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(54) Title: ROTATING PADDLE COMPOSITE DISPLAY

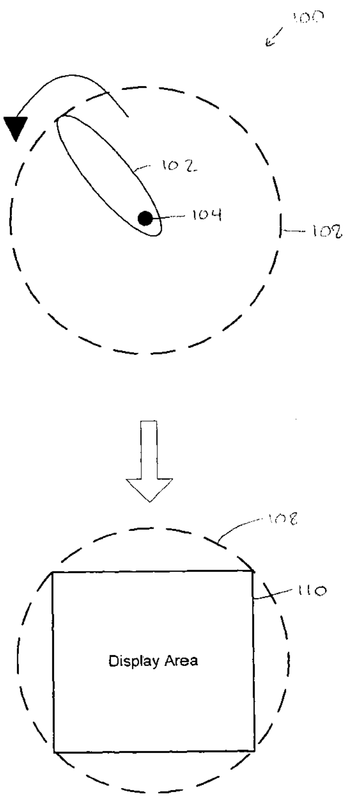

FIG. 1

(57) Abstract: A composite display is disclosed. In some embodiments, a composite display comprises a paddle configured to sweep out an area and a plurality of pixel elements mounted on the paddle. Selectively activating one or more of the plurality of pixel elements while the paddle sweeps the area causes at least a portion of an image to be rendered. In some embodiments, at least one pixel element of the plurality of pixel elements is mounted on an edge of the paddle such that at least a portion of the at least one pixel element extends beyond the edge of the paddle.

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ROTATING PADDLE COMPOSITE DISPLAY

CROSS REFERENCE TO OTHER APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. ________ (Attorney Docket No. BOUNP001) entitled COMPOSITE DISPLAY filed June 28, 2007, originally filed as non-provisional U.S. Patent Application No. 11/823,829 and subsequently converted to a provisional application by request submitted October 1, 2007, which application is incorporated herein by reference for all purposes.

BACKGROUND OF THE INVENTION

[0002] Digital displays are used to display images or video to provide advertising or other information. For example, digital displays may be used in billboards, bulletins, posters, highway signs, and stadium displays. Digital displays that use liquid crystal display (LCD) or plasma technologies are limited in size because of size limits of the glass panels associated with these technologies. Larger digital displays typically comprise a grid of printed circuit board (PCB) tiles, where each tile is populated with packaged light emitting diodes (LEDs). Because of the space required by the LEDs, the resolution of these displays is relatively coarse. Also, each LED corresponds to a pixel in the image, which can be expensive for large displays. In addition, a complex cooling system is typically used to sink heat generated by the LEDs, which may burn out at high temperatures. As such, improvements to digital display technology are needed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Various embodiments of the invention are disclosed in the following detailed description and the accompanying drawings.

[0004] Figure 1 is a diagram illustrating an embodiment of a composite display 100 having a single paddle.

[0005] Figure 2A is a diagram illustrating an embodiment of a paddle used in a composite display.

[0006] Figure 2B illustrates an example of temporal pixels in a sweep plane.

[0007] Figure 3 is a diagram illustrating an embodiment of a composite display 300 having two paddles.

[0008] Figure 4A illustrates examples of paddle installations in a composite display.

[0009] Figure 4B is a diagram illustrating an embodiment of a composite display 410 that uses masks.

[0010] Figure 4C is a diagram illustrating an embodiment of a composite display 430 that uses masks.

[0011] Figure 5 is a block diagram illustrating an embodiment of a system for displaying an image.

[0012] Figure 6A is a diagram illustrating an embodiment of a composite display 600 having two paddles.

[0013] Figure 6B is a flowchart illustrating an embodiment of a process for generating a pixel map.

[0014] Figure 7 illustrates examples of paddles arranged in various arrays.

[0015] Figure 8 illustrates examples of paddles with coordinated in phase motion to prevent mechanical interference.

[0016] Figure 9 illustrating examples of paddles with coordinated out of phase motion to prevent mechanical interference.

[0017] Figure 10 is a diagram illustrating an example of a cross section of a paddle in a composite display.

[0018] Figure 11A is a diagram illustrating an embodiment of a composite display 1100 comprised of circularly shaped paddles.

[0019] Figure 11B illustrates an embodiment of a cross section of the composite display of Figure 11A.

[0020] Figure 11C is a diagram illustrating an embodiment of the composite display of Figure 11A in which the pixel elements comprise a plurality of colors.

[0021] Figure 12A illustrates an embodiment of a grid of temporal pixels available for rendering an image or portion thereof in a display area 1202 of a composite display.

[0022] Figure 12B illustrates an example of rendering an image or portion thereof in a display area of a composite display.

[0023] Figure 12C illustrates an example of an angular misalignment in rendering an image or portion thereof in a display area of a composite display.

[0024] Figure 13 illustrates an embodiment of a stochastic grid of temporal pixels available for rendering an image or portion thereof in a display area 1302 of a composite display.

[0025] Figure 14 illustrates an embodiment of a cross section of a composite display 1400.

DETAILED DESCRIPTION

[0026] The invention can be implemented in numerous ways, including as a process, an apparatus, a system, a composition of matter, a computer readable medium such as a computer readable storage medium or a computer network wherein program instructions are sent over optical or communication links. In this specification, these implementations, or any other form that the invention may take, may be referred to as techniques. A component such as a processor or a memory described as being configured to perform a task includes both a general component that is temporarily configured to perform the task at a given time or a specific component that is manufactured to perform the task. In general, the order of the steps of disclosed processes may be altered within the scope of the invention.

[0027] A detailed description of one or more embodiments of the invention is provided below along with accompanying figures that illustrate the principles of the invention. The invention is described in connection with such embodiments, but the invention is not limited to any embodiment. The scope of the invention is limited only by the claims and the invention encompasses numerous alternatives, modifications and equivalents. Numerous specific details are set forth in the following description in order to provide a thorough understanding of the invention. These details are provided for the purpose of example and the invention may be practiced according to the claims without some or all of these specific details. For the purpose of clarity, technical material that is known in the technical fields related to the invention has not been described in detail so that the invention is not unnecessarily obscured.

[0028] Figure 1 is a diagram illustrating an embodiment of a composite display 100 having a single paddle. In the example shown, paddle 102 is configured to rotate at one end about axis of rotation 104 at a given frequency, such as 60 Hz. Paddle 102 sweeps out area 108 during one rotation or paddle cycle. A plurality of pixel elements, such as LEDs, is installed on paddle 102. As used herein, a pixel element refers to any element that may be used to display at least a portion of image information. As used herein, image or image information may include image, video, animation, slideshow, or any other visual information that may be displayed. Other examples of pixel elements include: laser diodes, phosphors, cathode ray tubes, liquid crystal, any transmissive or emissive optical modulator. Although LEDs may be described in the examples herein, any appropriate pixel elements may be used. In various embodiments, LEDS may be arranged on paddle 102 in a variety of ways, as more fully described below.

[0029] As paddle 102 sweeps out area 108, one or more of its LEDs are activated at appropriate times such that an image or a part thereof is perceived by a viewer who is viewing swept area 108. An image is comprised of pixels each having a spatial location. It can be determined at which spatial location a particular LED is at any given point in time. As paddle 102 rotates, each LED can be activated as appropriate when its location coincides with a spatial location of a pixel in the image. If paddle 102 is spinning fast enough, the eye perceives a continuous image. This is because the eye has a poor frequency response to luminance and color information. The eye integrates color that it sees within a certain time window. If a few images are flashed in a fast sequence, the eye integrates that into a single continuous image. This low temporal sensitivity of the eye is referred to as persistence of vision.

[0030] As such, each LED on paddle 102 can be used to display multiple pixels in an image. A single pixel in an image is mapped to at least one "temporal pixel" in the display area in composite display 100. A temporal pixel can be defined by a pixel element on paddle 102 and a time (or angular position of the paddle), as more fully described below.

[0031] The display area for showing the image or video may have any shape. For example, the maximum display area is circular and is the same as swept area 108. A rectangular image or video may be displayed within swept area 108 in a rectangular display area 110 as shown.

[0032] Figure 2A is a diagram illustrating an embodiment of a paddle used in a composite display. For example, paddle 202, 302, or 312 (discussed later) may be similar to paddle 102. Paddle 202 is shown to include a plurality of LEDs 206-216 and an axis of rotation 204 about which paddle 202 rotates. LEDs 206-216 may be arranged in any appropriate way in various embodiments. In this example, LEDs 206-216 are arranged such that they are evenly spaced from each other and aligned along the length of paddle 202. They are aligned on the edge of paddle 202 so that LED 216 is adjacent to axis of rotation 204. This is so that as paddle 202 rotates, there is no blank spot in the middle (around axis of rotation 204). In some embodiments, paddle 202 is a PCB shaped like a paddle. In some embodiments, paddle 202 has an aluminum, metal, or other material casing for reinforcement.

[0033] Figure 2B illustrates an example of temporal pixels in a sweep plane. In this example, each LED on paddle 222 is associated with an annulus (area between two circles) around the axis of rotation. Each LED can be activated once per sector (angular interval). Activating an LED may include, for example, turning on the LED for a prescribed time period (e.g., associated with a duty cycle) or turning off the LED. The intersections of the concentric circles and sectors form areas that correspond to temporal pixels. In this example, each temporal pixel has an angle of 42.5 degrees, so that there are a total of 16 sectors during which an LED may be turned on to indicate a pixel. Because there are 6 LEDs, there are 6*16 = 96 temporal pixels. In another example, a temporal pixel may have an angle of 1/10 of a degree, so that there are a total of 3600 angular positions possible.

[0034] Because the spacing of the LEDs along the paddle is uniform in the given example, temporal pixels get denser towards the center of the display (near the axis of rotation). Because image pixels are defined based on a rectangular coordinate system, if an image is overlaid on the display, one image pixel may correspond to multiple temporal pixels close to the center of the display. Conversely, at the outermost portion of the display, one image pixel may correspond to one or a fraction of a temporal pixel. For example, two or more image pixels may fit within a single temporal pixel. In some embodiments, the display is designed (e.g., by varying the sector time or the number/placement of LEDs on the paddle) so that at the outermost portion of the display, there is at least one temporal pixel per image pixel. This is to retain in the display the same level of resolution as the image. In some embodiments, the sector size is limited by how quickly LED control data can be transmitted to an LED driver to activate LED(s). In some embodiments, the arrangement of LEDs on the paddle is used to make the density of temporal pixels more uniform across the display. For example, LEDs may be placed closer together on the paddle the farther they are from the axis of rotation.

[0035] Figure 3 is a diagram illustrating an embodiment of a composite display 300 having two paddles. In the example shown, paddle 302 is configured to rotate at one end about axis of rotation 304 at a given frequency, such as 60 Hz. Paddle 302 sweeps out area 308 during one rotation or paddle cycle. A plurality of pixel elements, such as LEDs, is installed on paddle 302. Paddle 312 is configured to rotate at one end about axis of rotation 314 at a given frequency, such as 60 Hz. Paddle 312 sweeps out area 316 during one rotation or paddle cycle. A plurality of pixel elements, such as LEDs, is installed on paddle 312. Swept areas 308 and 316 have an overlapping portion 318.

[0036] Using more than one paddle in a composite display may be desirable in order to make a larger display. For each paddle, it can be determined at which spatial location a particular LED is at any given point in time, so any image can be represented by a multiple paddle display in a manner similar to that described with respect to Figure 1. In some embodiments, for overlapping portion 318, there will be twice as many LEDs passing through per cycle than in the nonoverlapping portions. This may make the overlapping portion of the display appear to the eye to have higher luminance. Therefore, in some embodiments, when an LED is in an overlapping portion, it may be activated half the time so that the whole display area appears to have the same luminance. This and other examples of handling overlapping areas are more fully described below.

[0037] The display area for showing the image or video may have any shape. The union of swept areas 308 and 316 is the maximum display area. A rectangular image or video may be displayed in rectangular display area 310 as shown.

[0038] When using more than one paddle, there are various ways to ensure that adjacent paddles do not collide with each other. Figure 4A illustrates examples of paddle installations in a composite display. In these examples, a cross section of adjacent paddles mounted on axes is shown.

[0039] In diagram 402, two adjacent paddles rotate in vertically separate sweep planes, ensuring that the paddles will not collide when rotating. This means that the two paddles can rotate at different speeds and do not need to be in phase with each other. To the eye, having the two paddles rotate in different sweep planes is not detectable if the resolution of the display is sufficiently smaller than the vertical spacing between the sweep planes. In this example, the axes are at the center of the paddles. This embodiment is more fully described below.

[0040] In diagram 404, the two paddles rotate in the same sweep plane. In this case, the rotation of the paddles is coordinated to avoid collision. For example, the paddles are rotated in phase with each other. Further examples of this are more fully described below.

[0041] In the case of the two paddles having different sweep planes, when viewing display area 310 from a point that is not normal to the center of display area 310, light may leak in diagonally between sweep planes. This may occur, for example, if the pixel elements emit unfocused light such that light is emitted at a range of angles. In some embodiments, a mask is used to block light from one sweep plane from being visible in another sweep plane. For example, a mask is placed behind paddle 302 and/or paddle 312. The mask may be attached to paddle 302 and/or 312 or stationary relative to paddle 302 and/or paddle 312. In some embodiments, paddle 302 and/or paddle 312 is shaped differently from that shown in Figures 3 and 4A, e.g., for masking purposes. For example, paddle 302 and/or paddle 312 may be shaped to mask the sweep area of the other paddle.

[0042] Figure 4B is a diagram illustrating an embodiment of a composite display 410 that uses masks. In the example shown, paddle 426 is configured to rotate at one end about axis of rotation 414 at a given frequency, such as 60 Hz. A plurality of pixel elements, such as LEDs, is installed on paddle 426. Paddle 426 sweeps out area 416 (bold dashed line) during one rotation or paddle cycle. Paddle 428 is configured to rotate at one end about axis of rotation 420 at a given frequency, such as 60 Hz. Paddle 428 sweeps out area 422 (bold dashed line) during one rotation or paddle cycle. A plurality of pixel elements, such as LEDs, is installed on paddle 428.

[0043] In this example, mask 412 (solid line) is used behind paddle 426. In this case, mask 412 is the same shape as area 416 (i.e., a circle). Mask 412 masks light from pixel elements on paddle 428 from leaking into sweep area 416. Mask 412 may be installed behind paddle 426. In some embodiments, mask 412 is attached to paddle 426 and spins around axis of rotation 414 together with paddle 426. In some embodiments, mask 412 is installed behind paddle 426 and is stationary with respect to paddle 426. In this example, mask 418 (solid line) is similarly installed behind paddle 428.

[0044] In various embodiments, mask 412 and/or mask 418 may be made out of a variety of materials and have a variety of colors. For example, masks 412 and 418 may be black and made out of plastic.

[0045] The display area for showing the image or video may have any shape. The union of swept areas 416 and 422 is the maximum display area. A rectangular image or video may be displayed in rectangular display area 424 as shown.

[0046] Areas 416 and 422 overlap. As used herein, two elements (e.g., sweep area, sweep plane, mask, pixel element) overlap if they intersect in an x-y projection. In other words, if the areas are projected onto an x-y plane (defined by the x and y axes, where the x and y axes are in the plane of the figure), they intersect each other. Areas 416 and 422 do not sweep the same plane (do not have the same values of z, where the z axis is normal to the x and y axes), but they overlap each other in overlapping portion 429. In this example, mask 412 occludes sweep area 422 at overlapping portion 429 or occluded area 429. Mask 412 occludes sweep area 429 because it overlaps sweep area 429 and is on top of sweep area 429.

