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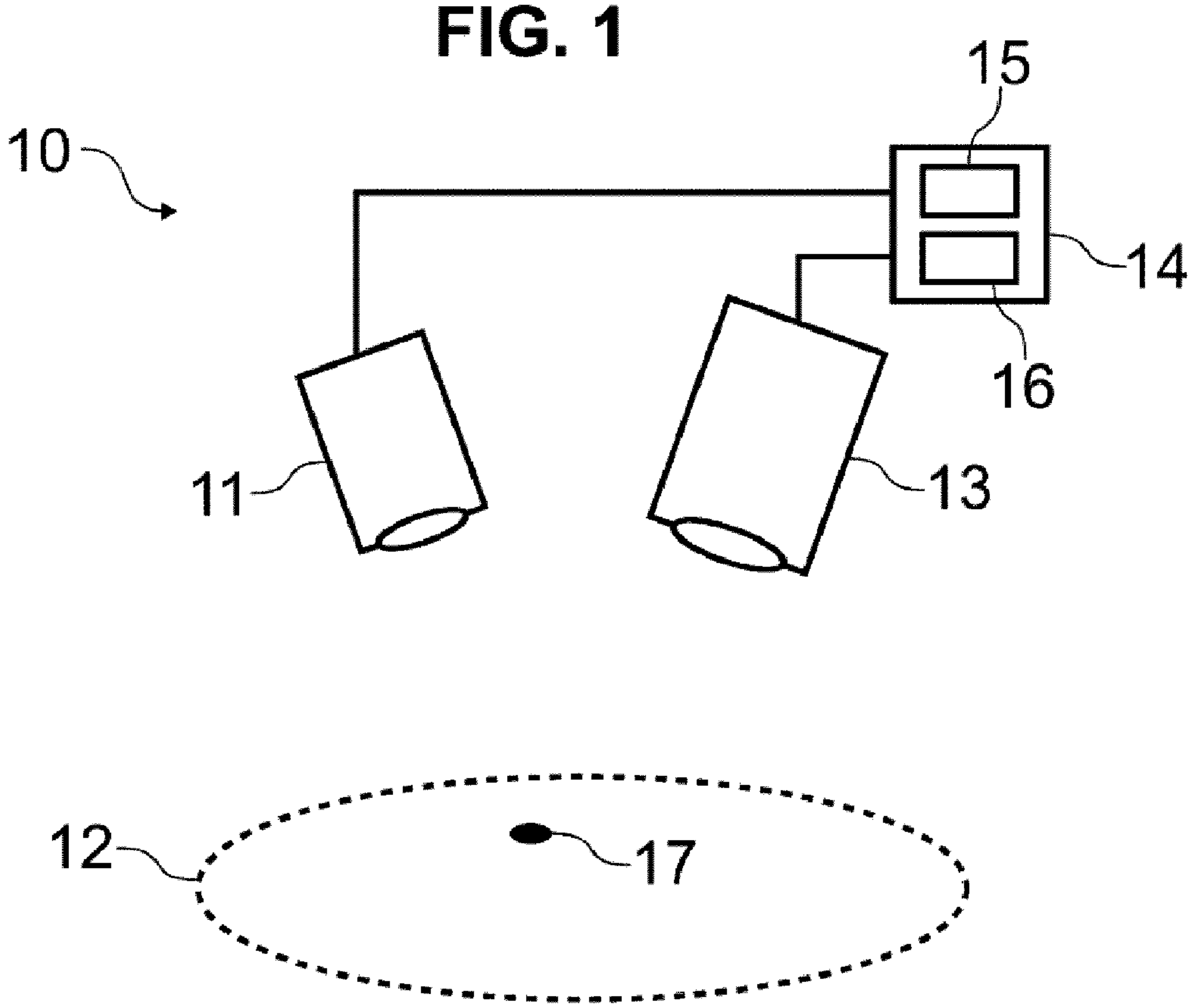
(54) Titre : SYSTEMES ET PROCEDES D'IMAGERIE A FLUORESCENCE PORTATIVE A CHAMP OUVERT
(54) Title: OPEN-FIELD HANDHELD FLUORESCENCE IMAGING SYSTEMS AND METHODS

