Claims

WE CLAIM:

1. A portable, handheld imaging system, comprising:

at least one excitation light source configured to emit excitation light during fluorescent imaging;

a fluorescent image sensor;

a first filter configured to ~~detect and~~ permit passage of optical signals, responsive to illumination of a target surface with the excitation light and having a wavelength corresponding to one or more of bacterial fluorescence, bacterial autofluorescence, tissue fluorescence, and tissue autofluorescence, to be detected by ~~a first~~ the fluorescent image sensor;

a white light source configured to emit white light during white light imaging;

a first white light image sensor and a second white light image sensor;

a second filter and a third filter, each of the second and third filters being configured to ~~detect and~~ permit passage of optical signals, responsive to illumination of the target surface with the white light and having a wavelength in the visible light range, to be detected by a respective one of the first and the second white light image sensors;

a thermal sensor configured to detect thermal information regarding the target surface; and

a processor configured to receive the detected fluorescent and white light optical signals and the thermal information detected by the thermal sensor and to output a representation of the target surface to a display based at least in part on the detected optical signals and detected thermal information, wherein the representation, based in part on the optical signals detected by the first and second white light image sensors, is a stereoscopic or three-dimensional image of the target surface and, wherein the representation, based in part on the optical signals detected by the fluorescent image sensor, provides an indication of a bacterial load of the target surface.

2. The system of claim 1, wherein the at least one excitation light source is configured to emit excitation light having a wavelength of ~~about~~ 350 nm – ~~about~~ 400 nm, ~~about~~ 400 nm – ~~about~~ 450 nm, ~~about~~ 450 nm – ~~about~~ 500 nm, ~~about~~ 500 nm – ~~about~~ 550 nm, ~~about~~ 550 nm – ~~about~~ 600 nm, ~~about~~ 600 nm – ~~about~~ 650 nm, ~~about~~ 650 nm – ~~about~~ 700 nm, ~~about~~ 700 nm – ~~about~~ 750 nm, ~~about~~ 750 nm – ~~about~~ 800 nm, ~~about~~ 800 nm – ~~about~~ 850 nm, ~~about~~ 850 nm – ~~about~~ 900 nm, and/or combinations thereof.

3. The system of claim 1 or claim 2, wherein the at least one excitation light source is configured to emit excitation light having a wavelength of ~~about~~ 400 nm to ~~about~~ 450 nm.

4. The system of any one of claims 1-3, wherein the at least one excitation light source is configured to emit excitation light having a wavelength of ~~about~~ 405 nm ± 10 nm.

5. The system of any one of claims 1-4, wherein the at least one excitation light source is coupled to a housing of the portable, handheld imaging system.

6. The system of any one of claims 1-5, wherein the first filter is further configured to block the passage of optical signals having a wavelength of 405 nm ± 10 nm.

7. The system of any one of claims 1-6, wherein the first filter is configured to permit optical signals having a wavelength between ~~about~~ 500 nm and ~~about~~ 550 nm and/or optical signals having a wavelength between ~~about~~ 600 nm and ~~about~~ 660 nm to pass through the first filter to the first image sensor.

8. The system of any one of claims 1-7, wherein the at least one excitation light source includes first and second violet/blue LEDs, each LED configured to emit light having a wavelength of 405 nm ± 10 nm.

9. The system of any one of claims 5-8, further comprising ~~a housing having~~ a display on a front side of the housing.

10. The system of claim 9, wherein the at least one excitation light source is positioned on a rear side of the housing.

11. The system of any one of claims 1-~~11~~10, wherein the at least one excitation light source includes first and second violet/blue LEDs, each LED configured to emit light having a wavelength of 405 nm ± 10 nm.

12. The system of claim 11, wherein the first and second violet/blue LEDs are positioned on opposite sides of a longitudinal axis of the housing, wherein the longitudinal axis passes through and top and bottom of the housing.

13. The system of claim 10, wherein the housing is a modular housing comprising a display unit and an optical unit.

14. The system of claim 13, wherein the optical unit is releasably attached to the display unit.

15. The system of claim 14, wherein the at least one excitation light source is contained in the optical unit.

16. The system of claim 15, wherein the white light source is contained in the optical unit.

17. The system of claim 16, wherein the display unit includes an interface configured to releasably receive an optical unit.

