



(51) International Patent Classification:

G06F 3/042 (2006.01)

(21) International Application Number:

PCT/SE2022/051106

(22) International Filing Date:

25 November 2022 (25.11.2022)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2130350-8

09 December 2021 (09.12.2021) SE

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(81) Designated States (unless otherwise indicated, for every

kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every

kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: IMPROVED TOUCH-SENSING APPARATUS

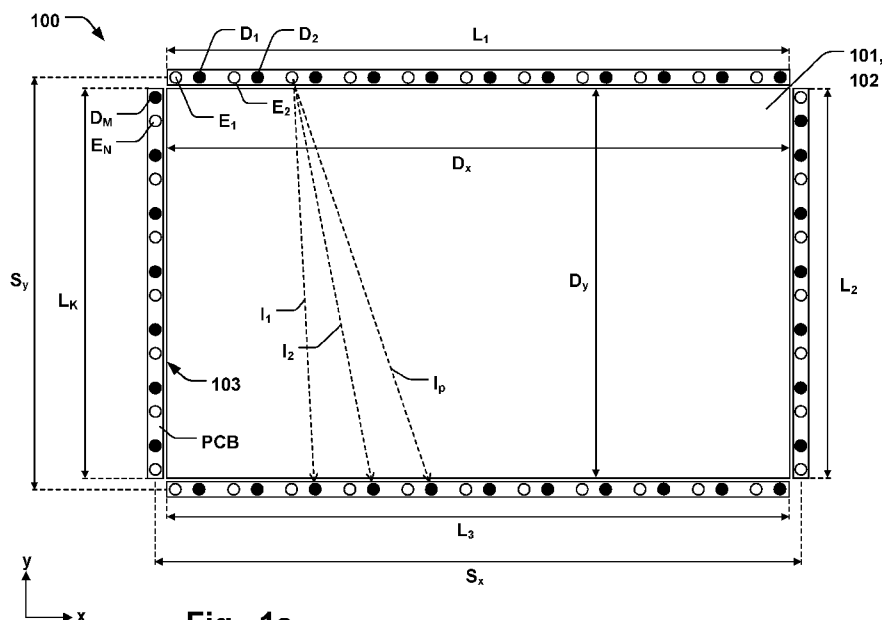


Fig. 1a

(57) Abstract: A touch sensing apparatus is disclosed comprising a panel that defines a touch surface, a plurality of emitters and detectors mounted to substrates and positioned along edges of the panel, the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines cross the touch surface, a perimeter spacing (P_{DP} , P_{SP} , P_{LE} , P_{LD}) of the emitters and/or detectors has a value above 20 mm and/or a scanline density (SD_D , SD_S) having a value below 120 scanlines/dm².

Published:

- *with international search report (Art. 21(3))*
- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

IMPROVED TOUCH-SENSING APPARATUS

Technical Field

The present invention relates to a touch sensing apparatus that operate by
5 propagating light above a panel, and in particular to solutions for arranging the
emitters and detectors around the panel.

Background Art

In one category of touch-sensitive panels known as 'above surface optical
10 touch systems', a set of optical emitters are arranged around the periphery of a
touch surface to emit light that is reflected to travel and propagate above the
touch surface. A set of light detectors are also arranged around the periphery of
the touch surface to receive light from the set of emitters from above the touch
surface. I.e. a grid of intersecting light paths are created above the touch
15 surface, also referred to as scanlines. An object that touches the touch surface
will attenuate the light on one or more scanlines of the light and cause a change
in the light received by one or more of the detectors. The location (coordinates),
shape or area of the object may be determined by analyzing the received light
at the detectors. Problems with previous prior art touch detection systems, in
20 particular as the size of the touch panel increases, is the complex incorporation
of an increased number of expensive optical components and associated
electronics. A common reason to increase the number of components is that the
light paths measured are typically narrow and attenuation of such a light path
gives positioning information over a limited area. Thus, the number of light
25 paths are typically increased for the purpose of sensing coverage over large
touch panels, with no concern of the associated increase in the manufacturing
costs. This leads to more expensive and less compact touch detection systems.

Summary

30 An objective is to at least partly overcome one or more of the above
identified limitations of the prior art.

One objective is to provide a touch-sensitive apparatus based on “above-surface” light propagation which is less complex and costly to manufacture while allowing for good resolution and detection accuracy of small objects.

One or more of these objectives, and other objectives that may appear
5 from the description below, are at least partly achieved by means of touch-sensitive apparatuses according to the independent claims, embodiments thereof being defined by the dependent claims.

According to a first aspect, a touch sensing apparatus is provided comprising a panel that defines a touch surface, a plurality of emitters (E_1 ,
10 $E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to substrates (PCB's) and positioned along edges of the panel, where N is the total number of emitters and M is the total number of detectors, wherein the positions of the emitters and detectors along the edges outline the length of a sensor perimeter (SP) extending around the panel, wherein the emitters are arranged to emit light to
15 the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface, wherein a perimeter spacing ($P_{DP}, P_{SP}, P_{LE}, P_{LD}$) of the emitters and/or detectors is defined as, $P_{DP} = DP/(N+M)$, $P_{SP} = SP/(N+M)$, $P_{LE} = LE/N$, $P_{LD} = LD/M$, where DP is a touch surface perimeter equal to a total length of the sides of the touch surface,

20 where LE is an emitter sensor length $= \sum_{k=1}^{K=K} L_k \cdot \frac{N_k}{M_k+N_k}$

where LD is a detector sensor length $= \sum_{k=1}^{K=K} L_k \cdot \frac{M_k}{N_k+M_k}$

wherein a first PCB has a length L_1 and the number of emitters and detectors on the first PCB is N_1 and M_1 , respectively, whereby the plurality of PCB's have respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's,
25 $N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB, $M_1, M_2, \dots, M_K$ are the number of detectors on the respective PCB, wherein any of $P_{DP}, P_{SP}, P_{LE}, P_{LD}$, has a value above 20 mm.

According to a second aspect, a system is provided comprising a touch sensing apparatus according to the first aspect and a stylus having a tip with a
30 width of less than 7 mm, wherein the touch sensor is configured to determine a position of the stylus tip on the touch surface based on the attenuation value.

According to a third aspect, a touch sensing apparatus is provided comprising a panel that defines a touch surface, a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to substrates (PCB's) and positioned along edges of the panel, where N is the total number of emitters and M is the total number of detectors, wherein the positions of the emitters and detectors along the edges outline the length of a sensor perimeter (SP) extending around the panel, the sensor perimeter defines a sensor area (SA), wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface, wherein a scanline density (SD_D, SD_S) is defined as $SD_D = P/DA$, $SD_S = P/SA$, where P is the total number of scanlines, DA is the area of the touch surface, wherein any of SD_D, SD_S , has a value below 120 scanlines/dm².

According to a fourth aspect, a system is provided comprising a touch sensing apparatus according to the third aspect and a first stylus having a tip with a width in the range 1-3 mm, and a second stylus having a tip with a width in the range 4-7 mm, wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

According to a fifth aspect a touch sensing apparatus comprising a panel that defines a touch surface, a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to substrates (PCB's) and positioned along edges of the panel, where N is the total number of emitters and M is the total number of detectors, wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface, wherein a perimeter spacing (P_{DP}) of the emitters and/or detectors is defined as: $P_{DP} = DP/(N+M)$, where DP is a touch surface perimeter equal to a total length of the sides of the touch surface, wherein P_{DP} has a value above 20 mm.

According to a sixth aspect, a system is provided comprising a touch sensing apparatus according to the fifth aspect and a first stylus having a tip with a width in the range 1-3 mm, and a second stylus having a tip with a width in the range 4-7 mm, wherein the touch sensor is configured to determine

whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface,

According to a seventh aspect a touch sensing apparatus is provided comprising a panel that defines a touch surface, a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to substrates (PCB's) and positioned along edges of the panel, where N is the total number of emitters and M is the total number of detectors, wherein the positions of the emitters and detectors along the edges outline the length of a sensor perimeter (SP) extending around the panel, wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface, wherein a perimeter spacing (P_{SP}) of the emitters and/or detectors is defined as: $P_{SP} = SP/(N+M)$, wherein P_{SP} has a value above 20 mm.

According to an eight aspect, a system is provided comprising a touch sensing apparatus according to the seventh aspect and a first stylus having a tip with a width in the range 1-3 mm, and a second stylus having a tip with a width in the range 4-7 mm, wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

According to a ninth aspect a touch sensing apparatus is provided comprising a panel that defines a touch surface, a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to a plurality of substrates (PCB's) and arranged along edges of the panel, where N is the total number of emitters and M is the total number of detectors, wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface, wherein a perimeter spacing (P_{LE}) of the emitters is defined as: $P_{LE} = LE/N$,

$$\text{where } LE \text{ is an emitter sensor length} = \sum_{k=1}^{K=L} L_k \cdot \frac{N_k}{M_k + N_k}$$

wherein a first PCB has a length L_1 , the number of emitters and detectors on the first PCB is N_1 and M_1 , respectively, whereby the plurality of PCB's have respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's, $N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB, $M_1, M_2, \dots, M_K$ are the

number of detectors on the respective PCB, wherein P_{LE} has a value above 20 mm.

According to a tenth aspect, a system is provided comprising a touch sensing apparatus according to the ninth aspect and a first stylus having a tip with a width in the range 1-3 mm, and a second stylus having a tip with a width in the range 4-7 mm, wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

According to an eleventh aspect a touch sensing apparatus is provided comprising a panel that defines a touch surface, a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to a plurality of substrates (PCB's) and arranged along edges of the panel, where N is the total number of emitters and M is the total number of detectors, wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface, wherein a perimeter spacing (P_{LD}) of the detectors is defined as: $P_{LD} = LD/M$,

$$\text{where } LD \text{ is a detector sensor length} = \sum_{k=1}^{K=K} L_k \cdot \frac{M_k}{N_k + M_k}$$

wherein a first PCB has a length L_1 , the number of emitters and detectors on the first PCB is N_1 and M_1 , respectively, whereby the plurality of PCB's have respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's, $N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB, $M_1, M_2, \dots, M_K$ are the number of detectors on the respective PCB, wherein P_{LD} has a value above 20 mm.

According to a twelfth aspect, a system is provided comprising a touch sensing apparatus according to the eleventh aspect and a first stylus having a tip with a width in the range 1-3 mm, and a second stylus having a tip with a width in the range 4-7 mm, wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

Some examples of the disclosure provide for a touch sensing apparatus with a reduced number of electro-optical components.

Some examples of the disclosure provide for a touch sensing apparatus with an efficient use of detection light.

Some examples of the disclosure provide for a touch sensing apparatus that is less complex to manufacture.

5 Some examples of the disclosure provide for a touch sensing apparatus that is less costly to manufacture.

Some examples of the disclosure provide for a touch sensing apparatus with a more uniform coverage of scanlines across the touch surface.

10 Some examples of the disclosure provide for a touch sensing apparatus for detecting small objects, such as styluses with narrow tips, while being less costly to manufacture.

Some examples of the disclosure provide for a touch sensing apparatus for distinguishing and identifying different types of objects, such as a stylus, brush or a finger, while being less costly to manufacture.

15 Still other objectives, features, aspects and advantages of the present disclosure will appear from the following detailed description, from the attached claims as well as from the drawings.

It should be emphasized that the term “comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, 20 steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

Brief Description of Drawings

25 These and other aspects, features and advantages of which examples of the invention are capable of will be apparent and elucidated from the following description of examples of the present invention, reference being made to the accompanying drawings, in which;

Figs. 1a-b are schematic illustrations of a touch sensing apparatus, in top-down views seen in a x-y plane, according to examples of the disclosure;

30 Fig. 2 is a schematic illustration of a detail of a touch sensing apparatus, seen in a x-y plane, according to an example of the disclosure;

Fig. 3 is a schematic illustration of a touch sensing apparatus, in a top-

down view seen in a x-y plane, according to an example of the disclosure;

Fig. 4 is a schematic illustration of a touch sensing apparatus, in a top-down view seen in a x-y plane, according to an example of the disclosure;

Figs. 5a-b are schematic illustrations of a touch sensing apparatus, in top-down views seen in a x-y plane, indicating scanlines across the touch surface, according to examples of the disclosure;

Figs. 5c-d are schematic illustrations of an emitter array and a detector array respectively, of the touch sensing apparatus, according to examples of the disclosure;

Fig. 6 is a schematic illustration of a touch sensing apparatus, in a top-down view seen in a x-y plane, according to an example of the disclosure;

Fig. 7 is a schematic illustration of a touch sensing apparatus, in a top-down view seen in a x-y plane, where different objects interact with the touch surface, according to an example of the disclosure;

Figs. 8a-b are schematic illustrations of different styluses for interacting with a touch surface of the touch sensing apparatus, according to examples of the disclosure;

Figs. 9a-b are schematic illustrations of a brush for interacting with a touch surface of the touch sensing apparatus, while applying different amounts of pressure into the touch surface, according to examples of the disclosure;

Fig. 9c is a schematic illustration of different shapes of a portion of a brush interacting with a touch surface of the touch sensing apparatus, while applying different amounts of pressure into the touch surface, according to examples of the disclosure;

Fig. 10 is a schematic illustration, in a cross-sectional side view, of a touch-sensing apparatus, according to one example;

Fig. 11 is a schematic illustration, in a cross-sectional side view, of a touch-sensing apparatus, according to one example;

Fig. 12a is a schematic illustration, in a cross-sectional side view, of a touch-sensing apparatus, according to one example;

Fig. 12b is a schematic illustration, in a top-down view, of the touch-sensing apparatus in Fig. 12a, according to one example;

Fig. 13a is a schematic illustration, in a cross-sectional side view, of a touch-sensing apparatus, according to one example; and

Fig. 13b is a schematic illustration, in a top-down view, of the touch-sensing apparatus in Fig. 13a, according to one example.

