

ACTIVE PIXEL SENSOR

FIELD OF INVENTION

The present invention relates to image sensors and, in particular, to an active pixel sensor for use in ambient light conditions together with a controlled light source,
5 the sensor being able to discount the effects of the ambient light.

CO-PENDING APPLICATIONS

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention simultaneously with the present invention:

10 PCT/AU02/01573, PCT/AU02/01572

The disclosures of these co-pending applications are incorporated herein by cross-reference. Each application is temporarily identified by its docket number. This will be replaced by the corresponding USSN when available.

15 Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention on 15 October 2002:

PCT/AU02/01391, PCT/AU02/01392, PCT/AU02/01393, PCT/AU02/01394 and PCT/AU02/01395.

20 The disclosures of these co-pending applications are incorporated herein by cross-reference.

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention on 26 November 2001:

25 PCT/AU01/01527, PCT/AU01/01528, PCT/AU01/01529, PCT/AU01/01530 and PCT/AU01/01531.

The disclosures of these co-pending applications are incorporated herein by cross-reference.

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention on 26 November 2001:

5 PCT/AU01/01527, PCT/AU01/01528, PCT/AU01/01529, PCT/AU01/01530 and PCT/AU01/01531.

The disclosures of these co-pending applications are incorporated herein by cross-reference.

10 Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention on 11 October 2001: PCT/AU01/01274. The disclosures of these co-pending applications are incorporated herein by cross-reference.

15 Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention on 14 August 2001: PCT/AU01/00996. The disclosures of these co-pending applications are incorporated herein by cross-reference.

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention on 27 November 2000:

20 PCT/AU00/01442, PCT/AU00/01444, PCT/AU00/01446, PCT/AU00/01445,
PCT/AU00/01450, PCT/AU00/01453, PCT/AU00/01448, PCT/AU00/01447,
PCT/AU00/01459, PCT/AU00/01451, PCT/AU00/01454, PCT/AU00/01452,
PCT/AU00/01443, PCT/AU00/01455, PCT/AU00/01456, PCT/AU00/01457,
PCT/AU00/01458 and PCT/AU00/01449.

25 The disclosures of these co-pending applications are incorporated herein by cross-reference.

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention on 20 October 2000:

PCT/AU00/01273, PCT/AU00/01279, PCT/AU00/01288, PCT/AU00/01282,
 PCT/AU00/01276, PCT/AU00/01280, PCT/AU00/01274, PCT/AU00/01289,
 PCT/AU00/01275, PCT/AU00/01277, PCT/AU00/01286, PCT/AU00/01281,
 PCT/AU00/01278, PCT/AU00/01287, PCT/AU00/01285, PCT/AU00/01284 and
 5 PCT/AU00/01283.

The disclosures of these co-pending applications are incorporated herein by cross-reference.

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the
 10 present invention on 15 September 2000: PCT/AU00/01108, PCT/AU00/01110 and PCT/AU00/01111. The disclosures of these co-pending applications are incorporated herein by cross-reference.

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the
 15 present invention on 30 June 2000:

PCT/AU00/00762, PCT/AU00/00763, PCT/AU00/00761, PCT/AU00/00760,
 PCT/AU00/00759, PCT/AU00/00758, PCT/AU00/00764, PCT/AU00/00765,
 PCT/AU00/00766, PCT/AU00/00767, PCT/AU00/00768, PCT/AU00/00773,
 PCT/AU00/00774, PCT/AU00/00775, PCT/AU00/00776, PCT/AU00/00777,
 20 PCT/AU00/00770, PCT/AU00/00769, PCT/AU00/00771, PCT/AU00/00772,
 PCT/AU00/00754, PCT/AU00/00755, PCT/AU00/00756 and PCT/AU00/00757.

The disclosures of these co-pending applications are incorporated herein by cross-reference.

