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(54) Title of the Invention: **Display device and apparatus**
Abstract Title: **Display Device with Photovoltaic layer**

(57) A self-powered or partially self-powered display device, 1, may be powered through photovoltaic energy generation utilising a photovoltaic (PV) layer, 3, which is integrated into the display itself and is positioned under a light-emitting or light reflecting layer, 2, of the display device. The display device may also include a light collecting lens system, 7, for distributing light to the photovoltaic layer. A light guide, 9, may be positioned between the light emitting/ reflecting layer and the photovoltaic layer and a conical shaped optical element, 10, may be positioned under individual light emitting/reflecting elements of the light emitting/reflecting layer. The device may further incorporate a rechargeable cell or battery which is charged by the photovoltaic layer. The display device may be integrated into a display unit, a plurality of which may be arranged in an array and which may communicate wirelessly with each other and/or share power within the array.

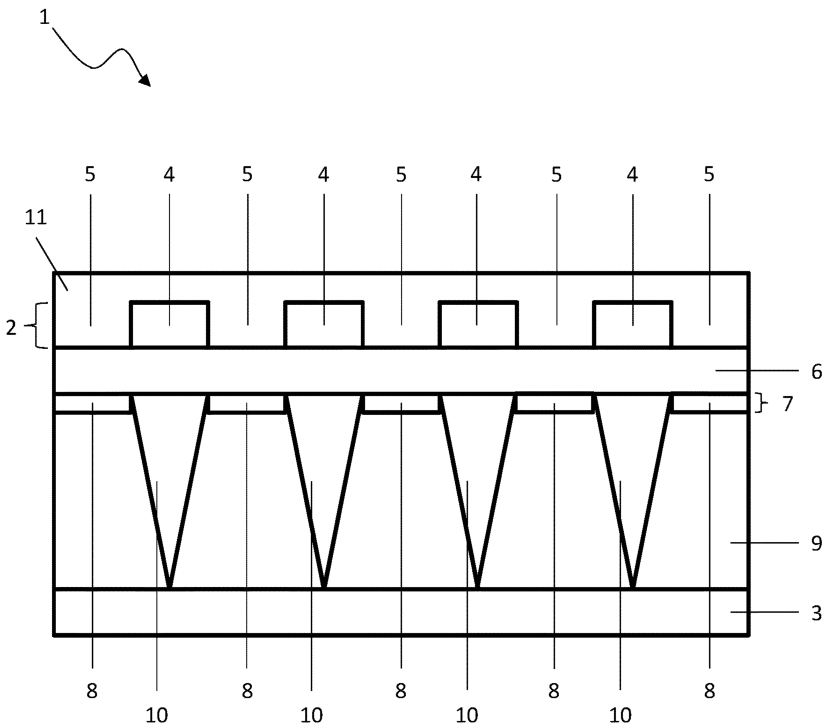

Figure 1

GB 2545490 A

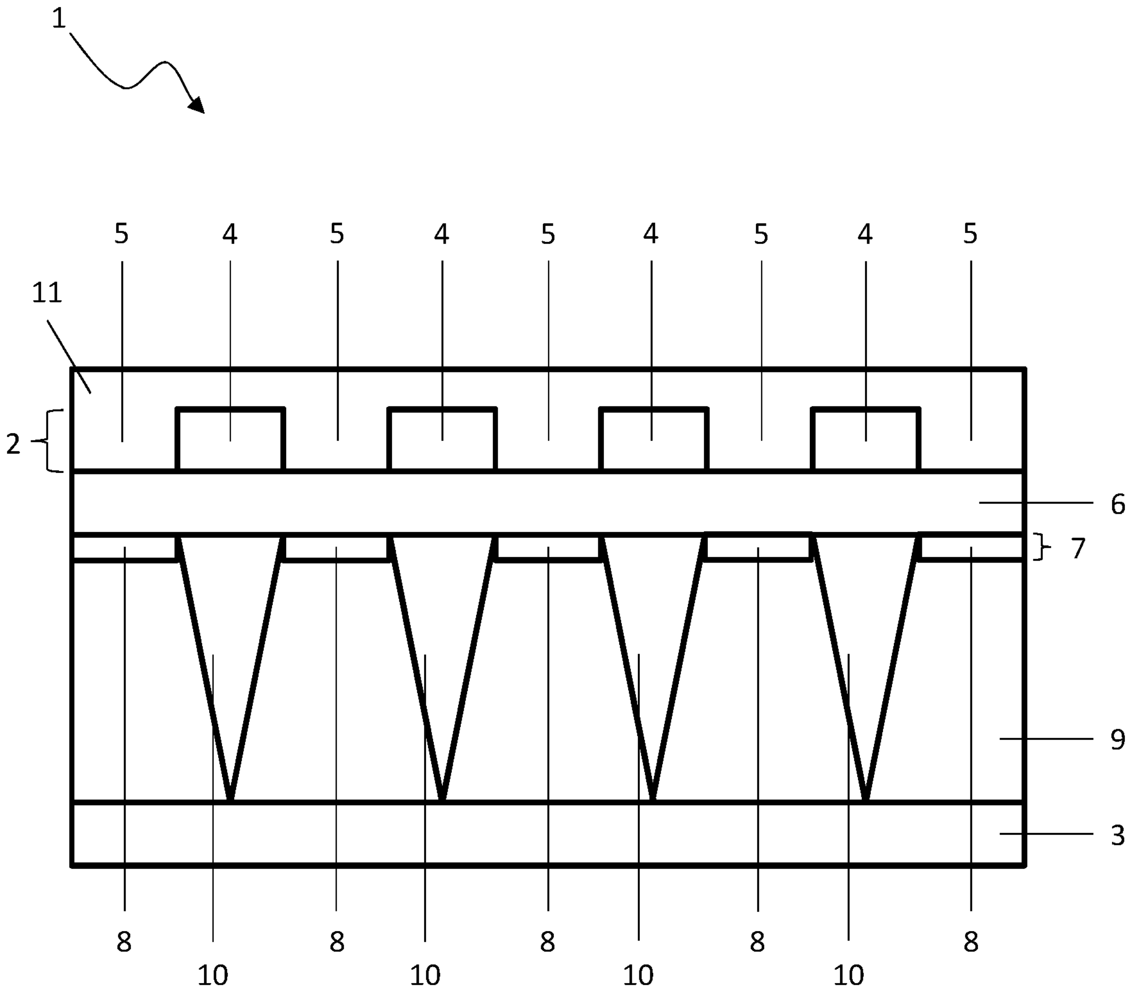

Figure 1

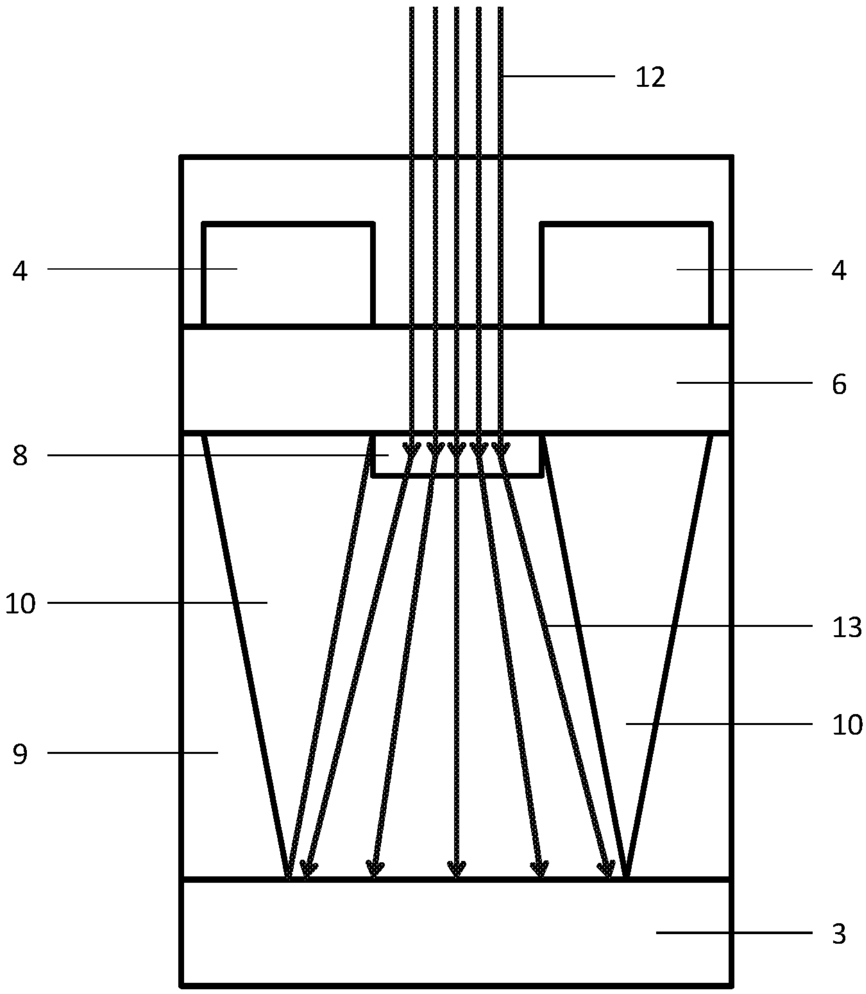

Figure 2

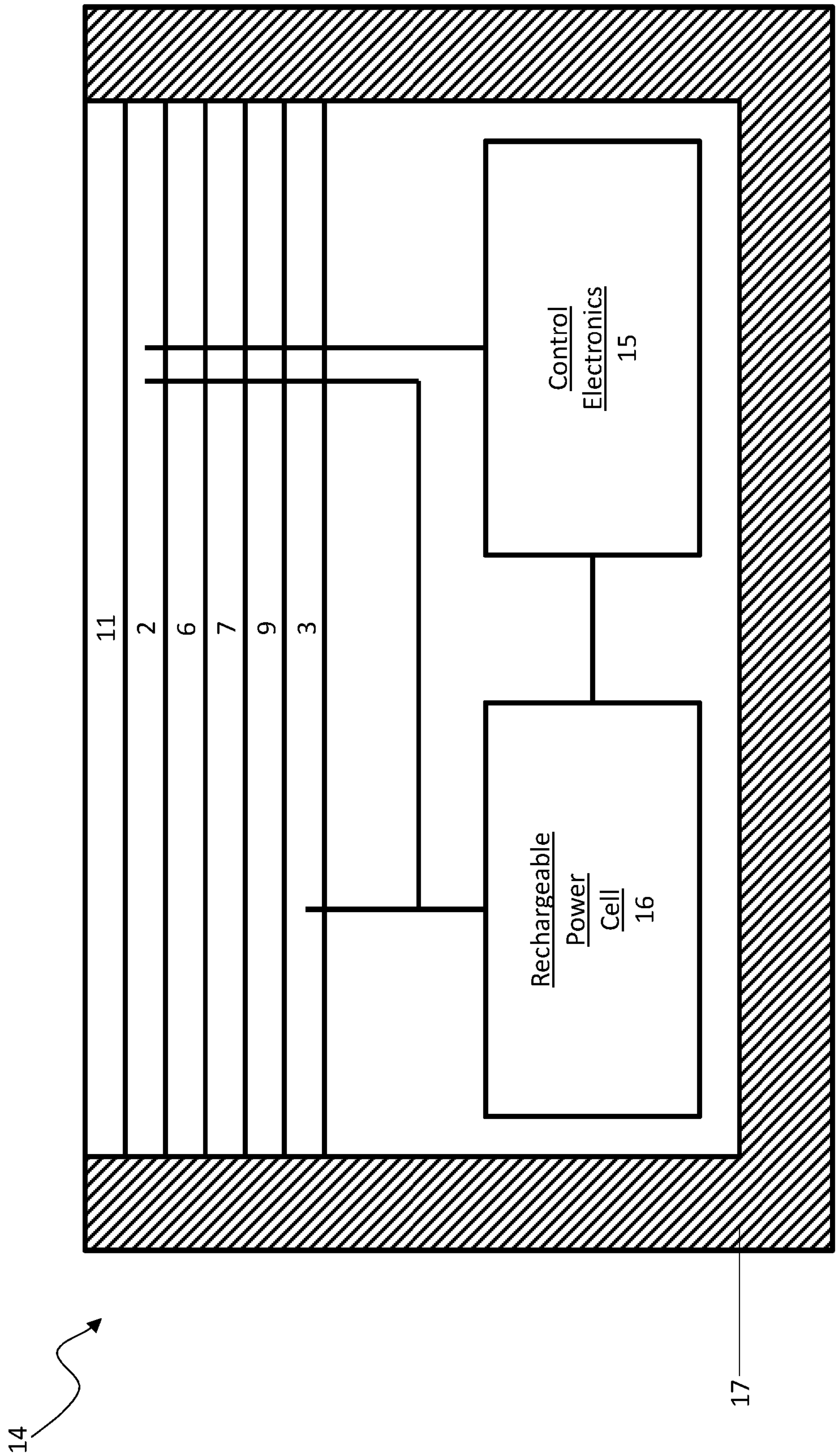
11
2
6
7
9
3
Control Electronics 15
Rechargeable Power Cell 16
14
17