5

Detailed Description of Example Embodiments

In the following, embodiments of the present invention will be presented for a specific example of a touch-sensitive apparatus. Throughout the description, the same reference numerals are used to identify corresponding elements.

10

Fig. 1a is a schematic illustration, in a top-down view, of a touch sensing apparatus 100 comprising a panel 101 that defines a touch surface 102 extending in a x-y plane. The panel 101 may be a light transmissive panel. The touch sensing apparatus 100 comprises a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to substrates (PCB's) and positioned along edges 103 of the panel 101. The emitters and detectors will be denoted with references E and D, respectively, for brevity in the below disclosure. N is the total number of emitters (E) and M is the total number of detectors (D). The emitters (E) are arranged to emit light to the touch surface 102 and to the detectors (D) so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface 102.

15

20

A perimeter spacing (P_{DP}) of the emitters (E) and/or detectors (D) is defined as:

$$P_{DP} = DP/(N+M),$$

25

where DP is a touch surface perimeter equal to a total length of the sides of the touch surface 102, i.e. the outside border of the touch surface 102. Fig. 2 is a detailed view of a portion of the touch sensing apparatus 100, such as the upper left corner of the top-down view in Fig. 1a. The touch surface perimeter DP is indicated according to the dashed lines along the border of the touch surface 102. The perimeter spacing P_{DP} is thus defined as the length of the touch surface perimeter DP (mm) divided by the total number of emitters (E) and detectors (D). In one example $DP = 2 \cdot D_x + 2 \cdot D_y$, where D_x is the width of

30

the touch surface 102 and D_y is the height of the touch surface 102, as indicated in Fig. 1a. It should be understood however that the touch surface 102 may have other geometries.

In one example the perimeter spacing P_{DP} has a value above 20 mm. E.g.
5 the touch sensing apparatus 100 as schematically illustrated in any of Figs. 1-7 may have a $P_{DP} > 20$ mm. This provides for a spacing between the components, i.e. the emitters (E) and detectors (D), along the edges 103 which is advantageous in that the number of components can be reduced to facilitate manufacturing and cost effectiveness. This is particularly advantageous as the
10 size of the touch surface 102 increases. At the same time the optimized perimeter spacing P_{DP} allows for the touch sensing apparatus 100 to accurately detect small objects, such as a stylus 109a, 109b, contacting the touch surface 102.

Figs. 5a-b show examples of scanline coverage across the touch surface
15 102, which will be described in more detail below, utilizing an optimized spacing between the emitters (E) and detectors (D), e.g. as defined by P_{DP} or any of the parameters P_{SP} , P_{LE} , P_{LD} , SD_D , SD_S defined further below. The scanline coverage provides for a resolution of the touch detection that is useful for detecting a stylus 109a, 109b, while allowing for scaling up of the touch surface
20 102 with a reduced impact on the manufacturing costs.

In one example the, as schematically illustrated in Fig. 7, the touch sensing apparatus 100 may comprise a touch sensor 108 configured to determine, based on output signals from the detectors (D), an attenuation value corresponding to the attenuation of the light resulting from an object touching
25 the touch surface 102. The touch sensor 108 may be configured to determine an object type of the object in dependence on the attenuation value, where the object type may be any of a stylus 109a, 109b, a brush 110 or a finger 111, or a combination thereof. This provides for distinguishing several different types of objects interacting with the touch surface 102. The touch sensor 108 may be
30 configured to determine an object type and touch coordinates (x,y) of a plurality of objects simultaneously interacting with the touch surface 102 based on a plurality of attenuation values. Such multi-touch capabilities of the touch sensing

apparatus 100 allows for simultaneous touch interaction with different objects such as e.g. different styluses 109a, 109b, and/or several fingers.

A system 200 is provided comprising a touch sensing apparatus 100 as described above and a stylus 109a, 109b, having a tip 112a, 112b, with a width
5 (w_1 , w_2) of less than 7 mm. Figs. 8a-b show examples of styluses 109a, 109b, having different widths (w_1 , w_2). The touch sensor 108 may be configured to determine a position (x , y) of the stylus tip on the touch surface 102 based on the attenuation value. The touch input coordinates (x , y) of the position may be output to a display unit (not shown) for a graphical representation of the touch
10 input. The system 200 may thus utilize an optimized spacing between the emitters (E) and detectors (D), e.g. as defined by P_{DP} or any of the parameters P_{SP} , P_{LE} , P_{LD} , SD_D , SD_s defined further below, while having a scanline coverage for touch input with the aforementioned stylus 109a, 109b.

In one example the width (w_1) of the tip 112a of the stylus 109a may be
15 less than 3 mm.

The system 200 may comprise a first stylus 109a having a tip 112a with a width (w_1) in the range 1-3 mm, and a second stylus 109b having a tip 112b with a width (w_2) in the range 4-7 mm. The touch sensor 108 may be configured to determine whether the tip 112a of the first stylus 109a or the tip 112b of the
20 second stylus 112b is in contact with the touch surface 102. The system 200 may thus utilize an optimized spacing between the emitters (E) and detectors (D), e.g. as defined by P_{DP} or any of the parameters P_{SP} , P_{LE} , P_{LD} , SD_D , SD_s defined further below, while having a scanline coverage for distinguishing between touch input of different styluses 109a, 109b.

Figs. 9a-c show a further example where the touch sensing apparatus 100
25 utilizes a flexible brush 110, or a stylus with a flexible tip, as the touch input object. The touch sensor 108 may be configured to determine a first shape (s_1) of a portion of the object in contact with the touch surface 102, as indicted in Fig. 9c at time t_1 . The touch sensor 108 may be configured to determine a
30 subsequent second shape (s_2) of a portion of the object in contact with the touch surface, as the object is pushed against the touch surface 102, as indicted in Fig. 9c at time t_2 . The touch sensor 108 may be configured to

determine a variation in the shape of the portion of the object in contact with the touch surface 102 over time based on the first and second shapes (s_1 , s_2). The touch sensing apparatus 100 thus provides for dynamically tracking the shape of an object and output corresponding coordinates to a display unit for a graphical representation of a flexible tip interacting with the touch surface 102.

Further, determining the variation in the shape may comprise determining a variation in size and/or angle (v) of the portion of the object in contact with the touch surface 102. The system 200 may thus utilize an optimized spacing between the emitters (E) and detectors (D), e.g. as defined by P_{DP} or any of the parameters P_{SP} , P_{LE} , P_{LD} , SD_D , SD_S defined further below, while having a scanline coverage for dynamically track variations in the shape of flexible objects 110 in contact with the touch surface 102.

In one example P_{DP} may have a value above 25 mm. This may provide for a particularly advantageous balance between the accuracy of the touch detection of e.g. a stylus 109a, 109b, and the cost effectiveness of the touch sensing apparatus 100. In a further example P_{DP} may have a value above 30 mm. This provides for a further optimization in some applications of cost effectiveness and accuracy of the touch detection of e.g. a stylus 109a.

The positions of the emitters (E_1 , $E_2, \dots$, E_N) and the detectors (D_1 , $D_2, \dots$, D_M) along the edges 103 of the panel 101 outline the length of a sensor perimeter (SP) extending around the panel 101, as schematically indicated by the dashed line (SP) in Fig. 2 crossing the midpoints of the emitters (E) and detectors (D). A perimeter spacing (P_{SP}) of the emitters (E) and/or detectors (D) is defined as:

$$P_{SP} = SP/(N+M),$$

where SP is the total length of the sides of the sensor perimeter. The perimeter spacing P_{SP} is thus defined as the length of the sensor perimeter SP (mm) divided by the total number of emitters (E) and detectors (D). The sensor perimeter defines a sensor area (SA). In one example $SP = 2 \cdot S_x + 2 \cdot S_y$, where S_x is the width of the sensor area (SA) and S_y is the height of the sensor area (SA), as indicated in e.g. Fig. 1a. It should be understood however that the emitters (E) and detectors (D) may be arranged in other configurations

depending on the geometry of the touch surface 102 and that the sensor area (SA) may have a corresponding geometry, such as non-rectangular geometries.

In one example P_{SP} has a value above 20 mm. E.g. the touch sensing apparatus 100 as schematically illustrated in any of Figs. 1-7 may have a $P_{SP} >$
 5 20 mm. This provides for a spacing between the components, i.e. the emitters (E) and detectors (D), along the edges 103 which is advantageous in that the number of components can be reduced to facilitate manufacturing and cost effectiveness. This is particularly advantageous as the size of the touch surface 102 increases. At the same time the optimized perimeter spacing P_{SP} allows for
 10 the touch sensing apparatus 100 and system 200 to accurately detect small objects, such as a stylus 109a, 109b, contacting the touch surface 102, as described above.

In one example P_{SP} may have a value above 25 mm. This may provide for a particularly advantageous balance between the accuracy of the touch
 15 detection of e.g. a stylus 109a, 109b, and the cost effectiveness of the touch sensing apparatus 100. In a further example P_{SP} may have a value above 30 mm. This provides for a further optimization in some applications of cost effectiveness and accuracy of the touch detection of e.g. a stylus 109a.

In one example a perimeter spacing (P_{LE}) of the emitters (E) is defined as:

$$P_{LE} = LE/N.$$

LE is an emitter sensor length = $\sum_{k=1}^{K=K} L_k \cdot \frac{N_k}{M_k + N_k}$,

where a first PCB has a length L_1 , and the number of emitters (E) and detectors (D) on the first PCB is N_1 and M_1 , respectively. The plurality of PCB's have thus respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's, and $N_1, N_2, \dots, N_K$ are the number of emitters (E) on the respective PCB, and $M_1, M_2, \dots, M_K$
 25 are the number of detectors (D) on the respective PCB. Same as defined above, N is the total number of emitters (E) of the touch sensing apparatus 100, and M is the total number of detectors (D) of the touch sensing apparatus 100, while N and M with a subscript character, e.g. N_k , and M_k , refers to the total
 30 number of emitters (E) or detectors (D) on a particular PCB. In the example of Fig. 1a four PCB's are shown, L_1, L_2, L_3 , and L_4 , i.e. $K = 4$. It should be understood however that any number of PCB's may be arranged along the

edges 103 of the panel 101, where each PCB may have any number of emitters (E) and/or detectors (D).

In one example P_{LE} has a value above 20 mm. E.g. the touch sensing apparatus 100 as schematically illustrated in any of Figs. 1-7 may have a $P_{LE} >$
 5 20 mm. This provides for a spacing between the components, i.e. the emitters (E) and detectors (D), along the edges 103 which is advantageous in that the number of components can be reduced to facilitate manufacturing and cost effectiveness. This is particularly advantageous as the size of the touch surface 102 increases. At the same time the optimized perimeter spacing P_{LE} allows for
 10 the touch sensing apparatus 100 and system 200 to accurately detect small objects, such as a stylus 109a, 109b, contacting the touch surface 102, as described above.

In one example P_{LE} may have a value above 25 mm. This may provide for a particularly advantageous balance between the accuracy of the touch
 15 detection of e.g. a stylus 109a, 109b, and the cost effectiveness of the touch sensing apparatus 100. In a further example P_{LE} may have a value above 30 mm. This provides for a further optimization in some applications of cost effectiveness and accuracy of the touch detection of e.g. a stylus 109a.

In one example a perimeter spacing (P_{LD}) of the detectors (D) is defined
 20 as:

$$P_{LD} = LD/M.$$

LD is a detector sensor length = $\sum_{k=1}^{K=K} L_k \cdot \frac{M_k}{N_k + M_k}$,

where a first PCB has a length L_1 , the number of emitters (E) and detectors (D) on the first PCB is N_1 and M_1 , respectively. The plurality of PCB's thus have
 25 respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's, $N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB, $M_1, M_2, \dots, M_K$ are the number of detectors on the respective PCB.

In one example P_{LD} has a value above 20 mm. E.g. the touch sensing apparatus 100 as schematically illustrated in any of Figs. 1-7 may have a $P_{LD} >$
 30 20 mm. This provides for a spacing between the components, i.e. the emitters (E) and detectors (D), along the edges 103 which is advantageous in that the number of components can be reduced to facilitate manufacturing and cost

effectiveness. This is particularly advantageous as the size of the touch surface 102 increases. At the same time the optimized perimeter spacing P_{LD} allows for the touch sensing apparatus 100 and system 200 to accurately detect small objects, such as a stylus 109a, 109b, contacting the touch surface 102, as described above.

In one example P_{LD} may have a value above 25 mm. This may provide for a particularly advantageous balance between the accuracy of the touch detection of e.g. a stylus 109a, 109b, and the cost effectiveness of the touch sensing apparatus 100. In a further example P_{LD} may have a value above 30 mm. This provides for a further optimization in some applications of cost effectiveness and accuracy of the touch detection of e.g. a stylus 109a.

