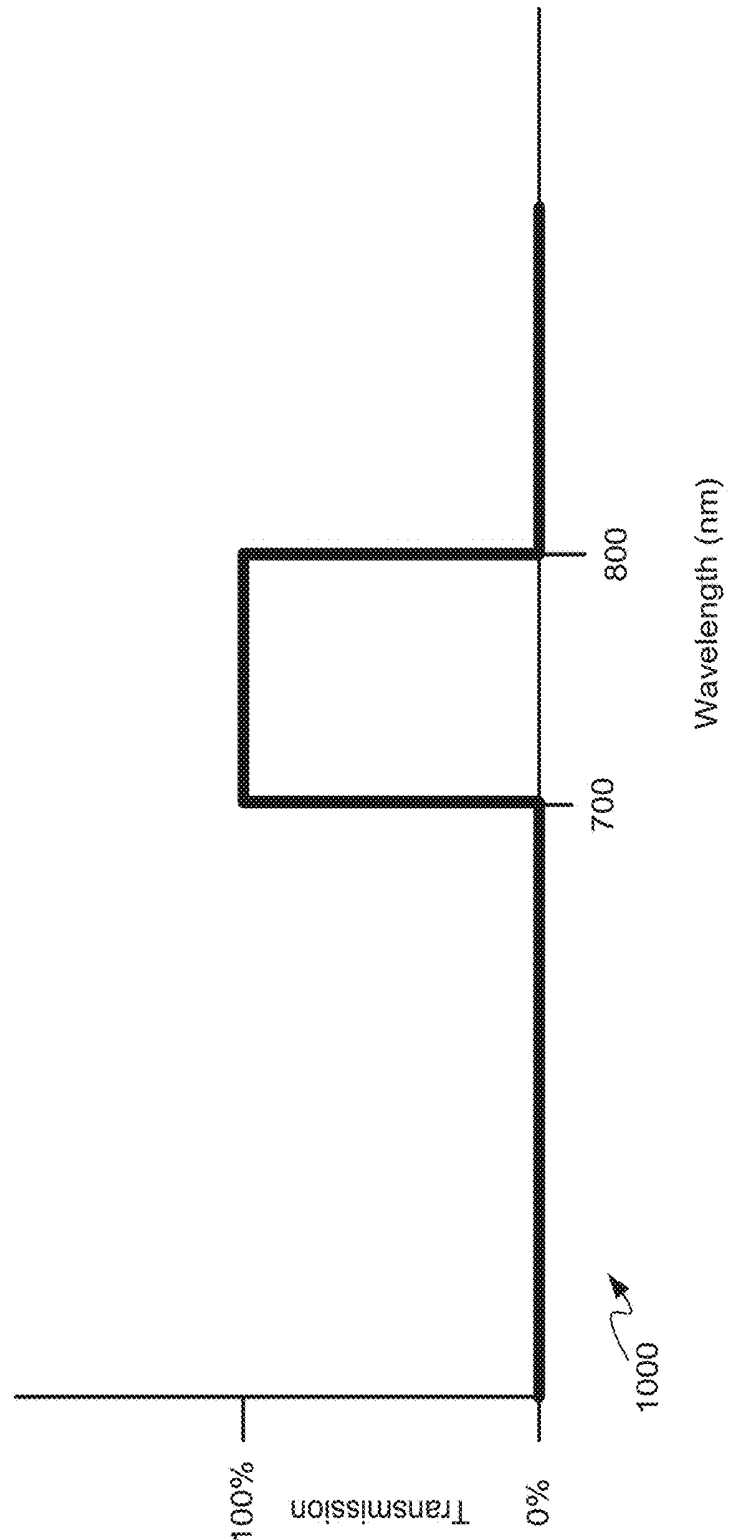


Figure 10

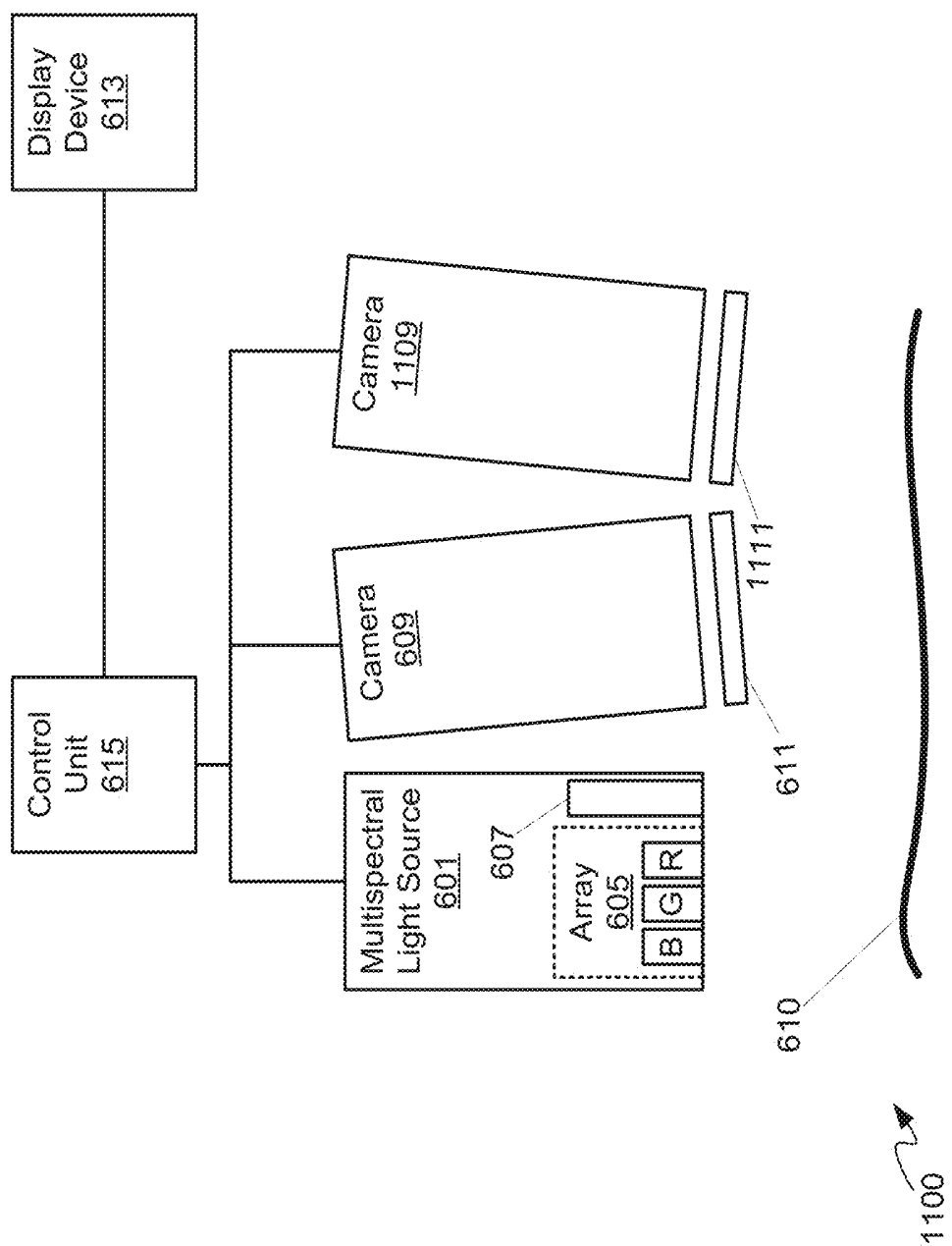


Figure 11

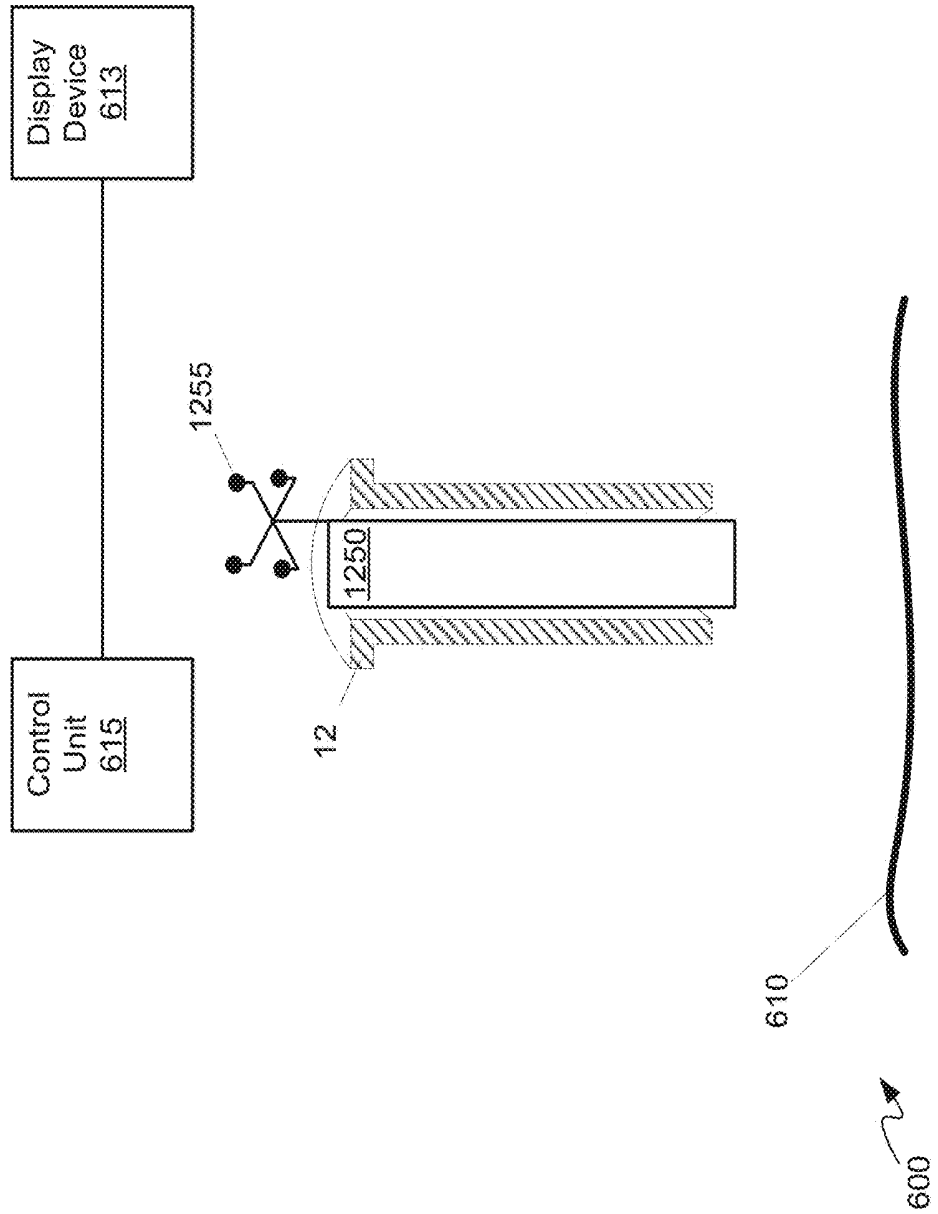


Figure 12

## MULTISPECTRAL SYNCHRONIZED IMAGING

### FIELD

**[0001]** The specification relates generally to medical imaging and methods for minimally invasive therapy and image guided medical procedures, and specifically to a system and method of multispectral synchronized imaging.

### BACKGROUND

**[0002]** Image guided medical procedures can include fluorescence guided surgery (FGS), which is a medical imaging technique used to facilitate the delineation of the tumor margin during surgery or vascular angiography. With the current mainstream technology, changing from normal white light surgery (WLS) to FGS requires a mechanical filter wheel for switching of the emission filter on the camera side and another filter wheel on the illumination side to constrict the wavelength to an optimal narrow band. This mechanical switching creates a significant delay that restricts the possibility of concurrent imaging of WLS and FGS. In addition, Indocyanine green (ICG) fluorescent dye, used in FGS, has an emission spectrum (820 nm-860 nm) can overlap with infrared tracking pulses used in intermittent tracking of surgical tools, which can create an artifact on the acquired image, restricting a concurrent tracking mode and ICG-FGS during surgery.

### SUMMARY

**[0003]** The present disclosure is generally directed to image guided medical procedures using an access port. This port-based surgery approach allows a surgeon, or robotic surgical system, to perform a surgical procedure involving tumor resection in which the residual tumor remaining after is minimized, while also minimizing the trauma to the intact white and grey matter of the brain. In such procedures, trauma may occur, for example, due to contact with the access port, stress to the brain matter, unintentional impact with surgical devices, and/or accidental resection of healthy tissue.

**[0004]** Hence, an aspect of the present specification provides a multispectral synchronized imaging system comprising: a multispectral light source comprising: a light emitting diode (LED) array comprising: at least one blue LED, at least one green LED and at least one red LED; and one or more non-visible light sources arranged side by side with the LED array, each of the at least one blue LED, the at least one green LED, the at least one red LED, and the one or more non-visible light sources being independently addressable such that the multispectral light source is configured to emit in a sequence: at least visible white light, and non-visible light in one or more given non-visible frequency ranges; a camera arranged to receive light from a tissue sample illuminated by the multispectral light source in the sequence; an optical filter arranged to filter the light from the tissue sample received at the camera, the optical filter configured to: transmit visible light from the LED array; filter out non-visible light from the one or more non-visible light sources in the one or more given non-visible frequency ranges; and otherwise transmit excited light emitted by the tissue sample under excitation by the non-visible light from the one or more non-visible light sources; a display device; and, at least one control unit configured to: control the

multispectral light source to emit the sequence; synchronize acquisition of respective images at the camera for each of blue light, green light, the visible white light, and the excited light received at the camera, as reflected by the tissue sample; and, output the respective images in a respective sequence to the display device.