Figure 3

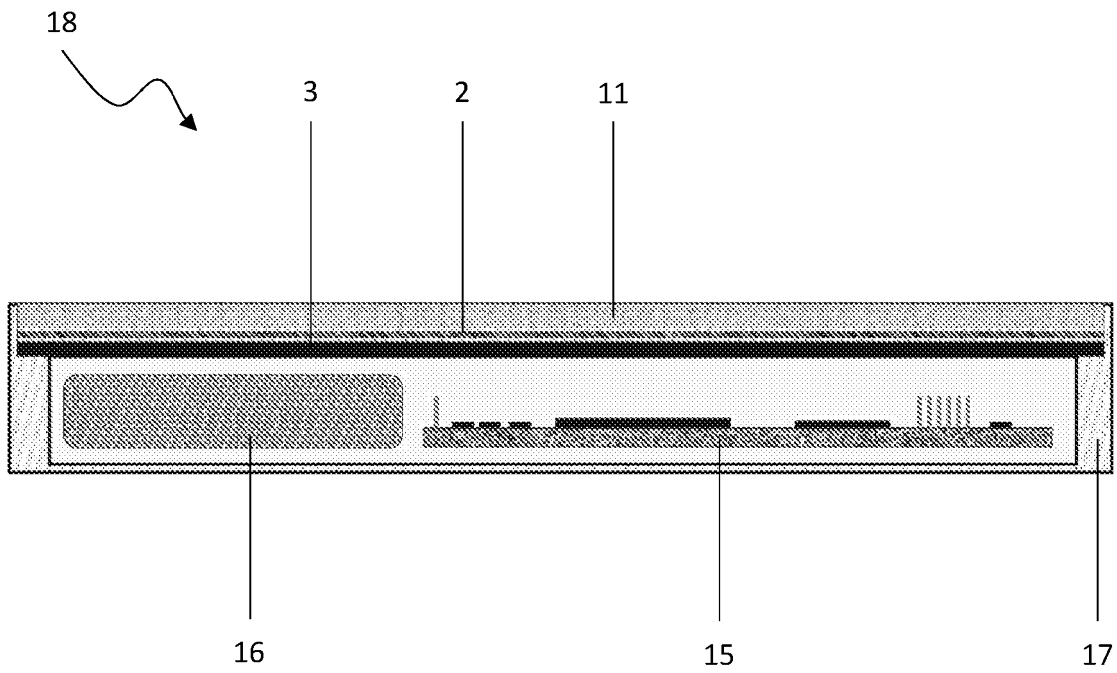

Figure 4

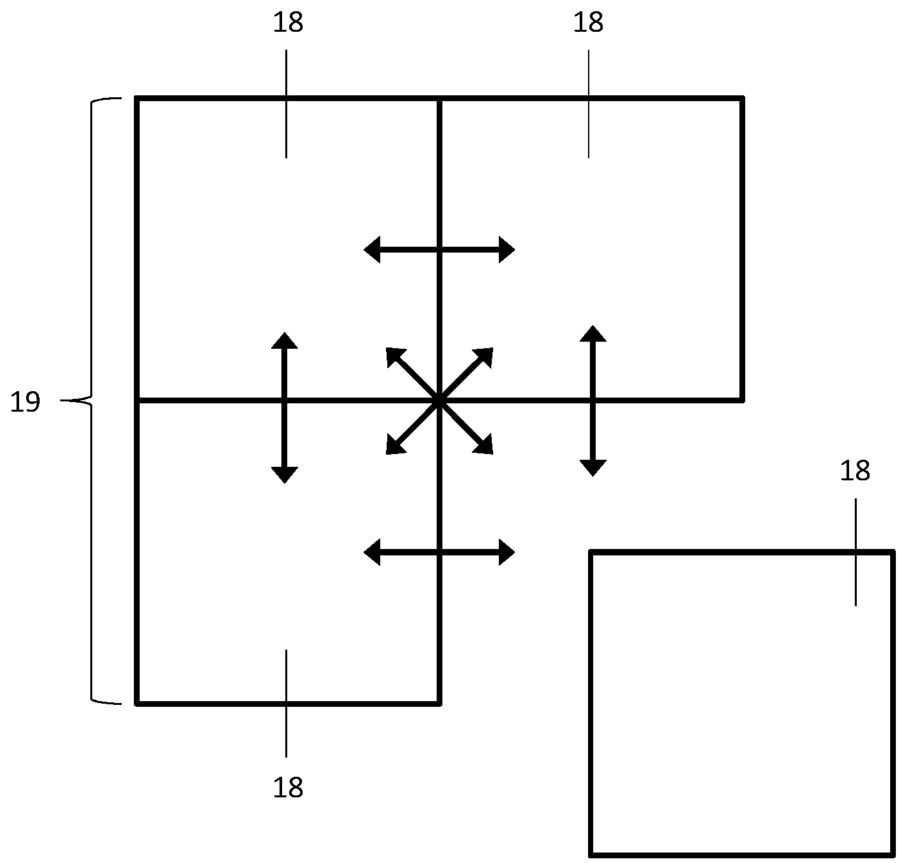

Figure 5

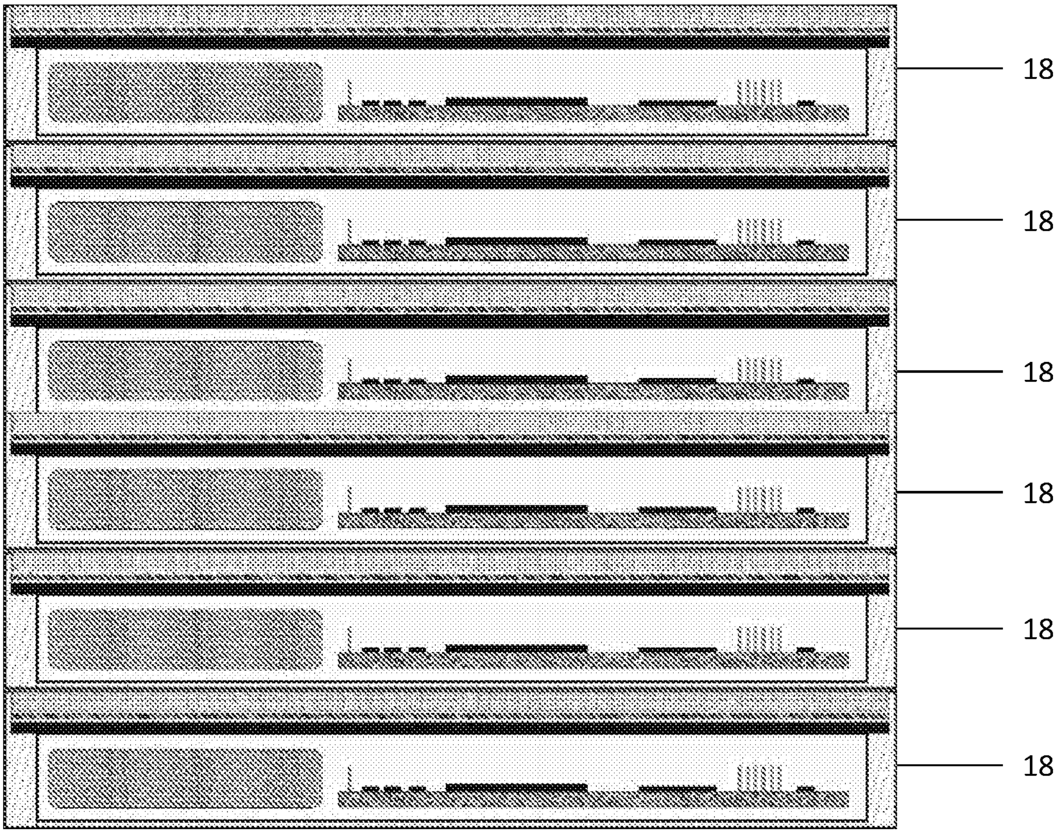