[0047] Figure 4C is a diagram illustrating an embodiment of a composite display 430 that uses masks. In this example, pixel elements are attached to a rotating disc that functions as both a mask and a structure for the pixel elements. Disc 432 can be viewed as a circular shaped paddle. In the example shown, disc 432 (solid line) is configured to rotate at one end about axis of rotation 434 at a given frequency, such as 60 Hz. A plurality of pixel elements, such as LEDs, is installed on disc 432. Disc 432 sweeps out area 436 (bold dashed line) during one rotation or disc cycle. Disc 438 (solid line) is configured to rotate at one end about axis of rotation 440 at a given frequency, such as 60 Hz. Disc 438 sweeps out area 442 (bold dashed line) during one rotation or disc cycle. A plurality of pixel elements, such as LEDs, is installed on disc 438.

[0048] In this example, the pixel elements can be installed anywhere on discs 432 and 438. In some embodiments, pixel elements are installed on discs 432 and 438 in the same pattern. In other embodiments, different patterns are used on each disc. In some embodiments, the density of pixel elements is lower towards the center of each disc so the density of temporal pixels is more uniform than if the density of pixel elements is the same throughout the disc. In some embodiments, pixel elements are placed to provide redundancy of temporal pixels (i.e., more than one pixel is placed at the same radius). Having more pixel elements per pixel means that the rotation speed can be reduced. In some embodiments, pixel elements are placed to provide higher resolution of temporal pixels.

[0049] Disc 432 masks light from pixel elements on disc 438 from leaking into sweep area 436. In various embodiments, disc 432 and/or disc 438 may be made out of a variety of materials and have a variety of colors. For example, discs 432 and 438 may be black printed circuit board on which LEDs are installed.

[0050] The display area for showing the image or video may have any shape. The union of swept areas 436 and 442 is the maximum display area. A rectangular image or video may be displayed in rectangular display area 444 as shown.

[0051] Areas 436 and 442 overlap in overlapping portion 439. In this example, disc 432 occludes sweep area 442 at overlapping portion or occluded area 439.

[0052] In some embodiments, pixel elements are configured to not be activated when they are occluded. For example, the pixel elements installed on disc 438 are configured to not be activated when they are occluded, (e.g., overlap with occluded area 439). In some embodiments, the pixel elements are configured to not be activated in a portion of an occluded area. For example, an area within a certain distance from the edges of occluded area 439 is configured to not be activated. This may be desirable in case a viewer is to the left or right of the center of the display area and can see edge portions of the occluded area.

[0053] Figure 5 is a block diagram illustrating an embodiment of a system for displaying an image. In the example shown, panel of paddles 502 is a structure comprising one or more paddles. As more fully described below, panel of paddles 502 may include a plurality of paddles, which may include paddles of various sizes, lengths, and widths; paddles that rotate about a midpoint or an endpoint; paddles that rotate in the same sweep plane or in different sweep planes; paddles that rotate in phase or out of phase with each other; paddles that have multiple arms; and paddles that have other shapes. Panel of paddles 502 may include all identical paddles or a variety of different paddles. The paddles may be arranged in a grid or in any other arrangement. In some embodiments, the panel includes angle detector 506, which is used to detect angles associated with one or more of the paddles. In some embodiments, there is an angle detector for each paddle on panel of paddles 502. For example, an optical detector may be mounted near a paddle to detect its current angle.

[0054] LED control module 504 is configured to optionally receive current angle information (e.g., angle(s) or information associated with angle(s)) from angle detector 506. LED control module 504 uses the current angles to determine LED control data to send to panel of paddles 502. The LED control data indicates which LEDs should be activated at that time (sector). In some embodiments, LED control module 504 determines the LED control data using pixel map 508. In some embodiments, LED control module 504 takes an angle as input and outputs which LEDs on a paddle should be activated at that sector for a particular image. In some embodiments, an angle is sent from angle detector 506 to LED control module 504 for each sector (e.g., just prior to the paddle reaching the sector). In some embodiments, LED control data is sent from LED control module 504 to panel of paddles 502 for each sector.

[0055] In some embodiments, pixel map 508 is implemented using a lookup table, as more fully described below. For different images, different lookup tables are used. Pixel map 508 is more fully described below.

[0056] In some embodiments, there is no need to read an angle using angle detector 506. Because the angular velocity of the paddles and an initial angle of the paddles (at that angular velocity) can be predetermined, it can be computed at what angle a paddle is at any given point in time. In other words, the angle can be determined based on the time. For example, if the angular velocity is ω, the angular location after time t is $\theta_{initial} + \omega t$ where $\theta_{initial}$ is an initial angle once the paddle is spinning at steady state. As such, LED control module can serially output LED control data as a function of time (e.g., using a clock), rather than use angle measurements output from angle detector 506. For example, a table of time (e.g., clock cycles) versus LED control data can be built.

[0057] In some embodiments, when a paddle is starting from rest, it goes through a start up sequence to ramp up to the steady state angular velocity. Once it reaches the angular velocity, an initial angle of the paddle is measured in order to compute at what angle the paddle is at any point in time (and determine at what point in the sequence of LED control data to start).

[0058] In some embodiments, angle detector 506 is used periodically to provide adjustments as needed. For example, if the angle has drifted, the output stream of LED control data can be shifted. In some embodiments, if the angular speed has drifted, mechanical adjustments are made to adjust the speed.

[0059] Figure 6A is a diagram illustrating an embodiment of a composite display 600 having two paddles. In the example shown, a polar coordinate system is indicated over each of areas 608 and 616, with an origin located at each axis of rotation 604 and 614. In some implementations, the position of each LED on paddles 602 and 612 is recorded in polar coordinates. The distance from the origin to the LED is the radius r. The paddle angle is θ. For example, if paddle 602 is in the 3 o'clock position, each of the LEDs on paddle 602 is at 0 degrees. If paddle 602 is in the 12 o'clock position, each of the LEDs on paddle 602 is at 90 degrees. In some embodiments, an angle detector is used to detect the current angle of each paddle. In some embodiments, a temporal pixel is defined by P, r, and θ, where P is a paddle identifier and (r, θ) are the polar coordinates of the LED.

[0060] A rectangular coordinate system is indicated over an image 610 to be displayed. In this example, the origin is located at the center of image 610, but it may be located anywhere depending on the implementation. In some embodiments, pixel map 508 is created by mapping each pixel in image 610 to one or more temporal pixels in display area 608 and 616. Mapping may be performed in various ways in various embodiments.

[0061] Figure 6B is a flowchart illustrating an embodiment of a process for generating a pixel map. For example, this process may be used to create pixel map 508. At 622, an image pixel to temporal pixel mapping is obtained. In some embodiments, mapping is performed by overlaying image 610 (with its rectangular grid of pixels (x, y) corresponding to the resolution of the image) over areas 608 and 616 (with their two polar grids of temporal pixels (r, θ), e.g., see Figure 2B). For each image pixel (x, y), it is determined which temporal pixels are within the image pixel. The following is an example of a pixel map:

Image pixel (x, y)	Temporal Pixel (P, r, θ)	Intensity (f)
(a1, a2)	(b1, b2, b3)	
(a3, a4)	(b4, b5, b6); (b7, b8, b9)	
(a5, a6)	(b10, b11, b12)	
etc.	etc.	

Table 1

[0062] As previously stated, one image pixel may map to multiple temporal pixels as indicated by the second row. In some embodiments, instead of r, an index corresponding to the LED is used. In some embodiments, the image pixel to temporal pixel mapping is precomputed for a variety of image sizes and resolutions (e.g., that are commonly used).

[0063] At 624, an intensity f is populated for each image pixel based on the image to be displayed. In some embodiments, f indicates whether the LED should be on (e.g., 1) or off (e.g., 0). For example, in a black and white image (with no grayscale), black pixels map to f = 1 and white pixels map to f = 0. In some embodiments, f may have fractional values. In some embodiments, f is implemented using duty cycle management. For example, when f is 0, the LED is not activated for that sector time. When f is 1, the LED is activated for the whole sector time. When f is 0.5, the LED is activated for half the sector time. In some embodiments, f can be used to display grayscale images. For example, if there are 256 gray levels in the image, pixels with gray level 128 (half luminance) would have f = 0.5. In some embodiments, rather than implement f using duty cycle (i.e., pulse width modulated), f is implemented by adjusting the current to the LED (i.e., pulse height modulation).

[0064] For example, after the intensity f is populated, the table may appear as follows:

Image pixel (x, y)	Temporal Pixel (P, r, θ)	Intensity (f)
(a1, a2)	(b1, b2, b3)	f1
(a3, a4)	(b4, b5, b6); (b7, b8, b9)	f2
(a5, a6)	(b10, b11, b12)	f3
etc.	etc.	etc.

Table 2

[0065] At 626, optional pixel map processing is performed. This may include compensating for overlap areas, balancing luminance in the center (i.e., where there is a higher density of temporal pixels), balancing usage of LEDs, etc. For example, when LEDs are in an overlap area (and/or on a boundary of an overlap area), their duty cycle may be reduced. For example, in composite display 300, when LEDs are in overlap area 318, their duty cycle is halved. In some embodiments, there are multiple LEDs in a sector time that correspond to a single image pixel, in which case, fewer than all the LEDs may be activated (i.e., some of the duty cycles may be set to 0). In some embodiments, the LEDs may take turns being activated (e.g., every N cycles where N is an integer), e.g., to balance usage so that one doesn't burn out earlier than the others. In some embodiments, the closer the LEDs are to the center (where there is a higher density of temporal pixels), the lower their duty cycle.

[0066] For example, after luminance balancing, the pixel map may appear as follows:

Image pixel (x, y)	Temporal Pixel (P, r, θ)	Intensity (f)

(a1, a2)	(b1, b2, b3)	f1
(a3, a4)	(b4, b5, b6)	f2
(a5, a6)	(b10, b11, b12)	f3
etc.	etc.	etc.

Table 3

[0067] As shown, in the second row, the second temporal pixel was deleted in order to balance luminance across the pixels. This also could have been accomplished by halving the intensity to f2/2. As another alternative, temporal pixel (b4, b5, b6) and (b7, b8, b9) could alternately turn on between cycles. In some embodiments, this can be indicated in the pixel map. The pixel map can be implemented in a variety of ways using a variety of data structures in different implementations.

[0068] For example, in Figure 5, LED control module 504 uses the temporal pixel information (P, r, θ, and f) from the pixel map. LED control module 504 takes θ as input and outputs LED control data P, r, and f. Panel of paddles 502 uses the LED control data to activate the LEDs for that sector time. In some embodiments, there is an LED driver for each paddle that uses the LED control data to determine which LEDs to turn on, if any, for each sector time.

[0069] Any image (including video) data may be input to LED control module 504. In various embodiments, one or more of 622, 624, and 626 may be computed live or in real time, i.e., just prior to displaying the image. This may be useful for live broadcast of images, such as a live video of a stadium. For example, in some embodiments, 622 is precomputed and 624 is computed live or in real time. In some implementations, 626 may be performed prior to 622 by appropriately modifying the pixel map. In some embodiments, 622, 624, and 626 are all precomputed. For example, advertising images may be precomputed since they are usually known in advance.

[0070] The process of Figure 6B may be performed in a variety of ways in a variety of embodiments. Another example of how 622 may be performed is as follows. For each image pixel (x, y), a polar coordinate is computed. For example, (the center of) the image pixel is converted to polar coordinates for the sweep areas it overlaps with (there may be multiple sets of polar coordinates if the image pixel overlaps with an overlapping sweep area). The computed polar coordinate is rounded to the nearest temporal pixel. For example, the temporal pixel whose center is closest to the computed polar coordinate is selected. (If there are multiple sets of polar coordinates, the temporal pixel whose center is closest to the computed polar coordinate is selected.) This way, each image pixel maps to at most one temporal pixel. This may be desirable because it maintains a uniform density of activated temporal pixels in the display area (i.e., the density of activated temporal pixels near an axis of rotation is not higher than at the edges). For example, instead of the pixel map shown in Table 1, the following pixel map may be obtained:

Image pixel (x, y)	Temporal Pixel (P, r, θ)	Intensity (f)
(a1, a2)	(b1, b2, b3)	
(a3, a4)	(b7, b8, b9)	
(a5, a6)	(b10, b11, b12)	
etc.	etc.	

Table 4

[0071] In some cases, using this rounding technique, two image pixels may map to the same temporal pixel. In this case, a variety of techniques may be used at 626, including, for example: averaging the intensity of the two rectangular pixels and assigning the average to the one temporal pixel; alternating between the first and second rectangular pixel intensities between cycles; remapping one of the image pixel to a nearest neighbor temporal pixel; etc.

[0072] Figure 7 illustrates examples of paddles arranged in various arrays. For example, any of these arrays may comprise panel of paddles 502. Any number of paddles may be combined in an array to create a display area of any size and shape.

[0073] Arrangement 702 shows eight circular sweep areas corresponding to eight paddles each with the same size. The sweep areas overlap as shown. In addition, rectangular display areas are shown over each sweep area. For example, the maximum rectangular display area for this arrangement would comprise the union of all the rectangular display areas shown. To avoid having a gap in the maximum display area, the maximum spacing between axes of rotation is $\sqrt{2}$ R, where R is the radius of one of the circular sweep areas. The spacing between axes is such that the periphery of one sweep area does not overlap with any axes of rotation, otherwise there would be interference. Any combination of the sweep areas and rectangular display areas may be used to display one or more images.

[0074] In some embodiments, the eight paddles are in the same sweep plane. In some embodiments, the eight paddles are in different sweep planes. It may be desirable to minimize the number of sweep planes used. For example, it is possible to have every other paddle sweep the same sweep plane. For example, sweep areas 710, 714, 722, and 726 can be in the same sweep plane, and sweep areas 712, 716, 720, and 724 can be in another sweep plane.

[0075] In some configurations, sweep areas (e.g., sweep areas 710 and 722) overlap each other. In some configurations, sweep areas are tangent to each other (e.g., sweep areas 710 and 722 can be moved apart so that they touch at only one point). In some configurations, sweep areas do not overlap each other (e.g., sweep areas 710 and 722 have a small gap between them), which is acceptable if the desired resolution of the display is sufficiently low.

[0076] Arrangement 704 shows ten circular sweep areas corresponding to ten paddles. The sweep areas overlap as shown. In addition, rectangular display areas are shown over each sweep area. For example, three rectangular display areas, one in each row of sweep areas, may be used, for example, to display three separate advertising images. Any combination of the sweep areas and rectangular display areas may be used to display one or more images.

[0077] Arrangement 706 shows seven circular sweep areas corresponding to seven paddles. The sweep areas overlap as shown. In addition, rectangular display areas are shown over each sweep area. In this example, the paddles have various sizes so that the sweep areas have different sizes. Any combination of the sweep areas and rectangular display areas may be used to display one or more images. For example, all the sweep areas may be used as one display area for a non-rectangular shaped image, such as a cut out of a giant serpent.

[0078] Figure 8 illustrates examples of paddles with coordinated in phase motion to prevent mechanical interference. In this example, an array of eight paddles is shown at three points in time. The eight paddles are configured to move in phase with each other; that is, at each point in time, each paddle is oriented in the same direction (or is associated with the same angle when using the polar coordinate system described in Figure 6A).

[0079] Figure 9 illustrating examples of paddles with coordinated out of phase motion to prevent mechanical interference. In this example, an array of four paddles is shown at three points in time. The four paddles are configured to move out of phase with each other; that is, at each point in time, at least one paddle is not oriented in the same direction (or is associated with the same angle when using the polar coordinate system described in Figure 6A) as the other paddles. In this case, even though the paddles move out of phase with each other, their phase difference (difference in angles) is such that they do not mechanically interfere with each other.

[0080] The display systems described herein have a naturally built in cooling system. Because the paddles are spinning, heat is naturally drawn off of the paddles. The farther the LED is from the axis of rotation, the more cooling it receives. In some embodiments, this type of cooling is at least 10x effective as systems in which LED tiles are stationary and in which an external cooling system is used to blow air over the LED tiles using a fan. In addition, a significant cost savings is realized by not using an external cooling system.

