CLAIMS

1. A system for defect detection and photoluminescence measurement of a sample comprising:

a first radiation source configured to direct a first beam of light onto a portion of the sample;

a second radiation source configured to direct a second beam of light onto a portion of the sample, wherein the second beam of light is suitable for causing one or more photoluminescing defects of the sample to emit photoluminescent light;

a set of collection optics configured to collect radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing defects of the sample;

a filter sub-system configured to receive at least a portion of the radiation collected by the set of collection optics, wherein the filter sub-system is configured to separate the radiation from the sample into two or more portions of radiation, wherein at least a first portion of radiation includes one or more wavelengths in the visible or near-infrared spectrum associated with the light emitted by the one or more photoluminescing defects of the sample;

a detection sub-system including at least a first sensor for measuring one or more characteristics of the first portion of radiation transmitted by the filter sub-system; and

a controller communicatively coupled to at least the first sensor, the controller configured to detect one or more photoluminescence defects based on at least the one or more characteristics measured by the first sensor.

2. The system of claim **1**, wherein the controller is further configured to detect one or more photoluminescence defects based on at least the one or more characteristics measured by the first sensor by comparing a signal from the first sensor in an area of the sample absent of photoluminescing defects to a signal from the first sensor acquired from a measured region of the sample.

3. The system of claim **1**, wherein the controller is further configured to map the detected one or more photoluminescence defects based on at least the one or more characteristics measured by the first sensor and a position of the detected one or more photoluminescence defects.

4. The system of claim **1**, wherein the controller is further configured to classify the detected one or more photoluminescence defects based on at least the one or more characteristics measured by the first sensor.

5. The system of claim **1**, wherein the one or more photoluminescing defects of the sample comprise:

at least one of one or more stacking fault defects and one or more basal plane dislocations.

6. The system of claim **1**, wherein the sample is a semiconductor device.

7. The system of claim **6**, wherein the semiconductor device is a wide-bandgap semiconductor device.

8. The system of claim **1**, wherein at least one of the first radiation source and the second source is a laser.

9. The system of claim **8**, wherein at least one of the first radiation source and the second source is an ultraviolet laser.

10. The system of claim **8**, wherein at least one of the first radiation source and the second source is a continuous wave (CW) laser.

11. The system of claim **1**, further comprising:

a sample stage assembly configured to secure the sample and selectively actuate the sample in order to perform a scanning process with at least the first radiation source and the second source.

12. The system of claim **1**, wherein the first sensor includes a photomultiplier tube (PMT).

13. The system of claim **1**, wherein the first sensor is configured to measure at least one of visible photoluminescence light and near-infrared light emitted from one or more photoluminescent defects of the sample.

14. The system of claim **1**, further comprising:

a second sensor configured to measure scattered radiation from one or more defects of the sample at a wavelength corresponding with the light emitted by the second radiation source.

15. The system of claim **14**, further comprising:

a third sensor configured to measure scattered radiation from one or more defects of the sample at a wavelength corresponding with the light emitted by the first radiation source.

16. The system of claim **15**, wherein at least one of the second sensor and third sensor is configured to measure ultraviolet photoluminescence light from one or more photoluminescent defects of the sample.

17. A system for defect detection and photoluminescence measurement of a sample comprising:

a first radiation source configured to direct a first beam of light onto a portion of the sample;

a second radiation source configured to direct a second beam of light onto a portion of the sample, wherein the second beam of light is suitable for causing one or more photoluminescing defects of the sample to emit photoluminescent light;

a set of collection optics configured to collect radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing defects of the sample;

a filter sub-system configured to receive at least a portion of the radiation collected by the set of collection optics, wherein the filter sub-system is configured to separate the radiation from the sample into at least one of a first portion of radiation including one or more wavelengths in the visible or near-infrared spectrum associated with the light emitted by the one or more photoluminescing defects of the sample, a second portion of radiation including light from the first radiation source, a third portion of radiation including light from the second radiation source, or at least a fourth portion of radiation including one or more wavelengths in the ultraviolet spectrum associated with the photoluminescent light emitted by the one or more photoluminescing defects of the sample;

a detection sub-system including at least one of a first sensor for measuring one or more characteristics of the first portion of radiation transmitted by the filter sub-system, a second sensor for measuring one or more characteristics of the second portion of radiation transmitted by the filter sub-system, a third sensor for measuring one or more characteristics of the third

portion of radiation transmitted by the filter sub-system, or a fourth sensor for measuring one or more characteristics of the fourth portion of radiation transmitted by the filter sub-system; and

a controller communicatively coupled to at least one of the first sensor, the second sensor or the third sensor, the controller configured to detect one or more photoluminescence defects based on the light detected by at least one of the first sensor, the second sensor, the third sensor, or the fourth sensor.