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the
 25 present invention on 24 May 2000:

PCT/AU00/00518, PCT/AU00/00519, PCT/AU00/00520, PCT/AU00/00521,
 PCT/AU00/00522, PCT/AU00/00523, PCT/AU00/00524, PCT/AU00/00525,
 PCT/AU00/00526, PCT/AU00/00527, PCT/AU00/00528, PCT/AU00/00529,
 30 PCT/AU00/00530, PCT/AU00/00531, PCT/AU00/00532, PCT/AU00/00533,
 PCT/AU00/00534, PCT/AU00/00535, PCT/AU00/00536, PCT/AU00/00537,
 PCT/AU00/00538, PCT/AU00/00539, PCT/AU00/00540, PCT/AU00/00541,
 PCT/AU00/00542, PCT/AU00/00543, PCT/AU00/00544, PCT/AU00/00545,
 PCT/AU00/00547, PCT/AU00/00546, PCT/AU00/00554, PCT/AU00/00556,
 35 PCT/AU00/00557, PCT/AU00/00558, PCT/AU00/00559, PCT/AU00/00560,
 PCT/AU00/00561, PCT/AU00/00562, PCT/AU00/00563, PCT/AU00/00564,

PCT/AU00/00565, PCT/AU00/00566, PCT/AU00/00567, PCT/AU00/00568,
 PCT/AU00/00569, PCT/AU00/00570, PCT/AU00/00571, PCT/AU00/00572,
 PCT/AU00/00573, PCT/AU00/00574, PCT/AU00/00575, PCT/AU00/00576,
 PCT/AU00/00577, PCT/AU00/00578, PCT/AU00/00579, PCT/AU00/00581,
 5 PCT/AU00/00580, PCT/AU00/00582, PCT/AU00/00587, PCT/AU00/00588,
 PCT/AU00/00589, PCT/AU00/00583, PCT/AU00/00593, PCT/AU00/00590,
 PCT/AU00/00591, PCT/AU00/00592, PCT/AU00/00594, PCT/AU00/00595,
 PCT/AU00/00596, PCT/AU00/00597, PCT/AU00/00598, PCT/AU00/00516,
 PCT/AU00/00517 and PCT/AU00/00511.

- 10 The disclosures of these co-pending applications are incorporated herein by cross-reference.

BACKGROUND

Image sensors need to overcome a number of obstacles when used in the presence of ambient light. One such obstacle is that ambient light may illuminate a scene in a non-uniform manner. In particular, objects obstructing the ambient light source may cast shadows on the scene thereby degrading the image quality. This can be particularly problematic for machine vision systems which attempt to extract certain key features from an image. Whilst it may be possible to post-process an image to reduce the effects of non-uniform illumination, the sensor itself must handle the full dynamic range of light arriving from the scene.

It is desirable to provide an image sensor which is able to be used with a controlled light source in such a way that the effect of illumination by ambient light is discounted. It is also desirable to provide an active pixel sensor which is able to discount the effects of ambient light at the pixel level.

25 SUMMARY OF INVENTION

According to a first aspect of the present invention there is provided a sensor for use with a controlled light source to generate an output signal, the sensor comprising a photodetector, a processing circuit and a storage circuit and being operable in first and second phases, wherein:

30 in the first phase:

- (a) the photodetector senses ambient light and generates an ambient light current in response thereto; and

- (b) the processing circuit memorises the ambient light current; and
in the second phase:
 - (c) the photodetector senses ambient light and light from the light source, and
generates a total light current in response thereto;
 - 5 (d) the sensor generates a difference signal representing the difference between the
ambient light current and the total light current; and
 - (e) the storage circuit stores charge based on the difference signal;
- wherein the sensor alternates between the first and second phases in response to
a strobe signal, the strobe signal and the controlled light source being synchronised, and
- 10 the storage circuit is configured to output the output signal based on the stored charge.

Preferably, the photodetector is a photodiode.

Preferably, the ambient light current is indicative of the intensity of ambient
light incident on the photodetector.

- Preferably, the total light signal is indicative of the intensity of light incident on
- 15 the photodetector due to both the controlled light source and the ambient light.

Preferably, the processing circuitry during the first phase uses a switched
current source to memorise the ambient light current.

Preferably, the switched current source is responsive to the strobing signal.

- Preferably, the switched current source includes at least one transistor and a
- 20 capacitance, the switched current source being configured to memorise the ambient light
current by setting a voltage across the capacitance based on the ambient light current
flowing through the transistor in the first phase, and using the set voltage to hold the
transistor on during the second phase.