**[0005]** The one or more non-visible light sources can comprise an ultraviolet (UV) LED, and the optical filter can be configured to filter out UV light from the UV LED, and transmit the excited light emitted by the tissue sample under excitation from the UV LED.

**[0006]** The one or more non-visible light sources can comprise an ultraviolet (UV) light source and an infrared (IR) light source, and the optical filter can be configured to: transmits light in a fluorescent range of about 430 nm to about 700 nm, and from about 820 nm to about 860 nm to allow light from emission of one or more of PpIX and ICG at the tissue sample to be imaged by the camera; and block light from both the UV light source and the IR light source from entering the camera

**[0007]** The one or more non-visible light sources can comprise an infrared (IR) laser, and the optical filter can be configured to filter out IR light from the IR laser, and transmit the excited light emitted by the tissue sample under excitation from the IR laser.

**[0008]** The one or more non-visible light sources can comprise an infrared (IR) laser, and the system can further comprise a second optical filter, exchangeable for the optical filter under control by the at least one control unit; the second optical filter can be configured to transmit light from the IR laser. The IR laser can be operable in one of a diffused mode, when the optical filter is filtering light to the camera, and a speckled mode when the second optical filter is filtering light to the camera. The IR laser can be operable in a speckled mode when the second optical filter is filtering light to the camera, and the sequence can include green light emitted from the green LED, and blue light emitted from the blue LED, when the optical filter is filtering light to the camera, speckled laser light from the IR laser in the speckled mode, the green light and the blue light used for functional imaging of blood flow in the tissue sample.

**[0009]** The sequence can comprise the visible white light, and the non-visible light alternating.

**[0010]** The sequence can comprise the visible white light, green light, blue light, and the non-visible light alternating.

**[0011]** The sequence can comprise: one or more of a user-configured sequence; and simultaneous emission of light from two or more of the at least one blue LED, the at least one green LED, the at least one red LED.

**[0012]** Respective relative intensity of each of the at least one blue LED, the at least one green LED, the at least one red LED can be adjusted to change one or more of: color temperature of the visible white light; and color rendering of the respective images at the display device.

**[0013]** The multispectral synchronized imaging system can further comprise: a second camera arranged relative to the camera to acquire three-dimensional images of the tissue sample; and a second optical filter can be configured to: transmit visible light from the LED array and transmit non-visible light from the one or more non-visible light sources in the one or more given non-visible frequency ranges. The one or more non-visible light sources can comprise an IR laser operable in one of a diffused mode and a speckled mode. The camera and the second camera can be

configured to capture images independent of one another. Image capture times of each the camera and the second camera can be off-set with respect to one another.