A perimeter spacing (P_{DP} , P_{SP} , P_{LE} , P_{LD}) of the emitters (E) and/or detectors (D) may thus be defined as any of;

$$\begin{aligned} P_{DP} &= DP/(N+M), \\ P_{SP} &= SP/(N+M), \\ P_{LE} &= LE/N, \\ P_{LD} &= LD/M, \end{aligned}$$

as defined above, wherein any of P_{DP} , P_{SP} , P_{LE} , P_{LD} , has a value above 20 mm in some examples.

Any of P_{DP} , P_{SP} , P_{LE} , P_{LD} , may have a value above 25 mm, as described above.

In one example a scanline density (SD_D , SD_S) may be defined as

$$SD_D = P/DA,$$

where P is the total number of scanlines ($l_1, l_2, \dots, l_p$), and DA is the area (dm^2) of touch surface 102. In one example $DA = D_x * D_y$, where D_x is the width of the touch surface 102 and D_y is the height of the touch surface 102, as indicated in Fig. 1a. It should be understood however that the touch surface 102 may have other geometries. A specific emitter (E) generates a scanline to the detectors (D) it can "see", i.e. to detectors (D) within the emitters line-of-sight. For example, detectors (D) placed on the same edge 103 as that emitter will typically not add to the number of scanlines generated in the geometry for that emitter. On one example, where a panel 101 has first and second long sides,

LS1 and LS2, and first and second short sides, SS1 and SS2, the total number of scan lines may be expressed as:

$$\begin{aligned}
 P = & E_LS1 * (D_SS1 + D_LS2 + D_SS2) \\
 & + E_SS1 * (D_LS2 + D_SS2 + D_LS1) \\
 5 \quad & + E_LS2 * (D_SS2 + D_LS1 + D_SS2) \\
 & + E_SS2 * (D_LS1 + D_SS1 + D_LS2),
 \end{aligned}$$

where E_LS1, E_LS2, E_SS1, E_SS2, are the number of emitters (E) on the respective sides, and D_LS1, D_LS2, D_SS1, D_SS2, are the number of detectors (D) on the respective sides.

10 For some geometries, e.g. as exemplified in Fig. 3 and Fig. 4, the total number of scan lines may be expressed as;

$$P = N * M.$$

In one example SD_D may have a value below 120 scanlines/dm². E.g. the touch sensing apparatus 100 and system 200 as schematically illustrated in any of Figs. 1-7 may have a $SD_D < 120$ scanlines/dm². The optimized scanline coverage provides for a resolution of the touch detection that is useful for detecting a stylus 109a, 109b, while allowing for reducing the number of emitters (E) and detectors (D) so that scaling up of the touch surface 102 has a reduced impact on the manufacturing costs. Alternatively, or in addition, any of P_{DP} , P_{SP} , P_{LE} , P_{LD} , may have a value above 20 mm the touch sensing apparatus 100 and system 200.

In one example a scanline density (SD_s) may be defined as

$$SD_s = P/SA,$$

where P is the total number of scanlines, and SA is the sensor area (dm²). As mentioned above the positions of the emitters ($E_1, E_2, \dots, E_N$) and the detectors ($D_1, D_2, \dots, D_M$) along the edges 103 of the panel 101 outline the length of a sensor perimeter (SP) extending around the panel 101, and the sensor perimeter (SP) defines the sensor area (SA). In one example $SP = 2 * S_x + 2 * S_y$, where S_x is the width of the sensor area (SA) and S_y is the height of the sensor area (SA), as indicated in e.g. Fig. 1a. It should be understood however that the emitters (E) and detectors (D) may be arranged in other configurations

depending on the geometry of the touch surface 102 and that the sensor area (SA) may have a corresponding geometry, such as non-rectangular geometries.

In one example SD_s may have a value below 120 scanlines/dm². E.g. the touch sensing apparatus 100 and system 200 as schematically illustrated in any of Figs. 1-7 may have a $SD_s < 120$ scanlines/dm². Alternatively, or in addition, any of P_{DP} , P_{SP} , P_{LE} , P_{LD} , may have a value above 20 mm the touch sensing apparatus 100 and system 200.

The total number of scanlines P ($l_1, l_2, \dots, l_p$) have in examples of the disclosure been described as the number of physically possible scanlines, e.g. as each light path between each physical emitter and physical detector in the touch sensing apparatus 100, provided the line-of-sight condition is satisfied as mentioned above.

A system 200 is provided comprising a touch sensing apparatus 100 as described above and a stylus 109a, 109b, having a tip 112a, 112b, with a width (w_1, w_2) of less than 7 mm. Figs. 8a-b show examples of styluses 109a, 109b, having different widths (w_1, w_2). The touch sensor 108 may be configured to determine a position (x, y) of the stylus tip on the touch surface 102 based on the attenuation value. The touch input coordinates (x, y) of the position may be output to a display unit (not shown) for a graphical representation of the touch input. The system 200 may thus utilize an optimized scan line density, e.g. as defined by SD_D or SD_s , while having a scanline coverage for touch input with the aforementioned stylus 109a, 109b. In one example the width (w_1) of the tip 112a of the stylus 109a may be less than 3 mm.

Any of SD_D , SD_s , may have a value below 100 scanlines/dm² in some examples. This may provide for a particularly advantageous balance between the accuracy of the touch detection of e.g. a stylus 109a, 109b, and the cost effectiveness of the touch sensing apparatus 100. In one example SD_D and/or SD_s , may have a value below 80 scanlines/dm². In a further example SD_D and/or SD_s , may have a value in the range 60 scanlines/dm², such as in the range 40 – 60 scanlines/dm². This provides for a further optimization of cost effectiveness and accuracy of the touch detection of e.g. a stylus 109a in some applications.

The touch sensing apparatus 100 may comprise a first array (E_a) of emitters (E), i.e. a first emitter array (E_a) arranged along a first edge 103a of the panel 101. Adjacent emitters (E) in the first emitter array (E_a) may be arranged in an emitter coordinate sequence (d_E) where the separation between adjacent emitters (e.g. between E_1 and E_2 , and between E_2 and E_3 in Fig. 3) is defined by a first pattern of emitter coordinates and an offset value ($\pm\Delta$) for the respective emitter in the first emitter array (E_a). The first pattern of emitter coordinates may alternate between two separation distances d_{E1} , d_{E2} . Thus, the emitters (E) are arranged in a sequence defined by the separation distances d_{E1} , d_{E2} , and an offset value ($\pm\Delta$) which is added to the separation distance d_{E1} , d_{E2} , for the respective emitter (E) to provide the coordinate at which the respective emitter (E) is mounted. Fig. 5c is a schematic illustration showing a first emitter array (E_a). Although the offset value ($\pm\Delta$) is illustrated for only one emitter it should be understood that any of the emitters (E) in the array (E_a) may have an offset value $\pm\Delta$ with respect to the first pattern of emitter coordinates d_{E1} , d_{E2} . The offset value $\pm\Delta$ may be different for each emitter (E) in the first emitter array (E_a). The offset value $\pm\Delta$ may be a randomized value. The offset value $\pm\Delta$ may be a randomized value in the range $-0.5 \cdot d_{E1}$ to $+0.5 \cdot d_{E1}$ in one example. In one example $d_{E2} = C \cdot d_{E1}$, where C is in the range 1.7 – 2.3.

The touch sensing apparatus 100 may comprise a first detector array (D_b) arranged along a second edge 103b of the panel 101, opposite the first edge 103a. Adjacent detectors (D) in the first detector array (D_b) may be arranged in a detector coordinate sequence (d_D) where the separation between adjacent detectors (D) is defined by a first pattern of detector coordinates and an offset value ($\pm\Delta'$) for the respective detector (D) in the first detector array (D_b). The first pattern of detector coordinates may alternate between two separation distances d_{D1} , d_{D2} , wherein $d_{D2} = C' \cdot d_{D1}$, where C' is in the range 1.7 – 2.3, and the offset values Δ' are in the range $-0.5 \cdot d_{D1}$ to $+0.5 \cdot d_{D1}$. Fig. 5d is a schematic illustration showing a first detector array (D_b). Although the offset value ($\pm\Delta'$) is illustrated for only one detector it should be understood that any of the detectors (D) in the array (D_b) may have an offset value $\pm\Delta'$ with respect to the first

pattern of detector coordinates d_{D1} , d_{D2} . The offset value $\pm\Delta'$ may be a randomized value in the range $-0.5 \cdot d_{D1}$ to $+0.5 \cdot d_{D1}$ in one example.

In one example d_{D2} may be essentially twice the length of d_{D1} , and d_{E2} may be essentially twice the length of d_{E1} , as further exemplified in Fig. 3. Such
5 1:2 spacing between emitters (E) and between detectors (D) is also illustrated in Fig. 5b, and it provides for a denser grid of scanlines compared to a 1:1 spacing as seen in Fig. 5a. The 1:2 spacing is advantageous for geometries such as those exemplified in Figs. 3 and 4 where the edges have components of a single type, i.e. either emitters (E) or detectors (D), whereas in mixed
10 geometries such as in Fig. 1a a 1:3 spacing may provide for a more optimal grid pattern of scanlines.

The touch sensing apparatus 100 may comprise a second emitter array (E_c) arranged along a third edge 103c of the panel 101, perpendicular to the first edge 103a. Adjacent emitters (E) along the third edge 103c may be arranged
15 according to the emitter coordinate sequence (d_E) as described above. A second detector array (D_d) may be arranged along a fourth edge 103d of the panel 101, perpendicular to the first edge 103a and opposite the third edge 103c. Adjacent detectors (D) along the third edge 103c may be arranged according to the detector coordinate sequence (d_D) as described above. An
20 example of such geometry is shown in Fig. 3.

The plurality of detectors (D) may be arranged along a top portion 104 of the panel 101, and the plurality of emitters (E) may be arranged along a bottom portion 105 of the panel 101 and along opposite sides 106, 107 of the panel 101 extending between the top and bottom portions 104, 105. Fig. 6 is a schematic
25 illustration of such arrangement of the emitters (E) and detectors (D). Such configuration, i.e. U-geometry, may be particularly advantageous in applications where the panel 101 is arranged vertically, e.g. on a wall with the top portion 104 towards the ceiling and the bottom portion 105 towards the floor. Such configuration may reduce the amount of ambient light, such as light from ceiling
30 lamps, reaching the detectors (D). The signal-to-noise ratio in the touch signal may thus be improved in such configuration. The U-geometry may also be advantageous in increasing the cost efficiency of the touch sensing apparatus

100 when one type of the components, such as the detectors (D), are more costly compared to the other, e.g. the emitters (E). Having emitters (E) arranged on both sides 106, 107, may thus contribute to further reduce complexity and costs for the touch sensing apparatus 100, in addition to incorporating the

5 perimeter spacing (P_{DP} , P_{SP} , P_{LE} , P_{LD}) and/or scanline density (SD_D , SD_S) as defined above. Such U-geometry may also be advantageous in applications where several individual panels 101 are arranged side by side, possibly with the respective touch surfaces 101 not being fully aligned in a single plane. E.g. multiple panels 101 may be arranged as a digital black board arrangement with

10 slightly tilted wing portions of individual panels 101. Such tilted configuration would not have valid scanlines from one side 106 of a first panel 101, e.g. from a first vertical short side, to another side 107 of a second panel 101, e.g. to a second vertical short side, due to the panels being tilted relative each other. Detectors (D) may thus be omitted along these sides, and emitters (E) may be

15 advantageously arranged as a U-configuration, i.e. as exemplified in Fig. 6, in such application.

A spacing between the emitters (E) and detectors (D), as defined by any of parameters P_{DP} , P_{SP} , P_{LE} , P_{LD} , SD_D , SD_S , described above may be combined with different scanline widths for providing an optimized scanline coverage of

20 the touch surface 102. The scanline width is the width of the portion of light travelling from the emitter (E) to the detector (D) that can be used to detect an interrupting object between the emitter (E) and detector (D), wherein the width is measured perpendicular to the scanline direction. The scanline width may in some examples be affected by arranging a light scattering element 113 in the

25 light path between the emitters (E) and the touch surface 102, such as a diffusive light scattering element 113 as exemplified in Figs. 10 – 13. The diffusive light scattering element 113 provides for diffusive scattering of the light in the plane of the touch surface 102, thus effectively broadening the scanlines in said plane. The scattering of light out of the plane of the touch surface 102

30 may be limited by an angular filter structure (not shown) configured to confine the emitted light, which is scattered by the diffusive light scattering element 113 in the light path, to a determined angular range in relation to the touch surface

102. Fig. 10 is a schematic example of a diffusive light scattering element 113 arranged on a frame element 114 of the touch sensing apparatus 100, in the light path from the emitter (E) to the touch surface 102. The distance between the emitter (E) and the diffusive light scattering element 113 may be varied, whereby increasing the aforementioned distance provides for broadening of the scanline. The diffusive light scattering element 113 may in one example be formed directly in a surface of the frame element 114, as schematically illustrated in Fig. 11. Frame element 114 may be an extruded profile component. The frame element 114 may be made from brushed sheet metal.