18. The system of claim **17**, wherein the one or more photoluminescing defects of the sample comprise:

at least one of one or more stacking fault defects and one or more basal plane dislocations.

19. The system of claim **17**, wherein the filter sub-system includes:

a first optical element configured to separate a first spectral range of radiation including the first portion of radiation from the radiation received from the sample and direct the first spectral range of radiation toward the first sensor;

a second optical element configured to receive radiation from the first optical element not included in the first spectral range of radiation, wherein the second optical element is configured to separate a second spectral range of radiation including the second portion of radiation from the radiation received from the first optical element and direct the second spectral range of radiation toward the second sensor; and

a third optical element configured to receive radiation from the second optical element not included in the first spectral range of radiation or the second spectral range of radiation, wherein the third optical element is configured to at least separate a portion of a third spectral

range of radiation including the third portion of radiation from the radiation received from the second optical element and direct the third spectral range of radiation toward the third sensor, the third optical element further configured to transmit radiation not included in the first spectral range of radiation, the second spectral range of radiation or the third spectral range of radiation toward the fourth sensor in a fourth spectral range of radiation including the fourth portion of radiation.

20. The system of claim **19**, wherein at least one of the first optical element, the second optical element, and the third optical element is a dichroic beam splitter.

21. The system of claim **19**, further comprising:

a first narrow pass filter positioned between the first sensor and the first optical element and configured to receive at least a portion of the first spectral range of radiation and transmit the first portion of radiation to the first sensor and block radiation not included in the first portion of radiation;

a second narrow pass filter positioned between the second sensor and the second optical element configured to receive at least a portion of the second spectral range of radiation and transmit the second portion of radiation to the second sensor and block radiation not included in the second portion of radiation;

a third narrow pass filter positioned between the third sensor and the third optical element configured to receive at least a portion of the third spectral range of radiation and transmit the third portion of radiation to the third sensor and block radiation not included in the third portion of radiation; and

a fourth narrow pass filter positioned between the fourth sensor and the third optical element configured to

receive at least a portion of the fourth spectral range of radiation and transmit the fourth portion of radiation to the fourth sensor and block radiation not included in the fourth portion of radiation.

22. The system of claim **17**, wherein at least one of the first sensor, the second sensor, the third sensor, and the fourth sensor includes a photomultiplier tube (PMT).

23. The system of claim **17**, wherein the controller is further configured to classify the detected one or more photoluminescence defects based on one or more spectral characteristics of light detected by at least one of the first sensor, the second sensor, the third sensor, and the fourth sensor.

24. The system of claim **17**, wherein the sample is a semiconductor device.

25. The system of claim **24**, wherein the semiconductor device is a wide-bandgap semiconductor device.

26. The system of claim **17**, wherein at least one of the first radiation source and the second radiation source is a laser.

27. The system of claim **26**, wherein at least one of the first radiation source and the second source is an ultraviolet laser.

28. The system of claim **26**, wherein at least one of the first radiation source and the second radiation source is a continuous wave (CW) laser.

29. The system of claim **17**, wherein the first sensor is configured to measure at least one of visible photoluminescence light and near-infrared light emitted from one or more photoluminescent defects of the sample and the fourth sensor is configured to measure ultraviolet photoluminescence light.

30. The system of claim **17**, wherein the second sensor is configured to measure scattered radiation from one or more

defects of the sample at a wavelength corresponding with the light emitted by the second radiation source.

31. The system of claim **17**, wherein the third sensor is configured to measure scattered radiation from one or more defects of the sample at a wavelength corresponding with the light emitted by the first radiation source.

32. The system of claim **17**, wherein at least one of the second sensor and third sensor is configured to measure ultraviolet photoluminescence light from one or more photoluminescent defects of the sample.