[0014] The at least one control unit can be further configured to output the respective images in the respective sequence to the display device at a rate where the respective images appear simultaneously rendered to a human vision system.

[0015] The camera can comprise an optical camera.

[0016] The multispectral synchronized imaging system can further comprise a thermal camera arranged to receive the light from the tissue sample illuminated by the multispectral light source in the sequence.

[0017] The at least one control unit can comprise one or more ports configured for communicate with one or more of: external computing devices; electronic surgical devices; trackers; and infrared trackers.

[0018] The camera and the optical filter can be configured for use with a surgical port configured for corridor based surgery.

#### BRIEF DESCRIPTIONS OF THE DRAWINGS

[0019] For a better understanding of the various implementations described herein and to show more clearly how they may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings in which:

[0020] FIG. 1 shows an example operating room setup for a minimally invasive access port-based medical procedure, according to non-limiting implementations.

[0021] FIG. 2 is a block diagram illustrating components of a medical navigation system that may be used to implement a surgical plan for a minimally invasive surgical procedure, according to non-limiting implementations.

[0022] FIG. 3 depicts a block diagram illustrating components of a planning system used to plan a medical procedure that may then be implemented using the navigation system of FIG. 2, according to non-limiting implementations.

[0023] FIG. 4 depicts an example implementation port based brain surgery using a video scope, according to non-limiting implementations.

[0024] FIG. 5 depicts insertion of an access port into a human brain, for providing access to interior brain tissue during a medical procedure, according to non-limiting implementations.

[0025] FIG. 6 depicts a multispectral synchronized imaging system, according to non-limiting implementations.

[0026] FIG. 7 depicts an example transmission spectrum of an optical filter in the multispectral synchronized imaging system of FIG. 6, according to non-limiting implementations.

[0027] FIG. 8 depicts a light emission sequence of a multispectral light source of the multispectral synchronized imaging system of FIG. 6, according to non-limiting implementations.

[0028] FIG. 9 depicts a multispectral synchronized imaging system adapted for use with multiple optical filters, according to non-limiting implementations.

[0029] FIG. 10 depicts an example transmission spectrum of one of the optical filters in the multispectral synchronized imaging system of FIG. 9, according to non-limiting implementations.

[0030] FIG. 11 depicts a multispectral synchronized imaging system adapted for use with two cameras, according to non-limiting implementations.

[0031] FIG. 12 depicts a multispectral synchronized imaging system adapted for use with an access port for corridor based surgery, according to non-limiting implementations.

#### DETAILED DESCRIPTION

[0032] Various implementations and aspects of the specification will be described with reference to details discussed below. The following description and drawings are illustrative of the specification and are not to be construed as limiting the specification. Numerous specific details are described to provide a thorough understanding of various implementations of the present specification. However, in certain instances, well-known or conventional details are not described in order to provide a concise discussion of implementations of the present specification.

[0033] The systems and methods described herein may be useful in the field of neurosurgery, including oncological care, neurodegenerative disease, stroke, brain trauma and orthopedic surgery; however persons of skill will appreciate the ability to extend these concepts to other conditions or fields of medicine. It should be noted that the surgical process is applicable to surgical procedures for brain, spine, knee and any other suitable region of the body.

[0034] Various apparatuses and processes will be described below to provide examples of implementations of the system disclosed herein. No implementation described below limits any claimed implementation and any claimed implementations may cover processes or apparatuses that differ from those described below. The claimed implementations are not limited to apparatuses or processes having all of the features of any one apparatus or process described below or to features common to multiple or all of the apparatuses or processes described below. It is possible that an apparatus or process described below is not an implementation of any claimed subject matter.

[0035] Furthermore, numerous specific details are set forth in order to provide a thorough understanding of the implementations described herein. However, it will be understood by those skilled in the relevant arts that the implementations described herein may be practiced without these specific details. In other instances, well-known methods, procedures and components have not been described in detail so as not to obscure the implementations described herein.

[0036] In this specification, elements may be described as “configured to” perform one or more functions or “configured for” such functions. In general, an element that is configured to perform or configured for performing a function is enabled to perform the function, or is suitable for performing the function, or is adapted to perform the function, or is operable to perform the function, or is otherwise capable of performing the function.

[0037] It is understood that for the purpose of this specification, language of “at least one of X, Y, and Z” and “one or more of X, Y and Z” may be construed as X only, Y only, Z only, or any combination of two or more items X, Y, and Z (e.g., XYZ, XY, YZ, ZZ, and the like). Similar logic may be applied for two or more items in any occurrence of “at least one . . .” and “one or more . . .” language.

[0038] Referring to FIG. 1, a non-limiting example navigation system 100 is shown to support minimally invasive access port-based surgery. In FIG. 1, a neurosurgeon 101

conducts a minimally invasive port-based surgery on a patient **102** in an operating room (OR) environment. The navigation system **100** includes an equipment tower, tracking system, displays and tracked instruments to assist the surgeon **101** during the procedure. An operator **103** may also be present to operate, control and provide assistance for the navigation system **100**.

[0039] Referring to FIG. 2, a block diagram is shown illustrating components of an example medical navigation system **200**, according to non-limiting implementations. The medical navigation system **200** illustrates a context in which a surgical plan including equipment (e.g., tool and material) tracking, such as that described herein, may be implemented. The medical navigation system **200** includes, but is not limited to, one or more monitors **205**, **211** for displaying a video image, an equipment tower **201**, and a mechanical arm **202**, which supports an optical scope **204**. The equipment tower **201** may be mounted on a frame (e.g., a rack or cart) and may contain a computer or controller (examples provided with reference to FIGS. 3 and 6 below), planning software, navigation software, a power supply and software to manage the mechanical arm **202**, and tracked instruments. In one example non-limiting implementation, the equipment tower **201** may comprise a single tower configuration with dual display monitors **211**, **205**, however other configurations may also exist (e.g., dual tower, single display, etc.). Furthermore, the equipment tower **201** may also be configured with a universal power supply (UPS) to provide for emergency power, in addition to a regular AC adapter power supply.

[0040] A patient's anatomy may be held in place by a holder. For example, in a neurosurgical procedure the patient's head may be held in place by a head holder **217**, and an access port **206** and an introducer **210** may be inserted into the patient's head. The introducer **210** may be tracked using a tracking camera **213**, which provides position information for the navigation system **200**. The tracking camera **213** may also be used to track tools and/or materials used in the surgery, as described in more detail below. In one example non-limiting implementation, the tracking camera **213** may comprise a 3D (three-dimensional) optical tracking stereo camera, similar to one made by Northern Digital Imaging (NDI), configured to locate reflective sphere tracking markers **212** in 3D space. In another example, the tracking camera **213** may comprise a magnetic camera, such as a field transmitter, where receiver coils are used to locate objects in 3D space, as is also known in the art. Location data of the mechanical arm **202** and access port **206** may be determined by the tracking camera **213** by detection of tracking markers **212** placed on these tools, for example the introducer **210** and associated pointing tools. Tracking markers may also be placed on surgical tools or materials to be tracked. The secondary display **205** may provide output of the tracking camera **213**. In one example non-limiting implementation, the output may be shown in axial, sagittal and coronal views as part of a multi-view display.

[0041] As noted above with reference to FIG. 2, the introducer **210** may include tracking markers **212** for tracking. The tracking markers **212** may comprise reflective spheres in the case of an optical tracking system and/or pick-up coils in the case of an electromagnetic tracking system. The tracking markers **212** may be detected by the tracking camera **213** and their respective positions are inferred by the tracking software.