10 The frame element 114 may be formed from anodized metal, such as anodized aluminum, and the diffusive light scattering element 113 may be formed by providing grooves in the frame element 114 by scratching or brushing the anodized layer of the aluminum. Figs. 12a-b show an example where the diffusive light scattering element 113 is arranged on a first surface of a light coupling element 115 facing the emitter (E), in a side view (a) and in a top-down view (b). The light coupling element 115 is arranged between the touch surface 102 and the frame element 114, and in the aforementioned light path between the emitter (E) and the touch surface 102. The light is diffusively scattered in the plane of the touch surface 102 as schematically indicated in the top-down view of Fig. 12b. The emitter (E) is in this example arranged above the touch surface 102, but it should be understood that the emitter (E) may be positioned below the touch surface 102 (similar to Fig. 10), to increase the distance between the emitter (E) and the diffusive light scattering element 113, to further increase the scanline width. Figs. 13a-b show another example where the diffusive light scattering element 113 is arranged on a second surface of a light coupling element 115 facing the touch surface 102, in a side view (a) and in a top-down view (b). The light is diffusively scattered in the plane of the touch surface 102 as schematically indicated in the top-down view of Fig. 13b. The diffusive light scattering element 113 may be attached to or incorporated into the light coupling element 115.

25 30

The diffusive light scattering element 113 may be a so-called engineered diffuser with well-defined light scattering properties. This provides for a

controlled light management and tailoring of the light scattering abilities. A film with groove-like or other undulating structures may be dimensioned to optimize light scattering at particular angles. The diffusive light scattering element 113 may be implemented as a coating, layer or film applied by e.g. by anodization, painting, spraying, lamination, gluing, etc. The diffusive light scattering element 113 may be implemented as a semi-randomized (non-periodic) micro-structure. A micro-structure may be provided by etching, embossing, molding, abrasive blasting, scratching, brushing etc. The diffusive light scattering element 113 may comprise lenticular lenses or diffraction grating structures.

The touch sensing apparatus 100 may comprise a diffusive light scattering element 113 in a light path between the emitters (E) and the touch surface 102. A diffusive light scattering element 113 provides for a broadening of the scanline width which is advantageous when combined with a spacing between the emitters (E) and detectors (D), as defined by any of parameters P_{DP} , P_{SP} , P_{LE} , P_{LD} , SD_D , SD_S , described above. Alternatively, or in combination, the length of the light path between the emitters (E) and the touch surface 102 may be increased for increasing the width of the scanlines, e.g. by directing the emitted light around the edges of the panel 101. The light paths between the emitters (E) and detectors (D) can thus be made wider, resulting in a scanline that provides positioning information over a larger area, which is advantageous when combined with an optimized spacing between the emitters (E) and detectors (D), as defined by any of parameters P_{DP} , P_{SP} , P_{LE} , P_{LD} , SD_D , SD_S . A cheaper system with fewer optical and electronic components can thus be provided. The number of emitters (E) and detectors (D) can be reduced while being able to accurately detect small objects, such as a stylus 109a, 109b, contacting the touch surface 102, as described above.

The scanline width may in one example be in the range 8 – 16 mm FWHM (full-width-half-maximum). This may be particularly advantageous in positioning information over a larger area when combined with a spacing between the emitters (E) and detectors (D), as defined by any of parameters P_{DP} , P_{SP} , P_{LE} , P_{LD} , SD_D , SD_S .

Examples:

Example 1. A touch sensing apparatus (100) comprising:

a panel (101) that defines a touch surface (102),

5 a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$)

mounted to substrates (PCB's) and positioned along edges (103) of the panel,

where N is the total number of emitters and M is the total number of detectors,

wherein the positions of the emitters and detectors along the edges outline the length of a sensor perimeter (SP) extending around the panel,

10 wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface,

wherein a perimeter spacing ($P_{DP}, P_{SP}, P_{LE}, P_{LD}$) of the emitters and/or detectors is defined as:

15 $P_{DP} = DP/(N+M),$

$P_{SP} = SP/(N+M),$

$P_{LE} = LE/N,$

$P_{LD} = LD/M,$

20 where DP is a touch surface perimeter equal to a total length of the sides of the touch surface,

where LE is an emitter sensor length $= \sum_{k=1}^{K=K} L_k \cdot \frac{N_k}{M_k+N_k}$

where LD is a detector sensor length $= \sum_{k=1}^{K=K} L_k \cdot \frac{M_k}{N_k+M_k}$

25 wherein a first PCB has a length L_1 and the number of emitters and detectors on the first PCB is N_1 and M_1 , respectively, whereby the plurality of PCB's have respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's, $N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB, $M_1, M_2, \dots, M_K$ are the number of detectors on the respective PCB,

30 wherein any of $P_{DP}, P_{SP}, P_{LE}, P_{LD}$, has a value above 20 mm.

Example 2. A touch sensing apparatus according to example 1, wherein any of P_{DP} , P_{SP} , P_{LE} , P_{LD} , has a value above 25 mm.

Example 3. A touch sensing apparatus according to example 1 or 2,
5 wherein a scanline density (SD_D , SD_S) is defined as

$$SD_D = P/DA,$$

$$SD_S = P/SA,$$

where P is the total number of scanlines,

DA is the area of touch surface,

10 wherein any of SD_D , SD_S , has a value below 120 scanlines/dm².

Example 4. A touch sensing apparatus according to example 3, wherein any of SD_D , SD_S , has a value below 100 scanlines/dm².

15 Example 5. A touch sensing apparatus according to example 3, wherein any of SD_D , SD_S , has a value below 60 scanlines/dm².

Example 6. A touch sensing apparatus according to any of examples 1 - 5, comprising

20 a first emitter array (E_a) arranged along a first edge (103a) of the panel, adjacent emitters in the first emitter array being arranged in an emitter coordinate sequence (d_E) where the separation between adjacent emitters is defined by a first pattern of emitter coordinates and an offset value ($\pm\Delta$) for the respective emitter in the first emitter array,

25 wherein the first pattern of emitter coordinates alternates between two separation distances d_{E1} , d_{E2} , wherein $d_{E2} = C \cdot d_{E1}$, where C is in the range 1.7 – 2.3, and the offset values Δ are in the range $-0.5 \cdot d_{E1}$ to $+0.5 \cdot d_{E1}$,

a first detector array (D_b) arranged along a second edge (103b) of the panel, opposite the first edge,

30 adjacent detectors in the first detector array being arranged in a detector coordinate sequence (d_D) where the separation between adjacent detectors is

defined by a first pattern of detector coordinates and an offset value ($\pm\Delta'$) for the respective detector in the first detector array,

wherein the first pattern of detector coordinates alternates between two separation distances d_{D1} , d_{D2} , wherein $d_{D2} = C' \cdot d_{E1}$, where C' is in the range 1.7 – 2.3, and the offset values Δ' are in the range $-0.5 \cdot d_{D1}$ to $+0.5 \cdot d_{D1}$.

Example 7. A touch sensing apparatus according to example 6, comprising

a second emitter array (E_c) arranged along a third edge (103c) of the panel, perpendicular to the first edge, adjacent emitters in the second emitter array being arranged in the emitter coordinate sequence (d_E),

a second detector array (D_d) arranged along a fourth edge (103d) of the panel, perpendicular to the first edge and opposite the third edge, adjacent detectors in the second detector array being arranged in the detector coordinate sequence (d_D),

Example 8. A touch sensing apparatus according to any of examples 1 - 6, wherein the plurality of detectors are arranged along a top portion (104) of the panel, and the plurality of emitters are arranged along a bottom portion (105) of the panel and along opposite sides (106, 107) of the panel extending between the top and bottom portions.

Example 9. A touch sensing apparatus according to any of examples 1 - 8, comprising a touch sensor (108) configured to

determine, based on output signals from the detectors, an attenuation value corresponding to the attenuation of the light resulting from an object touching the touch surface, and

determine an object type of the object in dependence on the attenuation value, wherein the object type is any of a stylus (109a, 109b), a brush (110) or a finger (111).

Example 10. A touch sensing apparatus according to example 9, wherein the touch sensor is configured to

determine a first shape (s_1) of a portion of the object in contact with the touch surface,

5 determine a subsequent second shape (s_2) of a portion of the object in contact with the touch surface, as the object is pushed against the touch surface,

determine a variation in the shape of the portion of the object in contact with the touch surface over time based on the first and second shapes.

10

Example 11. A touch sensing apparatus according to example 10, wherein determining the variation in the shape comprises determining a variation in size and/or angle (ν) of the portion of the object in contact with the touch surface.

15 Example 12. A system (200) comprising a touch sensing apparatus according to any of examples 9 - 11 and a stylus (109a, 109b) having a tip (112a, 112b) with a width (w_1 , w_2) of less than 7 mm,

wherein the touch sensor is configured to determine a position (x , y) of the stylus tip on the touch surface based on the attenuation value.

20

Example 13. A system according to example 12, wherein the width (w_1) of the tip (112a) is less than 3 mm.

25 Example 14. A system according to any of examples 12 – 13, comprising a first stylus (109a) having a tip (112a) with a width (w_1) in the range 1-3 mm, and

a second stylus (109b) having a tip (112b) with a width (w_2) in the range 4-7 mm,

30 wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

Example 15. A touch sensing apparatus (100) comprising:

a panel (101) that defines a touch surface (102),
 a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$)
 mounted to substrates (PCB's) and positioned along edges (103) of the panel,
 where N is the total number of emitters and M is the total number of detectors,
 5 wherein the positions of the emitters and detectors along the edges outline
 the length of a sensor perimeter (SP) extending around the panel, the sensor
 perimeter defines a sensor area (SA),
 wherein the emitters are arranged to emit light to the touch surface and to
 the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch
 10 surface,
 wherein a scanline density (SD_D, SD_S) is defined as
 $SD_D = P/DA$,
 $SD_S = P/SA$,
 where P is the total number of scanlines,
 15 DA is the area of the touch surface,
 wherein any of SD_D, SD_S , has a value below 120 scanlines/dm².

Example 16. A touch sensing apparatus according to example 15, wherein
 any of SD_D, SD_S , has a value below 100 scanlines/dm².

20

Example 17. A touch sensing apparatus according to example 15, wherein
 any of SD_D, SD_S , has a value below 60 scanlines/dm².

Example 18. A touch sensing apparatus according to example 15 or 16,
 25 wherein a perimeter spacing ($P_{DP}, P_{SP}, P_{LE}, P_{LD}$) of the emitters and/or
 detectors is defined as:

$$P_{DP} = DP/(N+M),$$

$$P_{SP} = SP/(N+M),$$

$$P_{LE} = LE/N,$$

$$30 \quad P_{LD} = LD/M,$$

where DP is a touch surface perimeter equal to a total length of the sides
 of the touch surface,

where LE is an emitter sensor length = $\sum_{k=1}^{k=K} L_k \cdot \frac{N_k}{M_k + N_k}$

where LD is a detector sensor length = $\sum_{k=1}^{k=K} L_k \cdot \frac{M_k}{N_k + M_k}$

- 5 wherein a first PCB has a length L_1 , the number of emitters and detectors on the first PCB is N_1 and M_1 , respectively, whereby the plurality of PCB's have respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's, $N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB, $M_1, M_2, \dots, M_K$ are the number of detectors on the respective PCB,
- 10 wherein any of $P_{DP}, P_{SP}, P_{LE}, P_{LD}$, has a value above 20 mm.

Example 19. A touch sensing apparatus according to example 18, wherein any of $P_{DP}, P_{SP}, P_{LE}, P_{LD}$, has a value above 25 mm.

- 15 Example 20. A touch sensing apparatus according to any of examples 15 - 19, comprising a touch sensor (108) configured to
- determine, based on output signals from the detectors, an attenuation value corresponding to the attenuation of the light resulting from an object touching the touch surface, and
- 20 determine an object type of the object in dependence on the attenuation value, wherein the object type is any of a stylus (109a, 109b), a brush (110) or a finger (111).

- Example 21. A system (200) comprising a touch sensing apparatus
- 25 according to example 20 and
- a first stylus (109a) having a tip (112a) with a width (w_1) in the range 1-3 mm, and
- a second stylus (109b) having a tip (112b) with a width (w_2) in the range 4-7 mm,
- 30 wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

Example 22. A touch sensing apparatus (100) comprising:
a panel (101) that defines a touch surface (102),
a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$)
5 mounted to substrates (PCB's) and positioned along edges (103) of the panel,
where N is the total number of emitters and M is the total number of detectors,
wherein the emitters are arranged to emit light to the touch surface and to
the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch
surface,
10 wherein a perimeter spacing (P_{DP}) of the emitters and/or detectors is
defined as:
$$P_{DP} = DP/(N+M),$$

where DP is a touch surface perimeter equal to a total length of the sides
of the touch surface,
15 wherein P_{DP} has a value above 20 mm.

Example 23. A touch sensing apparatus according to example 22, wherein
 P_{DP} has a value above 25 mm.

20 Example 24. A touch sensing apparatus according to example 22 or 23,
comprising a touch sensor (108) configured to
determine, based on output signals from the detectors, an attenuation
value corresponding to the attenuation of the light resulting from an object
touching the touch surface, and
25 determine an object type of the object in dependence on the attenuation
value, wherein the object type is any of a stylus (109a, 109b), a brush (110) or a
finger (111).

Example 25. A system (200) comprising a touch sensing apparatus
30 according to example 24 and
a first stylus (109a) having a tip (112a) with a width (w_1) in the range 1-3
mm, and

a second stylus (109b) having a tip (112b) with a width (w_2) in the range 4-7 mm,

wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

5

Example 26. A touch sensing apparatus (100) comprising:

a panel (101) that defines a touch surface (102),

a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$)

mounted to substrates (PCB's) and positioned along edges (103) of the panel,

10

where N is the total number of emitters and M is the total number of detectors,

wherein the positions of the emitters and detectors along the edges outline the length of a sensor perimeter (SP) extending around the panel,

wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch

15

surface,

wherein a perimeter spacing (P_{SP}) of the emitters and/or detectors is defined as:

$$P_{SP} = SP/(N+M),$$

wherein P_{SP} has a value above 20 mm.