More preferably, the processing circuitry uses a switch to route the difference signal for storage. Even more preferably, the switch is responsive to the strobe signal inverted.

Preferably, the storage circuitry is adapted to minimise degradation of the stored
5 difference signal. More preferably, the storage circuitry incorporates a light shield.

Preferably, the storage circuitry comprises a charge storage circuit.

Preferably, the sensor alternates between the first and second phases at least once during an integration period of the sensor.

Preferably, the processing circuitry further includes a current mirror. More
10 preferably, voltage across the photodetector varies between the first and second phases and wherein the current mirror is adapted to minimise the variation in the voltage across the photodetector between the first and second phases.

Preferably, the strobing signal and the controlled light source are synchronised by the strobing signal having a first level and a second level and being at the first level
15 when the controlled light source is on and being at the second level when the controlled light source is off.

Preferably, the strobing signal alternates between the first and second levels at least once during an integration period of the sensor.

Preferably, the first strobing signal level is a high level and the second strobing
20 signal level is a low level.

Alternatively, the first strobing signal level is a low level and the second strobing signal level is a high level.

Preferably, the sensor defined above comprises an active pixel sensor.

According to a second aspect of the present invention there is provided an array
25 of sensors as defined in the preceding paragraphs.

According to a third aspect of the present invention there is provided an image sensing device comprising;

a controlled light source; and

an array of sensors, at least one of the sensors being adapted for use in ambient
5 light conditions together with the controlled light source and being adapted to produce a difference signal indicative of the intensity of light incident on the at least one sensor from the controlled light source, the at least one sensor comprising a photodetector, a processing circuit and a storage circuit and being operational in first and second phases, wherein:

10 in the first phase:

(a) the photodetector senses ambient light and generates an ambient light current in response thereto; and

(b) the processing circuit memorises the ambient light current; and

in the second phase:

15 (c) the photodetector senses ambient light and light from the light source, and generates a total light current in response thereto;

(d) the sensor generates a difference signal representing the difference between the ambient light current and the total light current; and

(e) the storage circuit stores charge based on the difference signal;

20 wherein the sensor alternates between the first and second phases in response to a strobe signal, the strobe signal and the controlled light source being synchronised, and the storage circuit is configured to output the output signal based on the stored charge.

Preferably, the controlled light source is selected from the group comprising:

(a) a light-emitting diode;

- (b) a superluminescent light-emitting diode; and
- (c) a laser diode.

Preferably, the controlled light source provides the strobing signal to the array of sensors.

- 5 Preferably, the device defined in the preceding paragraphs further includes timing circuitry adapted to provide the strobing signal to the controlled light source.

Preferably, the controlled light source is turned on and off at least once during an integration period of the array of sensors.

10 BRIEF DESCRIPTION OF DRAWINGS

Preferred and other embodiments of the invention will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

- Figure 1 is a schematic diagram of a sensor according to the present invention
15 in its simplest form;

Figure 2 is a schematic diagram of a preferred embodiment of the sensor of the present invention; and

Figure 3 shows a timing diagram for waveforms applied to the sensors of Figures 1 and 2.

20 DETAILED DESCRIPTION OF PREFERRED AND OTHER EMBODIMENTS

- Figure 1 is a schematic diagram of a sensor according to the present invention in its simplest form. As shown in that Figure, the sensor 1 includes a photodetector 2, a switched current source 3, a switch 4, a current mirror 5 and a charge storage circuit 6. The sensor 1 also includes a strobe input 7 which provides a strobing signal 8 (Figure 3)
25 to both the switched current source 3 and the switch 4.

The strobing signal 8 is synchronised with a controlled light source 9 such that

when the controlled light source is on, the strobing signal is high and when the controlled light source is off, the strobing signal is low. A waveform of the strobing signal 8 is shown in Figure 3.

During an integration (or "exposure") period, the photodetector 2 produces a photocurrent which is proportional to the intensity of light incident upon the photodetector. When the controlled light source 9 is off the light incident upon the photodetector will primarily be ambient light. When the controlled light source is on, the light incident upon the photodetector will be due to light from both the controlled light source and from ambient light.