[0081] Although in the examples herein, the image to be displayed is provided in pixels associated with rectangular coordinates and the display area is associated with temporal pixels described in polar coordinates, the techniques herein can be used with any coordinate system for either the image or the display area.

[0082] Although rotational movement of paddles is described herein, any other type of movement of paddles may also be used. For example, a paddle may be configured to move from side to side (producing a rectangular sweep area, assuming the LEDs are aligned in a straight row). A paddle may be configured to rotate and simultaneously move side to side (producing an elliptical sweep area). A paddle may have arms that are configured to extend and retract at certain angles, e.g., to produce a more rectangular sweep area. Because the movement is known, a pixel map can be determined, and the techniques described herein can be applied.

[0083] Figure 10 is a diagram illustrating an example of a cross section of a paddle in a composite display. This example is shown to include paddle 1002, shaft 1004, optical fiber 1006, optical camera 1012, and optical data transmitter 1010. Paddle 1002 is attached to shaft 1004. Shaft 1004 is bored out (i.e., hollow) and optical fiber 1006 runs through its center. The base 1008 of optical fiber 1006 receives data via optical data transmitter 1010. The data is transmitted up optical fiber 1006 and transmitted at 1016 to an optical detector (not shown) on paddle 1002. The optical detector provides the data to one or more LED drivers used to activate one or more LEDs on paddle 1002. In some embodiments, LED control data that is received from LED control module 504 is transmitted to the LED driver in this way.

[0084] In some embodiments, the base of shaft 1004 has appropriate markings 1014 that are read by optical camera 1012 to determine the current angular position of paddle 1002. In some embodiments, optical camera 1012 is used in conjunction with angle detector 506 to output angle information that is fed to LED control module 508 as shown in Figure 5.

[0085] Figure 11A is a diagram illustrating an embodiment of a composite display 1100 comprised of circularly shaped paddles. In the given example, the paddles comprise rotating discs onto which pixel elements are attached or mounted, with the discs rotating in different sweep planes. Each disc functions as a (e.g., PCB) structure for pixel elements and/or as a mask and is similar to discs 432 and 438 of Figure 4C. In the example shown, disc 1102 is configured to rotate about axis of rotation 1104 at a given frequency, such as 60 Hz. A plurality of pixel elements, such as LEDs, is installed on disc 1102. Disc 1102 sweeps out area 1106 during one rotation or disc cycle. Disc 1108 is configured to rotate about axis of rotation 1110 at a given frequency, such as 60 Hz. A plurality of pixel elements, such as LEDs, is installed on disc 1108. Disc 1108 sweeps out area 1112 during one rotation or disc cycle. Areas 1106 and 1112 overlap in overlapping portion 1114. In this example, disc 1102 occludes or masks most of sweep area 1112 at overlapping portion or occluded area 1114. The display area for showing the image or video may have any shape. In some embodiments, the union of swept areas 1106 and 1112 is the maximum display area. A rectangular image or video may be displayed in rectangular display area 1116 as shown.

[0086] In the given example, pixel elements (e.g., LEDs) are radially installed on discs 1102 and 1108 in six spokes (i.e. one dimensional arrays) although in various embodiments each disc may have any number of spokes or may have other configurations. The number of spokes of pixel elements selected for each disc may be based at least in part on a target rotational rate for the disc, since a larger number of spokes allows a lower rotational rate for a given resolution. In the example of Figure 11A, a pixel element is installed on the axis of rotation 1104 and 1110 of each disc. In some embodiments, as depicted in the given example, a pixel element 1118 of each spoke at least in part extends beyond or hangs off of the edge of the disc (1102 or 1108). That is, the pixel element 1118 of each spoke is positioned slightly further than the circumference of the disc so that it sweeps out an area (1106 or 1112) larger than the area of the disc. A pixel element installed in such a manner on the edge of a disc is at least partially not backed and/or masked by a disc. Having one or more pixel elements positioned off of the edge of a disc helps in hiding the seam or edge of the disc that may be visible when the composite display is viewed from a position left or right of normal to the display area when an out-of-plane paddle configuration (i.e. paddles that have different sweep planes) is employed. Figure 11B illustrates an embodiment of a cross section of the composite display of Figure 11A. When display area 1116 is viewed from an angle other than normal, the pixel elements 1118 installed on the edges of discs 1102 and 1108 help hide visual effects arising from the edges or thicknesses of the discs, the overlapping portions of the discs, and/or the out-of-plane spacing 1120 between the discs. Although described with respect to discs, a similar effect for at least partially hiding visual effects arising from the edges, overlapping portions, and/or out-of-plane spacing of paddles may be achieved by mounting one or more pixel elements off of the edge of any other type of paddle shape and/or structure. Similar techniques may be employed for in-plane paddle configurations (i.e. paddles rotating in the same sweep plane), e.g., to hide the thicknesses of the edges of the paddles.

[0087] In various embodiments, disc 1102 and disc 1108 are made out of a variety of materials and have a variety of colors. In some embodiments, each disc 1102 and 1108 comprises a black printed circuit board on which LEDs are mounted. The black color of the printed circuit board aids in enhancing the contrast of an image or a portion of an image generated by the LEDs and minimizes reflections of incident light on the composite display such as from sunlight in an outdoor environment.

[0088] In some embodiments, the pixel elements on each disc comprise one or more colors, for example, so that a color image can be displayed. For instance, in some embodiments, the pixel elements may comprise red, green, and blue LEDs so that a (grayscale) RGB image can be displayed. Figure 11C is a diagram illustrating an embodiment of the composite display of Figure 11A in which the pixel elements comprise a plurality of colors. As depicted in the given example, each spoke of discs 1102 and 1108 is comprised of either red, green, or blue pixel elements. The central pixel element of each disc at the axis of rotation of the disc in some embodiments comprises a pixel element capable of producing red, green, or blue light, such as a tri-color RGB LED. In other embodiments, pixels elements of one or more colors may be arranged in any appropriate manner on any paddle shape used in a composite display.

[0089] The sweep location of a pixel element installed on a paddle of a composite display configured to sweep out an area varies with time and/or angle. Each temporal pixel of a composite display corresponds to a pixel element at a given sweep location. In various embodiments, any appropriate density or resolution of temporal pixels may be selected for the display. In some cases, the density or resolution of temporal pixels may not be uniform (i.e. may vary) across the display. Any desired grid density and/or resolution of a display may be obtained by appropriately selecting the number/placement of pixel elements and/or the rotation rate (i.e. sector time) of each paddle comprising the display.

[0090] Figure 12A illustrates an embodiment of a grid of temporal pixels available for rendering an image or portion thereof in a display area 1202 of a composite display having a single paddle with a circular sweep area 1204. For example, display area 1202 corresponds to display area 110 of Figure 1. One or more of the temporal pixels included in the grid may be employed to render an image 1206 (or a portion of the image or an image pixel of the image) in display area 1202. In the given example, the temporal pixels are aligned in rows and columns. Since the alignment of the grid gives the eye vertical and horizontal reference points in the plane of the display, in some cases, an image rendered using such an aligned grid is vulnerable to showing misalignments in image orientation and/or angular rotation. For example, suppose that the image (or portion of the image) 1206 is desired to be rendered in display area 1202. Ideally, as depicted in Figure 12B, the image 1206 (solid line) should overlap with the image rendered in display area 1202 (bold dashed line). If there is some misalignment in the angular orientation of the rendered image, however, the image rendered in display area 1202 (bold dashed line) may overlap with a rotated version of image 1206 (solid line) as depicted in Figure 12C. In some cases, for instance, a net angular rotation may result from imprecision in the image pixel to temporal pixel(s) mapping and/or the rendering technique used for the display. In some cases, such an angular rotation in a rendered image may be acceptable, such as in a composite display comprising a single paddle. However, when an image is rendered by a composite display comprising a plurality of paddles, any angular rotations in portions of the image rendered by each paddle may cause the composite image rendered by the composite display to appear distorted.

[0091] In some embodiments, instead of an aligned grid as depicted in Figures 12A-C, a grid of stochastically arranged temporal pixels is employed so that there is no sense of edges or boundaries and as a result the eye in some cases cannot perceive at least small rotational misalignments in a rendered image or a portion of a rendered image.

[0092] Figure 13 illustrates an embodiment of a grid of temporal pixels available for rendering an image or portion thereof in a display area 1302 of a composite display having a single paddle with a circular sweep area 1304. For example, display area 1302 corresponds to display area 110 of Figure 1. One or more of the temporal pixels included in the grid may be employed to render an image 1306 (or a portion of the image or an image pixel of the image) in display area 1302. In the given example, the temporal pixels are stochastically (i.e. randomly or pseudo-randomly) arranged. In some embodiments, a stochastic grid of temporal pixels is obtained using a higher resolution (of a in some cases aligned) grid of temporal pixels than needed or desired for the display. In some such cases, for example, the stochastic grid is obtained by randomly selecting a subset of temporal pixels included in such a higher resolution grid. The (average) resolution of the stochastic grid in some such cases is lower than the (average) resolution of the higher resolution grid employed to obtain the stochastic grid. In various embodiments, any desired density, resolution, and/or configuration of a stochastic grid of temporal pixels can be obtained by appropriately selecting the number/placement of pixel elements and/or the rotation rate (i.e. sector time) of a paddle. In various embodiments, in the cases in which a composite display comprises a plurality of paddles, the same and/or different stochastic grid positions may be employed in the display areas associated with the various paddles. Since an image rendered by a stochastic grid of temporal pixels may be invariant to at least slight angular rotations, in some cases it might not be necessary to have an absolute sense of where zero degrees is, for example, when aligning an image or portions of an image over the sweep areas of one or more paddles to determine the image pixel to temporal pixel mapping as described above with respect to the examples of Figures 6A-B. A stochastic grid of temporal pixel positions is useful for both in-plane and out-of-plane paddle configurations to mitigate the effects of angular misalignment.

[0093] Various techniques including the aforementioned technique of mounting one or more pixel elements on the edges of paddles as described with respect to Figures 11A-C may be employed to mitigate visual effects arising from the edges, overlapping portions, and/or spacing of two or more paddles in out-of-plane paddle configurations, which may be particularly visible when the image plane of such a composite display is viewed from an angle other than normal. In some embodiments, the resolution of the display and/or the out-of-plane spacing between paddles are appropriately adjusted to eliminate or at least mitigate such visual effects so that an image being displayed appears seamless from any viewing angle. As previously described, to the eye, having two paddles rotate in different sweep planes is not detectable if the resolution of the display is sufficiently smaller than the vertical spacing between the sweep planes. That is, the visual effects arising from out-of-plane paddle configurations are not detectable if the virtual or temporal pixel-to-pixel spacing is larger (i.e. the temporal pixel resolution is sufficiently smaller) than the out-of-plane spacing between paddles. Thus, using a lower resolution (i.e. less dense) grid of temporal pixels for out-of-plane paddle configurations aids in mitigating such visual effects. In some embodiments, any desired grid resolution may be employed for a display comprising an in-plane paddle configuration since in-plane paddle configurations do not suffer from out-of-plane seam issues.

[0094] As previously described, during image pixel to temporal pixel mapping, one image pixel may map to a plurality of temporal pixels. When an image pixel maps to multiple temporal pixels, the multiple temporal pixels include one or more redundant temporal pixels each of which may or may not be employed to render the image pixel in various embodiments. Table 5 is an embodiment of a pixel map in which at least some image pixels map to a plurality of temporal pixels. In some embodiments, the pixel map of Table 5 is generated using the process of Figure 6B. In some embodiments, the mapping of Table 5 is for a grayscale image.

Image pixel (x,y)	Temporal Pixel (P, r, θ)	Intensity (f)
(a1, a2)	(b1, b2, b3)	f1
(a3, a4)	(b4, b5, b6) (b7, b8, b9)	f2/2 f2/2
(a5, a6)	(b10, b11, b12) (b13, b14, b15) (b16, b17, b18)	f3/3 f3/3 f3/3
etc.	etc.	etc.

Table 5

[0095] In some embodiments, as in the example of Table 5, in the cases in which an image pixel maps to multiple temporal pixels, one or more of the temporal pixels to which the image pixel is mapped are employed to render the image pixel. In some embodiments, the intensity associated with the image pixel is divided in any appropriate manner across the temporal pixels selected to render the image pixel. In the example of Table 5, for instance, the intensity f2 of image pixel (a3, a4) is equally divided between the two temporal pixels to which it maps, and the intensity f3 of image pixel (a5,a6) is equally divided among the three temporal pixels to which it maps. In other embodiments, the intensity may not be equally divided. In some embodiments, the intensity comprises an amplitude and/or a duty cycle. Spreading out the intensity of an image pixel across as many as possible and/or at least a subset of temporal pixels to which it maps prevents or at least mitigates degenerate pixels (i.e. dark spots) from appearing in the rendered image, which may appear in the rendered image, for example, if redundant temporal pixels are not used in the rendering. In some embodiments, all or at least as many as possible temporal pixels to which image pixels are mapped are used to render an image. In some cases two (or more) image pixels may be mapped to one or more of the same temporal pixels. In such cases, a common temporal pixel is employed to at least partially render at least one of the image pixels mapped to it. Spreading out or dividing the intensity of an image pixel across multiple temporal pixels is in some embodiments possible using a driver chip (e.g., for doing pulse width modulation on pixel elements) that has sufficient bit depth to allow the intensity or grayscale value of the image pixel to be spread out across multiple temporal pixels. For example, in some cases, a 12-bit driver provides sufficient bit depth.

[0096] In some embodiments, due to the inherent convective cooling arising from the rotation of the paddles, the pixel elements of the paddles can be driven at a higher brightness, for example, to counter or overcome some brightness loss due to the spreading of intensity over multiple temporal pixels, duty cycle management, etc.

[0097] In some embodiments, a cover plate as further described below is installed in front of the composite display, for example, to protect the mechanical structure of the composite display and/or prevent external interference. Such a cover plate may be made of any appropriate material, such as plastic.

[0098] Various techniques may be employed to enhance or improve the quality of the image being displayed and/or remove or at least mitigate artifacts in the rendered image. In some embodiments, the rendering process for activating temporal pixels is configured to improve the quality of the rendered image and/or mitigate artifacts in the rendered image, for example, using one or more appropriate image processing techniques, such as color space remapping, non-linear gamma correction, fixed pattern dither, error diffusion based dithering, etc. In some embodiments, one or more secondary optics are employed to improve image quality and/or mitigate artifacts.

[0099] In some embodiments, diffusion is employed to mitigate artifacts in a rendered image. In some such cases, diffusion of the rendered image is achieved at least in part by mounting a diffuser film in front of the composite display. For example, a diffuser film can be laminated onto the inside surface of the cover plate of the composite display. In some embodiments, diffusion by itself may excessively degrade the image quality, for example, by making the image too blurry. Degradation may occur, for example, if the pixel elements comprise diffused light sources such as LEDs. In such cases, the light emitted by each pixel element diffuses over the distance it travels to reach the diffuser film on the cover plate. Further degradation may occur if an out-of-plane paddle configuration is used for the composite display since the light emitted by pixel elements on out-of-plane paddles travels different distances before reaching the diffuser film on the cover plate. Collimating the light prior to diffusing, for example, using a collimating film in front of the diffuser film on the cover plate does not help in some cases because the light emitted by each pixel element on the paddles has already diffused over the distance it has traveled to reach the collimating film on the cover plate and by different amounts for out-of-plane paddles. In the cases in which the pixel elements comprise diffused light sources, in some embodiments, it is useful to at least substantially locally collimate the light at each pixel element so that the light of each pixel element minimally diffuses over the distance it travels between the pixel element and the diffuser film. In some such cases, a diffuser film can be employed on the inside surface of a cover plate to diffuse the collimated light from the pixel elements hitting it so that visual artifacts in the rendered image can be mitigated. In some embodiments, LEDs packaged with lenslets attached to them that help to locally focus and collimate the light emitted by the LEDs may be used. In some embodiments, however, the thickness of such an

LED with an attached lenslet for local collimation is greater than the out-of-plane spacing desired for paddles in a composite display.