[0042] As shown in FIG. 2, a guide clamp **218** (or more generally a guide) for holding the access port **206** may be provided. The guide clamp **218** may optionally engage and disengage with the access port **206** without needing to remove the access port **206** from the patient. In some examples, the access port **206** may be moveable relative to the guide clamp **218**, while in the guide clamp **218**. For example, the access port **206** may be able to slide up and down (e.g., along the longitudinal axis of the access port **206**) relative to the guide clamp **218** while the guide clamp **218** is in a closed position. A locking mechanism may be attached to or integrated with the guide clamp **218**, and may optionally be actuable with one hand, as described further below. Furthermore, an articulated arm **219** may be provided to hold the guide clamp **218**. The articulated arm **219** may have up to six degrees of freedom to position the guide clamp **218**. The articulated arm **219** may be lockable to fix its position and orientation, once a desired position is achieved. The articulated arm **219** may be attached or attachable to a point based on the patient head holder **217**, or another suitable point (e.g., on another patient support, such as on the surgical bed), to ensure that when locked in place, the guide clamp **218** does not move relative to the patient's head.

[0043] Referring to FIG. 3, a block diagram is shown illustrating a control and processing unit **300** that may be used in the navigation system **200** of FIG. 2 (e.g., as part of the equipment tower). In one example non-limiting implementation, control and processing unit **300** may include one or more processors **302**, a memory **304**, a system bus **306**, one or more input/output interfaces **308**, a communications interface **310**, and storage device **312**. In particular, one or more processors **302** may comprise one or more hardware processors and/or one or more microprocessors. Control and processing unit **300** may be interfaced with other external devices, such as tracking system **321**, data storage device **342**, and external user input and output devices **344**, which may include, but is not limited to, one or more of a display, keyboard, mouse, foot pedal, and microphone and speaker. Data storage device **342** may comprise any suitable data storage device, including, but not limited to a local and/or remote computing device (e.g. a computer, hard drive, digital media device, and/or server) having a database stored thereon. In the example shown in FIG. 3, data storage device **342** includes, but is not limited to, identification data **350** for identifying one or more medical instruments **360** and configuration data **352** that associates customized configuration parameters with one or more medical instruments **360**. Data storage device **342** may also include, but is not limited to, preoperative image data **354** and/or medical procedure planning data **356**. Although data storage device **342** is shown as a single device in FIG. 3, in other implementations, data storage device **342** may be provided as multiple storage devices.

[0044] Medical instruments **360** may be identifiable using control and processing unit **300**. Medical instruments **360** may be connected to and controlled by control and processing unit **300**, and/or medical instruments **360** may be operated and/or otherwise employed independent of control and processing unit **300**. Tracking system **321** may be employed to track one or more of medical instruments **360** and spatially register the one or more tracked medical instruments **360** to an intraoperative reference frame. In another example, a sheath may be placed over a medical instrument

360 and the sheath may be connected to and controlled by control and processing unit 300.

[0045] Control and processing unit 300 may also interface with a number of configurable devices, and may intraoperatively reconfigure one or more of such devices based on configuration parameters obtained from configuration data 352. Examples of devices 320, as shown in FIG. 3, include, but are not limited, one or more external imaging devices 322, one or more illumination devices 324, a robotic arm, one or more projection devices 328, and one or more displays 305, 311.

[0046] Aspects of the specification may be implemented via processor(s) 302 and/or memory 304. For example, the functionalities described herein may be partially implemented via hardware logic in processor 302 and partially using the instructions stored in memory 304, as one or more processing modules 370 and/or processing engines. Example processing modules include, but are not limited to, user interface engine 372, tracking module 374, motor controller 376, image processing engine 378, image registration engine 380, procedure planning engine 382, navigation engine 384, and context analysis module 386. While the example processing modules are shown separately in FIG. 3, in one example non-limiting implementation the processing modules 370 may be stored in the memory 304 and the processing modules may be collectively referred to as processing modules 370.

[0047] It is to be understood that the system is not intended to be limited to the components shown in FIG. 3. One or more components of the control and processing unit 300 may be provided as an external component or device. In one example non-limiting implementation, navigation engine 384 may be provided as an external navigation system that is integrated with control and processing unit 300.

[0048] Some implementations may be implemented using processor 302 without additional instructions stored in memory 304. Some implementations may be implemented using the instructions stored in memory 304 for execution by one or more general purpose microprocessors. Thus, the specification is not limited to a specific configuration of hardware and/or software.

[0049] While some implementations may be implemented in fully functioning computers and computer systems, various implementations are capable of being distributed as a computing product in a variety of forms and are capable of being applied regardless of the particular type of machine or computer readable media used to actually effect the distribution.

[0050] At least some aspects disclosed may be embodied, at least in part, in software. That is, the techniques may be carried out in a computer system or other data processing system in response to its processor, such as a microprocessor, executing sequences of instructions contained in a memory, such as ROM, volatile RAM, non-volatile memory, cache and/or a remote storage device.

[0051] A computer readable storage medium, and/or a non-transitory computer readable storage medium, may be used to store software and data which, when executed by a data processing system, causes the system to perform various methods. The executable software and data may be stored in various places including for example ROM, volatile RAM, non-volatile memory and/or cache. Portions of this software and/or data may be stored in any one of these storage devices.

[0052] Examples of computer-readable storage media include, but are not limited to, recordable and non-recordable type media such as volatile and non-volatile memory devices, read only memory (ROM), random access memory (RAM), flash memory devices, floppy and other removable disks, magnetic disk storage media, optical storage media (e.g., compact discs (CDs), digital versatile disks (DVDs), etc.), among others. The instructions may be embodied in digital and analog communication links for electrical, optical, acoustical and/or other forms of propagated signals, such as carrier waves, infrared signals, digital signals, and the like. The storage medium may comprise the internet cloud, storage media therein, and/or a computer readable storage medium and/or a non-transitory computer readable storage medium, including, but not limited to, a disc.

[0053] At least some of the methods described herein are capable of being distributed in a computer program product comprising a computer readable medium that bears computer usable instructions for execution by one or more processors, to perform aspects of the methods described. The medium may be provided in various forms such as, but not limited to, one or more diskettes, compact disks, tapes, chips, USB (Universal Serial Bus) keys, external hard drives, wire-line transmissions, satellite transmissions, internet transmissions or downloads, magnetic and electronic storage media, digital and analog signals, and the like. The computer useable instructions may also be in various forms, including compiled and non-compiled code.

[0054] According to one aspect of the present application, one purpose of the navigation system 200, which may include control and processing unit 300, is to provide tools to a surgeon and/or a neurosurgeon that will lead to the most informed, least damaging neurosurgical operations. In addition to removal of brain tumors and intracranial hemorrhages (ICH), the navigation system 200 may also be applied to a brain biopsy, a functional/deep-brain stimulation, a catheter/shunt placement procedure, open craniotomies, endonasal/skull-based/ENT, spine procedures, and other parts of the body such as breast biopsies, liver biopsies, etc. While several examples have been provided, aspects of the present specification may be applied to other suitable medical procedures.

[0055] Attention is next directed to FIG. 4 which depicts a non-limiting example of a port-based brain surgery procedure using a video scope. In FIG. 4, operator 404, for example a surgeon, may align video scope 402 to peer down port 406. Video scope 402 may be attached to an adjustable mechanical arm 410. Port 406 may have a tracking tool 408 attached to it where tracking tool 408 is tracked by a tracking camera of a navigation system.

[0056] Even though the video scope 402 may comprise an endoscope and/or a microscope, these devices introduce optical and ergonomic limitations when the surgical procedure is conducted over a confined space and conducted over a prolonged period such as the case with minimally invasive brain surgery.

[0057] FIG. 5 illustrates the insertion of an access port 12 into a human brain 10, in order to provide access to interior brain tissue during a medical procedure. In FIG. 5, access port 12 is inserted into a human brain 10, providing access to interior brain tissue. Access port 12 may include, but is not limited to, instruments such as catheters, surgical probes, and/or cylindrical ports such as the NICO BrainPath. Surgical tools and instruments may then be inserted within a

lumen of the access port **12** in order to perform surgical, diagnostic or therapeutic procedures, such as resecting tumors as necessary. However, the present specification applies equally well to catheters, DBS needles, a biopsy procedure, and also to biopsies and/or catheters in other medical procedures performed on other parts of the body.

[0058] In the example of a port-based surgery, a straight and/or linear access port **12** is typically guided down a sulci path of the brain. Surgical instruments and/or surgical tools would then be inserted down the access port **12**.

