Sept. 29, 1970 R. J. STRAIN 3,531,585

SOLID-STATE DISPLAY DEVICE EMPLOYING CONTINUOUS PHOSPHOR LAYERS

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FIG. 1

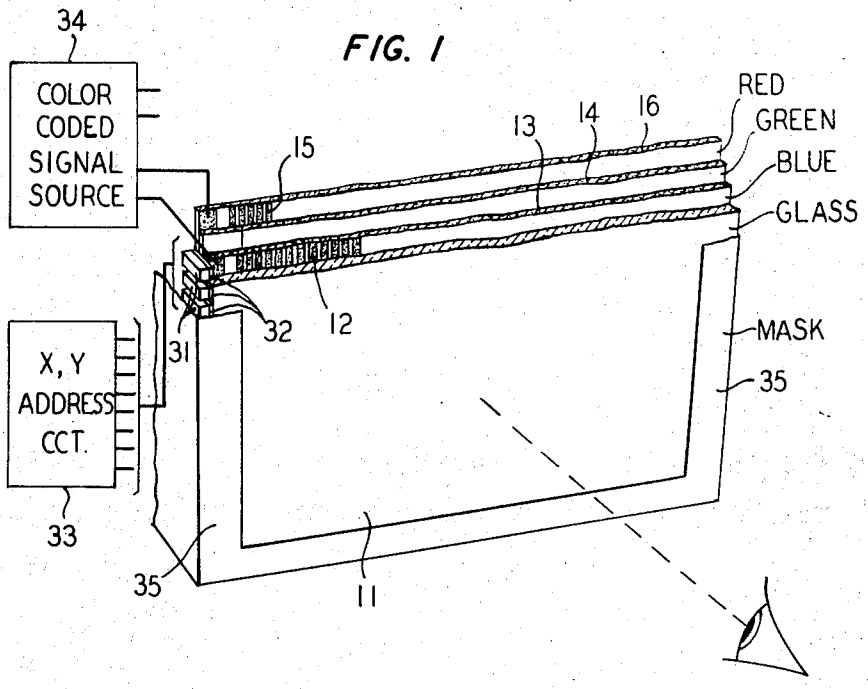
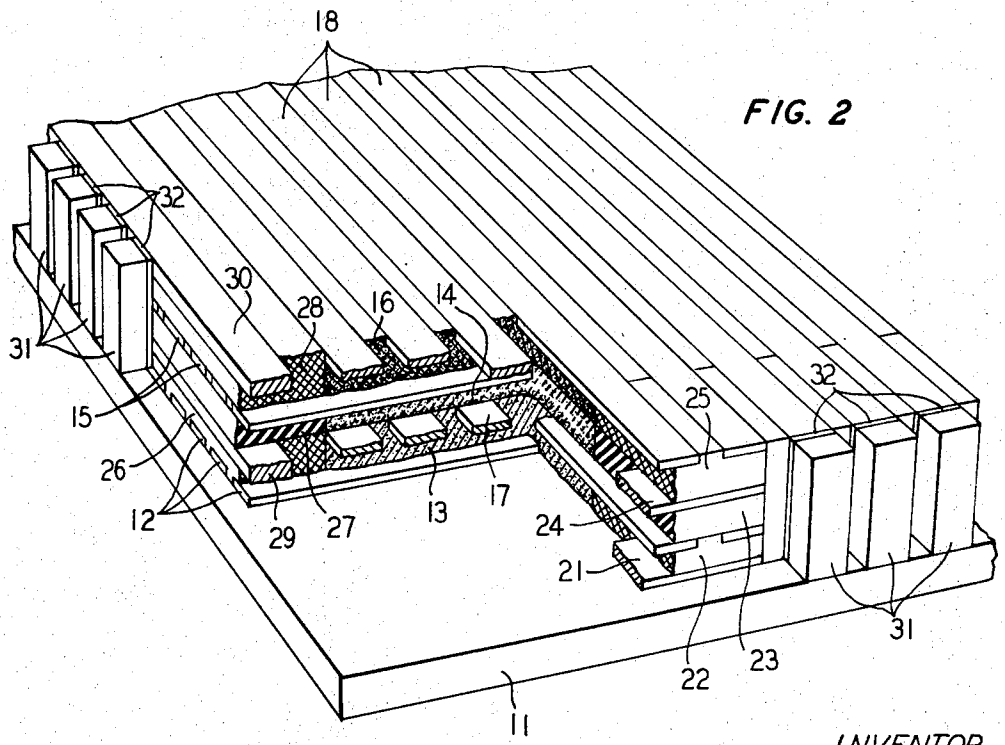