FIG. 1



(57) Abrégé/Abstract:
An imaging device having an imaging field of view, the imaging device including at least one illumination port configured to output light for illuminating a target; an imaging sensor to detect light traveling along an optical path to the imaging sensor; and a first

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(57) **Abrégé(suite)/Abstract(continued)**:
movable window positioned upstream of the sensor with respect to a direction of travel of light along the optical path, wherein the first movable window is configured to move into the optical path in a deployed position for modifying light received from the target.

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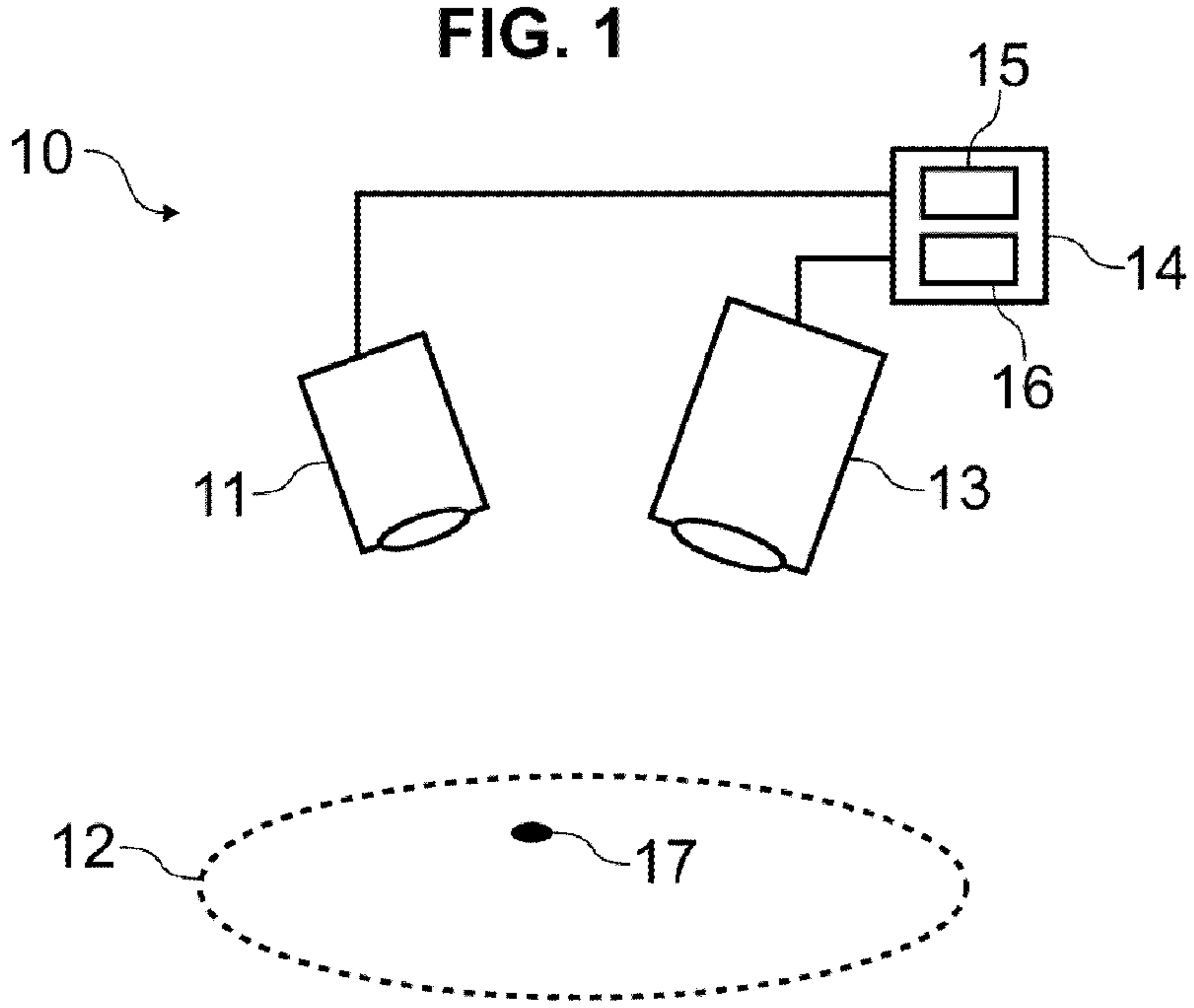
(54) Title: OPEN-FIELD HANDHELD FLUORESCENCE IMAGING SYSTEMS AND METHODS