[0059] Attention is next directed to FIG. 6, which depicts an example of a multispectral medical imaging system **600** that could be used with access port **12**. System **600** comprises: a multispectral light source **601** comprising: a light emitting diode (LED) array **605** comprising: at least one blue LED (as indicated by “B” in FIG. 6), at least one green LED (as indicated by “G” in FIG. 6) and at least one red LED (as indicated by “R” in FIG. 6); and one or more non-visible light sources **607** arranged side by side with LED array **605**, each of the at least one blue LED, the at least one green LED, the at least one red LED, and the one or more non-visible light sources **607** being independently addressable such that multispectral light source **601** is configured to emit in a sequence: at least visible white light, and non-visible light in one or more given non-visible frequency ranges; a camera **609** arranged to receive light from a tissue sample **610** illuminated by multispectral light source **601** in the sequence; an optical filter **611** arranged to filter the light from tissue sample **610** received at camera **609**, the optical filter configured to: transmit visible light from LED array **605**; filter out non-visible light from the one or more non-visible light sources **607** in the one or more given non-visible frequency ranges; and otherwise transmit excited light emitted by tissue sample **610** under excitation by the non-visible light from the one or more non-visible light sources **607**; a display device **613**; and, at least one control unit **615** configured to: control multispectral light source **601** to emit the sequence; synchronize acquisition of respective images at the camera **609** for each of blue light, green light, the white light, and the excited light received at camera **609**, as reflected by tissue sample **610**; and, output the respective images in a respective sequence to display device **613**.

[0060] For clarity, it is appreciated that the terms visible and non-visible as used herein refer to a human vision system (HVS); hence, the term “visible light”, as used herein, can comprise light that is considered visible in a human vision system, and/or is visible to an average human being; similarly, the term “non-visible light”, as used herein, can comprise light that is considered non-visible in a human vision system, and/or is non-visible to an average human being.

[0061] While not depicted, multispectral light source **601**, camera **609** and optical filter **611** can be adapted for use with access port **12** and/or corridor based surgery and the like. In other words, spectral light source **601**, camera **609** and filter **611** can be components of an endoscope, and the like, used with access port **12** and/or corridor based surgery and the like. Put another way, multispectral light source **601**, camera **609** and optical filter **611** can be configured for use with a surgical port configured for corridor based surgery, as described in more detail below with respect to FIG. 12.

[0062] Components of system **600** will now be described in detail. In particular, multispectral light source **601**, which

will interchangeably referred to hereafter as light source **601**, can comprise an integrated light source, for example, that includes LED array **605** (interchangeably referred to hereafter as array **605**) and one or more non-visible light sources **607**. While only one LED is depicted for each color LED in array **605** in FIG. 6, array **605** can include arrays of LEDs for each color. One or more non-visible light sources **607** can include, but is not limited, one or more infrared (IR) diodes and/or one or more IR lasers and/or one or more ultraviolet (UV) diodes and/or one or more UV laser.

[0063] Camera **609** can include, but is not limited to one or more of a CCD camera, a digital camera, an optical camera, and the like, and is generally configured to acquire digital images.

[0064] Optical filter **611**, which will be described in more detail below, can comprise a dichroic filter and the like, and can be located at least in front of an image sensor of camera **609** and/or in front of a lens of camera **609**. Either way, light imaged by camera **609** is generally filtered by optical filter **611**.

[0065] As described above, optical filter **611** is configured to: transmit visible light from LED array **605**; filter out non-visible light from one or more non-visible light sources **607** in the one or more given non-visible frequency ranges; and otherwise transmit excited light emitted by tissue sample **610** under excitation by the non-visible light from the one or more non-visible light sources **607**; a display device **613**. In other words, optical filter transmits light from LEDs in array **605**, does not transmit light from one or more non-visible light sources **607**, but transmits light emitted from tissue sample **610** when excited by non-visible light from one or more non-visible light sources **607**.

[0066] As such, a transmission spectrum of optical filter **611** is selected for compatibility with one or more non-visible light sources **607**, and any specific imaging techniques and/or dyes to be used in tissue sample **610** during surgery. For example, tissue sample **610** can be treated with a given dye, including, but not limited to fluorescence dyes that fluoresce when irradiated by non-visible light (including, but not limited to one or more of PpIX fluorophore, that fluoresces when irradiated by UV light, and ICG fluorophore, that fluoresces when irradiated by IR light). As such, in this example, a transmission spectrum of optical filter **611** can be selected that transmits fluorescent light emitted by tissue sample **610**, but does not transmit and/or blocks the excitation light from one or more non-visible light sources **607**.

[0067] Hence, in some implementations, one or more non-visible light sources **607** comprises an ultraviolet (UV) LED, and the like, and optical filter **611** is configured to filter out UV light from the UV LED, and transmit the excited light emitted by tissue sample **610** under excitation from the UV LED.

[0068] Alternatively, in other implementations, one or more non-visible light sources **607** comprises an infrared (IR) laser, and the like, and optical filter **611** is configured to filter out IR light from the IR laser, and transmit the excited light emitted by tissue sample **610** under excitation from the IR laser.

[0069] However, in other implementations, one or more non-visible light sources **607** can comprise both a UV light source and an IR light source, and optical filter **611** can be adapted accordingly to block light from both.

[0070] Attention is directed to FIG. 7 which depicts a non-limiting transmission spectrum 700 of optical filter 611, assuming that one or more non-visible light sources 607 comprises an infrared (IR) laser, and the like, and optical filter 611 is configured to filter out IR light from the IR laser, and transmit the excited light emitted by tissue sample 610 under excitation from the IR laser. Specifically, it is assumed in FIG. 7 that the IR laser emits light in a range of about 700 nm to about 800 nm and that tissue sample 610 emits light above about 800 nm when irradiated by light from the IR laser. Hence, in the range of about 700 nm to about 800 nm, light is not transmitted by optical filter 611 (e.g. transmission is about 0%), but outside of the range of about 700 nm to about 800 nm, light is transmitted (e.g. transmission is about 100%). Hence, in these implementations, camera 609 can image light in the visible range below 700 nm from LED array 605 that is reflected to camera 609 by tissue sample 610, and camera 609 can also image light emitted by tissue sample 610 when excited by light from one or more non-visible light sources 607.

[0071] While a specific range of wavelengths where the light is not transmitted is depicted in FIG. 7, in other implementations, other ranges of wavelengths can be selected that are compatible with light emitted from one or more non-visible light sources 607. Furthermore, while not depicted, optical filter 611 can be further configured to block transmission of light below a visible range of wavelengths and/or in a UV range of wavelengths, and/or configured to block transmission of light above a given wavelength (e.g. above 900 nm, or 1000 nm and/or in the far infrared, to ensure that far IR light does not interfere with operation of system 600).

[0072] Returning to FIG. 6, display device 613 can comprise any suitable display device including, but not limited to, cathode ray tubes, flat panel displays, and the like. For example, display device 613 can comprise one or more of monitors 205, 211, as depicted in FIG. 2, and/or displays 305, 311 depicted in FIG. 3.

[0073] At least one control unit 615 is generally configured to control light source 601 and display device 613 and to receive images from camera 609. Hence, at least one control unit 615 is interconnected with each of light source 601, camera 609 and display device 613. In some implementations, at least one control unit 615 can comprise control and processing unit 300 depicted in FIG. 3, and/or at least one control unit 615 can be in communication with control and processing unit 300 depicted in FIG. 3 and/or at least one control unit 615 can be under control of communication with control and processing unit 300 depicted in FIG. 3.

[0074] At least one control unit 615 can further comprise any suitable combination of computing devices, processors, memory devices and the like. In particular, at least one control unit 615 can comprise one or more of a data acquisition unit, configured to acquire data and/or images at least from camera 609, and an image processing unit, configured to process data and/or images from camera 609 for rendering at display device 613.

[0075] In particular, at least one control unit 615 controls control multispectral light source 601 to emit light in a sequence that includes visible white light (e.g. from array 605) and non-visible light (e.g. from one or more non-visible light sources 607). Hence, at least one control unit 615 causes tissue sample 610 to be irradiated with at least white

light and non-visible light in a sequence (e.g. see FIG. 8, described below). The sequence can also include blue light emitted from the blue LED, and green light emitted from the green LED.