18. The system of claim 17, wherein the interface is defined, at least in part, by a heat sink of the system.

19. The system of claim 18, wherein the heat sink surrounds an opening configured to releasably receive the optical unit.

~~20. The system of any one of claims 1 -19, further comprising a thermal sensor configured to detect thermal information regarding the target surface.~~

~~21~~20. The system of any one of claims 1-~~20~~19, further comprising an ambient light sensor configured to indicate when ambient lighting conditions are sufficient to permit fluorescent imaging.

~~22~~21. The system of any one of claims 1-~~21~~20, further comprising a range finder.

~~23. The system of any one of claims 1 -22, further comprising a third filter configured to detect and permit passage of optical signals, responsive to illumination of the target surface with the white light and having a wavelength in the visible light range, to a third image sensor.~~

~~24. The system of claim 23, wherein the processor is further configured to receive image data from the second and third image sensors and output a stereoscopic or three-dimensional image~~

~~25~~22. The system of any one of claims 1-~~24~~21, further comprising a Wi-Fi and/or Bluetooth antenna.

~~26~~23. The system of any one of claims 1-~~25~~22, wherein the processor is configured to wirelessly transmit and/or receive data.

~~27~~24. The system of any one of claims 1-~~26~~23, further comprising a power source.

~~28~~25. The system of any one of claims 1-~~27~~24, wherein the excitation light source includes a first excitation light source and a second excitation light source.

~~29~~26. The system of claim ~~28~~25, wherein the first excitation light source is configured to emit excitation light having a wavelength of about 350 nm – about 400 nm, about 400 nm – about 450 nm, about 450 nm – about 500 nm, about 500 nm – about 550 nm, about 550 nm – about 600 nm, about 600 nm – about 650 nm, about 650 nm – about 700 nm, about 700 nm – about 750 nm, about 750 nm – about 800 nm, about 800 nm – about 850 nm, about 850 nm – about 900 nm, and/or combinations thereof.

~~30~~27. The system of claim ~~29~~26, wherein the first excitation light source is configured to emit excitation light having a wavelength of about 400 nm to about 450 nm.

~~31~~28. The system of claim ~~30~~27, wherein the first excitation light source is configured to emit excitation light having a wavelength of about 405 nm ± 10 nm.

~~32~~29. The system of claim ~~28~~25, wherein the second excitation light source is configured to emit excitation light having a wavelength of ~~about~~ 350 nm – ~~about~~ 400 nm, ~~about~~ 400 nm – ~~about~~ 450 nm, ~~about~~ 450 nm – ~~about~~ 500 nm, ~~about~~ 500 nm – ~~about~~ 550 nm, ~~about~~ 550 nm – ~~about~~ 600 nm, ~~about~~ 600 nm – ~~about~~ 650 nm, ~~about~~ 650 nm – ~~about~~ 700 nm, ~~about~~ 700 nm – ~~about~~ 750 nm, ~~about~~ 750 nm – ~~about~~ 800 nm, ~~about~~ 800 nm – ~~about~~ 850 nm, ~~about~~ 850 nm – ~~about~~ 900 nm, and/or combinations thereof.

~~33~~30. The system of claim ~~32~~29, wherein the second excitation light source is configured to emit excitation light having a wavelength of ~~about~~ 750 nm – 800 nm.

~~34~~31. The system of claim ~~33~~30, wherein the second excitation light source is configured to emit excitation light having a wavelength of between ~~about~~ 760 nm and ~~about~~ 780 nm.

~~35~~32. The system of claim ~~34~~31, wherein the second excitation light source is configured to emit excitation light having a wavelength of ~~about~~ 760 nm ± 10 nm.

~~36~~33. The system of claim ~~34~~31, wherein the second excitation light source is configured to emit excitation light having a wavelength of ~~about~~ 770 nm ± 10 nm.

~~37~~34. The system of claim ~~34~~31, wherein the second excitation light source is configured to emit excitation light having a wavelength of ~~about~~ 780 nm ± 10 nm.

~~38~~35. The system of any one of claims 1-~~37~~34, wherein the first and second image sensors each comprise a complementary metal-oxide-semiconductor (CMOS) sensor.

~~39~~36. The system of any one of claims 1-~~38~~35, wherein the first filter is fixed to the first image sensor.