FIG. 1



(57) Abstract: An imaging device having an imaging field of view, the imaging device including at least one illumination port configured to output light for illuminating a target; an imaging sensor to detect light traveling along an optical path to the imaging sensor; and a first movable window positioned upstream of the sensor with respect to a direction of travel of light along the optical path, wherein the first movable window is configured to move into the optical path in a deployed position for modifying light received from the target.

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[Continued on next page]

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CLAIMS

What is claimed is:

1. An imaging device having an imaging field of view, the imaging device comprising:

at least one illumination port configured to output light for illuminating a target;

an imaging sensor to detect light traveling along an optical path to the imaging sensor; and

a first movable window positioned upstream of the sensor with respect to a direction of travel of light along the optical path, wherein the first movable window is configured to move into the optical path in a deployed position for modifying light received from the target.

2. The imaging device of claim 1, wherein the first movable window is configured to rotate into the optical path in a deployed position.

3. The imaging device of claim 1, wherein the first movable window is configured to translate into the optical path in a deployed position.

4. The imaging device of claim 1, wherein the first movable window extends perpendicularly to an optical axis in the deployed position.

5. The imaging device of claim 1, wherein the first movable window is configured to pivot into the optical path in a deployed position.

6. The imaging device of claim 5, wherein the first movable window is configured to pivot about a first pivot axis extending perpendicularly to an optical axis.

7. The imaging device of any one of claims 1-6, wherein the first movable window comprises a filter.

8. The imaging device of claim 7, wherein the filter is configured to filter out visible light.

9. The imaging device of any one of claims 1-8, comprising a second movable window positioned upstream of the imaging sensor with respect to the direction of travel of light along the optical path, wherein the second movable window is configured to move into the optical path in a deployed position for modifying light received from the target.

10. The imaging device of claim 9, wherein the second movable window is configured to pivot about a second pivot axis extending perpendicularly to an optical axis.

11. The imaging device of claim 10, wherein the first movable window is configured to pivot about a first pivot axis extending perpendicularly to the optical axis and the first pivot axis and the second pivot axis are coplanar with a plane extending perpendicularly to the optical axis.

12. The imaging device of any one of claims 9-11, wherein the first movable window and the second movable window are coupled to a linkage that is configured to simultaneously move the first and second pivoting windows.

13. The imaging device of any one of claims 9-12, wherein, when the first movable window is in the deployed position, the second movable window is moved out of the optical path in a stowed position.

14. The imaging device of any one of claims 1-13, wherein the image sensor is translatable with respect to the first movable window.

15. The imaging device of claim 14, wherein the first movable window extends perpendicularly to an optical axis in the deployed position and the image sensor is translatable along the optical axis.

16. The imaging device of any one of claims 1-15, comprising a first illumination port and a second illumination port, wherein the first illumination port is configured to generate a first illumination distribution at the target, the second illumination port is configured to generate a second illumination distribution at the target, the second illumination port is spaced apart from the first illumination port, the first and second illumination distributions are simultaneously provided to the target and overlap at the target, and the illumination from the first and second ports is matched to a same aspect ratio and field of view coverage as the imaging field of view.