[0076] Tissue sample 610 reflects the white light (and blue light and green light) into camera 609 through optical filter 611, and emits excited light under excitation from the non-visible light from one or more non-visible light sources 607, which is also received at camera 609 through optical filter 611 (which also removes the non-visible light from one or more non-visible light sources 607). Hence, camera 609 alternately (and/or in a sequence), produces optical images of tissue sample 610 when irradiated with white light, blue light and green light, and images of the excited light emitted by tissue sample 610.

[0077] Hence at least one control unit 615 is also configured to synchronize acquisition of respective images at camera 609 for each of the blue light, the green light, the white light, and the excited light received at camera 609, as reflected and/or emitted by tissue sample 610. For example, at least one control unit 615 can track when multispectral light source 601 is emitting a particular color and/or type of light (e.g. green, blue, white, non-visible), and can classify an image received from camera 609 simultaneous with such emission as being generated using the particular color and/or type of light. Hence, at least one control unit 615 can coordinate emission of light from multispectral light source 601 with acquisition of images produced by the light at camera 609.

[0078] Respective images that result from each particular color and/or type of light is output in a respective sequence to display device 613 for rendering thereupon. Such images can, for example, assist a surgeon with guiding surgical tools in an access port during corridor based surgery. For example, images produced using visible light can be used for an optical view of tissue sample 610, while images produced from excited light from tissue sample 610 can be used for fluorescence guided surgery; indeed, using system 600, a surgeon can switch back and forth between white light guided surgery (and/or surgery using blue light and/or green light) and fluorescence guided surgery.

[0079] Indeed, various sequence of light used to irradiate tissue sample 610 are within the scope of present implementations. For example, the sequence can comprise the visible white light, and the non-visible light alternating. Alternatively, the sequence can comprises visible white light, green light, blue light, and the non-visible light, alternating. However, the sequence can also comprise: one or more of a user-configured sequence; and simultaneous emission of light from two or more of the at least one blue LED, the at least one green LED, the at least one red LED. Indeed, any sequence that will assist a surgeon view tissue sample 610 using images rendered at display device 613 is within the scope of present implementations.

[0080] In some implementations, at least one control unit 615 can further control intensity of LEDs in array 605. For example, respective relative intensity of each of the at least one blue LED, the at least one green LED, the at least one red LED can be adjusted to change one or more of color temperature of the visible white light and color rendering of respective images output to display device 613. For example, color quality of light and/or white light can be described by two parameters: correlated color temperature (CCT) and color rendering index (CRI), and by respective

relative intensity of each of the at least one blue LED, the at least one green LED, the at least one red LED, a given and/or desired CCT and CRI can be provided to, in turn, achieve a given color appearance of tissue sample 610, including a CCT and CRI within desired ranges (e.g. for a “good” color appearance).

[0081] In any event, attention is next directed to FIG. 8, which depicts a sample sequence that can be implemented at multispectral light source 601 in which light from array (“1”) 605 alternates with non-visible light (“2”) from one or more non-visible light sources 607. In particular, the sequence depicted in FIG. 8 comprise the visible white light, and the non-visible light alternating, at a rate of 12 frames per second (FPS), which is also the rate at which the corresponding images are rendered at display device 613.

[0082] Indeed, images rendered at display device 613 can be at a rate (with multispectral light source 601 controlled at a corresponding rate) where the images appear to be simultaneously rendered to a human vision system. Hence, for example, images that result from tissue sample 610 being irradiated with white light appear to be combined with images formed from excited light emitted from tissue sample 610, thereby combining white light surgery and fluorescence guided surgery, and the like; in other words, features of tissue sample 610 that are visible only using fluorescence guided surgery are combined at display device 613 with features of tissue sample 610 visible when tissue sample 610 is irradiated with white light.

[0083] Hence, at least one control unit 615 can be further configured to output the respective images in the respective sequence to display device 613. In some implementations, such images can be static, for example, one or more acquired images can be rendered at display device 613, statically (e.g. one or more images are acquired and rendered at display device 613 rather than a stream of images). In other implementations, least one control unit 615 can be further configured to output the respective images in the respective sequence to display device 613 in a video stream and/or at a rate where the respective images appear simultaneously rendered to a human vision system. For example, in some implementations, such rates can, include, but are not limited to, 12 FPS and higher. However, the rate of rendering images at display device 613 can also depend on a rate at which images are acquired at camera 609; for example, if camera acquires images at a rate of 60 Hz, an output rate of images at display device 613 can be about half the camera rate and/or about 30 Hz, assuming that two frames are captured, one visible and one-non-visible (e.g. see FIG. 8, described below). However, other rates are within the scope of present implementations and can depend both on a configuration of camera 609 and/or a configuration of display device 613 and/or a number of light sources in multispectral light source 601 and/or a number of frames dedicated to each of the light sources in multispectral light source 601.

[0084] Indeed, LEDs of array 605, as well as one or more non-visible light sources 607 can be selected based on what rate images are to be provided at display device 613. For example, specific LEDs types (for array 605) and laser diodes (for one or more non-visible light sources 607) can be selected where transient times are less than a microsecond.

[0085] Similarly, wavelengths of each of LEDs of array 605 and laser diodes for one or more non-visible light sources 607 can be selected which maximize a number of modalities that can be measured in conjunction with the

camera synchronization. In a particular non-limiting implementation, two types of laser diodes can be used at one or more non-visible light sources 607 that emit both UV light and IR light; in one particular non-limiting implementation, array 605 can comprise: one or more 460 nm Blue LEDs, one or more 530 nm Green LEDs; and one or more 620 nm Red LEDs, and non-visible light sources 607 can comprise: one or more 415 nm UV LEDs, and one or more 785 nm IR laser diodes. As such, a transmission spectrum of optical filter 611 is adapted to transmit light in the range if the LEDs of array 605, and to block light emitted by both the one or more 415 nm UV LEDs, and the one or more 785 nm IR laser diodes.

[0086] Use of such LEDs, UV LEDs and IR laser diodes can enable several modes and/or use cases in system 600 which can include, but is not limited to:

[0087] UV LED: excitation of PpIX fluorophore for better tumor margin delineation (e.g. to produce excited light from a tissue sample);

[0088] Blue/Green/Red LEDs: trichromatic white light with tunable CRI (color rendering index);

[0089] Blue/Green interleaved: quantitative measure of blood oxygenation and volume (i.e. the sequence can include blue and green light);

[0090] Diffused IR laser: excitation of ICG fluorophore for angiography (e.g. to produce excited light from a tissue sample); and,

[0091] Speckled IR laser: quantitative measure of the blood flow.

[0092] In the last use case, system 600 can be modified to include at least a second optical filter that can be exchanged for optical filter 611, the second optical filter and optical filter 611 being exchangeable, depending on the operating mode.

[0093] For example, attention is next directed to FIG. 9 which depicts system 900 and is substantially similar to system 600, with like elements having like numbers, however in system 900, one or more non-visible light sources 607 specifically comprises an infrared (IR) laser, and system 900 further comprising a second optical filter 911, that can be exchanged for optical filter 611 under control by at least one control unit 615, second optical filter 911 configured to transmit light from the IR laser.

[0094] For example, as depicted, optical filters 611, 911 can be mounted in a filter wheel 912 configured to rotate about an axis 913. In other words, in FIG. 9 depicts a cross-sectional view of filter wheel 912. Furthermore, filter wheel 912 further comprises apparatus 914 configure to control a position of optical filters 611, 911 with respect to camera 609, apparatus 914 in communication with at least one control unit 615. For example, apparatus 914 can comprise a stepper motor, and the like. Alternatively optical filters 611, 911 can be mounted to a slideable arm, and the like, configured to exchange optical filters 611, 911 under control by at least one control unit 615; indeed, any device for exchanging optical filters 611, 911 under control by at least one control unit 615 is within the scope of present implementations, assuming such devices are compatible with the surgical techniques to be used with system 900.