~~40~~37. The system of any one of claims 1-~~39~~36, wherein the second filter is fixed to the ~~second~~ first white light image sensor and the third filter is fixed to the second white light image sensor.

~~41~~38. The system of any one of claims 1-~~40~~37, further comprising an infrared radiation source.

~~42~~39. The system of claim ~~41~~38, wherein the system is configured to project infrared radiation onto the target surface and detect infrared radiation reflected from the target surface as well as any infrared fluorescence emitted by the target when excited by the appropriate excitation wavelength.

~~43~~40. The system of claim ~~42~~39, wherein the processor is further configured to generate a three-dimensional map of the target surface based on the detected reflected infrared radiation.

~~44~~41. The system of claim ~~43~~40, wherein the processor is further configured to generate a three-dimensional fluorescence image of the target surface ~~surfaced~~ based on the three-dimensional map, a two-dimensional white light image of the target surface, and a two-dimensional fluorescence image of the target surface.

~~45. A portable, modular handheld imaging system, comprising:~~

~~a first housing portion comprising:~~

~~at least one excitation light source configured to emit excitation light during fluorescent imaging,~~

~~a first filter configured to detect and permit passage of optical signals, responsive to illumination of a target surface with the excitation light and having a wavelength corresponding to one or more of bacterial fluorescence, bacterial autofluorescence, tissue fluorescence, and tissue autofluorescence, to a first image sensor,~~

~~a white light source configured to emit white light during white light imaging, and~~

~~a second filter configured to detect and permit passage of optical signals, responsive to illumination of the target surface with the white light and having a wavelength in the visible light range, to a second image sensor; and a second housing portion configured to releasably receive the first housing portion and comprising:~~

~~a display, and~~

~~a processor configured to receive the detected fluorescent and white light optical signals and to output a representation of the target surface to the display based on the detected optical signals.~~

~~46. The system of claim 45, wherein the at least one excitation light source is configured to emit excitation light having a wavelength of about 350 nm - about 400 nm, about 400 nm - about 450 nm, about 450 nm - about 500 nm, about 500 nm -about 550 nm, about 550 nm - about 600 nm, about 600 nm - about 650 nm, about 650 nm - about 700 nm, about 700 nm - about 750 nm, about 750 nm - about 800 nm, about 800 nm - about 850 nm, about 850 nm - about 900 nm, and/or combinations thereof.~~

~~47. The system of claim 45 or claim 46, wherein the at least one excitation light source is configured to emit excitation light having a wavelength of about 400 nm to about 450 nm.~~

~~48. The system of any one of claims 45-47, wherein the at least one excitation light source is configured to emit excitation light having a wavelength of about 405 nm ± 10 nm.~~

~~49. The system of claim any one of claims 45-48, wherein the first filter is further configured to block the passage of optical signals having a wavelength of 405 nm ± 10 nm.~~

~~50. The system of any one of claims 45-49, wherein the first filter is configured to permit optical signals having a wavelength between about 500 nm and about 550 nm and/or optical signals having a wavelength between about 600 nm and about 660 nm to pass through the first filter to the first image sensor.~~

~~51. The system of any one of claims 45-50, wherein the at least one excitation light source includes first and second violet/blue LEDs, each LED configured to emit light having a wavelength of 405 nm ± 10 nm.~~

~~52. The system of any one of claims 45-51 , wherein the second housing portion further comprises a power source.~~

~~53. The system of claim 52, wherein the second housing further comprises an exterior surface with contacts for charging the power source.~~

~~54. The system of any one of claims 45-53, wherein the second housing further comprises a heat sink.~~

~~55. The system of claim 54, wherein the heat sink defines an opening in the second housing that is configured to releasably receive the first housing.~~

~~56. The system of any one of claims 45-55, wherein the first housing further comprises a thermal sensor configured to detect thermal information regarding the target surface.~~

~~57. The system of any one of claims 45-56, wherein the first housing further comprises an ambient light sensor configured to indicate when ambient lighting conditions are sufficient to permit fluorescent imaging.~~

~~58. The system of any one of claims 45-57, wherein the first housing further comprises a range finder.~~

~~59. The system of any one of claims 45-58, wherein the first housing further comprises a third filter configured to detect and permit passage of optical signals, responsive to illumination of the target surface with the white light and having a wavelength in the visible light range, to a third image sensor.~~