33. A system for defect detection and photoluminescence measurement of a sample comprising:

a radiation source configured to direct a beam of light of a first wavelength onto a portion of the sample, wherein the beam of light of the first wavelength is suitable for causing one or more photoluminescing defects of the sample to emit photoluminescent light;

a set of collection optics configured to collect radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing defects of the sample;

a filter sub-system configured to receive at least a portion of the radiation collected by the set of collection optics, wherein the filter sub-system is configured to separate the radiation from the sample into two or more portions of radiation, wherein at least a first portion of radiation includes one or more wavelengths in the visible or near-infrared spectrum associated with the light emitted by the one or more photoluminescing defects of the sample, and at least a second portion of radiation including one or more wavelengths in the ultraviolet spectrum associated with the light emitted by the one or more photoluminescing defects of the sample;

a detection sub-system including at least one of a first sensor for measuring one or more characteristics of the first portion of radiation transmitted by the filter sub-system or a second sensor for measuring one or more characteristics of the second portion of radiation transmitted by the filter sub-system; and

a controller communicatively coupled to the first sensor and the second sensor, the controller configured to detect one or more photoluminescence defects based on the light detected by at least one of the first sensor or the second sensor.

34. The system of claim **33**, wherein at least one of the first sensor and the second sensor are configured to measure ultraviolet photoluminescence light or near-ultraviolet photoluminescence light from one or more photoluminescent defects of the sample.

35. A system for defect detection and photoluminescence measurement of a sample comprising:

a first radiation source configured to direct a beam of light of a first wavelength onto a portion of the sample, wherein the beam of light of the first wavelength is suitable for causing one or more photoluminescing defects of the sample to emit photoluminescent light;

a set of collection optics configured to collect radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing defects of the sample;

a filter sub-system configured to receive at least a portion of the radiation collected by the set of collection optics, wherein the filter sub-system is configured to separate the radiation from the sample into a plurality of portions of photoluminescent radiation, each portion including one or more wavelengths in a different spectral range of the radiation emitted by the one or more

photoluminescing defects of the sample;

a detection sub-system including a plurality of sensors, each sensor suitable for measuring one or more characteristics of one of the plurality of portions of photoluminescent radiation transmitted by the filter sub-system; and

a controller communicatively coupled to each of the plurality of sensors, the controller configured to detect one or more photoluminescence defects based on the light detected by each of the plurality of sensors.

36. The system of claim **35**, wherein the controller is further configured to:

classify the one or more detected photoluminescence defects based on one or more signals measured by each of the plurality of sensors.

37. The system of claim **35**, further comprising:

a second radiation source configured to direct a beam of light of a second wavelength onto a portion of the sample.

38. The system of claim **37**, wherein the filter sub-system is further configured to separate the radiation into at least one of a portion of radiation including the first wavelength and at least an additional portion of radiation including the second wavelength.

39. The system of claim **38**, wherein the detection sub-system includes at least one of a sensor suitable for measuring one or more characteristics of the portion of radiation including the first wavelength transmitted by the filter sub-system and an additional sensor suitable for measuring the at least an additional portion of radiation including the second wavelength transmitted by the filter sub-system.

40. The system of claim **39**, wherein the controller is further configured to detect one or more scattering defects

based on the light measured by at least one of the sensor suitable for measuring one or more characteristics of the portion of radiation including the first wavelength and the additional sensor suitable for measuring the at least an additional portion of radiation including the second wavelength.

41. The system of claim **35**, wherein the filter sub-system includes a plurality of optical elements and a plurality of narrow band filters in order to separate the radiation received from the sample into a plurality of spectral bins.

42. The system of claim **41**, wherein the plurality of optical elements and the plurality of narrow band filters define each of the plurality of spectral bins according to one or more anticipated spectral characteristics of one or more photoluminescent defects of the sample.

43. The system of claim **42**, wherein the plurality of optical elements and the plurality of narrow band filters substantially match a plurality of full width half maximum values to a set of corresponding intensity peaks of a photoluminescent spectrum, wherein each intensity peak is indicative of the presence of a type of stacking fault.

44. The system of claim **35**, wherein the filter sub-system includes a plurality of optical elements and a plurality of narrow band filters in order to separate the radiation received from the sample into at least one of a plurality of NUV spectral bins, a plurality of UV bins, and a plurality of visible spectral bins.