[0095] Attention is next directed to FIG. 10, which depicts a transmission spectrum 1000 of optical filter 911. In contrast to the transmission spectrum 700 of optical filter 611 depicted in FIG. 7, transmission spectrum 1000 of optical filter 911 transmits light from IR laser of one or more

non-visible light sources 607 in a range of about 700 nm to about 800 nm, and does not transmit light outside this range. [0096] Hence, optical filter 611 can be used to operate system 900 in a manner similar to system 600 and described above. However, optical filter 911 can be exchanged for optical filter 611, and the IR laser of one or more non-visible light sources 607 can be operated in a speckled mode which can be used to quantitatively measure blood flow in tissue sample 610.

[0097] Hence, system 900 and/or IR laser of one or more non-visible light sources 607, can be operated in at least two modes. In particular, the IR laser can be operated in one of a diffused mode, when optical filter 611 is filtering light to camera 609, and a speckled mode when second optical filter 911 is filtering light to camera 609. In other words, the diffuse mode can be used when operating system 900 in a manner similar to system 600.

[0098] In yet further implementations, system 900 can be used in a third mode. In particular, the IR laser can be operated in a speckled mode when second optical filter 911 is filtering light to camera 609, and the sequence of light emitted by multispectral light source 601 includes green light emitted from the green LED, and blue light emitted from the blue LED, when optical filter 611 is filtering light to camera 609, speckled laser light from the IR laser in the speckled mode, the green light and the blue light used for functional imaging of blood flow in the tissue sample. In other words in the third mode, when optical filter 611 is filtering light to camera 609, green light and blue light can be used in sequence to irradiate tissue sample 610, and then optical filters 611, 911 can be exchanged, and the IR laser can be operated in a speckled mode (though the specific sequence of colors irradiating tissue sample 610 is generally irrelevant, presuming at least one control unit 615 is synchronizing such irradiation with filter position, and image acquisition).

[0099] In yet further implementations, one or more of systems 600, 900 can be adapted to include further optical filters and further light sources. For example, in some implementations, filter wheel 912 can be adapted to include three optical filters having the following transmission characteristics:

[0100] Filter 1: Transmits light in a visible range of about 400 nm to about 700 nm, allowing visible light reflected from tissue sample 610 to be imaged by camera 609, and which can be used for “standard” white light surgery.

[0101] Filter 2: Transmits light in an extended range of about 400 nm to about 800 nm, allowing light from an IR laser operated in a speckled mode to be imaged by camera 609, and which can be used for concurrent white light surgery and quantitative blood physiology measurement.

[0102] Filter 3: Transmits light in a fluorescent range of about 430 nm to about 700 nm, and from about 820 nm to about 860 nm, which blocks light from both UV and IR light sources while allowing light from the emission of PpIX & ICG from tissue sample 610 to be imaged by camera 609.

[0103] In other words, optical filters respective to light emitted from multispectral light source 601 can be used depending on a mode of operation of the system and what wavelengths of light are being reflected and/or emitted by tissue sample 610.

[0104] Persons skilled in the art will appreciate that there are yet more alternative implementations and modifications possible. For example, attention is next directed to FIG. 11 which depicts a system 1100 that is substantially similar to system 600, with like elements having like numbers. However, system 1100 further comprises: a second camera 1109 arranged relative to camera 609 to acquire three-dimensional images of tissue sample 610; hence, as depicted cameras 609, 1109 can be angled and/or positioned to image a same region of tissue sample 610. System 1100 further comprises a second optical filter 1111, positioned to filter light into second camera 1109, second optical filter 1111 configured to: transmit visible light from the LED array 605 and transmit non-visible light from one or more non-visible light sources 607 in the one or more given non-visible frequency ranges. For example, second optical filter 1111 can be configured to transmits light in a fluorescent range of about 430 nm to about 700 nm, and from about 820 nm to about 860 nm, which blocks light from both UV and IR light sources while allowing light from the emission of PpIX & ICG from tissue sample 610 to be imaged by camera 1109; such implementations assume that the one or more non-visible light sources 607 comprises an IR laser, which can be operable in one of a diffused mode and a speckled mode, and a UV laser.

[0105] Hence, using two sets of cameras and respective optical filters, different modes of imaging tissue sample 610 can be performed simultaneously. Alternatively, camera 609 and second camera 1109 can be configured to capture images independent of one another, such that system 1100 can be operated in different modes at different times.

[0106] Persons skilled in the art will appreciate that there are yet more alternative implementations and modifications possible. For example, in some implementations, one or more of system 600, 900, 1100 can further comprise a thermal camera arranged to receive light from tissue sample 610 illuminated by the multispectral light source 601 in the sequence, thereby performing thermal imaging of tissue sample 610; for example, in system 100, camera 1109 can comprise a thermal imaging camera and optical filter 1111 can either be removed from system 1100 or adapted to transmit light in a thermal imaging range.

[0107] Furthermore, in some implementations, light sources, filters and cameras can be packaged together in an apparatus compatible for use with an access port, such as access port 12. For example, attention is directed to FIG. 12, which depicts system 600, in which multispectral light source 601, camera 609, and optical filter 611 are assumed to be packaged in an apparatus 1250, which can comprise an endoscope and the like; as depicted, apparatus 1250 has been inserted through access port 12, depicted in cross-section.

[0108] As depicted, apparatus 1250 comprises an optional tracking device 1255 attached to a proximal end apparatus 1250. In other words, as depicted, system 600 optionally comprises tracking device 1255 configured to be tracked by a navigation system. Tracking device 1255 is generally configured to be tracked by a navigation system external to system 600, for example a navigation system that is part of surgical system, such as that depicted in FIGS. 1 to 4. While not depicted apparatus 1250 can further comprise a mount configured to removably attach tracking device 1255 at a proximal end thereof (e.g. an end that is away from tissue being imaged). Tracking device 1255 is generally positioned so that a camera, and the like, of a surgical navigation system

may track a position of tracking device 1255 and hence a relative position of a distal end of apparatus 1250 (e.g. an end of apparatus 1250 closest to tissue sample 610). As depicted, tracking device 1255 comprises four reflective spheres arranged in a configuration where each sphere is located at about a corner of a square. However, other numbers of spheres and other configurations are within the scope of present implementations. In particular or more of a number, arrangement, and configuration of such spheres may be selected to provide a given tracking accuracy, including, but not limited to, a tracking accuracy that is less than about half a diameter of a sensing array surface. However, tracking device 1255 may include tracking devices other than reflective spheres. For example, in some implementations, tracking device 1255 may include a flexible sheath configured to measure tip position deflection, for example deflection of a tip of the flexible sheath. Furthermore, system 600 can be adapted to include one or more tracking devices.

[0109] Furthermore, at least one control unit 615 can comprise one or more ports configured for communicate with one or more of: surgical navigation system; external computing devices; electronic surgical devices; trackers; and infrared trackers.

[0110] Persons skilled in the art will appreciate that there are yet more alternative implementations and modifications possible. For example, at least one control unit 615 can be configured to implement various image processing algorithms including, but not limited to: amplification of the color dynamics around the edge of the tumor margin under FGS mode, image fusion between WLS and FGS modes, division of the light reflectance under blue light to that of green light for blood oxygenation and volume computations, spatial computation under speckled laser illumination for blood perfusion.

[0111] When using two cameras, which can be used for combined three-dimensional vision, as in system 1100, image processing algorithms implemented by at least one control unit 615 can further include finding parameters to warp image from each camera onto another. In some of these implementations, at least one control unit 615 can control multispectral light source 601 to intermittently flash blue light from the blue LED into one camera and flash blue light from the blue LED into the other camera (e.g. assuming that at least one control unit 615 is synchronizing images from the cameras) to obtain a quantitative blood physiology while warping and merging images from each camera into a single image.

[0112] In yet further implementations, systems described herein can be adapted to include external sources and at least one control unit 615 can either comprise or be a component of other surgical systems and/or be in communication with a main control hub of surgical system. In such implementations, at given intervals (e.g. every second), such a main control hub cause camera acquisition of systems described herein to stop such that external source can be used to perform other imaging techniques, including, but not limited to, intraoperative Raman spectroscopy. Furthermore, when tracking devices are used with systems described herein (e.g. as depicted in FIG. 12), and such tracking devices are tracked using light in an infrared spectrum such infrared light can introduce artefacts from pulsing infrared diodes on the acquired images unless optical filters described herein are further adapted to filter out such artefacts. For example,

the sequence depicted in FIG. 8 could be modified to include an infrared tracking pulse in the 700 nm to 800 nm region between frames and/or within a frame that illuminates apparatus 1255, which is detected by a tracking system, but images of apparatus 1255 and/or the tracking pulse, is filtered out of camera 609 using optical filter 611 (e.g. see FIG. 7). Hence, by using system 600, infrared tracking can be used in conjunction with FGS without introducing artefacts into images of tissue sample 610 rendered at display device 613 from camera 609.