~~60. The system of any one of claims 45-59, wherein the first housing further comprises second excitation light source is configured to emit excitation light having a wavelength of about 350 nm - about 400 nm, about 400 nm - about 450 nm, about 450 nm - about 500 nm, about 500 nm - about 550 nm, about 550 nm - about 600 nm, about 600 nm - about 650 nm, about 650 nm - about 700 nm, about 700 nm -about 750 nm, about 750 nm - about 800 nm, about 800 nm - about 850 nm, about 850 nm - about 900 nm, and/or combinations thereof.~~

~~61 . The system of any one of claims 45-60, wherein the second excitation light source is configured to emit excitation light having a wavelength of about 750 nm -800 nm.~~

~~62. The system of claim 61 , wherein the second excitation light source is configured to emit excitation light having a wavelength of between about 760 nm and about 780 nm.~~

~~63. The system of claim 62, wherein the second excitation light source is configured to emit excitation light having a wavelength of about 760 nm ± 10 nm.~~

~~64. The system of claim 62, wherein the second excitation light source is configured to emit excitation light having a wavelength of about 770 nm ± 10 nm.~~

~~65. The system of claim 62, wherein the second excitation light source is configured to emit excitation light having a wavelength of about 780 nm ± 10 nm.~~

~~66. The system of any one of claims 45-65, wherein the first housing further comprises a polarizing filter.~~

~~67. A portable, modular handheld imaging system kit, comprising:~~

~~a plurality of optical housing portions, each of the plurality of optical housing portions comprising:~~

~~at least one excitation light source configured to emit excitation light during fluorescent imaging,~~

~~a first filter configured to detect and permit passage of optical signals, responsive to illumination of a target surface with the excitation light and having a wavelength corresponding to one or more of bacterial fluorescence, bacterial autofluorescence, tissue fluorescence, and tissue autofluorescence, to a first image sensor,~~

~~a white light source configured to emit white light during white light imaging, and~~

~~a second filter configured to detect and permit passage of optical signals, responsive to illumination of the target surface with the white light and having a wavelength in the visible light range, to a second image sensor; and~~

~~a base housing portion configured to releasably receive, interchangeably, each of the plurality of optical housing portions and comprising:~~

~~a display,~~

~~a power source configured to power the at least one excitation light source and the white light source, and~~

~~a processor configured to receive the detected fluorescent and white light optical signals and to output a representation of the target surface to the display based on the detected optical signals.~~

~~68. The kit of claim 67, wherein, in each of the plurality of optical housing portions, the at least one excitation light source is configured to emit excitation light having a wavelength of about 350 nm - about 400 nm, about 400 nm - about 450 nm, about 450 nm - about 500 nm, about 500 nm - about 550 nm, about 550 nm -about 600 nm, about 600 nm - about 650 nm, about 650 nm - about 700 nm, about~~

~~700 nm - about 750 nm, about 750 nm - about 800 nm, about 800 nm - about 850 nm, about 850 nm - about 900 nm, and/or combinations thereof.~~

~~69. The kit of claim 67 or 68, wherein the at least one excitation light source is configured to emit excitation light having a wavelength of about 400 nm to about 450 nm.~~

~~70. The kit of any one of claims 67-69, wherein the at least one excitation light source is configured to emit excitation light having a wavelength of about 405 nm ± 10 nm.~~

~~71. The kit of any one of claims 67-70, wherein the first filter is configured to permit optical signals having a wavelength between about 500 nm and about 550 nm and/or optical signals having a wavelength between about 600 nm and about 660 nm to pass through the first filter to the first image sensor.~~

~~72. The kit of any one of claims 67-71 , wherein the at least one excitation light source includes first and second violet/blue LEDs, each LED configured to emit light having a wavelength of 405 nm ± 10 nm.~~

~~73. The kit of any one of claims 67-72, wherein one of the plurality of optical housing portions further includes a third filter configured to detect and permit passage of optical signals, responsive to illumination of the target surface with the white light and having a wavelength in the visible light range, to a third image sensor.~~

~~74. The kit of claim 73, wherein a second one of the plurality of optical housing portions further includes a second excitation light source configured to emit excitation light having a wavelength different from a first excitation light source.~~