[00100] In some embodiments, a thin film optic such as a microlens array is employed for local collimation at each pixel element. In some embodiments, such a thin film optic is associated with Fresnel lens characteristics. In some embodiments, the thin film optic is implemented using an embossed film having the desired collimating (e.g., Fresnel) characteristics from which thin film lenses are punched out and adhered onto the outside surface of each pixel element.

[00101] Figure 14 illustrates an embodiment of a cross section of a composite display 1400. The composite display 1400 of the given example comprises an out-of-plane paddle configuration. In the given example, a thin film collimating lens 1404 is attached to each pixel element 1402 which locally focuses and (substantially) collimates the light emitted by the pixel element 1402. A cover plate 1406 is installed a small distance in front of the paddles 1408 of the composite display 1400, with a diffuser film 1410 laminated on the inside surface of the cover plate 1406. Any dispersion or diffusion of the collimated light over the distance it travels to reach the diffuser film on the cover plate and/or the difference in distance traveled for out-of-plane paddles is in many cases imperceptible to the eye. Upon hitting the diffuser film 1410 on the cover plate 1406, the collimated light is diffused at the image plane, which in some cases facilitates hiding visual artifacts in the image, especially when the display is viewed from a sufficient viewing distance. In some embodiments, local collimation and diffusion at the image plane (e.g., at the cover plate) as described helps hide the seams associated with out-of-plane paddle configurations since collimation of the light of the paddles prior to diffusion makes the out-of-plane spacing between the paddles less perceptible. In some such cases, it may be possible to use higher temporal pixel resolutions since the seams of the out-of-plane paddle configuration are more effectively hidden.

[00102] In some embodiments, the outside surface of the cover plate 1406 (optionally) includes an anti-reflective coating 1412. In various embodiments, for example, the anti-reflective coating 1412 may be directly applied to the outer surface of cover plate 1406, may be coated on a film laminated onto the outside surface of

cover plate 1406, etc. The anti-reflective coating 1412 helps mitigate interference of reflections of incident light (e.g., sunlight in an outdoor environment) with the light generated by the display.

[00103] Although some examples of image quality improvements have been described, any appropriate image processing techniques and/or secondary optics may be employed to improve the quality and/or hide artifacts of the displayed image.

[00104] Although the foregoing embodiments have been described in some detail for purposes of clarity of understanding, the invention is not limited to the details provided. There are many alternative ways of implementing the invention. The disclosed embodiments are illustrative and not restrictive.

[00105] WHAT IS CLAIMED IS:

CLAIMS

1. A composite display, comprising:

a paddle configured to sweep out an area; and

a plurality of pixel elements mounted on the paddle;

wherein at least one pixel element of the plurality of pixel elements is mounted on an edge of the paddle such that at least a portion of the at least one pixel element extends beyond the edge of the paddle and wherein selectively activating one or more of the plurality of pixel elements while the paddle sweeps the area causes at least a portion of an image to be rendered.

2. A display as recited in claim 1, wherein the paddle comprises a printed circuit board.

3. A display as recited in claim 1, wherein the paddle comprises a disc.

4. A display as recited in claim 1, wherein the area comprises a circle.

5. A display as recited in claim 1, wherein the paddle is configured to rotate about an axis of rotation.

6. A display as recited in claim 1, wherein at least one of the plurality of pixel elements comprises a light emitting diode.

7. A display as recited in claim 1, wherein the plurality of pixel elements are radially arranged in one or more spokes.

8. A display as recited in claim 7, wherein each spoke comprises red, green, or blue pixel elements.

9. A display as recited in claim 1, wherein at least one of the plurality of pixel elements is mounted on or adjacent to an axis of rotation of the paddle.

10. A display as recited in claim 1, wherein the plurality of pixel elements are uniformly spaced.

11. A display as recited in claim 1, wherein a spacing between adjacent pixel elements is based at least in part on a distance from an axis of rotation of the paddle.

12. A display as recited in claim 1, wherein the paddle is made of a black material.

13. A display as recited in claim 1, wherein the paddle functions as a mask.

14. A display as recited in claim 1, further comprising a mask to block light from another paddle from the sweep area of the paddle.

15. A display as recited in claim 1, wherein the at least one pixel element mounted on the edge at least in part hides a thickness of the edge.

16. A display as recited in claim 1, wherein the at least one pixel element mounted on the edge sweeps a different area than the area swept by the paddle.

17. A display as recited in claim 1, wherein the paddle is included in a set of paddles comprising the composite display.

18. A method, comprising:

obtaining a paddle configured to sweep out an area; and

mounting a plurality of pixel elements on the paddle;

wherein at least one pixel element of the plurality of pixel elements is mounted on an edge of the paddle such that at least a portion of the at least one pixel element extends beyond the edge of the paddle and wherein selectively activating one or more of the plurality of pixel elements while the paddle sweeps the area causes at least a portion of an image to be rendered.

19. A method as recited in claim 18, wherein the paddle comprises a printed circuit board.

20. A method as recited in claim 18, wherein the paddle comprises a disc.

21. A method for image to temporal pixel mapping, comprising:

obtaining a grid of stochastically arranged temporal pixels, wherein each temporal pixel corresponds to a pixel element at a given sweep location; and

mapping an image pixel to one or more temporal pixels in the grid;

wherein one or more of the one or more temporal pixels in the grid to which the image pixel is mapped are employed to render the image pixel.

22. A method as recited in claim 21, wherein the pixel element is installed on a paddle.

23. A method as recited in claim 22, wherein the paddle is configured to sweep out an area.

24. A method as recited in claim 21, wherein the sweep location of the pixel element varies with time.

25. A method as recited in claim 21, wherein the sweep location of the pixel element varies with angle.

26. A method as recited in claim 21, wherein the image pixel is included in an image being rendered by temporal pixels in a composite display.

27. A method as recited in claim 21, wherein temporal pixel positions in the grid are stochastically determined.

28. A method as recited in claim 21, wherein temporal pixel positions in the grid are not aligned.

29. A method as recited in claim 21, wherein the grid comprises a first grid and wherein obtaining the first grid of stochastically arranged temporal pixels comprises randomly selecting a subset of temporal pixels included in a second grid.

30. A method as recited in claim 29, wherein the second grid is of a higher resolution than the first grid.

31. A method as recited in claim 21, wherein obtaining a grid of stochastically arranged temporal pixels comprises selecting one or more of a number of pixel elements installed on a paddle, a placement of the pixel elements on the paddle, and a rotation rate of the paddle.

32. A method as recited in claim 21, wherein a density of temporal pixels in the grid varies across the grid.

33. A method as recited in claim 21, wherein at least a portion of an image comprising the image pixel rendered by the grid of stochastically arranged temporal pixels is invariant to slight angular rotations.

34. A method as recited in claim 21, wherein the grid of stochastically arranged temporal pixels is associated with a display area of a first paddle of a composite display and further comprising selecting a different grid of stochastically arranged temporal pixels for a display area of a second paddle of the composite display.

35. A system for image to temporal pixel mapping, comprising:

a processor configured to:

obtain a grid of stochastically arranged temporal pixels, wherein each temporal pixel corresponds to a particular pixel element at a given sweep location; and

map an image pixel to one or more temporal pixels in the grid, wherein one or more of the one or more temporal pixels in the grid to which the image pixel is mapped are employed to render the image pixel; and

a memory coupled to the processor and configured to provide instructions to the processor.

36. A system as recited in claim 35, wherein temporal pixel positions in the grid are stochastically determined.

37. A system as recited in claim 35, wherein temporal pixel positions in the grid are not aligned.

38. A computer program product for image to temporal pixel mapping, the computer program product being embodied in a computer readable medium and comprising computer instructions for:

obtaining a grid of stochastically arranged temporal pixels, wherein each temporal pixel corresponds to a particular pixel element at a given sweep location; and

mapping an image pixel to one or more temporal pixels in the grid;

wherein one or more of the one or more temporal pixels in the grid to which the image pixel is mapped are employed to render the image pixel.

39. A computer program product as recited in claim 38, wherein temporal pixel positions in the grid are stochastically determined.

40. A computer program product as recited in claim 38, wherein temporal pixel positions in the grid are not aligned.

41. A method for rendering an image pixel in a composite display, comprising:

mapping an image pixel to a plurality of temporal pixels, wherein each temporal pixel corresponds to a pixel element at a given sweep location; and

rendering the image pixel using at least a subset of the plurality of temporal pixels;

wherein an intensity of the image pixel is spread across the subset of temporal pixels.

42. A method as recited in claim 41, wherein the pixel element is installed on a paddle.

43. A method as recited in claim 42, wherein the paddle is configured to sweep out an area.

44. A method as recited in claim 41, wherein the sweep location of the pixel element varies with time.

45. A method as recited in claim 41, wherein the sweep location of the pixel element varies with angle.

46. A method as recited in claim 41, wherein the image pixel is included in an image being rendered by temporal pixels including the subset of temporal pixels in the composite display.

47. A method as recited in claim 41, wherein the plurality of temporal pixels includes one or more redundant temporal pixels.

48. A method as recited in claim 41, wherein the intensity is divided equally across the subset of temporal pixels.

49. A method as recited in claim 41, wherein the intensity is not divided equally across the subset of temporal pixels.

50. A method as recited in claim 41, wherein the intensity includes an amplitude.

51. A method as recited in claim 41, wherein the intensity includes a duty cycle.

52. A method as recited in claim 41, wherein the intensity comprises a grayscale value.

53. A method as recited in claim 41, further comprising using a driver chip for pixel elements including the pixel element that has sufficient bit depth to spread the intensity across the subset of temporal pixels.

54. A method as recited in claim 41, further comprising creating a pixel map.

55. A method as recited in claim 41, wherein mapping comprises overlaying an image over a display area of the composite display.

56. A system for rendering an image pixel in a composite display, comprising:

a processor configured to:

map an image pixel to a plurality of temporal pixels, wherein each temporal pixel corresponds to a pixel element at a given sweep location; and

render the image pixel using at least a subset of the plurality of temporal pixels, wherein an intensity of the image pixel is spread across the subset of temporal pixels; and

a memory coupled to the processor and configured to provide instructions to the processor.

57. A system as recited in claim 56, wherein the intensity includes one or more of an amplitude and a duty cycle.

58. A computer program product for rendering an image pixel in a composite display, the computer program product being embodied in a computer readable medium and comprising computer instructions for:

mapping an image pixel to a plurality of temporal pixels, wherein each temporal pixel corresponds to a pixel element at a given sweep location; and

rendering the image pixel using at least a subset of the plurality of temporal pixels;

wherein an intensity of the image pixel is spread across the subset of temporal pixels.

59. A computer program product as recited in claim 58, wherein the intensity includes one or more of an amplitude and a duty cycle.

60. A computer program product as recited in claim 58, wherein the intensity is divided equally across the subset of temporal pixels.

61. A light source, comprising:

a pixel element configured to emit light; and

a thin film optic configured to substantially collimate light emitted by the pixel element, wherein the thin film optic is attached to a surface of the pixel element.

62. A light source as recited in claim 61, wherein the pixel element comprises a diffused light source.

63. A light source as recited in claim 61, wherein the pixel element comprises a light emitting diode.

64. A light source as recited in claim 61, wherein the thin film optic is associated with Fresnel lens characteristics.

65. A light source as recited in claim 61, wherein the thin film optic comprises a microlens array.

66. A light source as recited in claim 61, further comprising a diffuser film configured to diffuse incident light.

67. A light source as recited in claim 66, wherein the diffuser film is mounted in front of the pixel element.

68. A light source as recited in claim 66, wherein the diffuser film is mounted on a surface of a cover plate positioned in front of the pixel element.

69. A composite display, comprising:

a set of one or more paddles, wherein each paddle is configured to sweep out an area;

a plurality of pixel elements installed on each paddle; and

an optic configured to substantially collimate light attached to a surface of each pixel element.

70. A display as recited in claim 69, wherein the set of paddles is arranged in an out-of-plane paddle configuration.

71. A display as recited in claim 69, wherein a spacing between adjacent temporal pixels associated with the composite display is larger than an out-of-plane spacing between paddles and wherein each temporal pixel of the composite display corresponds to a pixel element at a given sweep location.

72. A display as recited in claim 69, wherein the set of paddles is arranged in an in-plane paddle configuration.

73. A display as recited in claim 69, wherein at least one of the pixel elements comprises a diffused light source.

74. A display as recited in claim 69, wherein at least one of the pixel elements comprises a light emitting diode.

75. A display as recited in claim 69, wherein the optic comprises a lenslet configured to collimate light.

76. A display as recited in claim 69, wherein the optic comprises a thin film optic.

77. A display as recited in claim 69, wherein the optic comprises a microlens array.

78. A display as recited in claim 69, wherein the optic is associated with Fresnel lens characteristics.

79. A display as recited in claim 69, wherein the optic provides local collimation at each pixel element.

80. A display as recited in claim 69, further comprising a diffuser film mounted in front of the set of paddles, wherein the diffuser film diffuses incident collimated light from the pixel elements.

81. A display as recited in claim 69, further comprising a cover plate mounted in front of the set of paddles.

82. A display as recited in claim 69, further comprising a cover plate mounted in front of the set of paddles, wherein a diffuser film is mounted on an inside surface of the cover plate.

83. A display as recited in claim 69, further comprising a cover plate mounted in front of the set of paddles, wherein an anti-reflective coating or film is applied on an outside surface of the cover plate.

84. A display as recited in claim 69, wherein selectively activating one or more of the plurality of pixel elements on each paddle while the paddle sweeps out an area causes at least a portion of an image to be rendered.

85. A method, comprising:

obtaining a set of one or more paddles, wherein each paddle is configured to sweep out an area;

installing a plurality of pixel elements on each paddle; and

attaching an optic configured to substantially collimate light to a surface of each pixel element.