45. A method for defect detection and photoluminescence measurement of a sample comprising:

directing a beam of first wavelength light onto a portion of the sample;

directing a beam of second wavelength light onto a portion of the sample, wherein the beam of light of the second wavelength is suitable for causing one or more

photoluminescing defects of the sample to emit photoluminescent light;

collecting radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing defects of the sample;

separating the radiation from the sample into two or more portions of radiation, wherein at least a first portion of radiation includes one or more wavelengths in the visible or near-infrared spectrum associated with the light emitted by the one or more photoluminescing defects of the sample;

measuring one or more characteristics of the first portion of radiation; and

detecting one or more photoluminescence defects based on the measured one or more characteristics of at least one of the first portion of radiation.

46. A method for defect detection and photoluminescence measurement of a sample comprising:

directing a beam of first wavelength light onto a portion of the sample;

directing a beam of second wavelength light onto a portion of the sample, wherein the beam of light of the second wavelength is suitable for causing one or more photoluminescing defects of the sample to emit photoluminescent light;

collecting radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing defects of the sample;

separating the radiation from the sample into at least one of a first portion of radiation including one or more wavelengths in the visible or near-infrared spectrum

associated with the light emitted by the one or more photoluminescing defects of the sample, a second portion of radiation including light from the first radiation source, a third portion of radiation including light from the second radiation source, or at least a fourth portion of radiation including one or more wavelengths in the ultraviolet spectrum associated with the photoluminescent light emitted by the one or more photoluminescing defects of the sample;

measuring one or more characteristics of at least one of the first portion of radiation, one or more characteristics of the second portion of radiation, one or more characteristics of the third portion of radiation, or one or more characteristics of the fourth portion of radiation;

detecting one or more scattering defects based on the measured one or more characteristics of at least one of the second portion of radiation and the third portion of radiation; and

detecting one or more photoluminescence defects based on the measured one or more characteristics of at least one of the first portion of radiation, the second portion of radiation, the third portion of radiation, or the fourth portion of radiation.

47. A method for defect detection and photoluminescence measurement of a sample comprising:

directing a beam of first wavelength light onto a surface of the sample, wherein the beam of light of the first wavelength is suitable for causing one or more photoluminescing defects of the sample to emit photoluminescent light;

collecting radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing

defects of the sample;

separating the radiation from the sample into two or more portions of radiation, wherein at least a first portion of radiation includes one or more wavelengths in the visible or near-infrared spectrum associated with the light emitted by the one or more photoluminescing defects of the sample, and at least a second portion of radiation including one or more wavelengths in the ultraviolet spectrum associated with the light emitted by the one or more photoluminescing defects of the sample;

measuring one or more characteristics of at least one of the first portion of radiation or one or more characteristics of the second portion of radiation; and

detecting one or more photoluminescence defects based on the light detected by at least one of the first sensor or the second sensor.

48. A method for defect detection and photoluminescence measurement of a sample comprising:

directing a beam of light of a first wavelength onto a portion of the sample, wherein the beam of light of the first wavelength is suitable for causing one or more photoluminescing defects of the sample to emit photoluminescent light;

collecting radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing defects of the sample;

separating the radiation from the sample into a plurality of portions of photoluminescent radiation, each portion including one or more wavelengths in a different spectral range of the light emitted by the one or more photoluminescing defects of the sample;

measuring one or more characteristics of each of the plurality of portions of photoluminescent radiation; and

detecting one or more photoluminescence defects based on the measured one or more characteristics of each of the plurality of portions of photoluminescent radiation.

49. A method for defect detection and photoluminescence measurement of a sample comprising:

directing a beam of first wavelength light onto a portion of the sample, wherein the beam of light of the first wavelength is suitable for causing one or more photoluminescing defects of the sample to emit photoluminescent light;

directing a beam of second wavelength light onto a portion of the sample;

collecting radiation from the sample, the radiation from the sample including at least photoluminescence radiation emitted by the one or more photoluminescing defects of the sample;

separating the radiation from the sample into a visible portion of photoluminescent radiation and a near-ultraviolet (NUV) portion of photoluminescent radiation;

measuring one or more characteristics of the visible portion of photoluminescent radiation and the NUV portion of photoluminescent radiation; and

detecting one or more photoluminescence defects based on the measured one or more characteristics of the visible portion of photoluminescent radiation and the NUV portion of photoluminescent radiation.

50. The system of claim **49**, further comprising:

classifying the one or more detected photoluminescence defects based on one or more signals associated with the visible portion of photoluminescent radiation and the NUV portion of photoluminescent radiation.