10 The sensor is designed to operate in two phases. As shown in Figure 1, during the first phase the controlled light source 9 is off and the strobing signal 8 is low. During this phase the photocurrent in the photodetector 2 is principally due to ambient light ("the ambient light signal"). Because the strobing signal 8 is low it has the effect of turning the switch 4 off, so that the ambient light current set by the photodetector 2 flows
15 through the switched current source 3. During this first phase the switched current source adapts to the ambient light current and effectively memorises it.

In the second phase the controlled light source 9 is on and the strobing signal is high. At this stage the photocurrent in the photodetector 2 increases in proportion to the light incident upon the photodetector from both the controlled light source and the
20 ambient light. We shall refer to this combined signal as a "total light current."

Because the strobing signal 8 is high, the switched current source now draws a fixed amount of the photocurrent, corresponding to the memorised ambient light current. The current set by the photodetector in this phase exceeds the current memorized by the switched current source, and so a differential current corresponding to the
25 difference between the ambient light current and the total light current is pulled through switch 4, opened by the strobing signal 8. This in turn causes the current mirror 5 to generate a current that is related to the differential current drawn through the switch 4. The current generated by the current mirror 5 is stored in the charge storage circuit 6.

As the strobing signal 8 alternates between high and low signals during the
30 integration period, the difference signal is accumulated in the charge storage circuit 6.

Since the difference signal is proportional to light incident upon the photodetector 2 due principally to the controlled light source, the accumulated charge reflects the light incident on the pixel due to the controlled light source and effectively discounts the impact of ambient light.

5 Figure 2 shows a more detailed schematic diagram of a preferred embodiment of the sensor of the present invention. Common features of Figures 2 and 1 are referred to using the same numerals.

As shown in Figure 2, the sensor includes includes a photodiode 17, a switched current source 3, a switch 4, a current mirror 5 and a charge storage circuit 6. The circuit
10 1 also includes a strobe input 7 which provides a strobing signal 8 (Figure 3) to both the switched current source 3 and the switch 4.

As in the example of Figure 1, the strobing signal 8 is synchronised with a controlled light source 9 such that when the controlled light source is on, the strobing signal is high and when the controlled light source is off, the strobing signal is low.
15 Once again, a waveform of the strobing signal is shown in Figure 3.

In this embodiment, the switched current source 3 takes the form of transistors 11, 12 and 13, the current mirror 5 takes the form of transistors 14 and 15, and the switch 4 takes the form of a single transistor 16.

As with the example of Figure 1, the photodiode 17 in this example produces a
20 photocurrent which is proportional to the intensity of light incident upon the photodiode during the integration period. When the controlled light source is off the light incident upon the photodiode will primarily be ambient light. When the controlled light source is on, the light incident upon the photodiode will be due to light from both the controlled light source and from ambient light.

25 Again, the sensor is designed to operate in two phases. As shown in Figure 2, during the first phase the controlled light source 9 is off and the strobing signal 8 is low. During this phase the photocurrent in the photodiode 17 is determined by ambient light ("the ambient light current"). Because the strobing signal 8 is low it has the effect of

turning transistor 11 on and switch 4 (transistor 16) off. During this first phase the drain and gate of transistor 12 are connected together thereby causing transistor 12 to act like a diode. After a short time, the circuit reaches equilibrium and the current through transistor 12 is equal to the photocurrent of the photodiode 17. Transistor 13 provides
5 additional capacitance and has across it the corresponding voltage to support the current in transistor 12. In this way, the switched current source 3 effectively memorises the ambient light signal 10 which reflects the photocurrent in the photodiode 17 due principally to ambient light.

In the second phase the controlled light source 9 is on and the strobing signal
10 is high. At this stage the photocurrent in the photodiode 17 increases in proportion to the light incident upon the photodiode from both the controlled light source and the ambient light. As mentioned earlier, we shall refer to this combined signal as a "total light current." When the controlled light source 9 is on, the strobing signal 8 is high. This causes transistor 11 to turn off and switch 4 to turn on. The voltage across transistor 13
15 in the switched current source 3 is maintained by virtue of the capacitance in transistor 13 so that the current through transistor 12 remains the same as when the controlled light source was off.