17. The imaging device of claim 16, wherein the first and second illumination ports are fixed with respect to each other.

18. The imaging device of any one of claims 1-17 wherein the at least one illumination port is configured to output visible light and/or excitation light.

19. The imaging device as claimed in claim 18, wherein the image sensor is a single sensor that is configured to detect light from the target resulting from illumination by visible light and excitation light.

20. The imaging device of claim 19, comprising a wavelength-dependent aperture upstream of the image sensor, wherein the wavelength-dependent aperture is configured to block visible light outside a central region.

21. The imaging device of any one of claims 1-20, comprising one or more sensors for sensing an amount of light incident on the device.

22. The imaging device of claim 21, comprising a control system configured to adjust at least one image acquisition parameter based on output from the one or more sensors.

23. The imaging device of claim 22, wherein the at least one image acquisition parameter comprises an exposure duration, excitation illumination duration, excitation illumination power, or imaging sensor gain.

24. The imaging device of any one of claims 21-23, wherein at least one of the one or more sensors is configured to sense visible light and near infrared light.

25. The imaging device of any one of claims 21-24, wherein at least one of the one or more sensors is configured to sense near infrared light.

26. The imaging device of any one of claims 1-25, comprising one or more drape sensors configured to detect a drape mounted to the device.

27. The imaging device of claim 26, comprising one or more light emitters for emitting light for detection by the one or more drape sensors.

28. The imaging device of claim 27, wherein the one or more drape sensors are configured to detect light emitted from the one or more light emitters after reflection of the emitted light off of one or more reflectors on the drape.

29. The imaging device of claim 28, wherein the one or more reflectors comprise a prism.

30. An imaging system comprising an imaging device according to any one of claims 1-29, an illumination source for providing illumination to the imaging device, and a processor assembly for receiving imaging data generated by the imaging device.

31. A method for imaging a target, the method comprising:

illuminating the target with an illuminator of an imaging device;

receiving light from the target at an imaging sensor of the imaging device in a first imaging mode, wherein at least some of the light received at the imaging sensor in the first imaging mode comprises wavelengths in a first band;

switching to a second imaging mode; and

while in the second imaging mode:

blocking light of wavelengths outside of a second band received from the target from reaching the imaging sensor using a first movable filter of the imaging device, wherein at least some of the blocked light comprises wavelengths in the first band, and

receiving light of wavelengths within the second band received from the target on the imaging sensor.

32. The method of claim 31, wherein the second band comprises near infrared wavelengths.

33. The method of claim 31 or claim 32, wherein the first band comprises visible light wavelengths.

34. The method of any one of claims 31-33, comprising, while in the second imaging mode, sensing light levels at one or more light level sensors of the imaging device and adjusting one or more of image sensor signal gain, illumination pulse duration, image sensor exposure, and illumination power based on output of the one or more light level sensors.

35. The method of claim 34, comprising, while in the first imaging mode, sensing light levels at one or more light level sensors of the imaging device and adjusting one or more of image sensor signal gain, illumination pulse duration, image sensor exposure, and illumination power based on output of the one or more light level sensors.

36. The method of any one of claims 31-35, wherein switching to the second imaging mode comprises moving the first movable filter into an optical path along which light from the target travels to the imaging sensor.

37. The method of claim 36, wherein switching to the second imaging mode comprises moving a clear window out of the optical path.

38. The method of claim 36, wherein switching to the second imaging mode comprises moving a second movable filter out of the optical path.

39. The method of any one of claims 31-38, wherein the first imaging mode is switched to the second imaging mode in response to a user request.

40. The method of claim 39, wherein the user request comprises a user input to the imaging device.

41. The method of any one of claims 31-40, comprising:

while in the second imaging mode, receiving a request from the user to switch to the first imaging mode; and

in response to receiving the request from the user to switch to the first imaging mode, moving the movable filter out of the optical path.