Figure 6

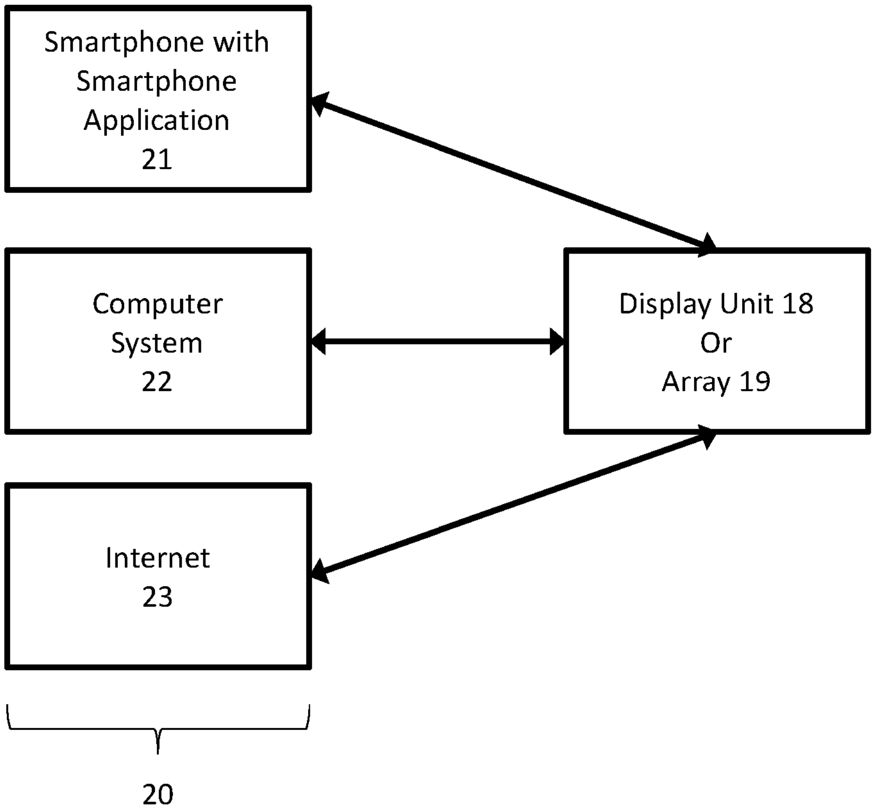
Smartphone with
Smartphone
Application
21
Computer
System
22
Internet
23
Display Unit 18
Or
Array 19
20

