FEMTOWATT NON-VACUUM TUBE DETECTOR ASSEMBLY

BACKGROUND

[0001] Photomultiplier tubes (PMTs for short), members of the class of vacuum tubes, and more specifically vacuum phototubes, are extremely sensitive detectors of light in the ultraviolet, visible, and near-infrared ranges of the electromagnetic spectrum. Unfortunately, current techniques of manufacturing PMTs is a tedious and costly process. Many manufacturers have opted to stop production of PMTs due these challenges. In addition to manufacturing issues, although highly sensitive, PMTs also saturate easily when too much light reaches it.

SUMMARY

[0002] At least some of the disadvantages associated with the prior art may be overcome by at least some embodiments of the devices and methods described herein.

[0002a] According to a first aspect of the present invention, there is provided a device comprising: ~~at least one~~a plurality of photodiodes; an analog amplification system comprising at least a high gain transimpedance amplifier (TIA) and at least a buffer on each of said photodiodes, followed by a fully differential amplifier to combine the outputs of the multiple TIAs; ~~and~~ a digital acquisition system comprising at least one ~~an~~ analog to digital converter (ADC), followed by a~~n~~ programmable processor, which is linked to a central processor as well as on board memory; and at least one shaped reflector to direct light to at least one of said photodiodes, wherein the shaped reflector comprises at least one opening sized and positioned to allow a sample vessel to be placed at a desired location in a cavity defined at least in part by the shaped reflector.

[0002b] ~~According to a second aspect of the present invention~~As disclosed, there is provided a method of optical signal detection.

[0002c] ~~According to a third aspect of the present invention~~As disclosed, there is provided a device for optical signal detection.

[0003] As disclosed, a femtowatt sensitivity optical detector is provided using one or more photodiodes, intended as a replacement for the photomultiplier based photon counting unit.

[0004] In one embodiment, the system is comprised of four main components: Multiple photodiodes, which act as optical transducers by producing an electrical signal in the

form of a current proportional to the detected optical power (number of photons). 1) Analog amplification system, composed of a high gain transimpedance amplifier (TIA) and buffer on each photodiode, followed by a fully differential amplifier to combine the outputs of the multiple TIAs. 2) Digital acquisition system, composed of an analog to digital converter (ADC), followed by an programmable processor, which is linked to the central processor as well as on board memory. The programmable processor implements the data acquisition algorithm such as an average or other algorithm. 3) Multiple digital to analog converters (DACs) on the programmable processor are used to provide feedback control - one for offset adjustment in the differential amplifier, and one to the set the reference level of the ADC. 4) Mechanical housing module, in which the electronics is contained.

[0005] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not

user interface. In embodiments in which a display comprises a user interface, a device may receive, e.g., information, commands, protocols, or other input.

[0054] In embodiments, devices comprising a femtowatt sensitivity photodiode assembly, and systems and methods comprising or using such devices, may comprise a communication assembly effective to communicate with one or more of a user, another device, a laboratory, a network, the cloud, or other communication target. In embodiments, a communication assembly may provide a communication target with information regarding the operation of the device, information regarding the progress of an assay performed by the device, or information regarding the results of an assay performed by the device. In embodiments, a communication assembly may be configured to allow a device to receive, e.g., information, commands, protocols, or other input from an outside source, such as, e.g., a user, another device, a laboratory, a network, the cloud, or other communication source.

[0055] As used herein the terms "sample handling system", "fluid handling system" and grammatical equivalents refer to systems configured to obtain, transport, and deliver fluids. In embodiments disclosed herein, such systems comprise pipettes, nozzles, pipette tips, mechanical components configured to move a pipette, a nozzle, or a pipette tip to a desired location. Such a desired location is typically within a housing of a device. In embodiments, a pipette tip may be mounted on a nozzle; in embodiments, a pipette tip may be removably mounted on a nozzle, effective that a nozzle may engage and mount a first pipette tip, use the first pipette tip, discard the first pipette tip, and then engage and mount a second pipette tip. Such systems comprise means for aspirating liquid into a pipette tip. Such systems comprise means for dispensing liquid from a pipette tip. In embodiments of such systems, a pipette and nozzle may engage and mount an element other than a pipette tip; for example, in embodiments disclosed herein, a pipette and nozzle may engage and mate with a mating socket of a vessel ~~(see, e.g., Figures 10 and 11)~~. In embodiments, a pipette and nozzle mated with a mating socket of a vessel may be used to transport the vessel to a desired location within a device. In embodiments, a pipette and nozzle mated with a mating socket of a vessel may be used to apply force to a vessel ~~(see, e.g., Figure 11 for a configuration where such application of force may be useful)~~.