FIG. 2



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SOLID-STATE DISPLAY DEVICE EMPLOYING CONTINUOUS PHOSPHOR LAYERS

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FIG. 3

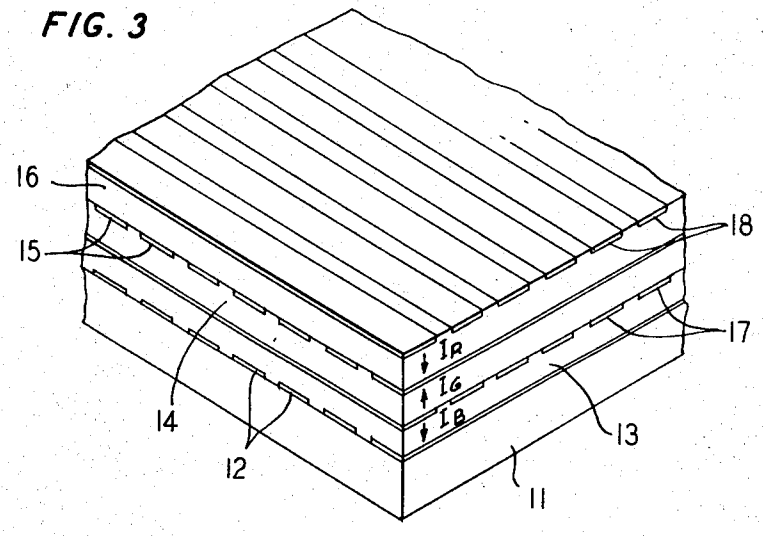


FIG. 4

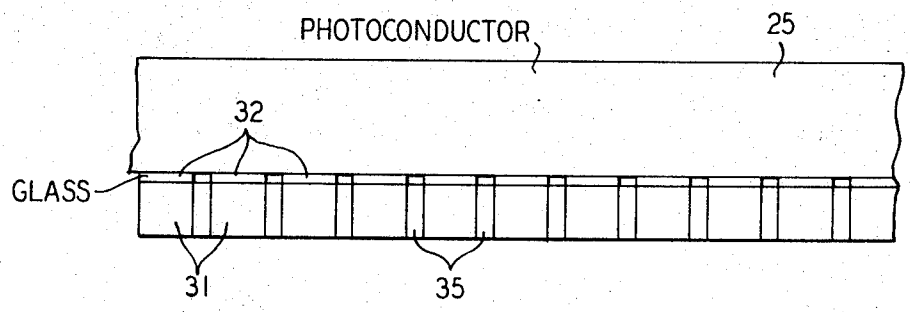
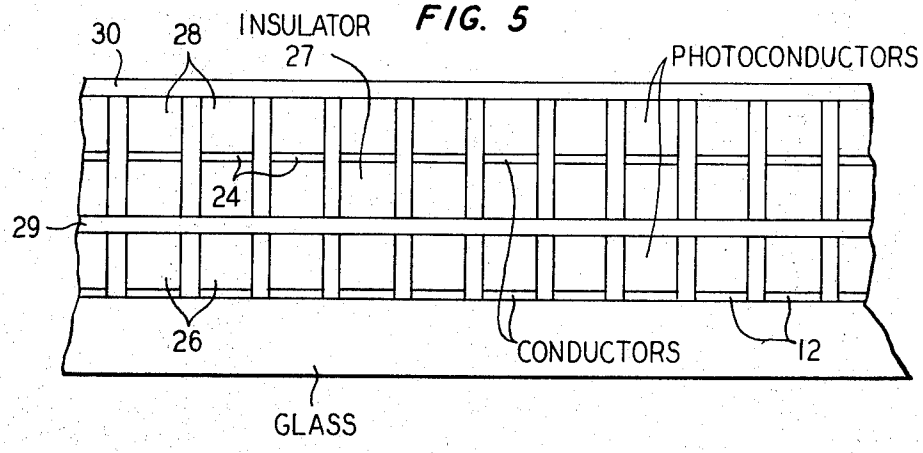