Figure 7

The following terms are registered trade marks and should be read as such wherever they occur in this document:

Wi-Fi (page 6)

Display Device and Apparatus

Field of the Invention

[0001] The invention relates to a display device, and apparatus using such a display device.

Background of the Invention

[0002] The increasing processing and computational demands imposed upon electronic devices, coupled with the development of larger and higher resolution display units, leads to higher rates of power consumption in said devices. It would therefore be desirable to integrate energy harvesting into these electronic devices for self-powering or partial self-powering.

[0003] It is known to arrange modular display devices in an array, for providing a large display area. However, greater flexibility is desirable in the operation of these arrays.

Summary of the Invention

[0004] According to one aspect of the present invention there is provided a self-powered or partially self-powered display device that can be powered through photovoltaic energy generation utilising a photovoltaic layer which may be integrated into the display itself, and may be positioned under a light-emitting layer of the display device. In embodiments of the invention the display device may also include a light collecting lens system for distributing light to the photovoltaic layer.

[0005] According to another aspect of the invention there is provided an array of wirelessly communicating self-powered or partially self-powered display units which comprise display devices which comprising photovoltaic layers. In embodiments of the invention the display units of the array of display units may comprise rechargeable power cells. There may be provided means to transfer electrical charge between the display units of the array of display units. In further embodiments the display units may include sound emitting devices which emit sound that sounds to the listener as if it is being directly emitted from the display device of the display unit. In further embodiments where the display units are arranged in an array, the emitted sound can be unified across all the displays, or sound can move dynamically across the display units of the array, or a combination of both the unified and dynamic sound can be output.

Brief Description of the Drawings

[0006] Following, by way of example only, are descriptions of the drawings which are to serve illustrative purposes only. Alternative embodiments that may become apparent are also claimed.

Figure 1 shows a schematic cross sectional diagram of the arrangement of a display with an integrated photovoltaic layer according to an embodiment of the invention.

Figure 2 shows a diagram depicting the operation of a light collection lens system according to the embodiment in Figure 1.

Figure 3 is a schematic cross sectional diagram of an embodiment of a display unit with an energy harvesting photovoltaic layer integrated into the display itself.

Figure 4 is a cross-sectional diagram of another embodiment of a display unit.

Figure 5 shows an array of display units according to embodiments of the invention.

Figure 6 shows a stack of display units according to embodiments of the invention.

Figure 7 is a block diagram showing control entities interacting with a display unit or array of display units.

Detailed Description of the Embodiments of the Invention

[0007] Figure 1 is a cross sectional diagram illustrating the structure of a display device 1 incorporating a light emitting display layer 2 and photovoltaic layer 3. The photovoltaic layer 3 is positioned underneath the light emitting display layer 2 such that light rays can pass through gaps 5 between light emitting elements 4 of the light emitting display layer 2 thereby reaching the photovoltaic layer 3 for power generation, which may be for self-powering or partially self-powering the display device 1.

[0008] In this embodiment, the light emitting elements 4 are arranged on a transparent substrate 6 comprising transparent circuitry connecting the light emitting elements 4, to allow for the maximum possible amount of incident light to reach the photovoltaic layer 2. In other embodiments the substrate and circuitry 6 can be any combination of a transparent substrate or semi-transparent substrate, with the circuitry being transparent, semi-transparent, non-transparent or comprising a mixture of transparent semi-transparent and non-transparent components. The substrate and circuitry 6 are preferably fabricated as a flexible layer using flexible electronics. In other embodiments the substrate and circuitry 6 can be fabricated using semi-flexible or non-flexible components.

[0009] In some embodiments the display device 1 may comprise, instead of the light emitting display layer 2 comprising light emitting elements 4, a light reflecting display layer and light reflecting components.

[0010] In the embodiment shown in Figure 1, a light collection lens system 7 is positioned above the photovoltaic layer 3. The light collection lens system 7 comprises an array of lenses 8 positioned in the gaps 5 between the light emitting elements 4 of the light emitting display layer 2. The purpose of the light collecting lenses 8 is to distribute the light rays incident on the display across the entire photovoltaic layer 3 rather than only the areas underneath the gaps 5 between the light emitting elements 4. This is described in further detail below.

[0011] The light collection lens system 7 in some embodiments is incorporated into the bottom side of the substrate 6. In other embodiments the light collection lens system 7 is integrated into a separate substrate and positioned at an optically optimal position in the device structure. In some embodiments the light collection lens system 7 is formed from at least one thin sheet onto which a lens pattern is embossed, the sheet being of plastic or any other suitable material.

[0012] With reference to the embodiment present in Figure 1, a light guide layer 9 is positioned between light collection lens system 7 and the photovoltaic layer 3. This light guide layer 9 is used to ensure as much light as possible reaches the photovoltaic layer 3 from that which is collected. In other embodiments the light guide layer 9 can be positioned above the light collection lens system 7 to direct as much light as possible to the light collection lens system 7 before the photovoltaic layer 3. In some embodiments the light collection lens system 7 and/or the light guide layer 9 are not present. In such embodiments the photovoltaic layer 3 may be positioned directly underneath the transparent substrate and circuitry 6. The light guide layer may be made from any material that can trap light inside its structure and channel it to a predetermined location, for example a glass, plastic or transparent resin material.