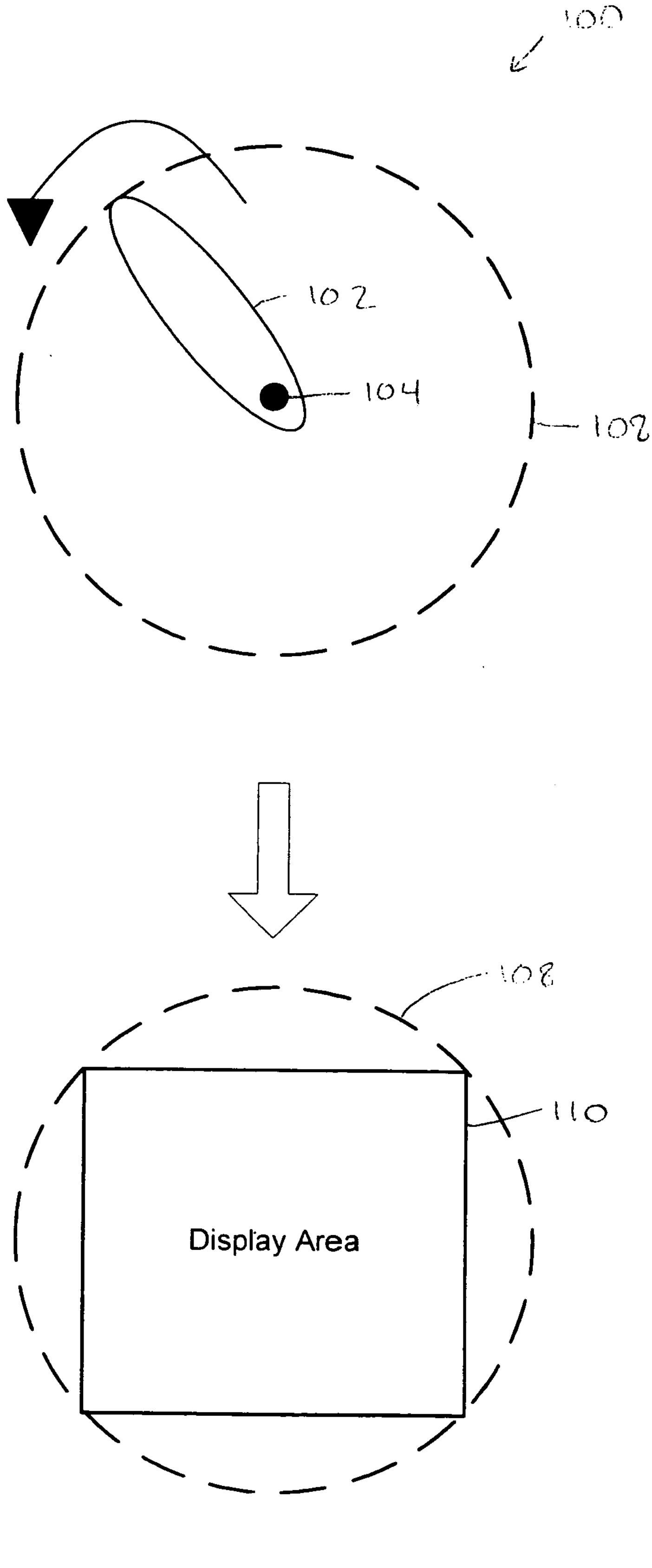


FIG. 1

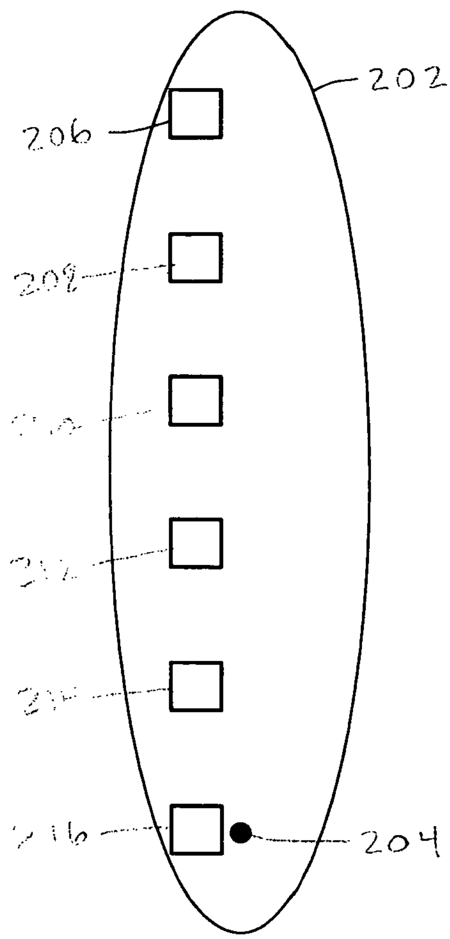


FIG. 2A

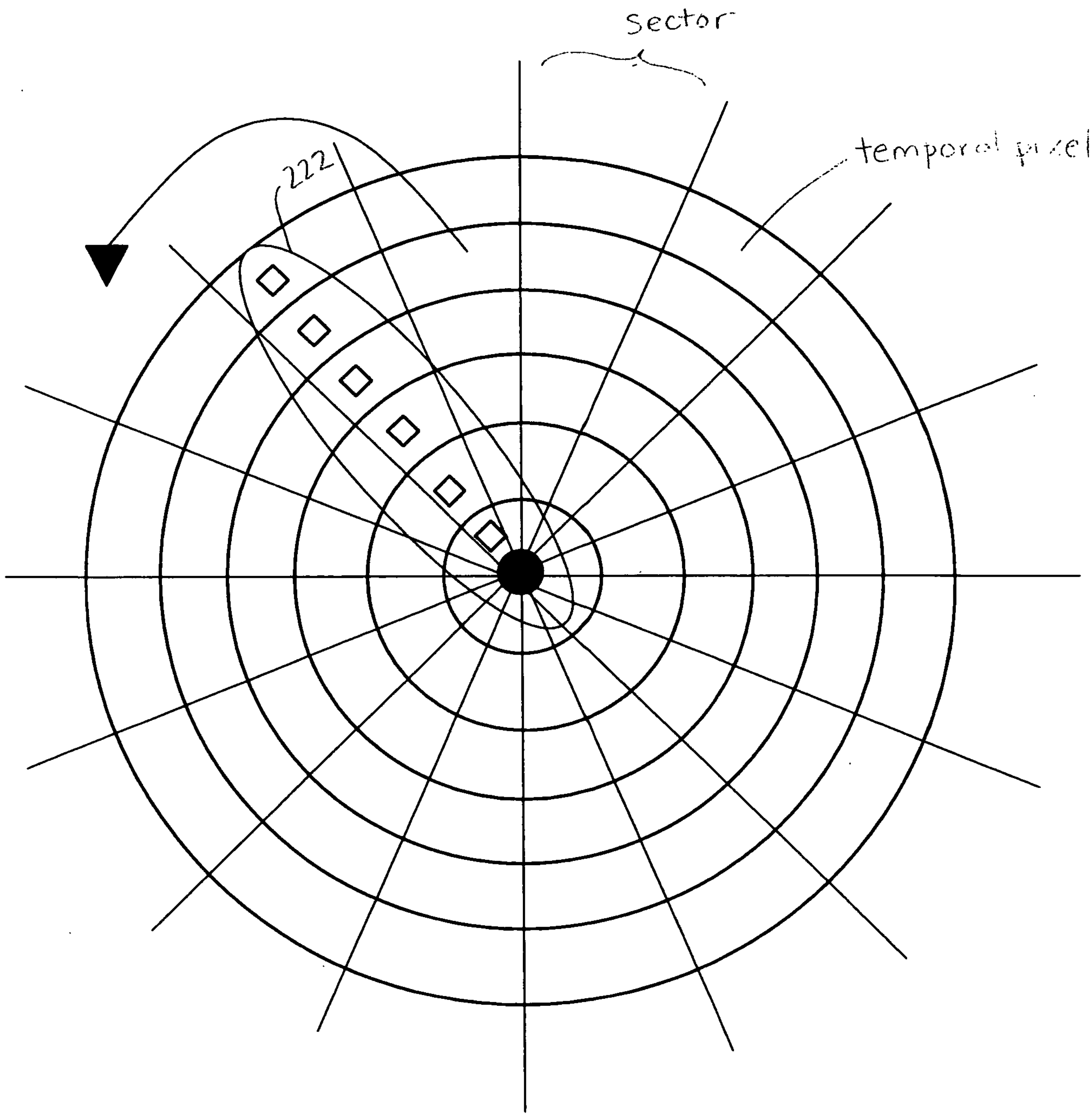


FIG. 2B

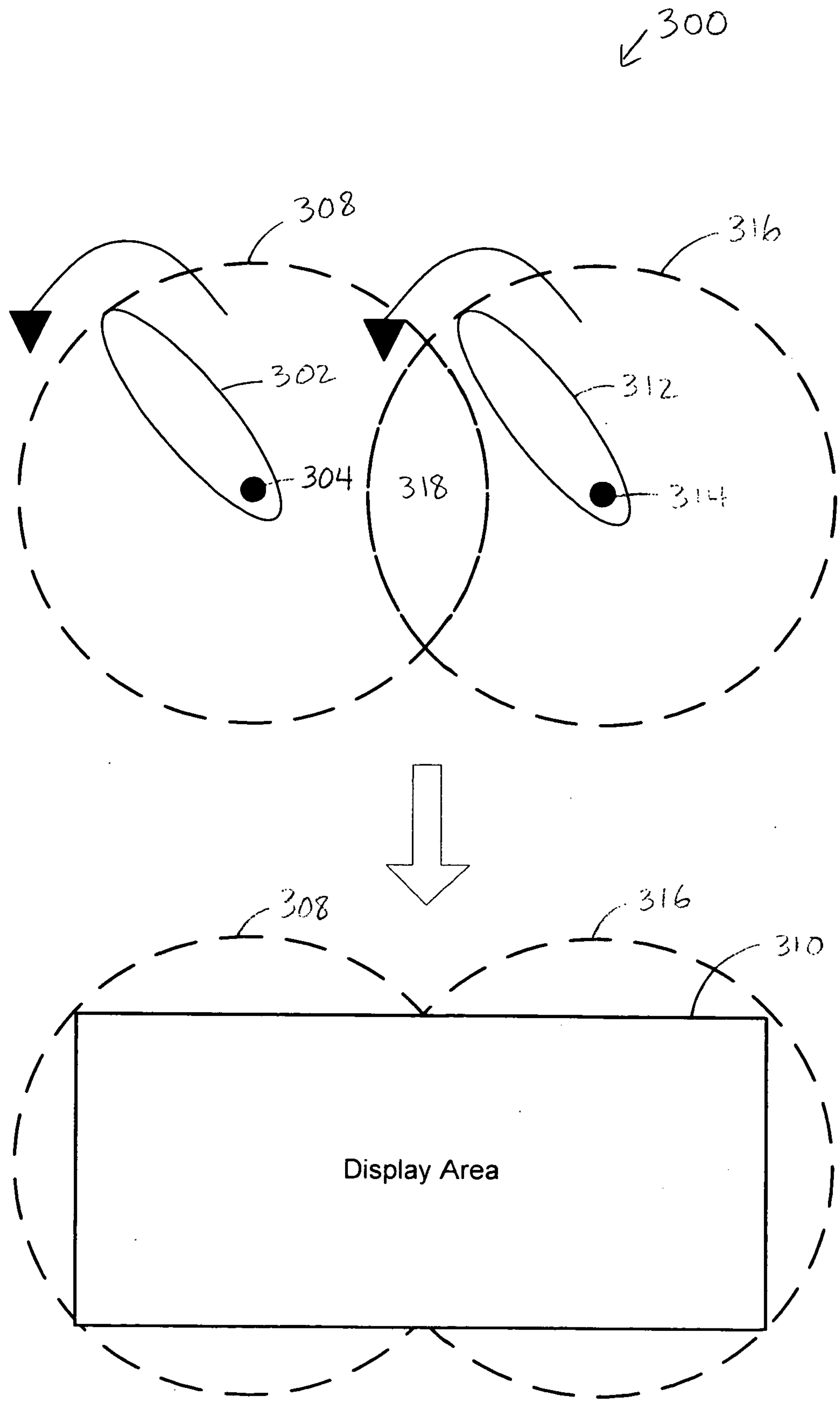


FIG. 3

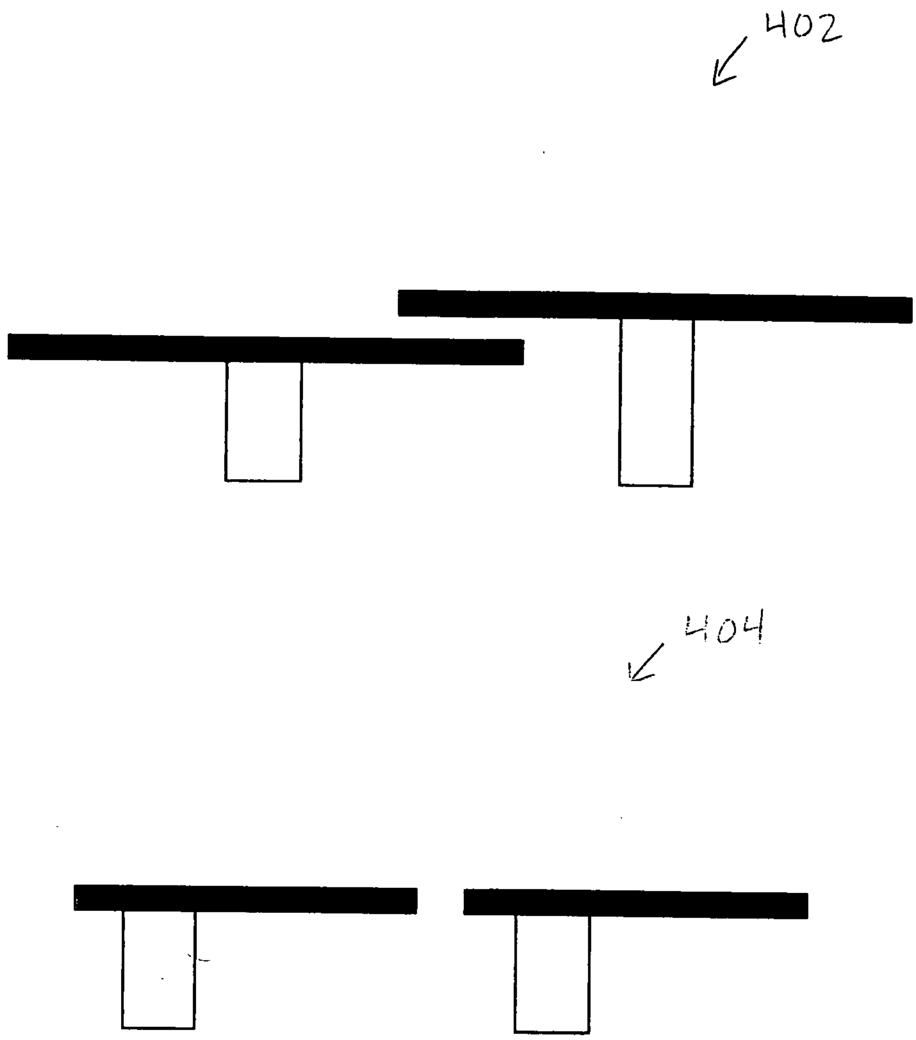


FIG. 4A

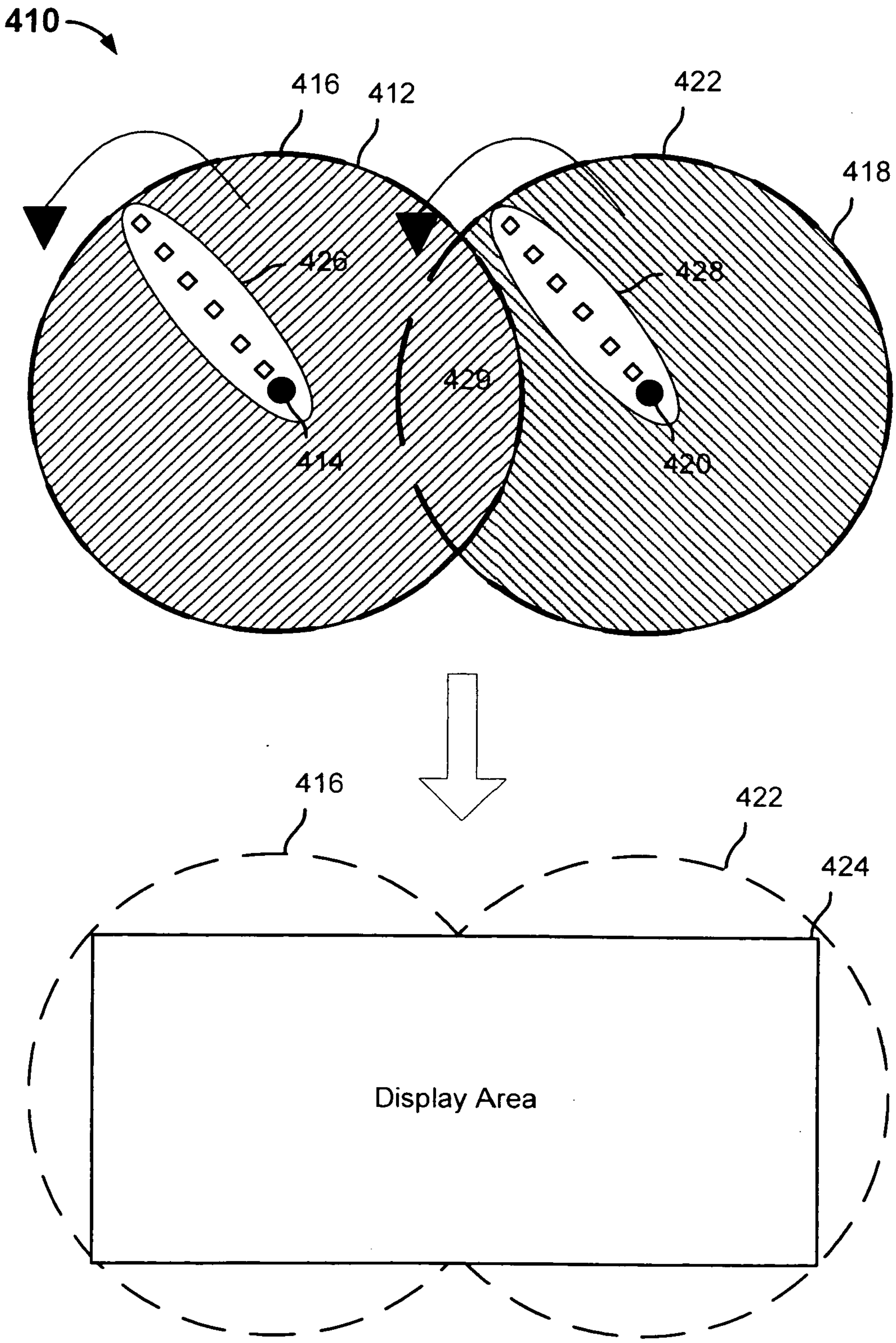

410
416
412
422
418
426
428
429
414
420
416
422
424
Display Area

FIG. 4B

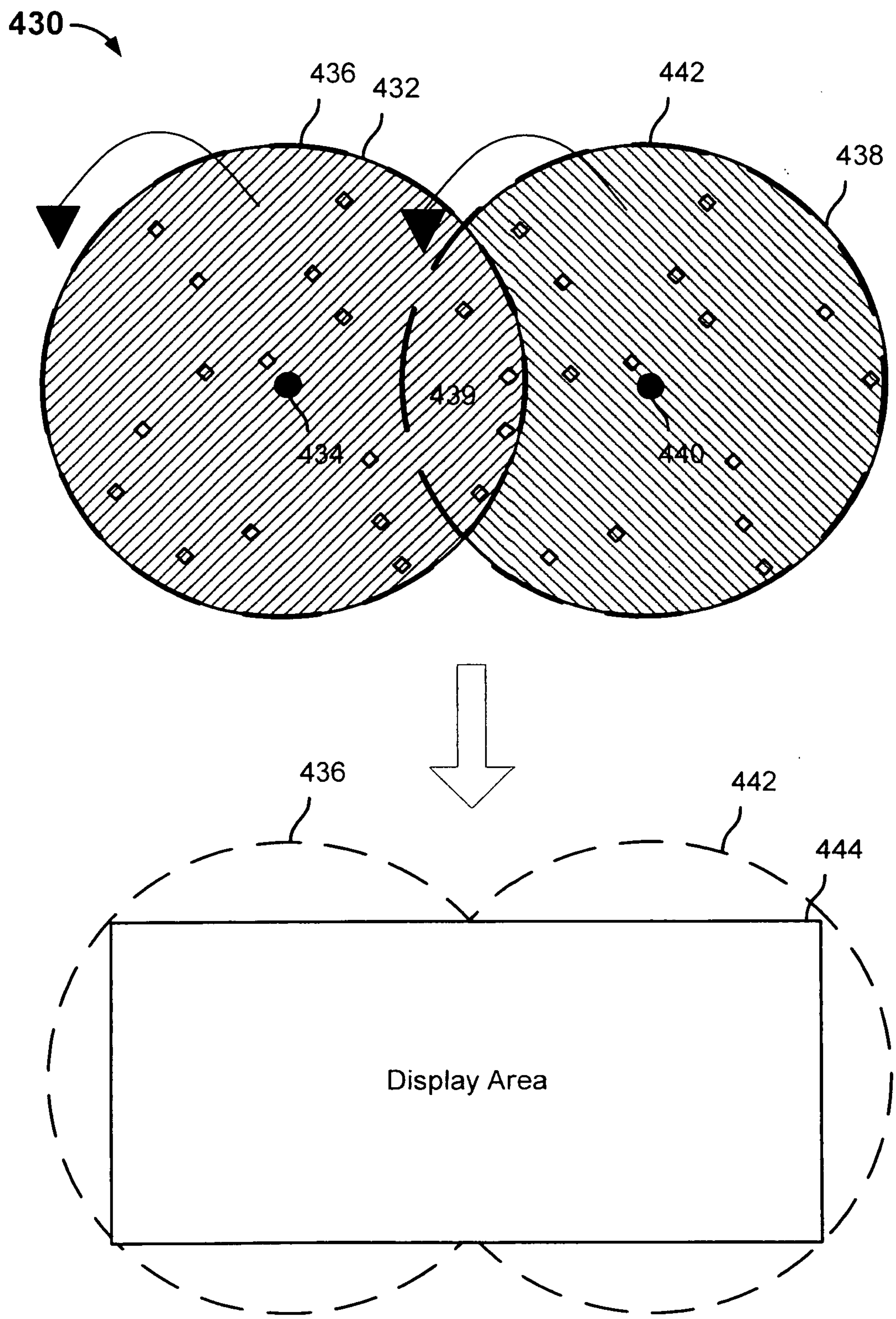


FIG. 4C

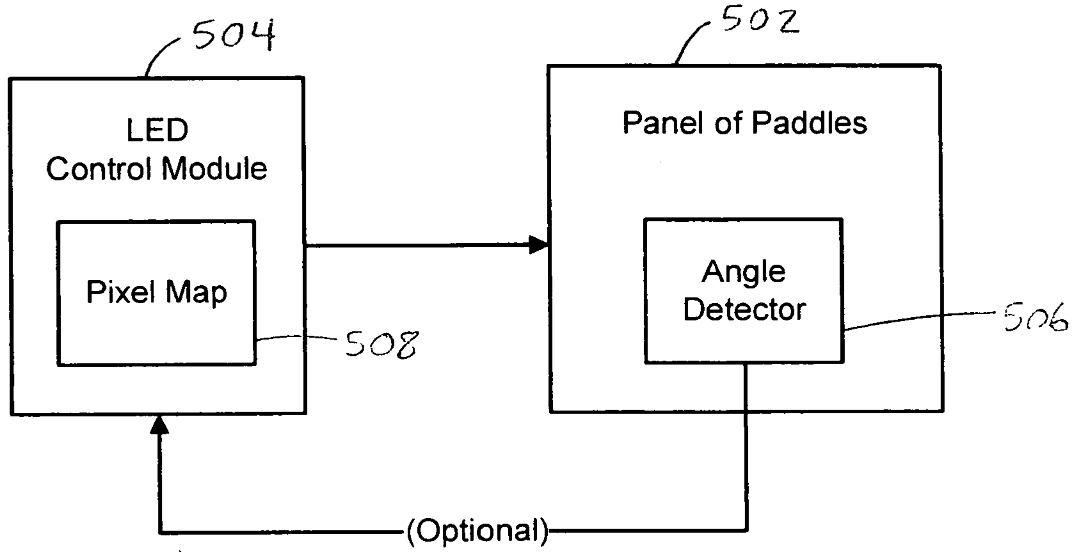