[0113] In yet further implementations, at least one control device 615 can be adapted to perform sub-frame synchronization, for example by controlling camera shutter speeds and/or camera “sync” pulses to stagger image acquisition on a sub-frame basis; such a feature can obviate reductions in frame rate in a global acquisition of images, for example in different spectral and/or wavelength ranges. Such a feature can also be referred to as “time multiplexing of image acquisition and illumination”, which can be used for different modalities of systems 600, 900, 1100 that include a plurality of cameras that can acquire images in different spectral and/or wavelength ranges. For example, systems 600, 900, 1100 can be used as a kind of “global image and illumination scheduler” using the mentioned sync pulses, and the like, which can ensure that the various image acquisitions in the different spectral and/or wavelength ranges (e.g. tracking, visible, non-visible, etc.) don’t interfere with each other as they all require different lighting and capture environments. For example, in a specific non-limiting example, such sub-frame synchronization could be implemented in a system comprising multiple cameras, each with a frame rate of 60 Hz; hence a frame is acquired every  $\frac{1}{60}$  of a second (however, camera speeds are often faster, and such acquisitions can occur at rates on the order of every  $\frac{1}{250}$  of a second to every  $\frac{1}{1000}$  of a second, and faster); in such implementations, image capture times of each camera can be slightly off-set with respect to one another, and images from each camera can be acquired within the  $\frac{1}{60}$ th of a second, within different spectral and/or wavelength ranges, and hence multispectral image can be acquired without reducing frame rate.

[0114] The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

1. A multispectral synchronized imaging system comprising:

a multispectral light source comprising:

a light emitting diode (LED) array comprising: at least one blue LED, at least one green LED and at least one red LED; and

one or more non-visible light sources arranged side by side with the LED array, each of the at least one blue LED, the at least one green LED, the at least one red LED, and the one or more non-visible light sources being independently addressable such that the multispectral light source is configured to emit in a sequence: at least visible white light, and non-visible light in one or more given non-visible frequency ranges,

wherein the sequence further comprises: one or more of a user-configured sequence; and simultaneous emission of light from two or more of the at least one blue LED, the at least one green LED, the at least one red LED;

a camera arranged to receive light from a tissue sample illuminated by the multispectral light source in the sequence;

an optical filter arranged to filter the light from the tissue sample received at the camera, the optical filter configured to:

- transmit visible light from the LED array;
- filter out non-visible light from the one or more non-visible light sources in the one or more given non-visible frequency ranges;
- and otherwise transmit excited light emitted by the tissue sample under excitation by the non-visible light from the one or more non-visible light sources;

a display device; and,

at least one control unit configured to:

- control the multispectral light source to emit the sequence;
- synchronize acquisition of respective images at the camera for each of blue light, green light, the visible white light, and the excited light received at the camera, as reflected by the tissue sample; and,
- output the respective images in a respective sequence to the display device.

2. The multispectral synchronized imaging system of claim 1, wherein the one or more non-visible light sources comprises an ultraviolet (UV) LED, and the optical filter is configured to filter out UV light from the UV LED, and transmit the excited light emitted by the tissue sample under excitation from the UV LED.

3. The multispectral synchronized imaging system of claim 1, wherein the one or more non-visible light sources comprises an ultraviolet (UV) light source and an infrared (IR) light source, and the optical filter is configured to: transmits light in a fluorescent range of about 430 nm to about 700 nm, and from about 820 nm to about 860 nm to allow light from emission of one or more of PpIX and ICG at the tissue sample to be imaged by the camera; and block light from both the UV light source and the IR light source from entering the camera.

4. The multispectral synchronized imaging system of claim 1, wherein the one or more non-visible light sources comprises an infrared (IR) laser, and the optical filter is configured to filter out IR light from the IR laser, and transmit the excited light emitted by the tissue sample under excitation from the IR laser.

5. The multispectral synchronized imaging system of claim 1, wherein the one or more non-visible light sources comprises an infrared (IR) laser, and further comprising a second optical filter, exchangeable for the optical filter under control by the at least one control unit, the second optical filter configured to transmit light from the IR laser.

6. The multispectral synchronized imaging system of claim 5, wherein the IR laser is operable in one of a diffused

mode, when the optical filter is filtering light to the camera, and a speckled mode when the second optical filter is filtering light to the camera.

7. The multispectral synchronized imaging system of claim 5, wherein the IR laser is operable in a speckled mode when the second optical filter is filtering light to the camera, and the sequence includes green light emitted from the green LED, and blue light emitted from the blue LED, when the optical filter is filtering light to the camera, speckled laser light from the IR laser in the speckled mode, the green light and the blue light used for functional imaging of blood flow in the tissue sample.

8. The multispectral synchronized imaging system of claim 1, wherein the sequence comprises the visible white light, and the non-visible light alternating.

9. The multispectral synchronized imaging system of claim 1, wherein the sequence further comprises the visible white light, green light, blue light, and the non-visible light alternating.

10. (canceled)

11. The multispectral synchronized imaging system of claim 1, wherein respective relative intensity of each of the at least one blue LED, the at least one green LED, the at least one red LED is adjusted to change one or more of: color temperature of the visible white light; and color rendering of the respective images at the display device.

12. The multispectral synchronized imaging system of claim 1, further comprising: a second camera arranged relative to the camera to acquire three-dimensional images of the tissue sample; and a second optical filter configured to: transmit visible light from the LED array and transmit non-visible light from the one or more non-visible light sources in the one or more given non-visible frequency ranges.

13. The multispectral synchronized imaging system of claim 12, wherein the one or more non-visible light sources comprises an IR laser operable in one of a diffused mode and a speckled mode.

14. The multispectral synchronized imaging system of claim 12, wherein the camera and the second camera are configured to capture images independent of one another.

15. The multispectral synchronized imaging system of claim 12, wherein image capture times of each the camera and the second camera are off-set with respect to one another.

16. The multispectral synchronized imaging system of claim 1, wherein the at least one control unit is further configured to output the respective images in the respective sequence to the display device at a rate where the respective images appear simultaneously rendered to a human vision system.

17. The multispectral synchronized imaging system of claim 1, wherein the camera comprises an optical camera.

18. The multispectral synchronized imaging system of claim 1, further comprising a thermal camera arranged to receive the light from the tissue sample illuminated by the multispectral light source in the sequence.

19. The multispectral synchronized imaging system of claim 1, wherein the at least one control unit comprises one or more ports configured for communicate with one or more of: external computing devices; electronic surgical devices; trackers; and infrared trackers.

20. The multispectral synchronized imaging system of claim 1, wherein the multispectral light source, the camera and the optical filter are configured for use with a surgical port configured for corridor based surgery.

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|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|
| 专利名称(译)        | 多光谱同步成像                                                                                                                                                                                                                                                                                              |         |            |
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| 外部链接           | <a href="#">Espacenet</a> <a href="#">USPTO</a>                                                                                                                                                                                                                                                      |         |            |

#### 摘要(译)

提供多光谱同步成像系统。该系统的多光谱光源包括：蓝色，绿色和红色LED以及一个或多个不可见光源，每个不可见光源可独立寻址并且被配置为以下列顺序发射：至少可见的白光和不可见光在一个或多个给定的不可见频率范围内。该系统还包括照相机和光学滤波器，该照相机和光学滤波器布置成通过以下步骤过滤在照相机处接收到的光：从LED发射可见光；过滤掉不可见光源中的不可见光；否则透射由不可见光激发的组织样本发出的激发光。相机获取的图像被输出到显示设备。控制单元针对由组织样本反射的蓝色光，绿色光，可见白色光和在相机处接收到的激励光中的每一个同步获取相机处的各个图像。