FIG. 5



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3,531,585

SOLID-STATE DISPLAY DEVICE EMPLOYING CONTINUOUS PHOSPHOR LAYERS

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U.S. Cl. 178—5.4 2 Claims

ABSTRACT OF THE DISCLOSURE

Solid-state color television utilizes an electroluminescent display device employing photoconductive coordinate access to an electroluminescent display matrix in which continuous layers of the blue, green and red phosphors are stacked in that order upon the ground glass viewing screen and interleaved with four sets of transparent electrodes, a Y-coordinate set succeeding an X-coordinate set and vice versa. All three colors will travel to the viewing screen without substantial absorption in the intervening layers because of the respective sizes of the band gaps of the layers. The access arrangement includes at each X or Y position two photoconductors each separating one of four address bus bars from one electrode in one of the four sets of X and Y electrodes. Color coding is achieved simply through appropriate combinations of currents in the four bus bars.

BACKGROUND OF THE INVENTION

My invention relates to apparatus for scanned multicolor display. Typically, it could be used for color television.

Although color television sets employing cathode ray tubes for display are presently a standard commercial item, a substantial research and development effort has been made for many years in the area of solid-state, and particularly electroluminescent, apparatus for color television. It has been recognized that such apparatus might be more rugged and reliable and substantially less expensive to manufacture than the present sets.

The realization of such benefits has not occurred because of a number of problems that have been encountered. One such problem is that the methods of depositing the electroluminescent phosphors in side-by-side spots or side-by-side strips in proper relationship to access electrodes are exacting and relatively expensive, as compared to most other solid-state techniques. Another problem is that the external access circuitry has been made excessively complex by such arrangements of phosphors.

SUMMARY OF THE INVENTION

To solve these problems, according to my invention, I employ an electroluminescent matrix in which layers of the blue, green and red phosphorus, for example, each extending continuously in two dimensions, are disposed substantially parallel to the viewing screen and are separated therefrom in that order. These layers are interleaved with a plurality of sets, four in this example, of transparent electrodes, a Y-coordinate set succeeding an X-coordinate set and vice versa. The access arrangement includes at each X or Y position two photoconductors each separating one of four address bus bars from one electrode in one of the four sets of X and Y electrodes. Color coding is achieved simply through appropriate combinations of currents in the four bus bars.

Since the color-producing phosphors are stacked upon the viewing screen in the order of decreasing size of the energy band gaps present in the phosphors, all of the

colors will travel to the viewing screen without substantial absorption in the intervening layers.

The continuity of the respective layers of phosphors facilitates manufacture, since no control of the lateral dimensions of the phosphors is needed.

BRIEF DESCRIPTION OF THE DRAWING

Other features and advantages of my invention can be explained and appreciated more easily with reference to the drawing, in which:

FIG. 1 is a partially pictorial and partially block diagrammatic illustration of a preferred embodiment of my invention in its typical environment;

FIG. 2 is a more detailed perspective view of the portions of the preferred embodiment that are of primary interest;

FIG. 3 is a perspective view of the phosphor matrix and interleaved electrodes of the preferred embodiment, which will be useful in explaining how color coding is achieved;

FIG. 4 is a top view of the photoconductive and illuminating portions of the access circuitry of the preferred embodiment; and

FIG. 5 is a side view of an alternative arrangement of the photoconductive portion of the access circuitry.

DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENT

In FIG. 1, the preferred embodiment is oriented to be viewed from the exposed side of the glass plate **11**. A set of transparent X-coordinate electrodes **12** are deposited on the other side of plate **11**; and over the electrodes **12** is deposited a layer of the blue phosphor **13**. A set of transparent Y-coordinate electrodes (not shown in FIG. 1) are deposited on the blue phosphor **13** and covered with the layer of green phosphor **14**. Next are deposited a set of transparent X-coordinate electrodes **15**, a layer of the red phosphor **16**, and another set of Y-coordinate electrodes (not shown in FIG. 1).

The essential thing to notice with respect to the phosphor matrix of FIG. 1 is that, from the ground glass plate **11**, the phosphors are arranged in the order of decreasing size of the energy band gaps of the materials. As a result, the red light from phosphor **16** is not absorbed by the green phosphor **14**; and the red light and the green light from phosphors **16** and **14**, respectively, are not absorbed by the blue phosphor **13**. Thus, all three colors of light will reach the glass plate **11**.