504
502
LED
Control Module
Pixel Map
508
Panel of Paddles
Angle
Detector
506
(Optional)

FIG. 5

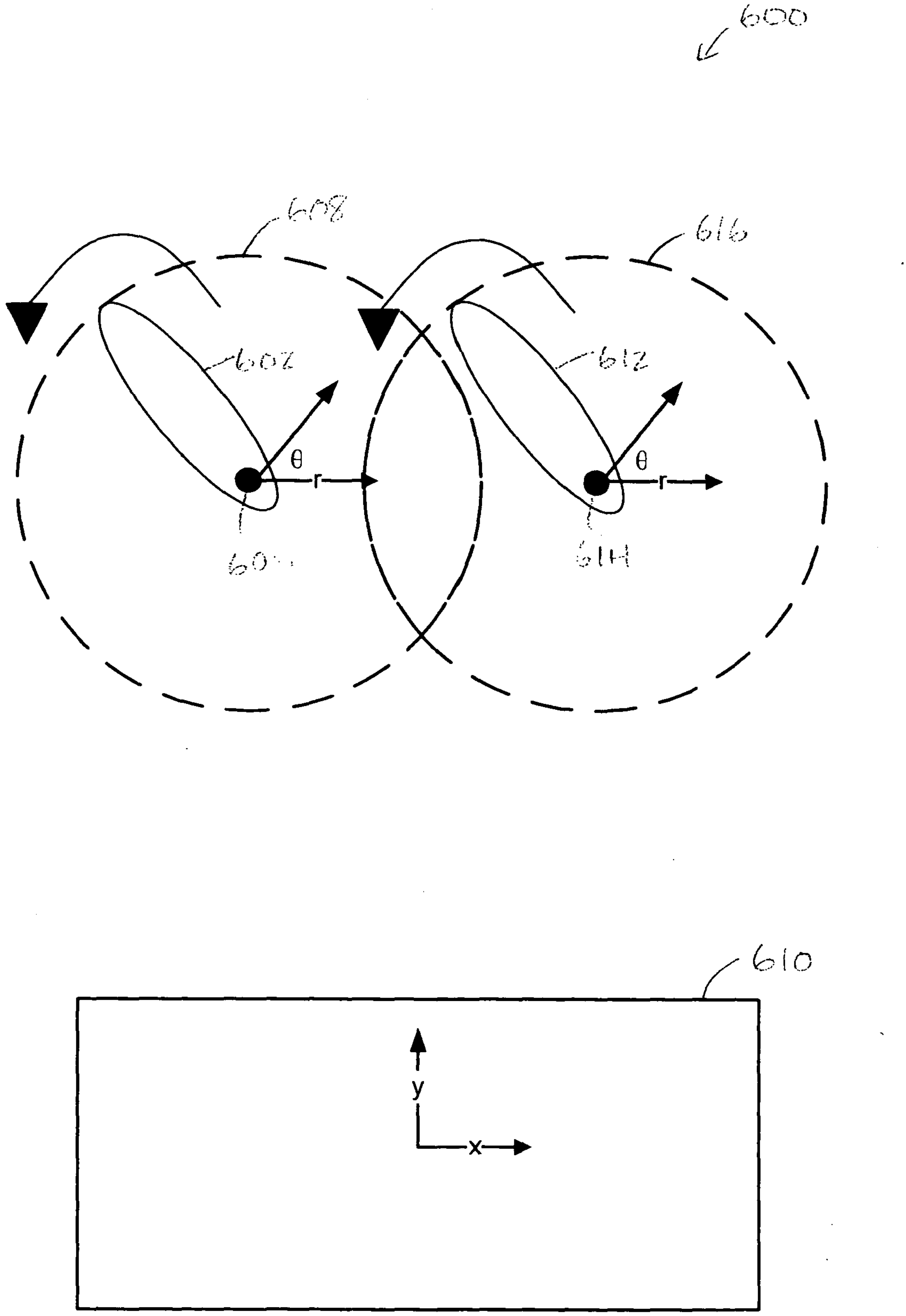


FIG. 6A

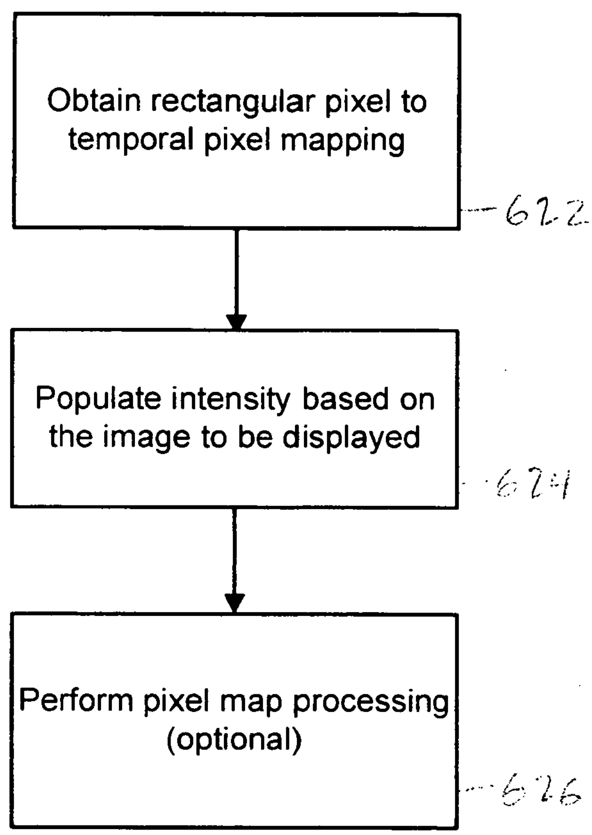
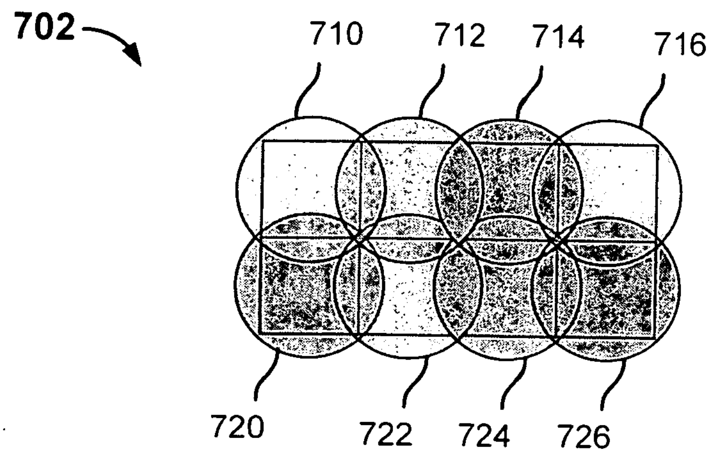
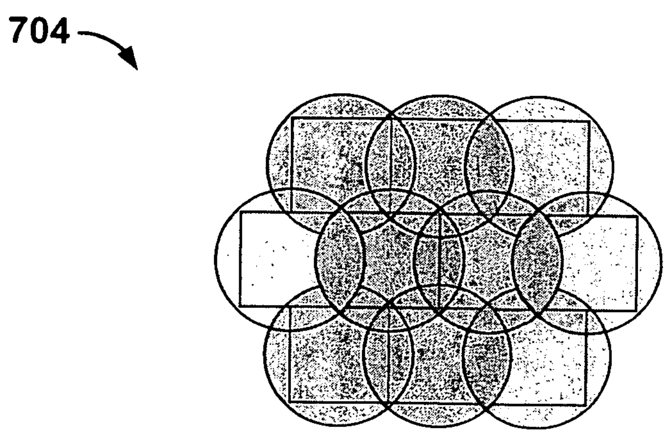

Obtain rectangular pixel to temporal pixel mapping
622
Populate intensity based on the image to be displayed
624
Perform pixel map processing (optional)
626