20

Example 27. A touch sensing apparatus according to example 22, wherein P_{SP} has a value above 25 mm.

25

Example 28. A touch sensing apparatus according to example 26 or 27, comprising a touch sensor (108) configured to

determine, based on output signals from the detectors, an attenuation value corresponding to the attenuation of the light resulting from an object touching the touch surface, and

30

determine an object type of the object in dependence on the attenuation value, wherein the object type is any of a stylus (109a, 109b), a brush (110) or a finger (111).

Example 29. A system (200) comprising a touch sensing apparatus according to example 28 and

a first stylus (109a) having a tip (112a) with a width (w_1) in the range 1-3 mm, and

5 a second stylus (109b) having a tip (112b) with a width (w_2) in the range 4-7 mm,

wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

10 Example 30. A touch sensing apparatus (100) comprising:

a panel (101) that defines a touch surface (102),

a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$)

mounted to a plurality of substrates (PCB's) and arranged along edges (103) of the panel, where N is the total number of emitters and M is the total number of

15 detectors,

wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface,

wherein a perimeter spacing (P_{LE}) of the emitters is defined as:

20 $P_{LE} = LE/N$,

where LE is an emitter sensor length = $\sum_{k=1}^{K=K} L_k \cdot \frac{N_k}{M_k + N_k}$

25 wherein a first PCB has a length L_1 , the number of emitters and detectors on the first PCB is N_1 and M_1 , respectively, whereby the plurality of PCB's have respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's,

$N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB,

$M_1, M_2, \dots, M_K$ are the number of detectors on the respective PCB,

wherein P_{LE} has a value above 20 mm.

30

Example 31. A touch sensing apparatus according to example 30, wherein P_{LE} has a value above 25 mm.

Example 32. A touch sensing apparatus according to example 30 or 31, comprising a touch sensor (108) configured to

- determine, based on output signals from the detectors, an attenuation value corresponding to the attenuation of the light resulting from an object touching the touch surface, and
- determine an object type of the object in dependence on the attenuation value, wherein the object type is any of a stylus (109a, 109b), a brush (110) or a finger (111).

10

Example 33. A system (200) comprising a touch sensing apparatus according to example 32 and

- a first stylus (109a) having a tip (112a) with a width (w_1) in the range 1-3 mm, and
- a second stylus (109b) having a tip (112b) with a width (w_2) in the range 4-7 mm,
- wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

20

Example 34. A touch sensing apparatus (100) comprising:

- a panel (101) that defines a touch surface (102),
- a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to a plurality of substrates (PCB's) and arranged along edges (103) of the panel, where N is the total number of emitters and M is the total number of detectors,

25

wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface,

30

wherein a perimeter spacing (P_{LD}) of the detectors is defined as:

$$P_{LD} = LD/M,$$

$$\text{where LD is a detector sensor length} = \sum_{k=1}^{k=K} L_k \cdot \frac{M_k}{N_k + M_k}$$

wherein a first PCT has a length L_1 , the number of emitters and detectors on the first PCB is N_1 and M_1 , respectively, whereby the plurality of PCB's have respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's,
5 $N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB,
 $M_1, M_2, \dots, M_K$ are the number of detectors on the respective PCB,
wherein P_{LD} has a value above 20 mm.

Example 35. A touch sensing apparatus according to example 34, wherein
10 P_{LD} has a value above 25 mm.

Example 36. A touch sensing apparatus according to example 34 or 35,
comprising a touch sensor (108) configured to
determine, based on output signals from the detectors, an attenuation
15 value corresponding to the attenuation of the light resulting from an object
touching the touch surface, and
determine an object type of the object in dependence on the attenuation
value, wherein the object type is any of a stylus (109a, 109b), a brush (110) or a
finger (111).

20

Example 37. A system (200) comprising a touch sensing apparatus
according to example 36 and

a first stylus (109a) having a tip (112a) with a width (w_1) in the range 1-3
mm, and
25 a second stylus (109b) having a tip (112b) with a width (w_2) in the range 4-
7 mm,

wherein the touch sensor is configured to determine whether the tip of the
first stylus or the tip of the second stylus is in contact with the touch surface.

30 The present invention has been described above with reference to specific
examples. However, other examples than the above described are equally
possible within the scope of the invention. The different features and steps of

the invention may be combined in other combinations than those described.

The scope of the invention is only limited by the appended patent claims.

More generally, those skilled in the art will readily appreciate that all parameters, dimensions, materials, and configurations described herein are
5 meant to be exemplary and that the actual parameters, dimensions, materials, and/or configurations will depend upon the specific application or applications for which the teachings of the present invention is/are used.

CLAIMS

1. A touch sensing apparatus (100) comprising:
 a panel (101) that defines a touch surface (102),
 5 a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$)
 mounted to substrates (PCB's) and positioned along edges (103) of the panel,
 where N is the total number of emitters and M is the total number of detectors,
 wherein the positions of the emitters and detectors along the edges outline
 the length of a sensor perimeter (SP) extending around the panel,
 10 wherein the emitters are arranged to emit light to the touch surface and to
 the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch
 surface,
 wherein a perimeter spacing ($P_{DP}, P_{SP}, P_{LE}, P_{LD}$) of the emitters and/or
 detectors is defined as:
 15 $P_{DP} = DP/(N+M)$,
 $P_{SP} = SP/(N+M)$,
 $P_{LE} = LE/N$,
 $P_{LD} = LD/M$,
 where DP is a touch surface perimeter equal to a total length of the sides
 20 of the touch surface,
 where LE is an emitter sensor length = $\sum_{k=1}^{k=K} L_k \cdot \frac{N_k}{M_k + N_k}$
 where LD is a detector sensor length = $\sum_{k=1}^{k=K} L_k \cdot \frac{M_k}{N_k + M_k}$
 25 wherein a first PCB has a length L_1 and the number of emitters and
 detectors on the first PCB is N_1 and M_1 , respectively, whereby the plurality of
 PCB's have respective lengths $L_1, L_2, \dots, L_K$, where K = total number of PCB's,
 $N_1, N_2, \dots, N_K$ are the number of emitters on the respective PCB,
 $M_1, M_2, \dots, M_K$ are the number of detectors on the respective PCB,
 30 wherein any of $P_{DP}, P_{SP}, P_{LE}, P_{LD}$, has a value above 20 mm.

2. A touch sensing apparatus according to claim 1, wherein any of P_{DP} , P_{SP} , P_{LE} , P_{LD} , has a value above 25 mm.

3 A touch sensing apparatus according to claim 1 or 2, wherein a scanline
5 density (SD_D , SD_S) is defined as

$$SD_D = P/DA,$$

$$SD_S = P/SA,$$

where P is the total number of scanlines,

DA is the area of touch surface,

10 SA is a sensor area defined by the sensor perimeter (SP),

wherein any of SD_D , SD_S , has a value below 120 scanlines/dm².

4. A touch sensing apparatus according to claim 3, wherein any of SD_D , SD_S , has a value below 100 scanlines/dm².

15

5. A touch sensing apparatus according to claim 3, wherein any of SD_D , SD_S , has a value below 60 scanlines/dm².

6. A touch sensing apparatus according to any of claims 1 - 5, comprising

20 a first emitter array (E_a) arranged along a first edge (103a) of the panel,

adjacent emitters in the first emitter array being arranged in an emitter coordinate sequence (d_E) where the separation between adjacent emitters is defined by a first pattern of emitter coordinates and an offset value ($\pm\Delta$) for the respective emitter in the first emitter array,

25 wherein the first pattern of emitter coordinates alternates between two separation distances d_{E1} , d_{E2} , wherein $d_{E2} = C \cdot d_{E1}$, where C is in the range 1.7 – 2.3, and the offset values Δ are in the range $-0.5 \cdot d_{E1}$ to $+0.5 \cdot d_{E1}$,

a first detector array (D_b) arranged along a second edge (103b) of the panel, opposite the first edge,

30 adjacent detectors in the first detector array being arranged in a detector coordinate sequence (d_D) where the separation between adjacent detectors is

defined by a first pattern of detector coordinates and an offset value ($\pm\Delta'$) for the respective detector in the first detector array,

wherein the first pattern of detector coordinates alternates between two separation distances d_{D1} , d_{D2} , wherein $d_{D2} = C' \cdot d_{E1}$, where C' is in the range 1.7 – 2.3, and the offset values Δ' are in the range $-0.5 \cdot d_{D1}$ to $+0.5 \cdot d_{D1}$.

7. A touch sensing apparatus according to claim 6, comprising
a second emitter array (E_c) arranged along a third edge (103c) of the panel, perpendicular to the first edge, adjacent emitters in the second emitter
10 array being arranged in the emitter coordinate sequence (d_E),
a second detector array (D_d) arranged along a fourth edge (103d) of the panel, perpendicular to the first edge and opposite the third edge, adjacent detectors in the second detector array being arranged in the detector coordinate sequence (d_D),

15

8. A touch sensing apparatus according to any of claims 1 - 6, wherein the plurality of detectors are arranged along a top portion (104) of the panel, and the plurality of emitters are arranged along a bottom portion (105) of the panel and along opposite sides (106, 107) of the panel extending between the top and
20 bottom portions.

9. A touch sensing apparatus according to any of claims 1 - 8, comprising a touch sensor (108) configured to
determine, based on output signals from the detectors, an attenuation
25 value corresponding to the attenuation of the light resulting from an object touching the touch surface, and
determine an object type of the object in dependence on the attenuation value, wherein the object type is any of a stylus (109a, 109b), a brush (110) or a finger (111).

30

10. A touch sensing apparatus according to claim 9, wherein the touch sensor is configured to

determine a first shape (s_1) of a portion of the object in contact with the touch surface,

determine a subsequent second shape (s_2) of a portion of the object in contact with the touch surface, as the object is pushed against the touch surface,

determine a variation in the shape of the portion of the object in contact with the touch surface over time based on the first and second shapes.

11. A touch sensing apparatus according to claim 10, wherein determining the variation in the shape comprises determining a variation in size and/or angle (v) of the portion of the object in contact with the touch surface.

12. A system (200) comprising a touch sensing apparatus according to any of claims 9 - 11 and a stylus (109a, 109b) having a tip (112a, 112b) with a width (w_1 , w_2) of less than 7 mm,

wherein the touch sensor is configured to determine a position (x , y) of the stylus tip on the touch surface based on the attenuation value.

13. A system according to claim 12, wherein the width (w_1) of the tip (112a) is less than 3 mm.

14. A system according to any of claims 12 – 13, comprising a first stylus (109a) having a tip (112a) with a width (w_1) in the range 1-3 mm, and a second stylus (109b) having a tip (112b) with a width (w_2) in the range 4-7 mm,

wherein the touch sensor is configured to determine whether the tip of the first stylus or the tip of the second stylus is in contact with the touch surface.

15. A touch sensing apparatus (100) comprising: a panel (101) that defines a touch surface (102),

a plurality of emitters ($E_1, E_2, \dots, E_N$) and detectors ($D_1, D_2, \dots, D_M$) mounted to substrates (PCB's) and positioned along edges (103) of the panel, where N is the total number of emitters and M is the total number of detectors, wherein the positions of the emitters and detectors along the edges outline the length of a sensor perimeter (SP) extending around the panel, the sensor perimeter defines a sensor area (SA), wherein the emitters are arranged to emit light to the touch surface and to the detectors so that a plurality of scanlines ($l_1, l_2, \dots, l_p$) cross the touch surface,