[0056] The methods disclosed herein can be readily incorporated into and used in device for processing a sample, or a system for processing a sample, which may be an automated assay device, or may be an automated assay system. Such assay devices and assay systems may comprise devices and systems disclosed, for example, in U.S. Patent 8,088,593;

WHAT IS CLAIMED IS:

1. A device comprising:

at least one photodiode;

an analog amplification system comprising a high gain transimpedance amplifier (TIA) and buffer on each photodiode, followed by a fully differential amplifier to combine the outputs of the multiple TIAs; and

digital acquisition system comprising at least one an analog to digital converter (ADC), followed by an programmable processor, which is linked to a central processor as well as on board memory.

2. The device of any one of the foregoing claims further comprising Mechanical housing module, in which the electronics is contained.

3. The device of any one of the foregoing claims wherein the programmable processor implements the data acquisition algorithm (either a long time average or median).

4. The device of claim 1 further comprising multiple digital to analog converters (DACs) on the programmable processor are used to provide feedback control - one for offset adjustment in the differential amplifier, and one to the set the reference level of the ADC.

5. The device of claim 1 further comprising multiple digital to analog converters (DACs) on the programmable processor are used to provide feedback control - one for offset adjustment in the differential amplifier, and one to the set the reference level of the ADC.

6. The device of claim 1 further comprising a shaped reflector to direct light to at least one of said photodetectors.

7. A method of optical signal detection.

8. A device for optical signal detection.

9. A method comprising at least one technical feature from any of the prior claims.

10. A method comprising at least any two technical features from any of the prior claims.

11. A device comprising at least one technical feature from any of the prior claims.

12. A device comprising at least any two technical features from any of the prior claims.

13. A system comprising at least one technical feature from any of the prior claims.

14. A system comprising at least any two technical features from any of the prior claims.

WHAT IS CLAIMED IS:

1. A device comprising:

a plurality of photodiodes;

an analog amplification system comprising at least a high gain transimpedance amplifier (TIA) and at least a buffer on each of said photodiodes, followed by a fully differential amplifier to combine outputs of multiple TIAs;

a digital acquisition system comprising at least one analog-to-digital converter (ADC), followed by a programmable processor, which is linked to a central processor as well as on-board memory; and

at least one shaped reflector to direct light to at least one of said photodiodes, wherein the shaped reflector comprises at least one opening sized and positioned to allow a sample vessel to be placed at a desired location in a cavity defined at least in part by the shaped reflector.

2. The device of claim 1 further comprising a mechanical housing module of the analog amplification system are contained.

3. The device of claim 1 wherein the programmable processor implements the data acquisition algorithm.

4. The device of claim 1 further comprising multiple digital-to-analog converters (DACs) on the programmable processor configured to provide feedback control.

5. The device of claim 4 wherein one of said DACs is configured for offset adjustment in the differential amplifier, and one of said DACs is set the reference level of the ADC.

6. The device of claim 1 wherein the shaped reflector has a semi-hemispherical shape.

7. The device of claim 4, wherein one of the DACS is configured for offset adjustment in the differential amplifier.

8. The device of claim 4, wherein one of the DACS is configured to set a reference level of the ADC.

9. The device of claim 5, wherein one of the DACS is configured for offset adjustment in the differential amplifier.

10. The device of claim 5, wherein one of the DACS is configured to set a reference level of the ADC.

11. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: smoothing data processing.

12. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: Savitzky-Golay smoothing.

13. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: moving average smoothing.

14. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: local regression smoothing.

15. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: recursive filter median.

16. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: long time average.

17. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: Butterworth filtering.

18. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: Kalman filtering.

19. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: Kernel smoothing.

20. The device of claim 3, wherein data acquisition algorithm uses the following digital signal processing: Laplacian smoothing.