FIG. 6B





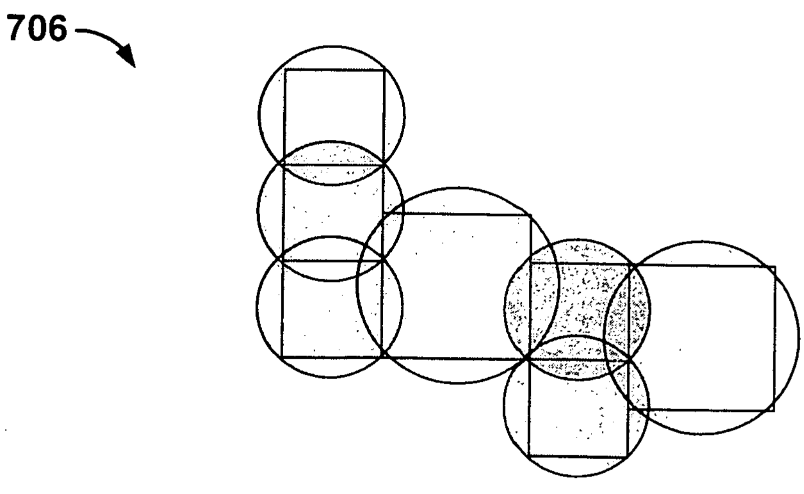


FIG. 7

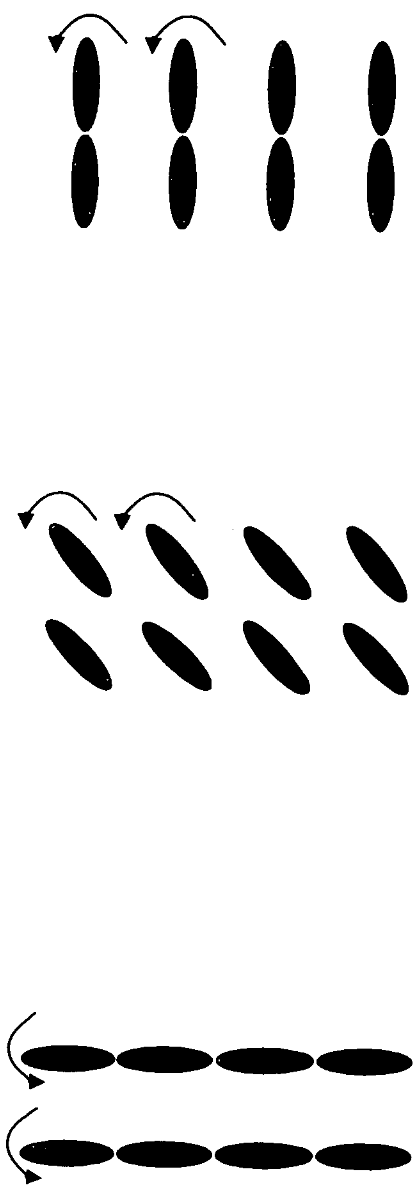


FIG.8

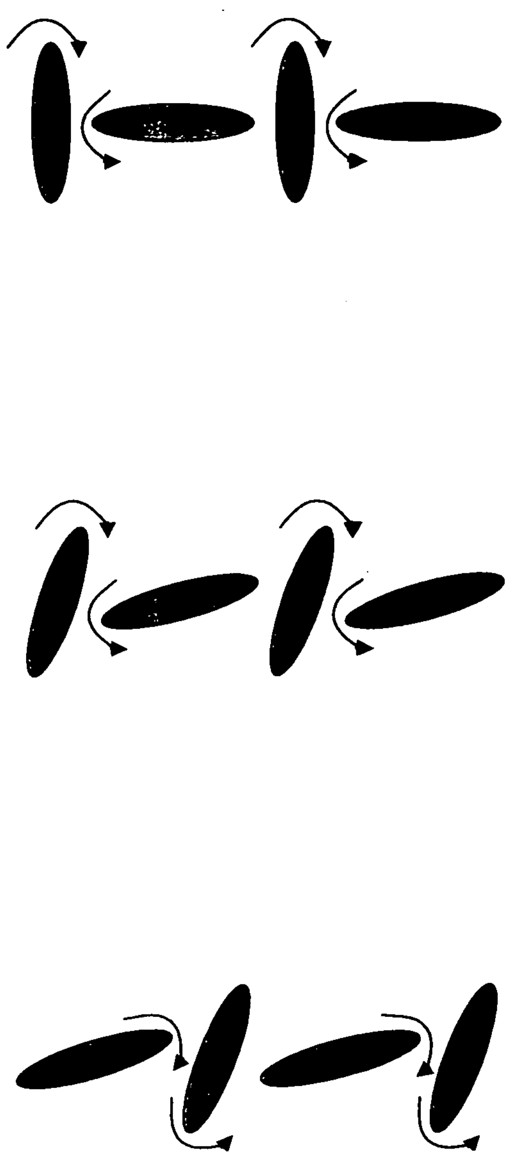


FIG.9

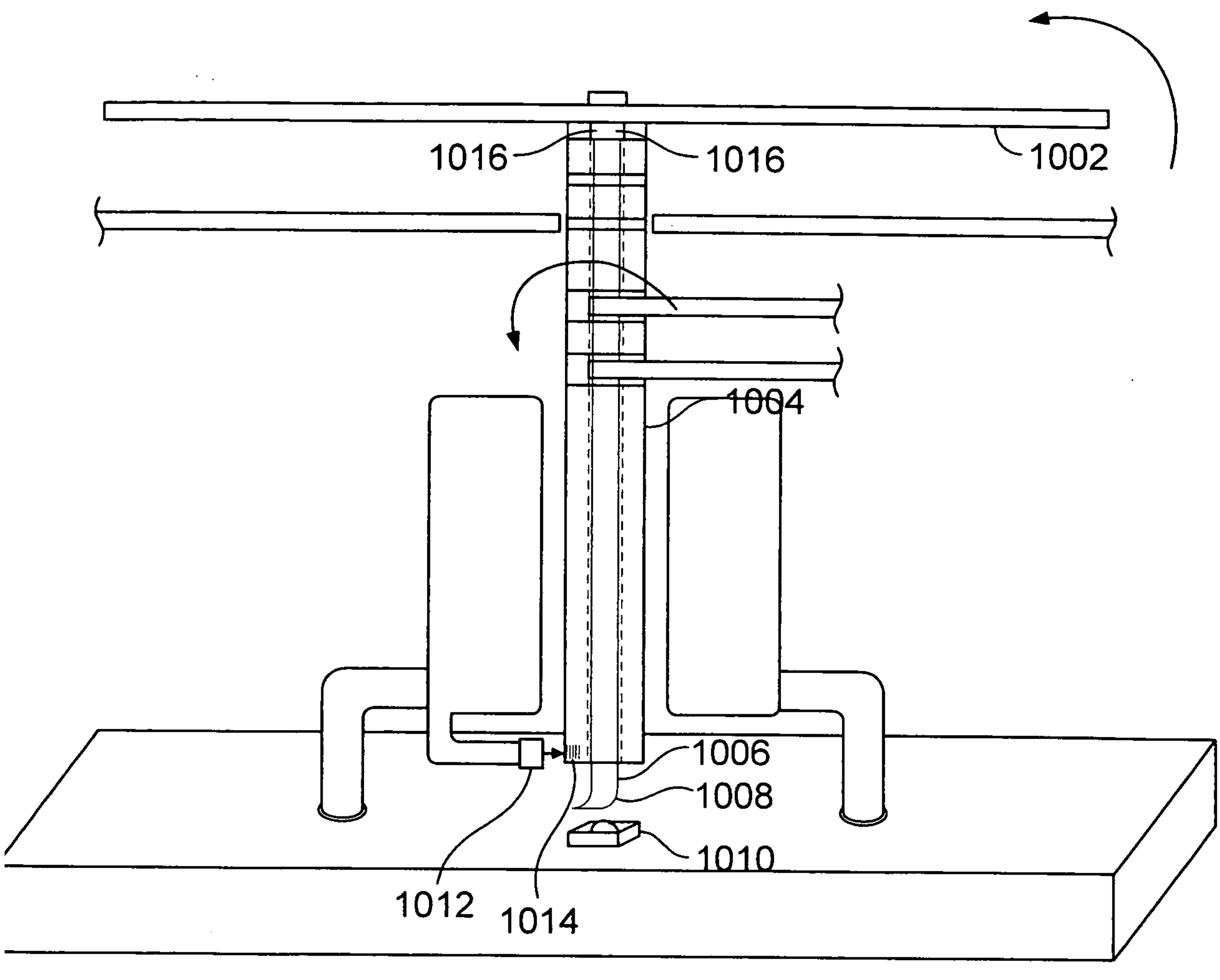


FIG. 10

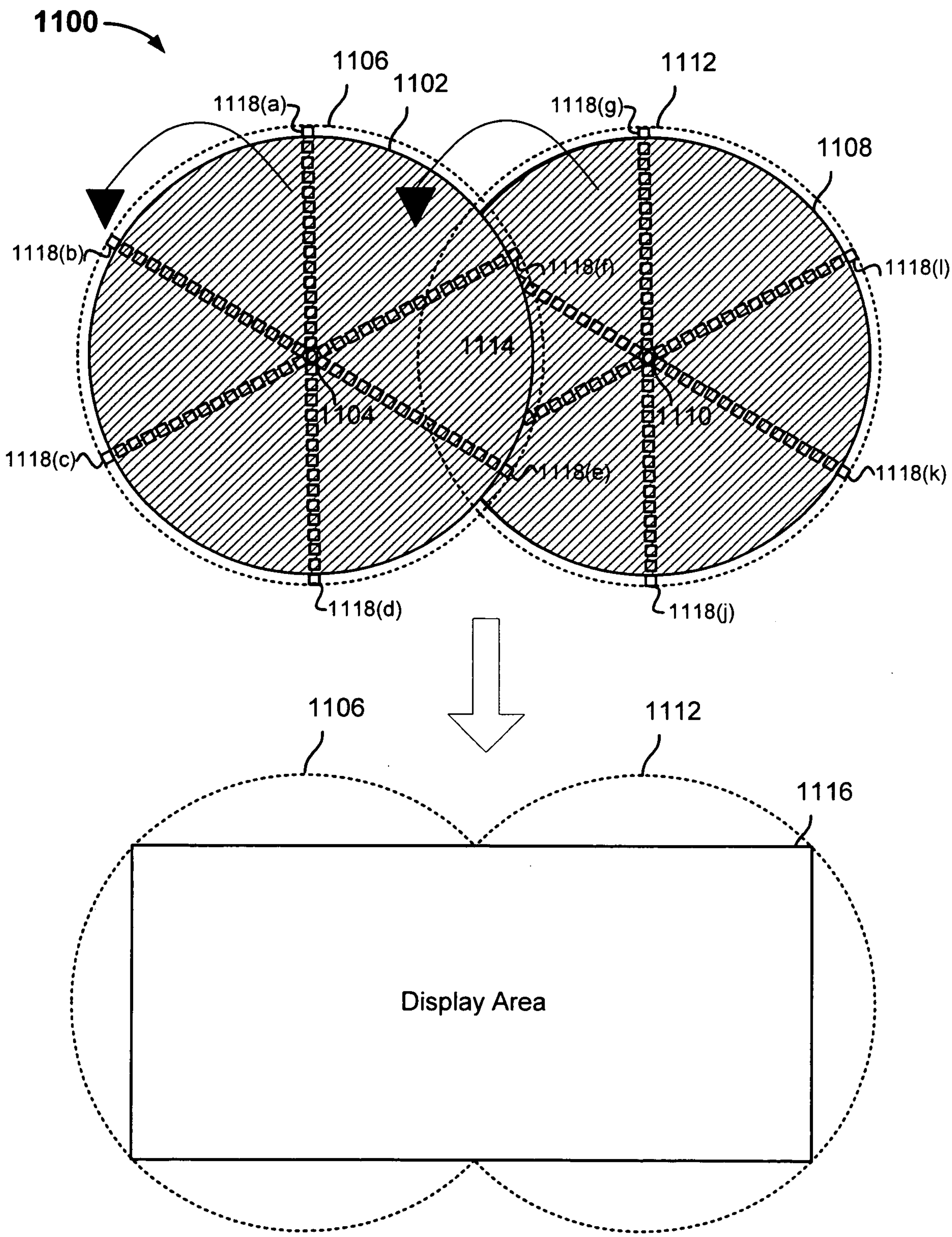

1100
1106
1102
1112
1118(a)
1118(g)
1108
1118(b)
1118(f)
1118(l)
1114
1104
1110
1118(c)
1118(e)
1118(k)
1118(d)
1118(j)
1106
1112
1116
Display Area

FIG. 11A

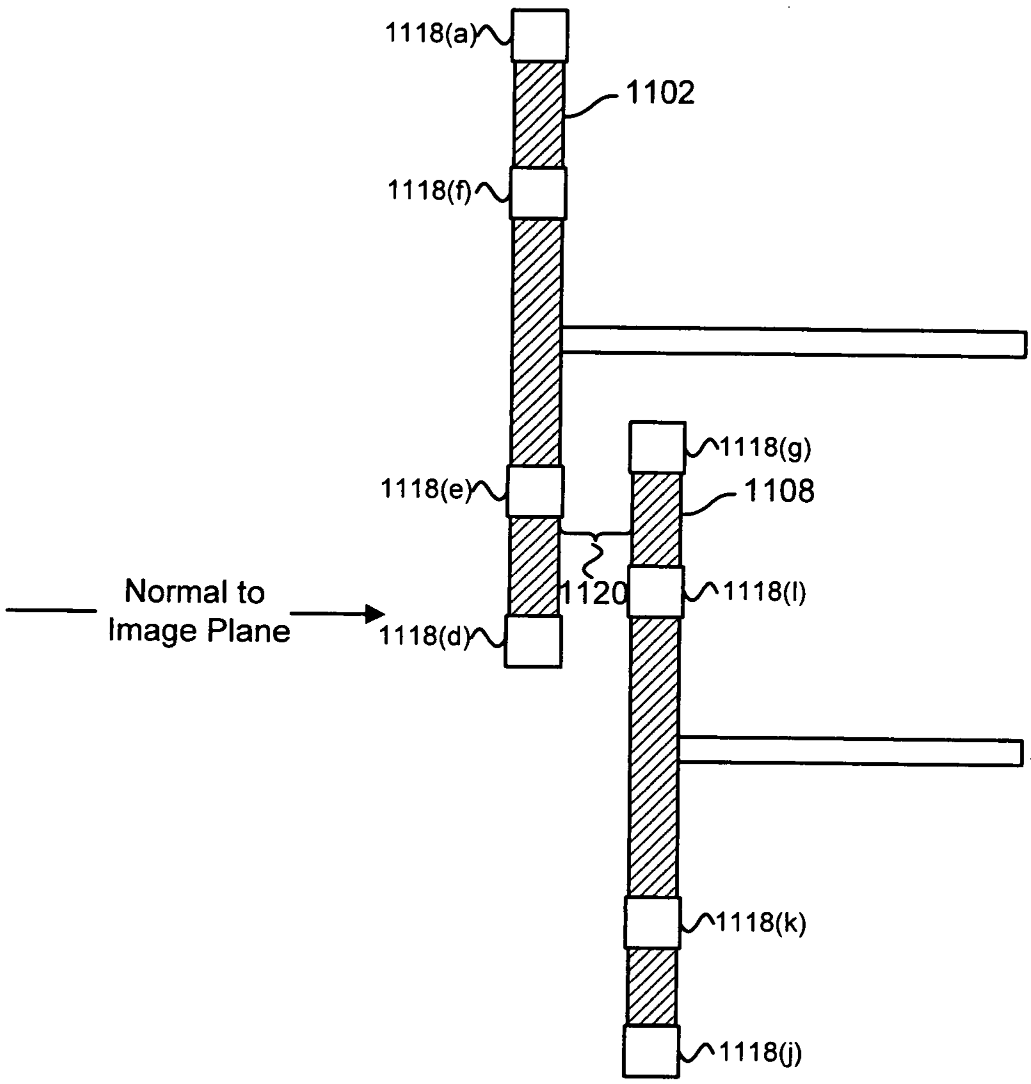

1118(a)
1102
1118(f)
1118(g)
1108
1118(e)
Normal to
Image Plane
1120
1118(l)
1118(d)
1118(k)
1118(j)