[0013] In the embodiment shown in Figure 1 a series of conical shaped optical elements 10 are positioned under the light emitting elements 4. These conical shaped optical elements 10 are used to diminish the effects of shadowing of incident light from the light emitting elements 4 located above them, thus allowing for incident light to reach as much of the photovoltaic layer 3 as possible.

[0014] A protective layer 11 is positioned above the light emitting display layer 2 in the embodiment displayed in Figure 1. The purpose of this protective layer 11 is to protect the light emitting elements 4 from damage, typically by water and/or UV radiation. In some embodiments the protective layer 11 is transparent; in other embodiments the protective layer 11 is semi-transparent.

[0015] The display technology used in the light emitting display layer 2 may include, but is not limited to, LED displays, OLED displays, LCD displays and the like. In preferred embodiments the light emitting display layer 2 is fabricated from flexible components; however in other embodiments the light emitting display layer 2 can be fabricated from semi-flexible or non-flexible components. The photovoltaic layer 3 may be constructed of, but is not limited to, organic photovoltaics, silicon photovoltaics, thin film photovoltaics and the like. In preferred embodiments the photovoltaic layer 3 is fabricated from flexible components; however in other embodiments the photovoltaic layer 3 can be fabricated from semi-flexible or non-flexible components.

[0016] Figure 2 illustrates the operation of the light collecting lens system 7 previously introduced. The incident light rays 12 which are incident upon the gaps 5 between the light emitting elements 4 are refracted by the light collection lenses 8 of the light collection lens system 7. The lenses 8 act as diverging lenses refracting the incident light rays 12 outwards across the photovoltaic layer 3. The refracted light rays are transported to the photovoltaic layer 3 by the light guide layer 9 where they are absorbed for photovoltaic power generation. In other embodiments the light collecting lens system 7 comprises converging lenses which focus the light rays onto specific areas of the photovoltaic layer 3. This embodiment has the advantage that an array of small photovoltaic cells is required, thus using less photovoltaic material.

[0017] Figure 3 shows an exemplary arrangement for a self-powered or partially self-powered display device 14 comprising a light emitting display layer 2 and photovoltaic layer 3. The light emitting display layer 2 is electrically connected to the control electronics 15 which are in turn connected to a rechargeable power cell 16. The photovoltaic layer 3 is also connected to the rechargeable power cell 16. In embodiments the control electronics 15 can include, but are not limited to, data storage, micro-processing and power management means. In operation the control electronics 15 send data signals to the display 1 for an image or images which are to be displayed. Simultaneously, ambient light 12 which is incident on the display 1, and passes through the display layer 2, is absorbed by the photovoltaic layer 3 so as to generate power to charge the rechargeable power cell 16 in the device 14. In other aspects the photovoltaic layer 3 can charge the rechargeable power cell 16 when the display 1 is not in use. The self-powered or partially self-powered device 14 is encased in a casing 17 which can be either a flexible, semi-flexible or non-flexible material.

[0018] Figure 4 demonstrates an exemplary display unit 18 incorporating the self-powering or partially self-powering display device 1 described herein. In this embodiment the display unit 18 comprises a light emitting or reflecting display layer 2, between a protective layer 11 and a photovoltaic layer 3. The display device 1 is connected to a rechargeable power cell 16 and control electronics 15. The control electronics 15 control the information which is sent to an array of light emitting elements 4 in display layer 2, manages the energy collected by the photovoltaic layer 3, and manages the rechargeable power cell charging and energy usage. In other embodiments display unit 18 also includes combinations of the light collecting lens system 7, the light guiding layer 9 and the conical optical elements 10.

[0019] In some embodiments the display unit 18 includes sensors on the peripheries of the display unit 18. The sensors are able to detect other nearby display units 18 of the same type. In such embodiments the display unit 18 also includes means for wireless communication with the nearby display units. The wireless communication may be carried out by a direct (e.g. P2P) or networked wireless connection suitable to transfer the required amount of data, for example Wi-Fi or Bluetooth® wireless connections. The display units are able to communicate with one another. In embodiments, multiple display units 18 can wirelessly communicate with one another forming an array of display units as is shown in Figure 5, which shows an exemplary array 19 of four display units 18. These display units 18 each interact with one another when in close proximity, as is shown by the arrows indicating the directions of communication between each of the display units 18. The sensors at the peripheries of each display unit 18 allow for the display unit 18 to identify its orientation with respect to each of the other display units 18, for example by detecting an electromagnetic field of transition, by using proximity sensors, or other known methods. In such an embodiment a first display unit 18 displays an image, and when a second unit 18 is brought within proximity of the first display unit 18 the image displayed on the first unit 18 is shared across both the first and second display units 18 in the most logical manner based upon their orientation with respect to one another.

[0020] In some embodiments, in the event that the first and second display units 18 are displaying different data when brought into proximity with one another, a choice can be made between the two sets of data to display across the first and second display units 18, or one set is given priority, depending for example on a mode setting on the display units 18 or a remote controller. The same protocol may apply as more display units 18 are introduced to the array, as in Figure 5 where a third display unit 18 is included in the array.

[0021] As the fourth display unit 18 (the lower rightmost display unit 18 in Figure 5) is brought closer to the array 19 it will be detected by the first, second and third display units 18 and the display data will be distributed across all four display units 18 as they all interact with one another. The distance required for a display unit 18 to be detected by other display units 18 in the array 19, and thus incorporated into the array 19, is programmable and can be set in a system administration application. In embodiments the display data is shared amongst the display units in the array by the means for wireless communication. In addition to display data, in some embodiments, processing resources are also shared between the display units 18 in the array 19.