The Y-coordinate access circuitry is shown in FIG. 1 only to the extent that it is seen to run along one edge of the phosphor matrix. Similarly, the X-coordinate access circuitry runs along the bottom edge of the matrix of FIG. 1. These details will be more fully explained with reference to FIG. 2.

The television set of FIG. 1 includes a mask **35** surrounding the electroluminescent diode and the photoconductor portion of the matrix so that the viewer is not annoyed by the light emanating directly from the access circuitry and so that light from the surroundings of the set does not interfere with the scanning.

The structural details of the display matrix will now be more fully explained with reference to FIG. 2. The perspective of FIG. 2 is that which would be obtained if the set of FIG. 1 were placed face downward and viewed from the left bottom corner in FIG. 1. In the Y-coordinate access circuitry, a bus bar **21**, parallel to but wider than any of the X-coordinate electrodes **12**, is deposited on the glass plate **11**. A photoconductor strip **22** is deposited on top of the bus bar **21** to make contact with the first set of Y-coordinate electrodes **17**. An insulating strip **23** is deposited on top of photoconductor strip **22**. A bus bar **24** is deposited on top of the insulating strip **23**; and a

photoconductor strip **25** is deposited on top of the bus bar **24** to make contact with the second set of Y-coordinate electrodes **18**.

In similar fashion the X-coordinate electrodes **12** and **15** are contacted by photoconductor strips **26** and **28**, respectively (which would run horizontally in FIG. 1), which in turn are contacted by bus bars **29** and **30**. The photoconductor strips **26** and **28** are separated by an insulator strip **27**.

It may be seen that the X-coordinate electrodes **12** are disposed in contact with the glass plate **11** and the blue phosphor **13**, and they also extend far enough to contact the portion of photoconductor **26** that is in proximity to ground glass plate **11**. The Y-coordinate electrodes **17** are disposed in contact with both the blue phosphor **13** and the green phosphor **14** and extend far enough to contact the photoconductor **22** between photoconductor **22** and the insulator strip **23** of the Y-coordinate access circuitry. The X-coordinate electrodes **15** are disposed in contact with both the green phosphor **14** and the red phosphor **16** and extend far enough to contact the photoconductor strip **28** between photoconductor **28** and insulator **27**. The Y-coordinate electrodes **18** contact the blue phosphor **16** and extend far enough to contact the photoconductor strip **25**. Bus bar **21** contacts photoconductor **22** between both plate **11** and photoconductor **22**; and bus bar **24** contacts photoconductor **25** between both insulator strip **23** and photoconductor **25**. Bus bar **29** contacts photoconductor **26** between photoconductor **26** and insulator strip **27**, and bus bar **30** contacts photoconductor strip **28**. It should be noted that a substantial portion of photoconductor in each case isolates each of the bus bars from a parallel electrode to which it should not have access. If this isolation is not sufficient, strips of insulation can be deposited in these locations.

Along the edges of the photoconductor and insulator strips are deposited the electroluminescent scanning diodes **31**, which are separated from the photoconductor strips **22** and **25** by thin glass plates **32** that serve as light pipes. The electroluminescent diodes **31** are provided with appropriate terminal connections and are energized from the X, Y address circuit **33**. The diodes then illuminate both photoconductors at the selected coordinate location in response to a given X- or Y-coordinate signal from circuit **33**. Preferably, the plane of their junctions would be parallel to the plane of the display matrix in order to facilitate batch fabrication of the array. In other respects, the orientation of the junctions of diodes **31** is not critical so long as the light from each can propagate into the adjacent light pipe **32**. It should be noted that dimensions normal to array are greatly exaggerated for purposes of illustration and actually would be much less than the lateral dimensions of the access electrodes or the spaces between the electrodes.

The bus bars **21** and **24** are connected to appropriate inputs of color-coded signal source **34** to receive color-coded signal currents.

The colors blue, green and red are selected by the routing of current over particular bus bars. The intensity of these colors is then determined by the magnitude of these currents. Combination colors are selected both by the routing of a combination of currents over the various bus bars and by the relative magnitudes of these currents.