FIG. 11B

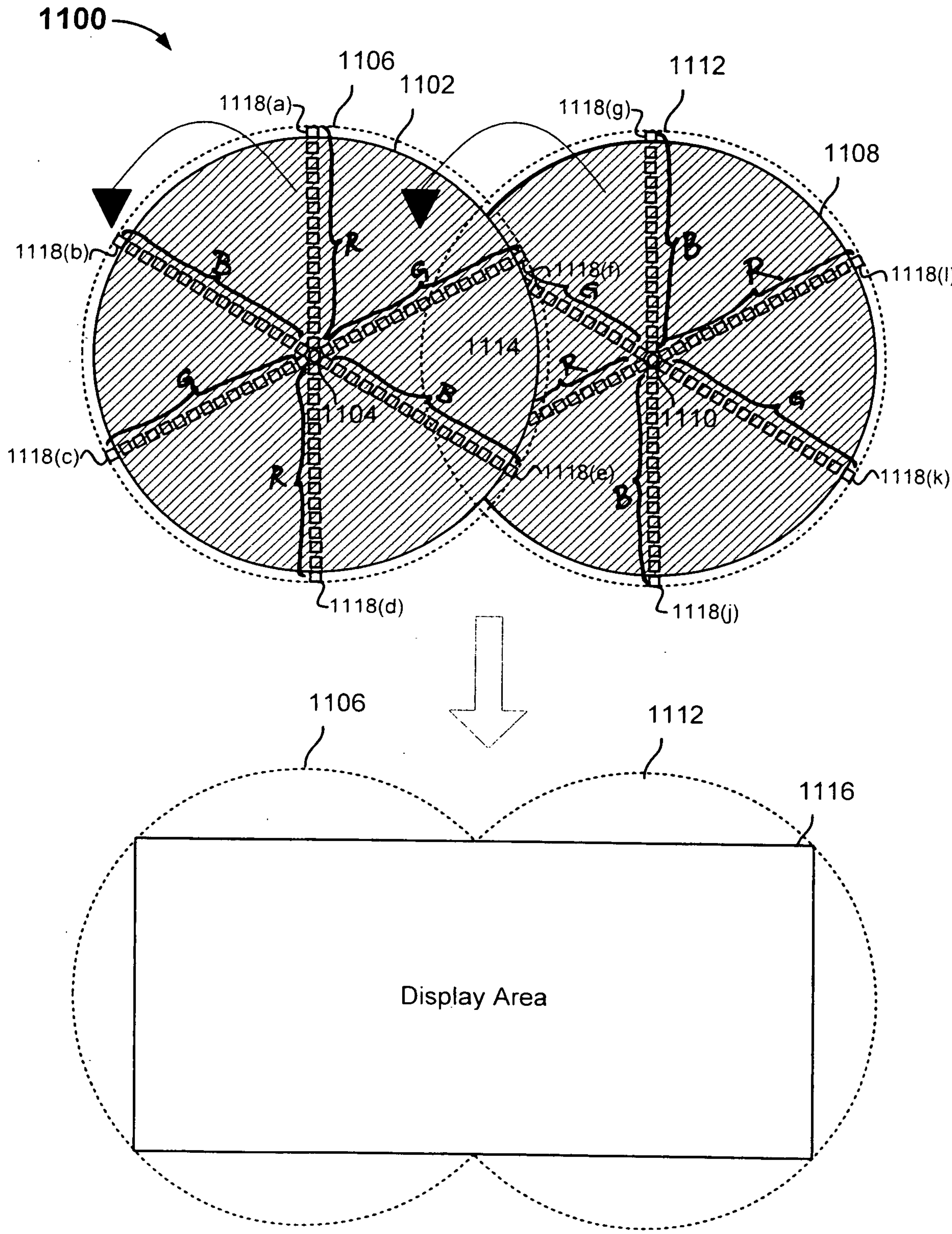

1100
1106
1102
1118(a)
1112
1118(g)
1108
1118(b)
R
B
G
1118(f)
G
B
R
1118(l)
1114
G
1104
B
R
1110
G
1118(c)
R
1118(e)
B
1118(k)
1118(d)
1118(j)
1106
1112
1116
Display Area

FIG. 11C

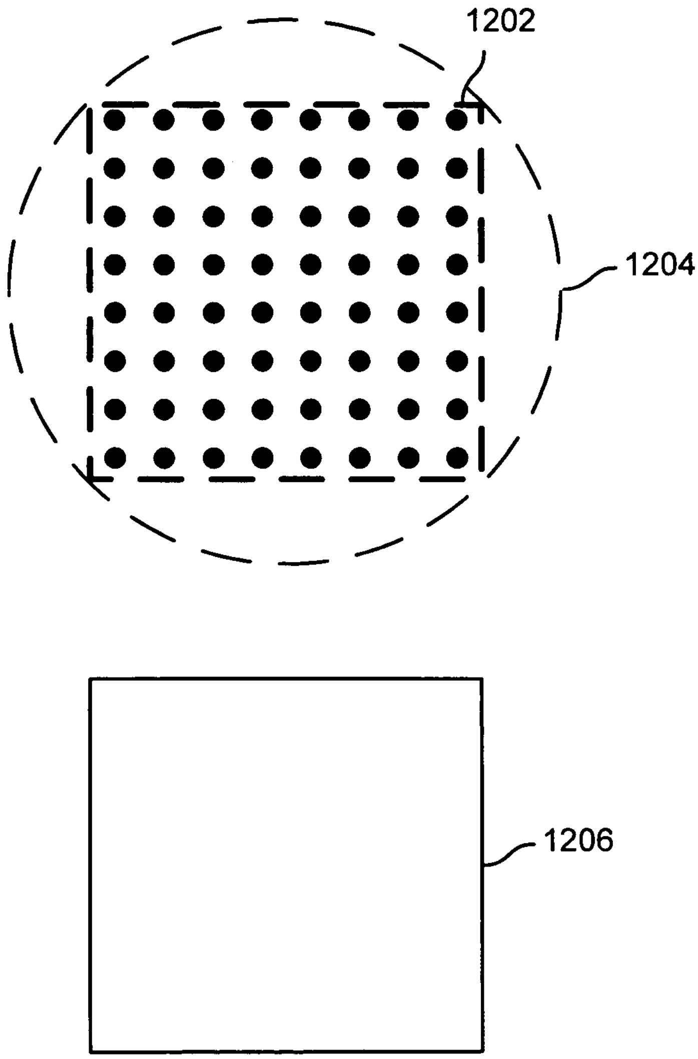


FIG. 12A

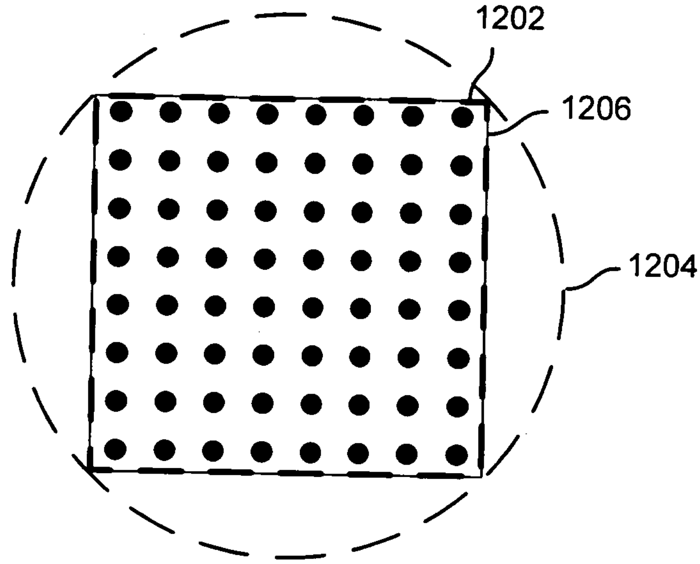


FIG. 12B

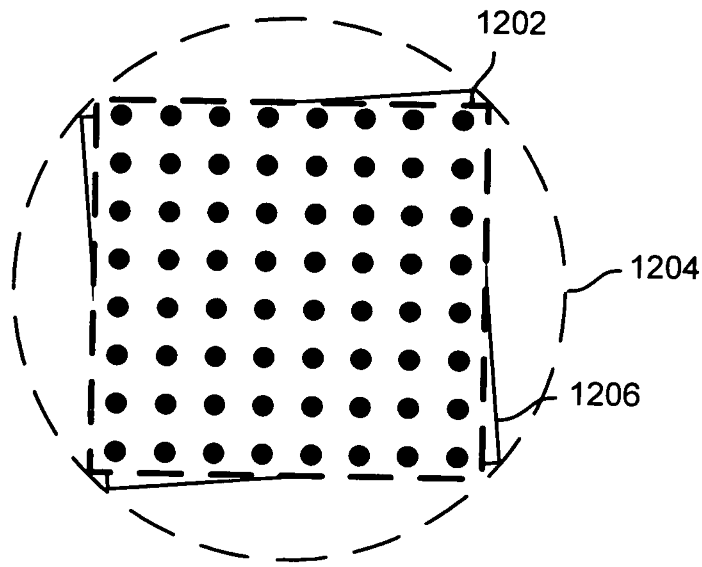


FIG. 12C

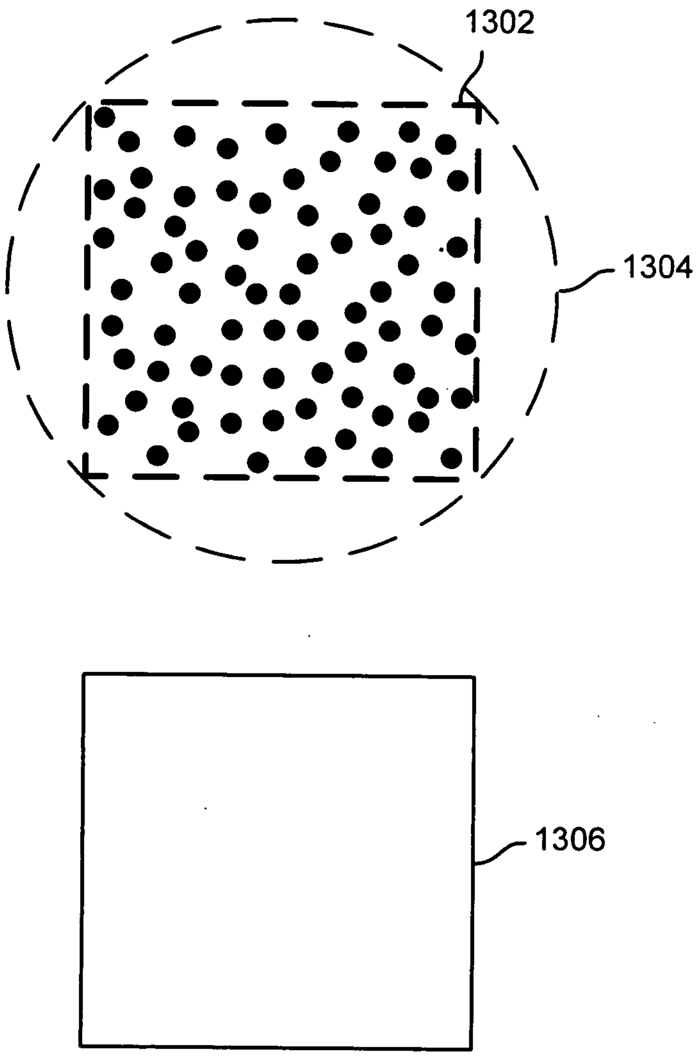


FIG. 13

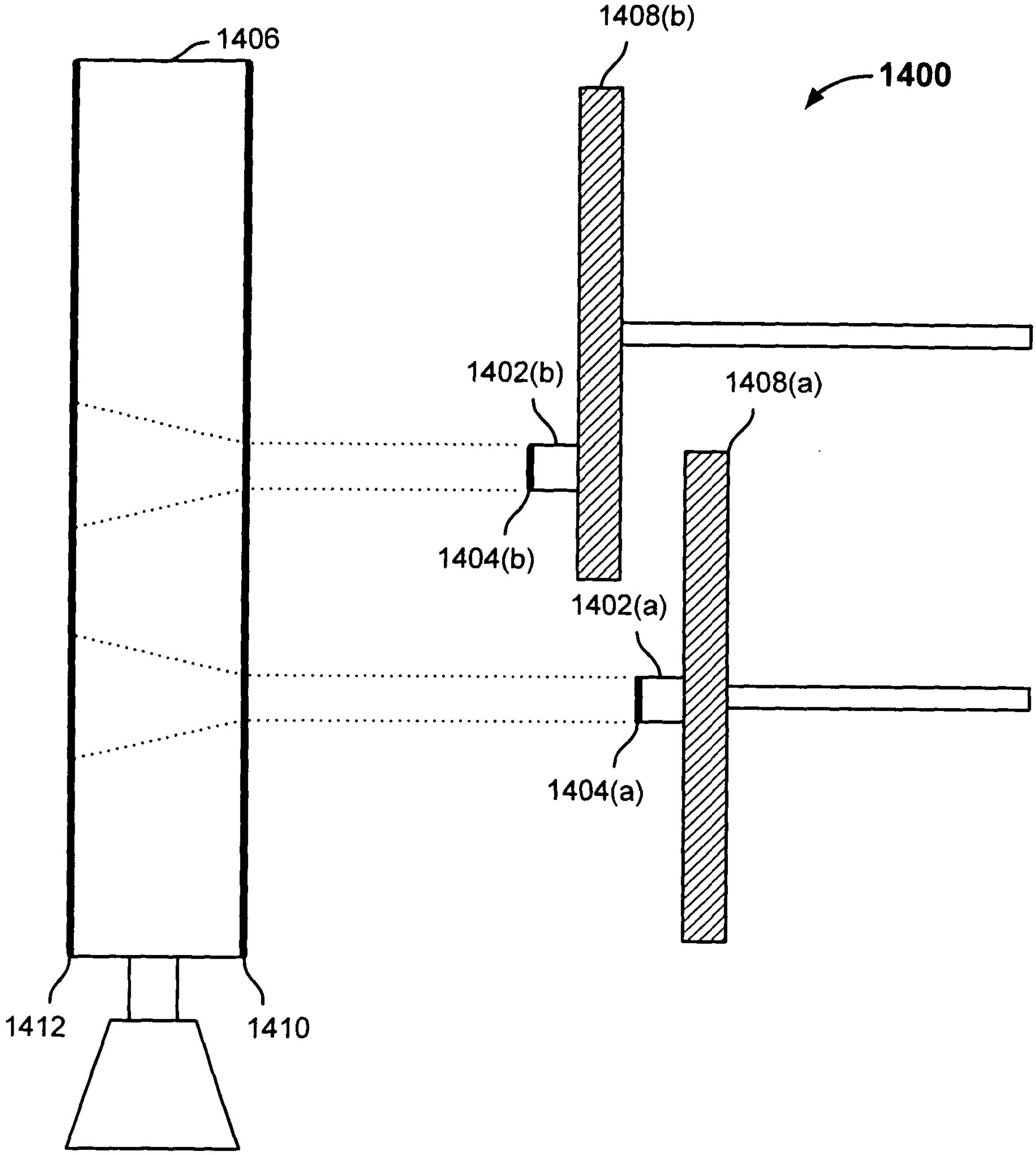


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 08/08106

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G09G 3/34 (2008.04)
USPC - 345/110
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)
345/110

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
348/743, 758; 349/8, 18, 64,65; 352/107, 112, 115, 118; 345/110

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Google; Google Scholar; Google Patents; PubWest(PGPB,USPT,USOC,EPAB,JPAB);
Search Terms Used: composite, digital, display, paddle, pixel elements, edge, printed circuit board, PCB, disc, axis, light emitting diode, LED, uniform, spokes, mask

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/0244741 A1 (KIMURA et al.) 02 November 2006 (02.11.2006), para [0002], para [0017], para [0031]-[0033], para [0132]-[0136], para [0261]-[0289], para [0342], para [0438]-[0452]	1-85
Y	US 2003/0218881 A1 (HANSEN et al.) 27 November 2003 (27.11.2003), para [0016]-[0035]	1-85
A	US 2004/0114714 A1 (MINYARD et al.) 17 June 2004 (17.06.2004), entire document	1-85
A	US 6,243,149 B1 (SWANSON et al.) 05 June 2001 (05.06.2001), entire document	1-85

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"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
"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
"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
"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 September 2008 (30.09.2008)	07 OCT 2008

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774