[0022] In further embodiments different display information may be displayed on each display unit 18 of said array 19. In such embodiments the display data on each display unit 18 can be distinct from display data on other units, but also associated with the display data of the other display units as part of a collective display image.

[0023] In further embodiments, where the display units 18 are arranged in an array 19, in the event that one or more units 18 fails to function correctly, the still functioning units 18 will reconfigure to display the display data in the most logical way. In such an embodiment, when replacing the failing display unit 18 with a new properly functioning display unit 18, the new display unit 18 will automatically configure itself to carry out the same functions and display the same data as the failed display unit 18. In further embodiments a technical diagnostic signal or report is sent to the administrator of the array 19 when one or more units fail to function correctly.

[0024] In some embodiments the display units 18, when arranged within close proximity to one another, share stored electrical charge with one another through means for wired or wireless exchange of electrical charge through techniques known in the art, such as inductive charging. Figure 6 depicts a stack of display units 18 of such an embodiment; however stored electrical charge can also be shared between display units when arranged in array 19 such as that in Figure 5, or any other orientation when located proximately to one another. With reference to the embodiment of Figure 6, by way of example only, within the stacked collection of display units 18 a master unit is assigned. In other embodiments this process also occurs when the display units 18 are arranged in an array such as that in in Figure 5, or any other orientation when located proximately to one another. Each of the display units 18 in proximity to the master unit will identify themselves to the master unit; the master unit will manage the electrical charge stored in each display unit by instructing the exchange of electrical charge between display units 18 such that after a period of time each display unit in the collective will contain an approximately equal level of electrical charge. In embodiments the electrical charge stored in the display units 18 is harvested through photovoltaic power generation in the photovoltaic layer 3. In other embodiments the electrical charge stored in the display units 18 is supplied by an external power supply. In other embodiments the electrical charge stored in the display units 18 is supplied by a combination of photovoltaic power generation and an external power supply. In further embodiments the master unit 18 can be charged from a power supply, such as a mains power supply, and transfer electrical charge to each of the other display units in the collective until each display unit 18 is fully charged.

[0025] In some embodiments the display unit 18 comprises a sound emitting unit designed to emit sound such that from the perspective of a listener the sound is being transferred directly from the front of the display unit 18. The sound emitting unit may be a conventional speaker, and preferably a relatively thin/flat speaker integrated into the display unit 18.

[0026] In embodiments where two or more display units 18 are arranged in an array as described previously, such as in Figure 5, the emitted sound can be arranged to be transmitted from both units as a unified sound. In other embodiments the emitted sound can be arranged to be transmitted from each unit so as to dynamically arrange sounds which can move across display units 18 of the array. In further embodiments, combinations of unified sounds and dynamically arranged sounds are emitted from an array 19 of display units 18. The emitted sound may be controlled by the control electronics 15 of one or more of the display units.

[0027] Figure 7 shows a block diagram demonstrating means by which control entities 20 can interact with a display unit 18 or display units 18 in an array 19 to carry out various function including but not limited to switching on or off the device(s), scheduling functions of the device(s), controlling and amending pre-set schedules of the device(s), transferring display information to the device(s), receiving information from the device(s) and the like. In some embodiments a display unit 18 or an array 19 of display units 18 can be controlled from, for example but not limited to, control entities 20 such as a smartphone application 21, or directly from a computer system 22 at the location of the display unit(s) 18, or by communication from the Internet 23. In embodiments, control software which sends information to a display unit 18 or array 19 of display units 18 uses an encrypted command structure. The encrypted information transferred to the display unit 18 or array 19 of display units 18 instructs the units of the function which they are to perform as well as when to perform said function.

[0028] The display unit 18 can be formed in many different physical shapes, such but not limited to: square-shaped, rectangular, circular, semi-circular, quarter-circular, triangular and others.

[0029] Alternative embodiments, which may be apparent from reading the above description, may nevertheless fall within the scope of the present invention, for example as defined by the accompanying claims.

Claims

1. A display device, comprising:
   i. a light emitting or reflecting display layer which allow light to pass through; and
   ii. a photovoltaic layer,

   wherein the photovoltaic layer is placed under the light emitting or reflecting display layer so as to receive light passing therethrough.

2. The device of claim 1, wherein a light collection lens system is arranged to collect the light and distribute it to the photovoltaic layer.

3. The device of claim 2, wherein the light collection lens system comprises diverging lenses to distribute refracted light over the photovoltaic layer.

4. The device of claim 2, wherein the light collection lens system comprises converging lenses to focus the refracted light on the photovoltaic layer.

5. The device of any preceding claim, wherein the photovoltaic layer comprises at least one photovoltaic cell.

6. The device of any preceding claim, wherein the light emitting or reflecting display layer comprises at least one light emitting element or light reflecting element.

7. The device of claim 6, wherein the at least one light emitting or reflecting element(s) are printed or mounted on a substrate.

8. The device of claim 7, wherein the substrate is a transparent or semi-transparent substrate.

9. The device of claim 7 or claim 8, wherein transparent components of connecting circuitry are printed or mounted on the substrate.

10. The device of claim 7 or claim 8, wherein transparent and non-transparent components of connecting circuitry are printed or mounted on the substrate.

11. The device of claim any one of claims 6 to 10, wherein the light collection lens system comprises at least one light collection lens structure positioned in at least one space between the light emitting or reflecting elements.

12. The device of any preceding claim, wherein a light guide layer is positioned between the light emitting or reflecting display layer and the photovoltaic layer.

13. The device of any one of claims 6 to 12, wherein at least one conical shaped optical element is positioned under at least one light emitting or reflecting element.