10 wherein a scanline density (SD_D, SD_S) is defined as

$$SD_D = P/DA,$$

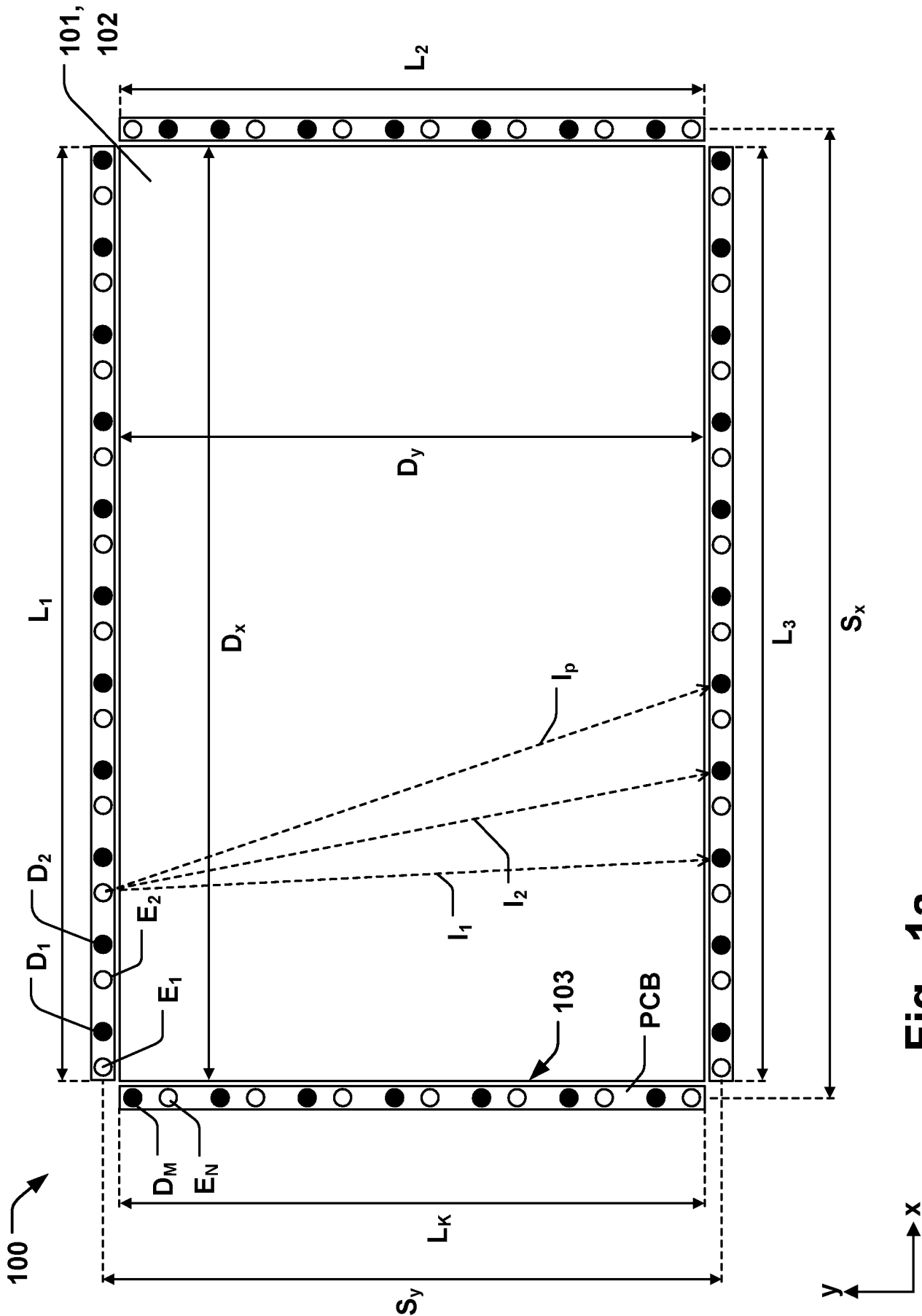
$$SD_S = P/SA,$$

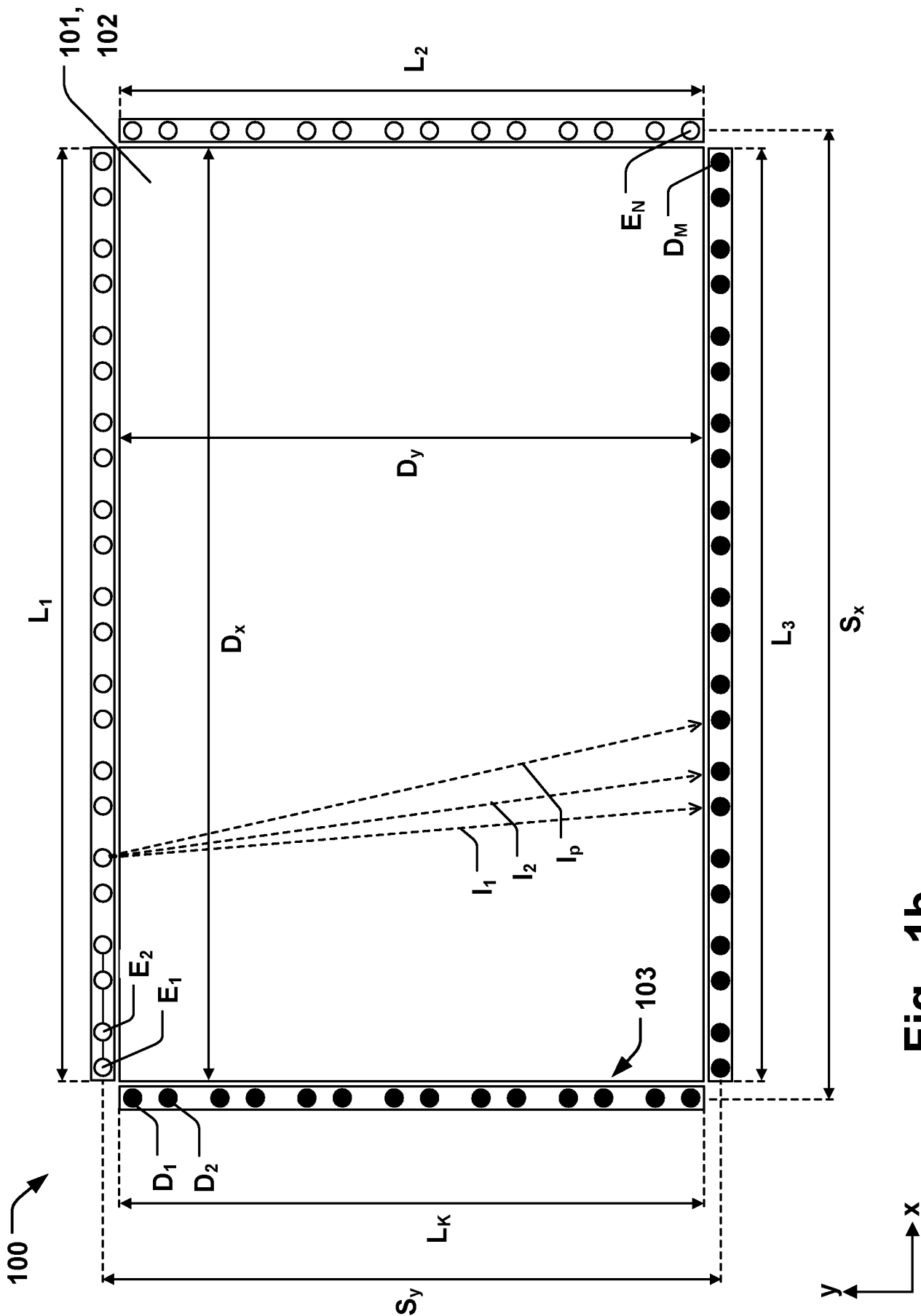
where P is the total number of scanlines,

DA is the area of the touch surface,

15 wherein any of SD_D, SD_S , has a value below 120 scanlines/dm².