~~75. The kit of claim 74, wherein a second one of the plurality of optical housing portions is formed as an endoscopic housing portion.~~

~~76. The kit of any one of claims 67-75, wherein one of the plurality of optical housing portions further comprises a range finder.~~

~~77. The kit of any one of claims 67-76, wherein one of the plurality of optical housing portions further comprises a thermal sensor configured to detect thermal information regarding the target surface.~~

~~78. The kit of any one of claims 67-77, wherein the first housing further comprises an ambient light sensor configured to indicate when ambient lighting conditions are sufficient to permit fluorescent imaging.~~

~~79. The kit of any one of claims 67-78, wherein the base housing further comprises an exterior surface with contacts for charging the power source.~~

~~80. The kit of any one of claims 67-79, wherein the base housing further comprises a heat sink.~~

~~81. The kit of any one of claims 67-80, wherein the heat sink defines an opening in the base housing that is configured to releasably receive one of the plurality of optical housings.~~

~~82. The kit of any one of claims 67-81 , further comprising a darkening drape configured to be attached to a one of the plurality of optical housings.~~

~~83. The kit of claim 82, wherein the darkening drape is configured to reduce ambient light in a field of view of the first image sensor.~~

84. The kit of claim 82, further comprising a plurality of darkening drapes, each darkening drape configured to be attached to a respective one of the plurality of optical housings.

85. The kit of claim 75, further comprising a darkening drape configured to be attached to the endoscopic optical housing.

86. The kit of claim 85, wherein the darkening drape is configured to reduce ambient light in a field of view of the first image sensor.

87. The kit of claim 86, wherein the darkening drape is further configured to provide sterility in a surgical field and/or protect the optical housing portion from contaminants.

88. The kit of any one of claims 67-87 wherein one of the plurality of optical housing portions further comprises a polarizing filter.

89. The kit of any one of claims 67-88, wherein the base housing and one of the plurality of optical housing portions together form an imaging device and further comprising a sterile drape configured to create a sterile barrier between the imaging device and the environment in which the imaging device is used.

90. The kit of any one of claims 67-89, further comprising one or more imaging agents or contrast agents.

91. A method of operating a modular, handheld fluorescence-based imaging device, comprising:

selecting an optical housing comprising optical components including at last one excitation light source for fluorescence imaging;

connecting the selected optical housing to a base body housing of the imaging device to provide power from a power source in the base body housing to the optical components in the optical housing;

~~illuminating a target with the at least excitation light source to cause one or more of a part, a component, and a biomarker of the illuminated portion of the target to fluoresce, to reflect light, or to absorb light;~~

~~filtering optical signals responsive to the illumination of the target with the excitation light, wherein filtering the plurality of optical signals includes preventing passage of reflected excitation light and permitting passage of optical signals having a wavelength corresponding to one or more of bacterial fluorescence, bacterial autofluorescence, tissue autofluorescence and exogenous tissue fluorescence through a fluorescent filter contained in the optical housing;~~

~~detecting the filtered optical signals with an image sensor contained in the optical housing;~~

~~displaying the detected, filtered signals on at least one display of the base body housing as a composite image of the illuminated portion of the target, the composite image comprising fluorescent representations of various tissue components present in the illuminated portion of the target.~~

~~92. The method of claim 91 , further comprising:~~

~~illuminating a target with a white light source contained in the optical housing;~~

~~filtering optical signals responsive to the illumination of the target with the white light with a visible light filter contained in the optical housing;~~

~~detecting the filtered optical signals with an image sensor contained in the optical housing.~~

42. A portable, handheld imaging system, comprising:

at least one excitation light source configured to emit excitation light during fluorescent imaging;

a fluorescent image sensor;

a first filter configured to permit passage of optical signals, responsive to illumination of a target surface with the excitation light and having a wavelength corresponding to one or more of bacterial fluorescence, bacterial autofluorescence,

tissue fluorescence, and tissue autofluorescence, to be detected by the fluorescent image sensor;

a white light source configured to emit white light during white light imaging;

a first white light image sensor and a second white light image sensor;

a second filter and a third filter, each of the second and third filters being configured to permit passage of optical signals, responsive to illumination of the target surface with the white light and having a wavelength in the visible light range, to be detected by a respective one of the first and the second white light image sensors;

a processor configured to receive the detected fluorescent and white light optical signals and to output a representation of the target surface to a display based at least in part on the detected optical signals,

wherein the system comprises a modular housing including an optical unit detachably connected to a display unit,

wherein the optical unit includes the at least one excitation light source, the fluorescent image sensor, the white light source, and the first and second white light image sensors, and

wherein the display unit includes the processor and a display.