14. The device of any preceding claim, wherein a protective layer is positioned over the light emitting or reflecting display layer.

15. The device of claim 14, wherein the protective layer is transparent or semi-transparent.

16. The device of any preceding claim, wherein power generated by the photovoltaic layer is used to charge a rechargeable power cell in the device.

17. The device of any preceding claim, wherein power generated by the photovoltaic layer is used to self-power or partially self-power the device.

18. The device of any preceding claim, wherein the device is flexible.

19. The device of any preceding claim, wherein the device is made flexible through the application of flexible components.

20. A device as herein described with reference to and/or as shown in any one of Figure 1-3 of the drawings.

21. A display unit including the device of any preceding claim.

22. The display unit of claim 21, wherein said display unit comprises a rechargeable power cell.

23. The display unit of claim 22, wherein the rechargeable power cell is charged by photovoltaic power generation or through means of an external power supply.

24. The display unit of claim 21 or 22, wherein said display unit comprises sensor means for detecting nearby display units.

25. The display unit of claim 24, wherein said sensor means are located at the peripheries of the display unit.

26. The display unit of claim 24 or 25, wherein the sensor means provide means for the display unit to orientate itself with respect to nearby display units.

27. The display unit of any one of claims 21 to 26, wherein the display unit comprises a means for wireless communication with other similar display units.

28. The display unit of any one of claims 22 to 27, including means for transferring stored electrical charge to similar display units.

29. The display unit of any one of claims 21 to 28, including one or more sound emitting units arranged to emit sound such that from the perspective of a listener the sound is being transferred directly from the display device of said display unit.

30. An array of display units each as claimed in any one of claims 21 to 29.

31. The array of display units of claim 30, wherein the display units comprising said array are arranged to wirelessly communicate with one another.

32. The array of display units of any one of claims 30 to 31, wherein the display units of the array orientate themselves with respect to one another using sensors located at the peripheries of the display units.

33. The array of display units of any one of claims 30 to 32, wherein display information is shared across all display units of said array.

34. The array of display units of claim 33, wherein a first said display unit displays display information which is shared across a second said display unit when said second display unit is proximately located to said first display unit.

35. The array of display units of any one of claims 30 to 34, arranged such that adding at least one additional display unit to said array of display units, by positioning said additional display unit(s) proximately to said array of display units, shares the display

information displayed on the array of display units across all display units, including the at least one additional display unit, of said array.

36. The array of display units of any of claims 33 to 35, arranged such that the display information on at least one display unit of said array is distinct from the display information on the other display units of said array of display units, but is associated with the display information of the other display units as part of a collective information display.

37. The array of display units of any one of claims 33 to 36, wherein said display information is human readable data such as picture, text, moving images, colour patterns or other types of information that may be visually interpreted by a person or group of people.

38. The array of display units of any one of claims 30 to 36, arranged such that in the event of at least one display unit of the array of display units failing to operate correctly the array is programmed to reconfigure the display information by a programming means in at least one display unit or in a separate control unit.

39. The array of display units of any one of claims 30 to 38, wherein a master display unit is arranged to manage the distribution of stored charge by wireless charge transfer amongst the at least one other display units of said array of display units.

40. The array of display units of claim 39, wherein the master display unit is arranged to manage the transfer of stored charge amongst the array of display units such that after a period of time all display units of said array of display units have approximately the same level of charge.

41. The array of display units of any one of claims 30 to 36 or 38 to 40, each when dependent directly or indirectly on claim 29, wherein the sound emitted from the sound emitting units of the display devices of the array of display units is arranged such that it forms a unified sound from all display units.

42. The array of display units of any one of claims 30 to 36 or 38 to 41, each when dependent directly or indirectly on claim 29, wherein the sound emitted from the sound emitting units of the display devices of the array of display units is dynamically

arranged such that each display unit transmits different sounds which correspond to the movement of display information across the display units of said array of display units.

43. The display unit of any one of claims 21 to 30 or the array of display units of any one of claims 30 to 36 or 38 to 42, wherein said display units or array of display units are controlled by an external control entity.

44. The external control entity of claim 43, wherein said external control entity comprises control software which encrypts the information transferred between the external control entity and display unit or array of display units.

45. An array of display units substantially as herein described with reference to and/or as shown in Figure 5 or Figure 6 of the accompanying drawings.

Intellectual Property Office

Application No:	GB1522381.1	**Examiner:**	Stephen Procter
Claims searched:	1 in part	**Date of search:**	1 June 2016

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 5-10, 14-17, 21-23, 30, 43 & 44 at least	US 2012/0091473 A1 (GWANGJU INSTITUTE OF SCIENCE & TECHNOLGY) See Figure 5 and paragraphs [0070] to [0074]
X	1, 5-10, 14-17, 21-23, 30, 43 & 44 at least	US 2011/0317121 A1 (AU OPTRONICS CORPORATION) See Figure 4 and paragraph [0049]
X	1, 5-10, 14-17, 21-23, 30, 43 & 44 -at least	US 2011/0249219 A1 (EVANS et al) See Figure 4 and paragraphs [0035] & [0101]
X	1, 5-10, 14-17, 21-23, 30, 43 & 44 at least	US 2009/0103161 A1 (QUALCOMM MEMS TECHNOLOGIES INC) See Figures 10 & 11 and paragraphs [0084] & [0085]
X	1, 5-10, 14-17, 21-23, 30, 43 & 44 at least	WO 2005/043228 A2 (MOTOROLA INC) See Figure 1 and page 2, lines 16 to 21

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Intellectual Property Office

Worldwide search of patent documents classified in the following areas of the IPC

G02F

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
G02F	0001/1335	01/01/2006
G02F	0001/133	01/01/2006