A specific example of the respective components is as follows: The glass plate **11** is selected to provide sufficient diffusion of the light passing through to make the picture agreeable to the viewer's eye, as is customary in the television art. The transparent electrodes **12, 15, 17, 18** are illustratively stannic oxide. The blue phosphor **13** is illustratively zinc sulfide (ZnS) doped with activators to provide blue electroluminescence. The green phosphor **14** is illustratively zinc cadmium sulfide (ZnCdS) doped with activators to provide green electroluminescence. The red phosphor **16** is illustratively gallium phosphide (GaP) doped with zinc, oxygen and tellurium to provide red electroluminescence. Specifically, red electroluminescence can be obtained by doping the gallium phosphide as disclosed in the copending patent application of R. A. Logan et al., Ser. No. 428,904, filed Jan. 29, 1965, and assigned to the assignee hereof. The photoconductors **22, 25, 26** and **28** are illustratively uniformly doped gallium arsenide (GaAs); and the insulators **23** and **27** are illustratively silicon dioxide (SiO_2). The scanning diodes **31** are illustratively gallium arsenide (GaAs) junction diodes and the glass plates **32** are illustratively ordinary sodium glass. The X, Y address circuit **33** is of the conventional type employed for television coordinate scanning of solid-state display devices. An example of such a circuit can be found in the article entitled "A 180-Stage Integrated Thin-Film Scan Generator" by P. K. Weimer et al., Proceedings of the Institute of Electrical and Electronics Engineers, Inc., volume 54, page 354, March 1966. The color-coded signal source **34** comprises a receiver for the transmitted video signal and appropriate conventional circuitry for separating the modulations of the received signal which corresponds to the intensity information needed for the blue, green, and red phosphors, respectively. The signals thus separated are subjected to a logic operation so that one of the four output currents is the red intensity signal, another is the blue intensity signal, a third is the sum of the green and the red intensity signals and the fourth is the sum of the green and the blue intensity signals. These four signals are applied to the four bus bars in a fashion that will be more completely explained hereinafter with reference to FIG. 3.

The manner in which the currents supplied to the bus bars divide can be explained as follows: The blue signal current flows into bus bar **21** and through the photoconductor **22** at the illuminated Y-coordinate location to the corresponding one of the electrodes **17**. From that electrode **17** the blue current must flow through the blue phosphor **13** to an X-coordinate electrode **12** and thence through the photoconductor **26** at the illuminated X-coordinate to the bus bar **29**. The red signal current flows from bus bar **24** through photoconductor **25** at the illuminated Y-coordinate to the corresponding one of the Y-coordinate electrodes **18** and then through the red phosphor **16** to one of the X-coordinate electrodes **15**. From there it flows through the photoconductor **28** at the illuminated X-coordinate to the bus bar **30**. The green signal current, like the blue signal current, flows from the bus bar **21** through the photoconductor **22** at the illuminated Y-coordinate to the one of the Y-coordinate electrodes **17**. From that electrode **17** it then departs from the path of the blue current and flows through the green phosphor **14** to the one of the X-coordinate electrodes **15** at an illuminated X-coordinate location and then flows, with the red signal current, through the illuminated portion of the photoconductor **28** to the bus bar **30**. It will be noted that both the blue and green signal currents flow in through bus bar **21**; and both the green and the red signal currents flow out through bus bar **30**. Thus, the logic circuitry in the color-coded signal source **34** must determine the values of the currents on these bus bars accordingly in order to compel the proper value of current to flow through the green phosphor **14**.

The resulting representative directions of the currents in the phosphors are illustrated on the diagram of FIG. 3. It will be seen that the blue signal current flows downward through the blue phosphor **13** toward electrodes **12**. The green signal current in the phosphor **14** flows upward toward electrodes **17** toward the electrodes **15** and the red signal current flows downward through the red phosphor **16** from the electrodes **18** toward the electrodes **15**.

The multicolor matrix of the present invention can, from a study of the foregoing principles, be generalized so that an *n*-color matrix, arranged in order of decreas-

ing size of band gaps from the viewing screen, can be energized with (n+1) modulated signal currents which bear the information needed to produce *n*-pure colors.

Pure color tones are provided by supplying only the appropriate pairs of currents through the bus bar; while additive color combinations are created by appropriate combinations of all signal currents.