43. The system of claim 42, wherein the representation, based in part on the optical signals detected by the first and second white light image sensors, is a stereoscopic or three-dimensional image of the target surface and, wherein the representation, based in part on the optical signals detected by the fluorescent image sensor, provides an indication of a bacterial load of the target surface.

44. The system of claim 42 or 43, wherein the system further comprises a thermal sensor configured to detect thermal information regarding the target surface.

45. The system of claim 44, wherein the processor is further configured to receive the detected thermal information and to output a representation of the target surface based on the thermal information.

46. The system of any one of claims 42-45, further comprising an infrared radiation source.

47. The system of claim 46, wherein the system is configured to project infrared radiation onto the target surface and detect infrared radiation reflected from the target surface as well as any infrared fluorescence emitted by the target when excited by the appropriate excitation wavelength.

48. The system of claim 47, wherein the processor is further configured to generate a three-dimensional map of the target surface based on the detected reflected infrared radiation.

49. The system of claim 48, wherein the processor is further configured to generate a three-dimensional fluorescence image of the target surface based on the three-dimensional map, a two-dimensional white light image of the target surface, and a two-dimensional fluorescence image of the target surface.

50. A portable, handheld imaging system, comprising:

at least one excitation light source configured to emit excitation light during fluorescent imaging;

a fluorescent image sensor;

a first filter configured to permit passage of optical signals, responsive to illumination of a target surface with the excitation light and having a wavelength corresponding to one or more of bacterial fluorescence, bacterial autofluorescence, tissue fluorescence, and tissue autofluorescence, to be detected by the fluorescent image sensor;

a white light source configured to emit white light during white light imaging;

a first white light image sensor and a second white light image sensor;

a second filter and a third filter, each of the second and third filters being configured to permit passage of optical signals, responsive to illumination of the target

surface with the white light and having a wavelength in the visible light range, to be detected by a respective one of the first and the second white light image sensors;

an infrared radiation source, wherein the system is configured to project infrared radiation onto the target surface and to detect infrared radiation reflected from the target surface as well as any infrared fluorescence emitted by the target when excited by the appropriate excitation wavelength; and

a processor configured to receive the detected fluorescent and white light optical signals and to output a representation of the target surface to a display based at least in part on the detected optical signals, and

wherein the processor is further configured to generate a three-dimensional fluorescence image of the target surface based at least in part on the detected reflected infrared radiation.

51. The system of claim 50, wherein the processor is further configured to generate a three-dimensional map of the target surface based on the detected reflected infrared radiation.

52. The system of claim 51, generating a three-dimensional fluorescence image of the target surface with the processor is based on the three-dimensional map, a two-dimensional white light image of the target surface, and a two-dimensional fluorescence image of the target surface.

53. The system of any one of claims 50-52, wherein the representation, based in part on the optical signals detected by the first and second white light image sensors, is a stereoscopic or three-dimensional image of the target surface and, wherein the representation, based in part on the optical signals detected by the fluorescent image sensor, provides an indication of a bacterial load of the target surface.

54. The system of any one of claims 50-53, wherein the system further comprises a thermal sensor configured to detect thermal information regarding the target surface.

55. The system of claim 54, wherein the processor is further configured to receive the detected thermal information and to output a representation of the target surface based on the thermal information.

~~93~~56. An imaging system kit, comprising:

the imaging system of any one of claims ~~1-66~~ 1-55; and

a sterile drape configured to create a sterile barrier between the imaging system and an environment the imaging system is used in.

~~94~~57. The kit of claim ~~93~~56, further comprising an imaging drape configured to reduce ambient light in an imaging environment of the imaging system.

~~95~~58. The kit of claim ~~94~~57, wherein the imaging drape includes a connector element configured to receive an optical housing of the imaging system.

~~96~~59. The kit of any one of claims ~~93~~56-~~95~~58, further comprising one or more imaging agents or contrast agents.