16. A touch sensing apparatus according to claim 15, wherein any of SD_D, SD_S , has a value below 60 scanlines/dm².





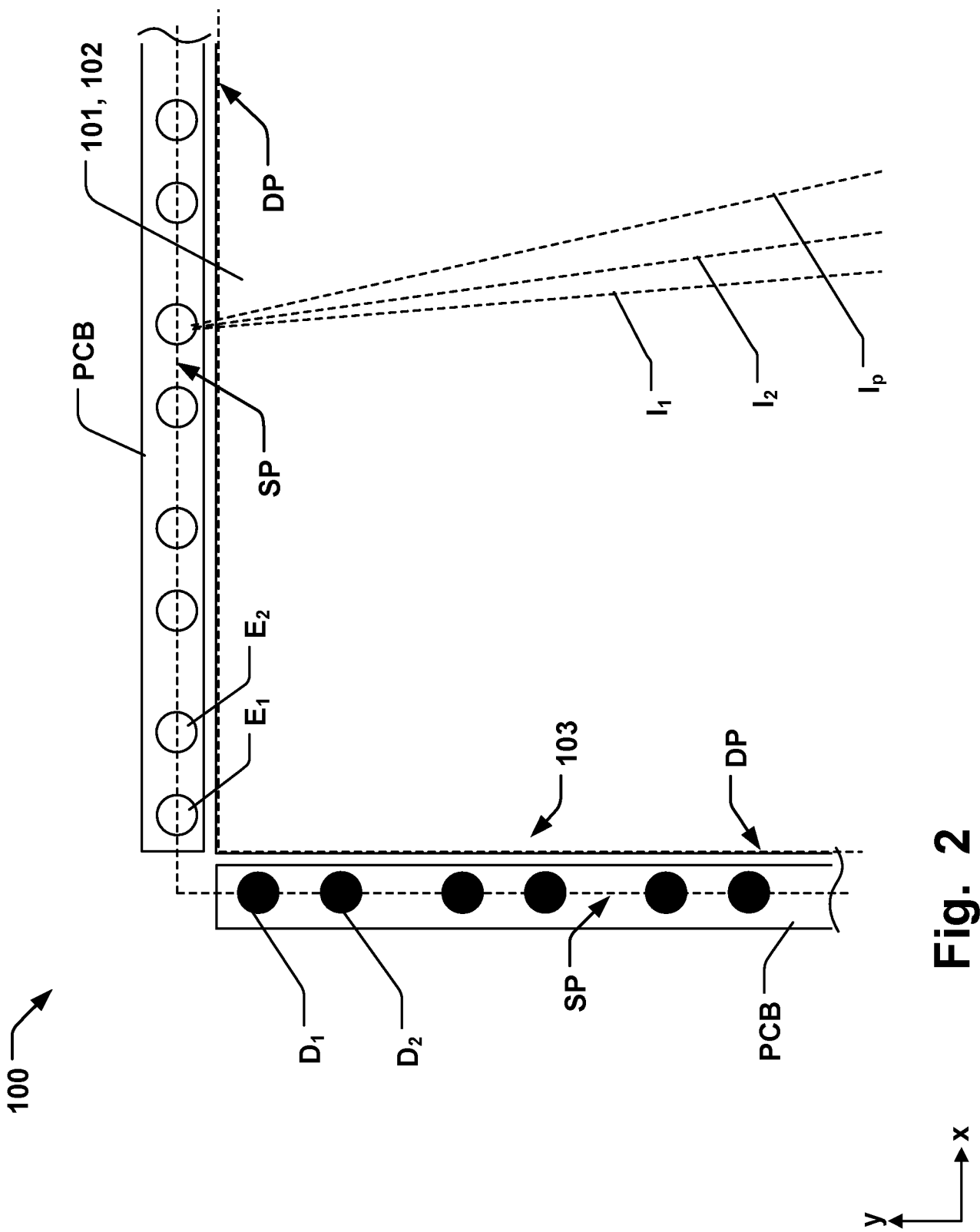


Fig. 2

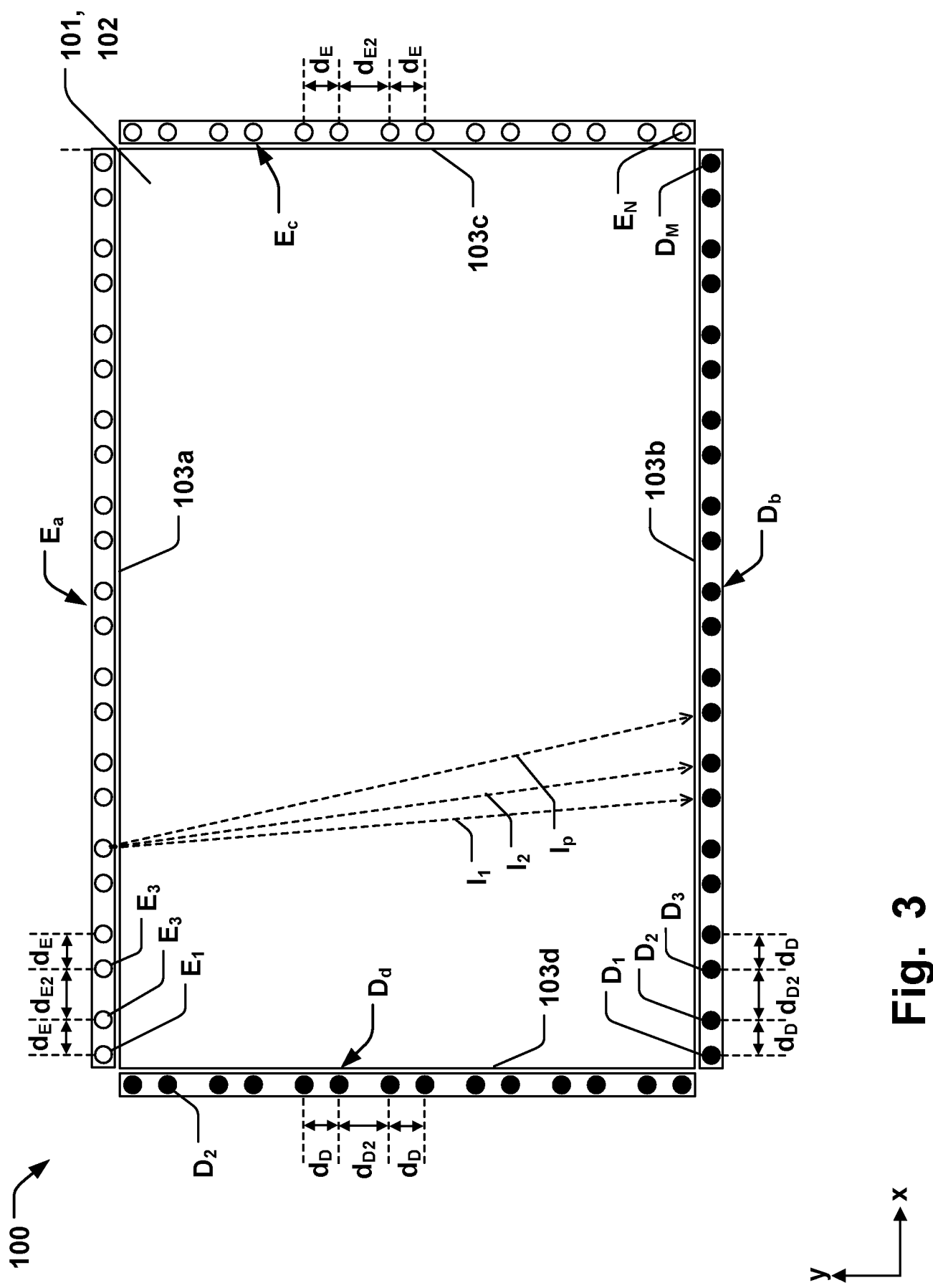


Fig. 3

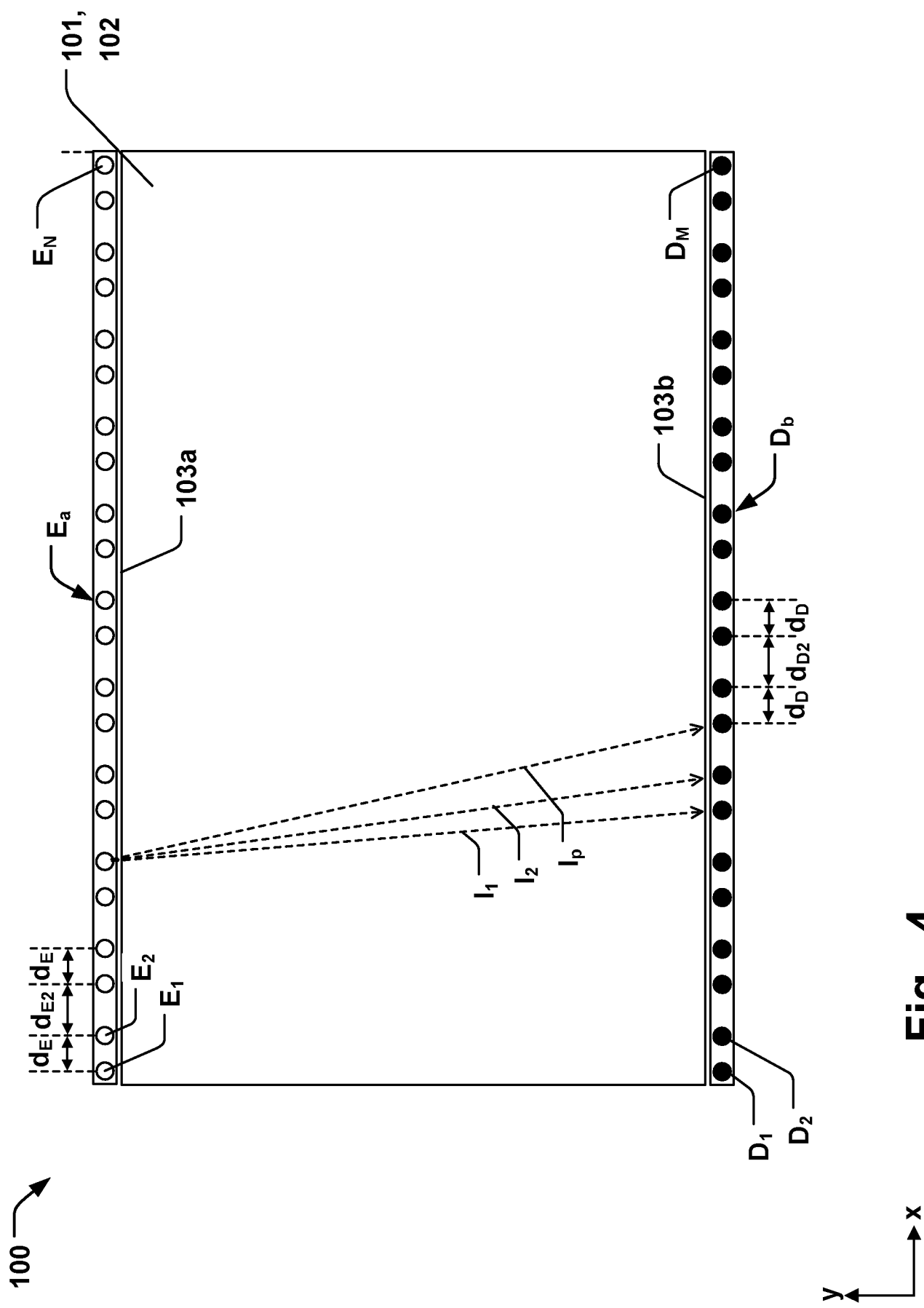
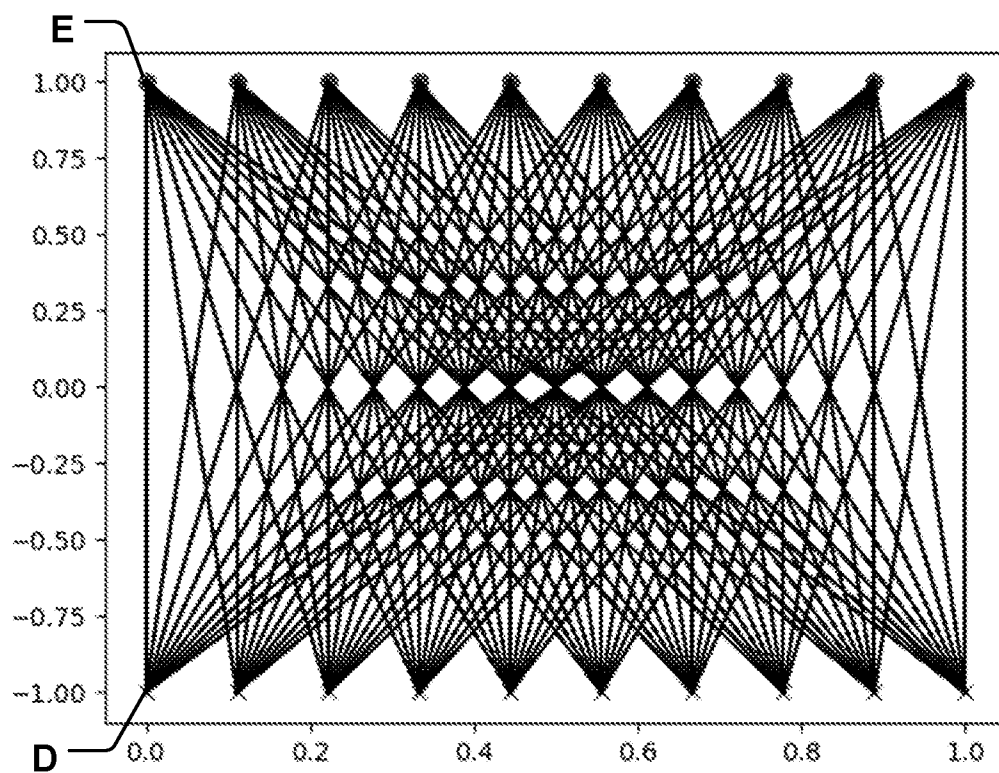
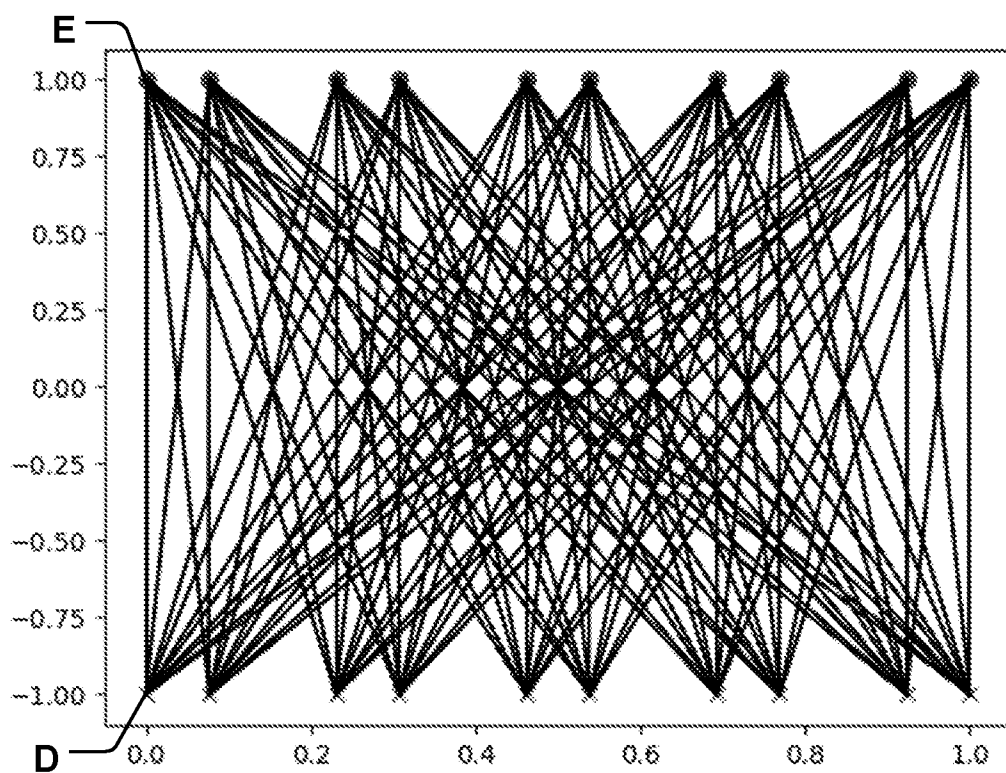