The arrangement and function of the thin glass plates **32** which serve as light pipes for the scanning diodes **31** will now be explained with reference to the top view of FIG. 4. For purposes of illustration only the diodes and a photoconductor, illustratively photoconductor **25**, are shown in relation to the glass plates **32** in FIG. 4. Even though the glass plates **32** are relatively thin in the direction of propagation of light from the diodes **31** to the photoconductor **25**, they act as light pipes in that light tending to propagate laterally instead of directly through the plates **32** is reflected at dielectric discontinuities at the thin edges of the plates **32** to propagate into the photoconductor **25** within a region having substantially the same lateral extent as the energized diode **31**. If not reflected at the edges of glass plates **32**, such light would tend to propagate into adjacent portions of the photoconductor **25** and produce cross-talk between adjacent coordinate locations of the display matrix.

To provide the dielectric discontinuities at the edges of plates **32**, a gap, illustratively filled with ambient gas, may be left between the thin edges of neighboring plates **32**. This technique requires that the insulators **35** between neighboring diodes have no lateral support in the side toward photoconductor **25**. Such an arrangement is feasible if the insulator strips **35** can be deposited by integrated circuit techniques after the diodes have been deposited. Where such a procedure is not feasible, the insulator strips **35** can be deposited so that they intrude between the edges of the glass plates **32**, and the material of the insulator **35** is selected to provide a sufficiently large dielectric discontinuity with respect to the glass plates **32**. Then the thin edges of the glass plates **32** will be sufficiently reflective. It should be noted that the glass plates **32** will extend the full length of the diodes **31** with which they are respectively in contact and that this will typically be the entire thickness of the display matrix.

A side view of an alternative construction of a photoconductive access circuit is shown in FIG. 5. Here the photoconductors, for example, **26** and **28**, and the insulator **27** are deposited in discrete blocks at each coordinate location instead of in continuous strips. This arrangement will substantially eliminate the need for the glass plates **32** of FIG. 4, or any similar light pipe arrangement. Again, it should be noted that dimensions normal to the array are greatly exaggerated.

What is claimed is:

1. In combination, an electroluminescent device comprising a viewing screen and a plurality of layers of phosphors each extending continuously in two dimensions substantially parallel to said viewing screen, said layers being respectively capable of electroluminescence of differing colors and separated from said viewing screen in the sequence of decreasing size of the energy gaps present in said phosphors, a plurality of sets of electrodes interleaved with said layers, successive sets of which electrodes represent coordinate values in orthogonal coordinates, a plurality of photoconductive access switches each connected to one of said electrodes, means comprising within each of said coordinates a plurality of electroluminescent cells at respective positions of said coordinate each in proximity to two of said switches and two address bus bars respectively connected to said two switches and traversing other positions of said coordinate for actuating said switches in selected value ranges of said coordinates, and means for supplying color-coded combinations of currents through said bus bars to said switches.

2. An electroluminescent device according to claim **1** in which a first set of switches connecting a first one of the bus bars to a first set of coordinate electrodes comprises a first continuous strip of photoconductive material extending through a plurality of positions of the coordinate, the actuating means includes a first strip of insulating material isolating said first set of coordinate electrodes from a second one of said bus bars oriented parallel to the first bus bar, a second set of said switches connecting said second bus bar to a second set of coordinate electrodes comprises a second strip of photoconductive material extending through said plurality of positions of said coordinate, a third set of said switches connecting a third set of the coordinate electrodes to a third bus bar oriented orthogonal to said first and second bus bars comprises a third strip of photoconductive material extending through a plurality of positions of a coordinate orthogonal to the first coordinate, said actuating means includes a second strip of insulating material isolating said third set of coordinate electrodes from a fourth one of said bus bars oriented parallel to said third bus bar, and the fourth set of said switches connecting the fourth bus bar to a fourth set of coordinate electrodes comprises a fourth strip of photoconductive material extending through said plurality of positions of said orthogonal coordinate.

References Cited

UNITED STATES PATENTS

2,925,532	2/1960	Larach.	
3,021,387	2/1962	Rajehman.	
3,070,701	12/1962	Wasserman.	
3,242,482	3/1966	Simon.	
3,249,804	5/1966	Aiken.	
2,928,980	10/1960	Williams	313—108
3,223,886	12/1965	Glaser	178—54

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U.S. Cl. X.R.

315—169; 313—108