42. The method of claim 41, comprising:

while in the second imaging mode, sensing light levels at one or more light level sensors of the imaging device and adjusting one or more of image sensor signal gain, illumination pulse duration, image sensor exposure, and illumination power based on output of the one or more light level sensors; and

in response to receiving the request from the user to switch to the first imaging mode, ceasing to adjust one or more of image sensor signal gain, illumination pulse duration, image sensor exposure, and illumination power based on output of the one or more light level sensors.

43. The method of any one of claims 31-42, comprising detecting an object at least partially blocking an illumination beam of the illuminator, and in response to detecting the object, adjusting an illumination power of the illuminator.

44. A kit for imaging an object, the kit comprising a fluorescence imaging agent and the device of any one of claims 1-29, the system of claim 30, or the system of any one of claims 56-63.

45. A fluorescence imaging agent for use with the device of any one of claims 1-29, the system of claim 30, the system of any one of claims 56-63, the method of any one of claims 31-43, the method of any one of claims 64-71, or the kit of claim 44 for imaging an object.

46. The fluorescence imaging agent of claim 45, wherein imaging an object comprises imaging an object during blood flow imaging, tissue perfusion imaging, lymphatic imaging, or a combination thereof.

47. The fluorescence imaging agent of claim 46, wherein blood flow imaging, tissue perfusion imaging, and/or lymphatic imaging comprises blood flow imaging, tissue perfusion imaging, and/or lymphatic imaging during an invasive surgical procedure, a minimally invasive surgical procedure, or during a non-invasive surgical procedure.

48. The fluorescence imaging agent of claim 47, wherein the invasive surgical procedure comprises a cardiac-related surgical procedure or a reconstructive surgical procedure.

49. The fluorescence imaging agent of claim 48, wherein the cardiac-related surgical procedure comprises a cardiac coronary artery bypass graft (CABG) procedure.

50. The fluorescence imaging agent of claim 49, wherein the CABG procedure is on pump or off pump.

51. The fluorescence imaging agent of claim 47, wherein the non-invasive surgical procedure comprises a wound care procedure.

52. The fluorescence imaging agent of any of claims 46-51, wherein the lymphatic imaging comprises identification of a lymph node, lymph node drainage, lymphatic mapping, or a combination thereof.

53. The fluorescence imaging agent of any one of claims 46-52, wherein the lymphatic imaging relates to the female reproductive system.

54. Use of the device of any one of claims 1-29, the system of claim 30, the system of any one of claims 56-63, the method of any one of claims 31-43, the method of any one of claims 64-71, or the kit of claim 44 for lymphatic imaging.

55. Use of the device of any one of claims 1-29, the system of claim 30, the system of any one of claims 56-63, the method of any one of claims 31-43, the method of any one of claims 64-71, or the kit of claim 44 for blood flow imaging, tissue perfusion imaging, or a combination thereof.

56. A system for imaging a target, the system comprising:

one or more processors;

memory; and

one or more programs, wherein the one or more programs are stored in the memory and configured to be executed by the one or more processors, the one or more programs including instructions for, within a period:

activating an excitation light source to generate an excitation pulse to illuminate the target;

receiving an ambient light intensity signal from a sensor during a portion of the period in which the excitation light source is not activated;

exposing an image sensor for a fluorescent exposure time during the excitation pulse;

receiving outputs from the image sensor;

compensating for ambient light based on the ambient light intensity signal; and

storing a resultant image in the memory.

57. The system of claim 56, wherein the one or more programs include instructions for, within the period:

activating a white light source to generate a white light pulse to illuminate the target such that the white light pulse does not overlap the excitation pulse; and

exposing the image sensor for a visible exposure time during at least one white light pulse.

58. The system of claim 56 or 57, wherein the one or more programs include instructions for exposing the image sensor for a background exposure time when the target is not illuminated.