Fig. 4

**Fig. 5a****Fig. 5b**

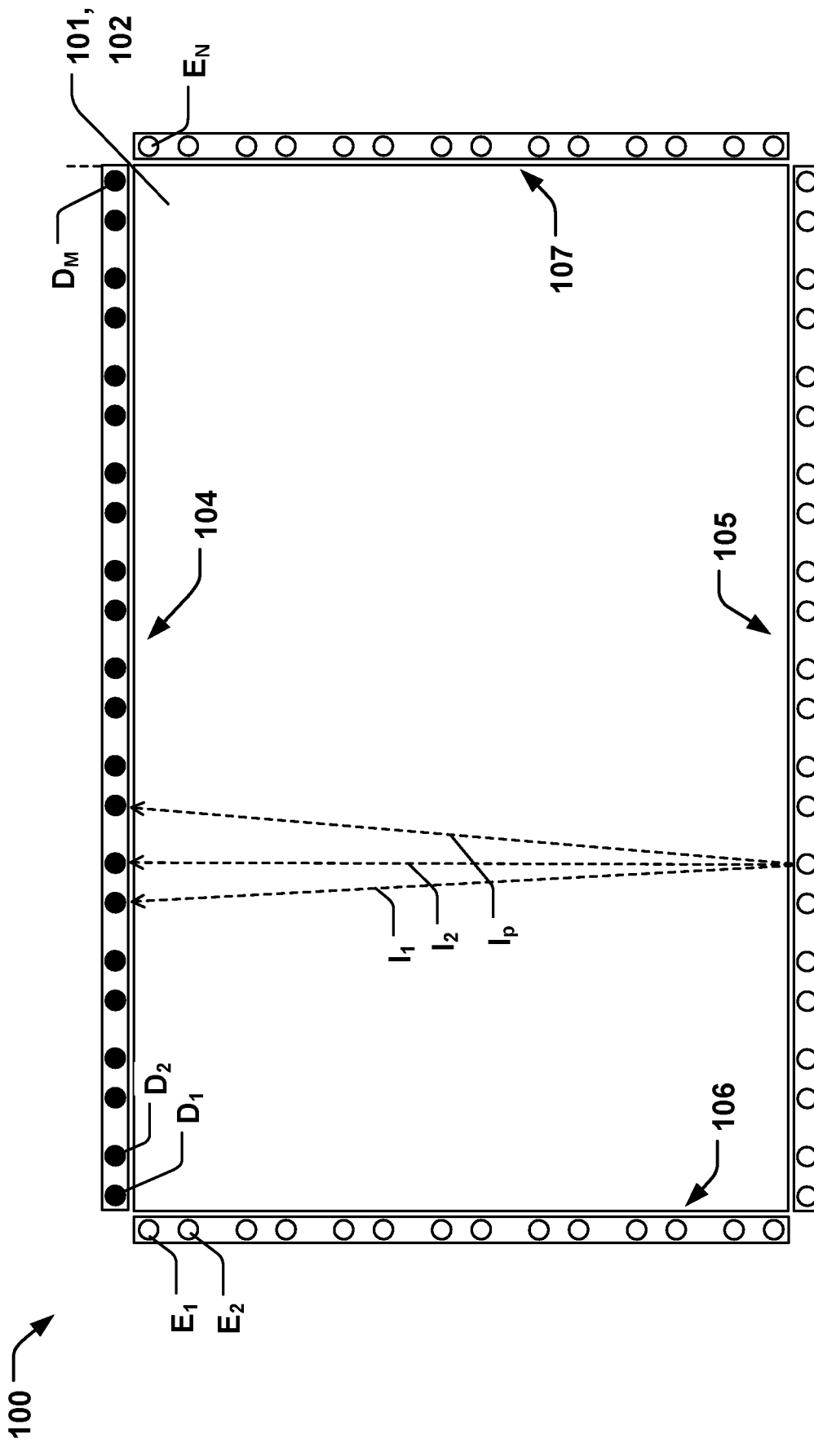


Fig. 6

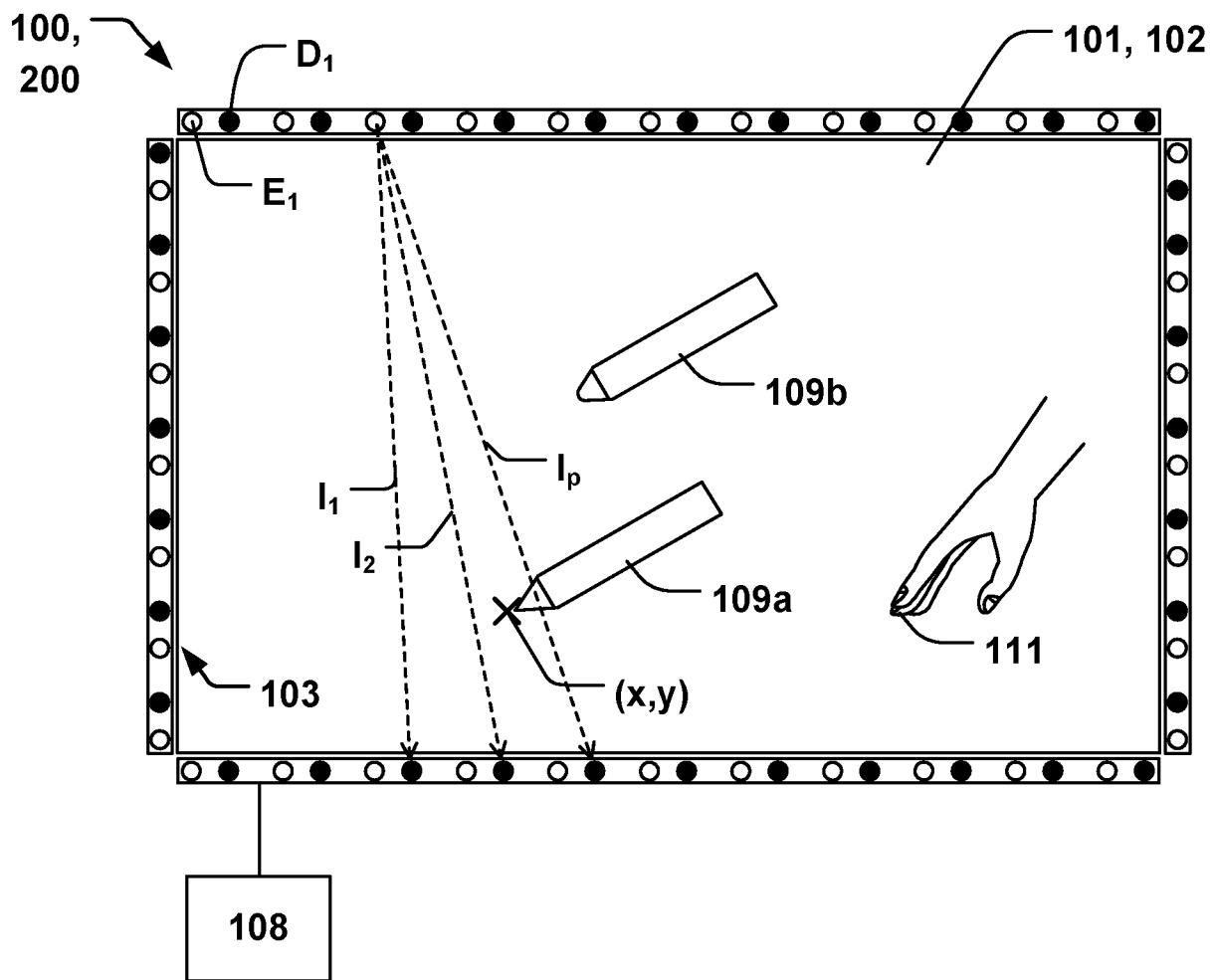


Fig. 7

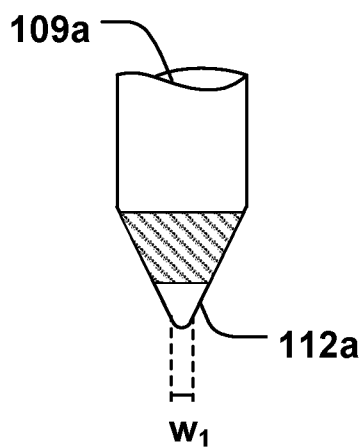


Fig. 8a

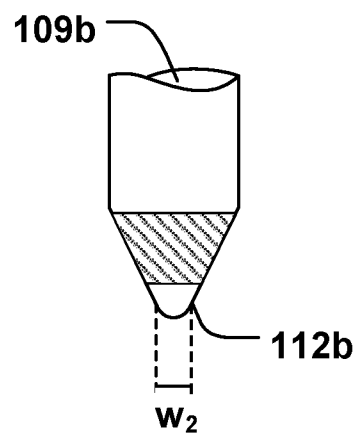


Fig. 8b

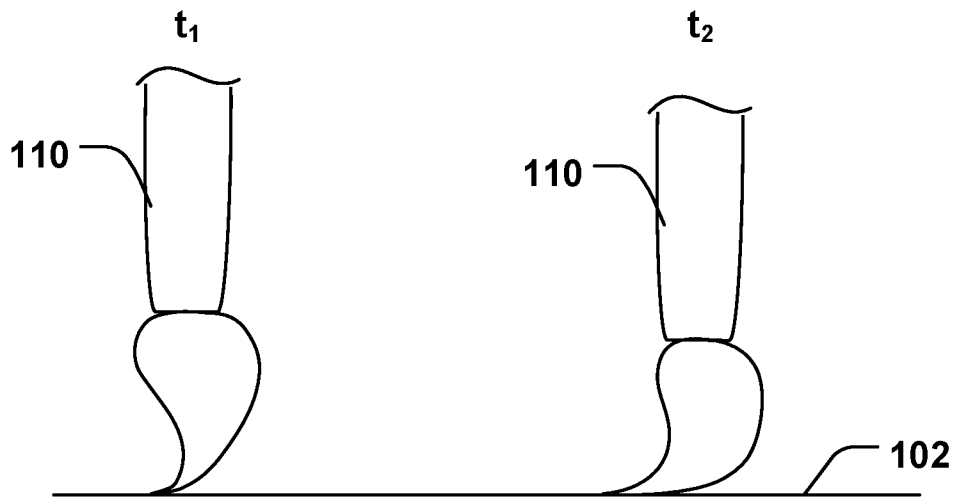


Fig. 9a

Fig. 9b

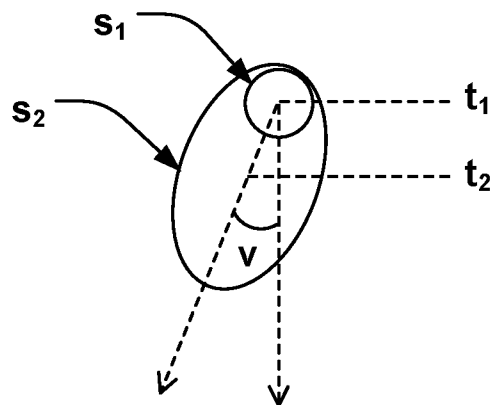


Fig. 9c

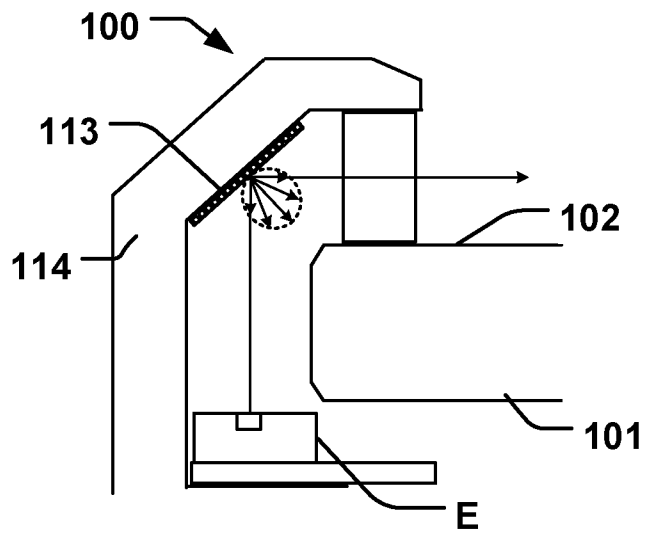


Fig. 10

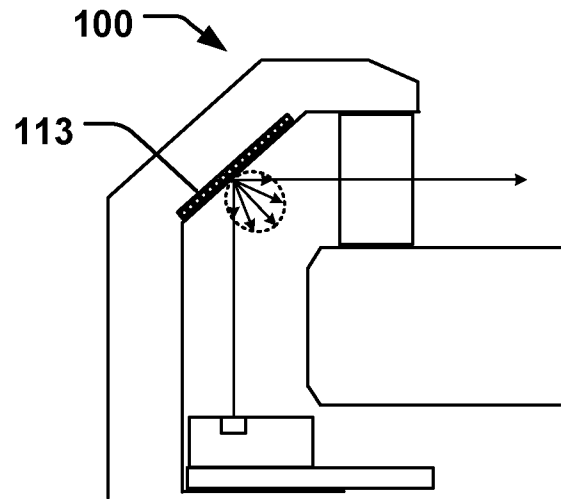


Fig. 11

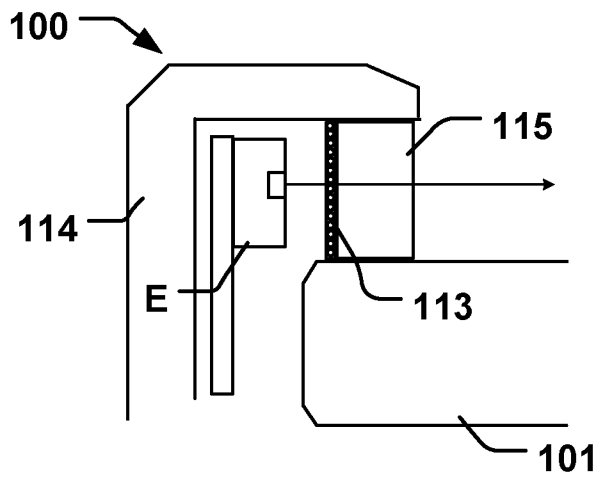


Fig. 12a

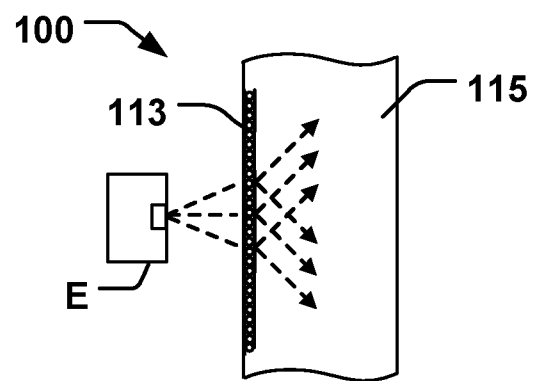


Fig. 12b

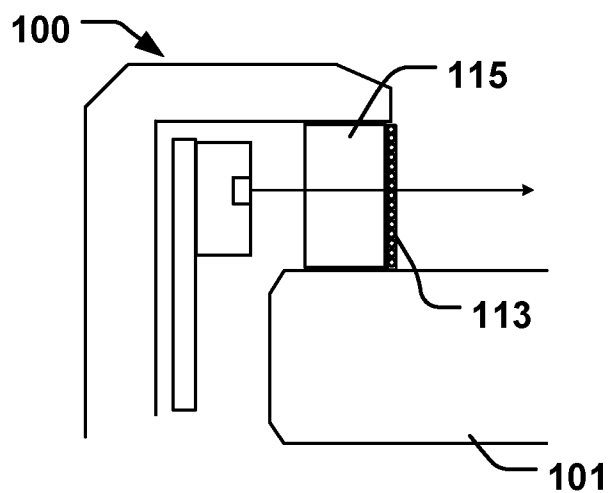


Fig. 13a

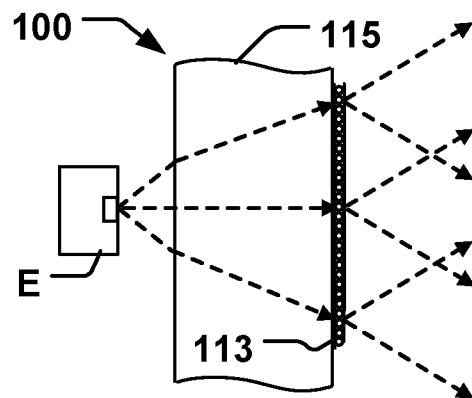


Fig. 13b

INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/SE2022/051106

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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P, X	WO 2022086396 A1 (FLATFROG LAB AB), 28 April 2022 (2022-04-28); page 21, line 1 - page 21, line 3; page 32, line 23 - page 32, line 27; page 37, line 1 - page 38, line 11 --	1-5, 8, 9, 15, 16
A	WO 2021107840 A1 (FLATFROG LAB AB), 3 June 2021 (2021-06-03); whole document --	1-16
A	US 20200167033 A1 (KIM HYEONGGWON ET AL), 28 May 2020 (2020-05-28); whole document --	1-16

☒ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D" document cited by the applicant in the international application	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

 Date of the actual completion of the international search
 13-02-2023

 Date of mailing of the international search report
 13-02-2023

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2022/051106

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Continuation of: second sheet
International Patent Classification (IPC)
G06F 3/042 (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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