Because the strobing signal 8 is high, the switched current source now draws a fixed amount of the photocurrent, corresponding to the memorised ambient light current.
20 The excess photocurrent, corresponding to the difference between the ambient light signal and the total light signal, is drawn through switch 4, opened by the strobing signal 8. This, in turn, causes a current to be established through both transistors 14 and 15 of the current mirror 5. As mentioned earlier we refer to this difference current as a "difference signal."

25 The effect of the current mirror is that the voltage across the photodiode 17 remains approximately constant thus minimising the effect of parasitic capacitance and output impedance of transistor 12 in the switched current source 3.

The output of transistor 15 is connected to the charge storage circuit 6. The charge storage circuit is controlled by a reset signal indicated as "RST" and an optional
30 "HOLD" signal. When the reset condition is removed, the difference signal in the form of current pulses from transistor 15 may be accumulated as charge during the integration

period of the pixel. The final voltage may then be sampled on signal "OUT" by enabling signal "ROW."

The number of current pulses used during the integration period is determined by the needs of a particular implementation. The number of current pulses chosen
5 should balance the dual needs of minimising any error due to image motion with the speed requirements of the circuit.

The charge storage circuit 6 may incorporate mechanisms to protect the integrity of the stored difference signal in order to prevent or minimise degradation of the signal after the end of the integration period and before signal readout. As described
10 in Published PCT Patent Application No WO 01/63905 (Fossum, E. et al), the contents of which are herein incorporated by reference, these protection mechanisms may include a light shield to prevent or minimise a light-induced signal from affecting the stored signal. Such protection mechanisms may also include an enclosing guard band to prevent unwanted signal incursion from adjacent areas.

Those skilled in the art will appreciate that a number of alternative embodiments are available, including inverting the circuit and the strobing signal so that the strobing signal is low when the controlled light source is on and so that the strobing signal is high when the controlled light source is off. Along the same lines, although it is assumed that the photo diode D1 is an N-type diffusion on P-type substrate, a P-type
20 diffusion in an N-well photo diode may also be used provided the polarity of all transistors and supply voltage is changed accordingly. In addition, the circuit may be replicated many times to form an array of pixels. Such an array of pixels is included in the scope of the present invention. Furthermore, the current mirror 5 may technically be excluded from the circuit. The purpose of the current mirror 5 is to account for voltage
25 changes in the circuit by ensuring that the voltage drop across the current mirror is approximately equal to the voltage drop across the switched current source 3. The inventors are of the opinion that the circuit works better with a current mirror, but this feature may be excluded.

It will be appreciated from the foregoing discussion that the present invention
30 may advantageously be used to provide an improved image suitable for machine vision

applications where the scene is in motion with respect to the image sensor, and in particular such as in motion sensing pens of the types described in US Patent 5,051,736 (Bennett, W.E. et al), US Patent 5,477,012 (Sekendur, O.F.), US Patent 5,652,412 (Lazzouni, M. et al), PCT Patent Application WO 00/72230 (Silverbrook, K. et al), PCT

5 Patent Application WO 01/16872 (Faahraeus, C. et al). The contents of each of these patent specifications and applications are herein incorporated by reference thereto. In such embodiments of the present invention it is desirable that the sensing device incorporate timing circuitry adapted to provide the strobing signal to both the controlled light source and the array of pixels.

10 The present invention has been described with reference to a number of preferred embodiments. However, it will be appreciated by those skilled in the art that a number of other embodiments, differing from those specifically described, will also fall within the spirit and scope of the present invention as described herein. Accordingly, it will be understood that the invention is not intended to be limited to the specific embodiments

15 described in the present specification, including documents incorporated by cross-reference as appropriate.