59. The system of any one of claims 56-58, wherein the one or more programs include instructions for detecting a periodic frequency of the ambient light intensity.

60. The system of claim 59, wherein compensating for ambient light comprises:

setting an image acquisition frame rate equal to a multiple or a factor of the periodic frequency prior to exposing the image sensor for the background exposure time and prior to exposing the image sensor for the fluorescent exposure time during the excitation pulse; and

subtracting image sensor output received for the background exposure time from the image sensor output received for the fluorescence exposure time to form the resultant image.

61. The system of claim 59, wherein compensating for ambient light comprises:

synthesizing or extracting, from one or more received ambient light intensity signals, a complete periodic cycle of ambient light intensity having the detected periodic frequency;

extending the ambient light intensity periodic cycle to a time period corresponding to the fluorescence exposure time;

calculating a first accumulated ambient light value corresponding to an area under the curve of ambient light intensity during a background exposure time;

calculating a second accumulated ambient light value corresponding to an area under the curve of the ambient light intensity during the fluorescence exposure time;

scaling the received image sensor output for the background exposure time and the received image sensor output for the fluorescence exposure time based on a ratio of the first and second accumulated ambient light values; and

subtracting the scaled image sensor output for the background exposure time from the scaled image sensor output for the fluorescence exposure time to form the resultant image.

62. The system of claim 61, wherein the one or more programs include instructions for receiving an ambient light intensity signal from the sensor during the background exposure time.

63. The system of claim 61, wherein the one or more programs include instructions for extending the ambient light intensity periodic cycle to the time period corresponding to the fluorescence exposure time.

64. A method for imaging a target, the method comprising:

at a system having one or more processors and memory:

activating an excitation light source to generate an excitation pulse to illuminate the target;

receiving an ambient light intensity signal from a sensor during a portion of the period in which the excitation light source is not activated;

exposing an image sensor for a fluorescent exposure time during the excitation pulse;

receiving outputs from the image sensor;

compensating for ambient light based on the ambient light intensity signal; and

storing a resultant image in the memory.

65. The method of claim 64, further comprising, within the period:

activating a white light source to generate a white light pulse to illuminate the target such that the white light pulse does not overlap the excitation pulse; and

exposing the image sensor for a visible exposure time during at least one white light pulse.

66. The method of claim 64 or 65, further comprising exposing the image sensor for a background exposure time when the target is not illuminated.

67. The method of any one of claims 64-66, further comprising detecting a periodic frequency of the ambient light intensity.

68. The method of claim 67, wherein compensating for ambient light comprises:

setting an image acquisition frame rate equal to a multiple or a factor of the periodic frequency prior to exposing the image sensor for the background exposure time and prior to exposing the image sensor for the fluorescent exposure time during the excitation pulse; and

subtracting image sensor output received for the background exposure time from the image sensor output received for the fluorescence exposure time to form the resultant image.

69. The method of claim 67, wherein compensating for ambient light comprises:

synthesizing or extracting, from one or more received ambient light intensity signals, a complete periodic cycle of ambient light intensity having the detected periodic frequency;

extending the ambient light intensity periodic cycle to a time period corresponding to the fluorescence exposure time;

calculating a first accumulated ambient light value corresponding to an area under the curve of ambient light intensity during a background exposure time;

calculating a second accumulated ambient light value corresponding to an area under the curve of the ambient light intensity during the fluorescence exposure time;

scaling the received image sensor output for the background exposure time and the received image sensor output for the fluorescence exposure time based on a ratio of the first and second accumulated ambient light values; and subtracting the scaled image sensor output for the background exposure time from the scaled image sensor output for the fluorescence exposure time to form the resultant image.

70. The method of claim 69, further comprising receiving an ambient light intensity signal from the sensor during the background exposure time.

71. The method of claim 69, further comprising extending the ambient light intensity periodic cycle to the time period corresponding to the fluorescence exposure time.