CLAIMS

1. A sensor for use with a controlled light source to generate an output signal, the sensor comprising a photodetector, a processing circuit and a storage circuit and being
5 operable in first and second phases, wherein:
in the first phase:
(a) the photodetector senses ambient light and generates an ambient light current in response thereto; and
(b) the processing circuit memorises the ambient light current; and
10 in the second phase:
(c) the photodetector senses ambient light and light from the light source, and generates a total light current in response thereto;
(d) the sensor generates a difference signal representing the difference between the ambient light current and the total light current; and
15 (e) the storage circuit stores charge based on the difference signal;
wherein the sensor alternates between the first and second phases in response to a strobe signal, the strobe signal and the controlled light source being synchronised, and the storage circuit is configured to output the output signal based on the stored charge.
- 20 2. The sensor of claim 1 wherein the photodetector is a photodiode.
3. The sensor of claim 1 wherein the ambient light current is indicative of the intensity of ambient light incident on the photodetector.
- 25 4. The sensor of claim 1 wherein the total light current is indicative of the intensity of light incident on the photodetector due to both the controlled light source and the ambient light.
5. The sensor of claim 1 wherein the processing circuitry during the first phase
30 uses a switched current source to memorise the ambient light current.
6. The sensor of claim 5 wherein the switched current source is responsive to the strobing signal.

7. The sensor of claim 5, wherein the switched current source includes at least one transistor and a capacitance, the switched current source being configured to memorise the ambient light current by setting a voltage across the capacitance based on the ambient light current flowing through the transistor in the first phase, and using the set voltage to hold the transistor on during the second phase.
8. The sensor of claim 1 wherein the processing circuitry uses a switch to route the difference signal to generate a current for supplying the charge to the storage circuit for storage.
9. The sensor of claim 8 wherein the switch is responsive to the strobe signal inverted.
10. The sensor of claim 1 wherein the storage circuitry is adapted to minimise degradation of the stored difference signal.
11. The sensor of claim 10 wherein the storage circuitry incorporates a light shield.
12. The sensor of claim 1 wherein the storage circuitry comprises a charge storage circuit.
13. The sensor of claim 1 wherein the sensor alternates between the first and second phases at least once during an integration period of the sensor.
14. The sensor of claim 1 wherein the processing circuitry further includes a current mirror.
15. The sensor of claim 14 wherein voltage across the photodetector varies between the first and second phases and wherein the current mirror is adapted to minimise the variation in the voltage across the photodetector between the first and second phases.

16. The sensor of claim 1 wherein the strobing signal and the controlled light source are synchronised by the strobing signal having a first level and a second level and being at the first level when the controlled light source is on and being at the second level when the controlled light source is off.
- 5 17. The sensor of claim 16 wherein the strobing signal alternates between the first and second levels at least once during an integration period of the sensor.
18. The sensor of claim 16 wherein the first strobing signal level is a high level and
10 the second strobing signal level is a low level.
19. The sensor of claim 16 wherein the first strobing signal level is a low level and the second strobing signal level is a high level.
- 15 20. The sensor of claim 1 comprising an active pixel sensor.
21. An array of sensors as claimed in claim 1.
22. An image sensing device comprising;
20 a controlled light source; and
an array of sensors, at least one of the sensors being adapted for use in ambient light conditions together with the controlled light source and being adapted to produce a difference signal indicative of the intensity of light incident on the at least one sensor from the controlled light source, the at least one sensor comprising a photodetector, a
25 processing circuit and a storage circuit and being operational in first and second phases, wherein:
in the first phase:
(a) the photodetector senses ambient light and generates an ambient light current in response thereto; and
30 (b) the processing circuit memorises the ambient light current; and
in the second phase:
(c) the photodetector senses ambient light and light from the light source, and

generates a total light current in response thereto;

(d) the sensor generates a difference signal representing the difference between the ambient light current and the total light current; and

(e) the storage circuit stores charge based on the difference signal;

5 wherein the sensor alternates between the first and second phases in response to a strobe signal, the strobe signal and the controlled light source being synchronised, and the storage circuit is configured to output the output signal based on the stored charge.

23. The device of claim 22 wherein the controlled light source is selected from the group comprising:

(a) a light-emitting diode;

(b) a superluminescent light-emitting diode; and

(c) a laser diode.

15 24. The device of claim 22 wherein the controlled light source provides the strobing signal to the array of sensors.

25. The device of claim 24 further including timing circuitry adapted to provide the strobing signal to the controlled light source.

20

26. The device of claim 22 wherein the controlled light source is turned on and off at least once during an integration period of the array of sensors.